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Dual sourcing and backup production: Coexistence versus exclusivity

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ABSTRACT

Supply risk is one of the most important enterprise risks. Dual sourcing and backup production are the two operational strategies that firms most commonly use to mitigate supply risk. The base model examines the strategic use of dual sourcing and backup supply options in a two-stage dynamic programming model for one period. In the first stage the firm decides whether to employ single or dual sourcing for primary supply and whether to reserve backup option. In the second stage, if backup option has been reserved, the firm decides the backup production quantity after observing the realized primary delivery. The optimal sourcing strategies are separately characterized under deterministic and uncertain demand. The results show that dual sourcing coexists with backup production when the two primary suppliers have similar and moderate reliabilities and the backup reservation cost is relatively small. When the reliabilities of the two primary suppliers differ significantly, dual sourcing and backup can become mutually exclusive strategies. Furthermore, the existence of the backup production option decreases the probability of selecting dual sourcing; compared with deterministic demand, uncertain demand increases the area of coexistence of dual sourcing and backup production. In particular, when the firm employs dual sourcing, backup production is activated under deterministic demand only when both primary suppliers fail, while can be activated under uncertain demand when one of the primary suppliers fails. We extend the base model to a two-period structure where the reliability of one primary supplier is uncertain, and the firm updates its assessment of supplier reliability based on the delivery in previous period. Based on Bayesian forecast-updating approach, we find that reliability learning weakly increases the area of coexistence of dual sourcing and backup, and weakly decreases the probability of contingent backup production in the coexistence area.

1. Introduction

Enterprise risks (ER) are of many aspects and can be categorized into different groups. In terms of field based classification, operational risk is one of the most concerns for supply chain risk management [42]. In particular, supply risk at supplier side has drawn wide attentions from both practitioner and scholar. A survey by consulting company PRTM found that "supply chain volatility and uncertainty have permanently increased, and poor supplier performance (quality and on-time delivery) is one of the top eight challenges to supply chain flexibility that companies struggle with" [29]. As global supply chains become longer and more complex, supply risk management becomes essential to ensure sustainable and profitable operations. Companies have taken different actions to mitigate their supply risks. American manufacturers traditionally prefer to source from dual/multi-suppliers. Thus Deloitte Consulting often handles cases like the following: "a client — a $10 billion, high-tech U.S. manufacturer of wireless transmission components — wanted to know, how much should I buy from each of my sources in China and Mexico?" [37]. In contrast, Japanese manufacturers tend to use sole sourcing, but simultaneously always consider a backup (contingency) plan to cope with disruptions — e.g. the earthquake in 2011 [12].

Generally, dual sourcing and backup sourcing are two of the most commonly applied instruments firms use to reduce supply disruption or risk, and the literature has widely researched their effects. Anupindi and Akella [2], Swaminathan and Shanthikumar [31], Babich et al. [5], Tomlin [35], Wang et al. [38] and Tang and Kouvelis [33] all studied the core benefit of dual sourcing: ex-ante risk diversification. Meanwhile, backup sourcing is usually activated after a firm learns more about production or demand risk [4,34,44], which can be regarded as ex-post (interim) expediting orders. One of the most famous backup sourcing cases is that of Ericsson and Nokia, both of whom faced a fire at the Philips microchip plant in New Mexico in 2000 [21]. Nokia swiftly moved to tie up spare

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capacity at other Philips plants and other external suppliers, while Ericsson found its production operations halted due to its strategy of buying key components from a single source.

In the real world, firms are not limited to choosing between two strategies. In many circumstances, a combination of strategies may be more appropriate to manage supply risks [34]. In 2007, although Nokia continued to maintain backup options, the firm announced its plan to develop dual sourcing capability in all product categories [30]. The executive VP commented that the increased pool of potential chipset suppliers would decrease the company's supply disruption risks. Apple is now planning to use Samsung for backup production of high-resolution 7.9-in. Retina panels, since it has found its current dual primary manufacturers, Sharp and LG Display, to be having trouble achieving required production volumes [3]. Motivated by such real world examples, this paper examines an interesting theoretical and practical question: how do dual sourcing and backup production interact with each other? Is it better for a firm to combine these two strategies rather than using just one to mitigate supply disruption/risk? This paper thus focuses on the coexistence of dual sourcing and backup production versus exclusive reliance on one or the other. To the best of our knowledge, this is the first study to investigate the two sourcing strategies in a sequential decision model from both theoretical and practical perspectives.

We consider a supply chain in which a firm manages two primary suppliers and one backup supplier for a critical component. The primary suppliers have intrinsic supply risks that result in all-or-nothing yield uncertainties, while the backup supplier fulfills orders precisely but is more expensive. The all-or-nothing supply uncertainty has various causes, such as natural disasters, supplier bankruptcy and machines breakdown, etc. Supply disruptions are common in the bio-manufacturing and pharmaceutical industries [13,9]. We first examine the firm's strategic use of dual sourcing and backup option in two-stage dynamic programming in a single period model. In the first stage the firm simultaneously decides on dual sourcing or single sourcing and on whether to reserve a backup option. In the second stage, if a backup option is applicable, the firm decides the backup production quantity contingent on observation of realized primary delivery. To understand how demand uncertainty influences the coexistence and exclusivity of two instruments, we analyze the scenarios of deterministic and uncertain demand separately. Generally, under both deterministic and uncertain demand the analysis shows that dual sourcing coexists with backup production when the reliabilities of two primary suppliers are close and moderate and the backup reservation cost is relatively small. When the difference between the reliabilities of two primary supplier reliabilities is significant, dual sourcing and backup supply can become mutually exclusive. When both primary suppliers have low reliabilities then single sourcing from one primary supplier could be substituted by backup production. Compared with deterministic demand, we found that uncertain demand increases the area of coexistence between dual sourcing and backup, and also increases the probability of backup production being activated when dual sourcing has been employed in the first stage. Finally, we extend the base model to a two-period model where the reliability of one primary supplier (S_1) is uncertain. The firm can update its assessment of supplier reliability based on delivery in the previous period. By applying a Bayesian forecast-updating approach, we find that learning the reliability of a supplier (S_1) encourages the firm to source from that supplier in period 1. In particular, learning weakly increases the area of coexistence of dual sourcing and backup, and weakly decreases the probability of contingent backup production in the coexistence area.

The remainder of this paper is organized as follows. Section 2 surveys the literature. Section 3 presents the model setting. We characterize the optimal sourcing strategies under deterministic and uncertain demand respectively in Section 4. Section 5 extends the base model by allowing for uncertain reliability of one primary supplier. Section 6 presents conclusions. A list of modeling notation and definitions is contained in Appendix A and all proofs can be found in Appendix B.

2. Literature review

Enterprise risk management (ERM) is the methodologies, processes and strategies to control or mitigate, within its risk appetite, all kinds of risks for an individual firm, where risk refers to uncertain events that have effects on objectives of the organization [10,7]. In recent years, Desheng Wu and his coauthors, as the most pioneer researchers in this active domain, have examined the characteristics of various enterprise risks in detail and promoted ERM in diversified fields by applying different methods and approaches [6]. For example, Wu and Olson [41] specified the definitions of and relationships between the main enterprise risks. Another work which closely relates to the theme of our paper is Olson and Wu [23], where DEA and Monte Carlo simulation are applied and compared in the process of supplier selection. Closed to the analysis framework of current paper, Wu et al. [40] and Wu [39] analyzed the equilibrium behaviors of competing supply chains facing uncertain demand at market side.

In general, supply risk from supplier within chain should be regarded as one kind of crucial enterprise risk that firms usually face [42]. Numerous studies have examined supply risk management (refer to the reviews by [32,36,43,18,16]). The literature usually models unreliable supply as random yield. Yano and Lee [45] comprehensively reviewed the yield uncertainty literature. In the random yield model, the delivered quantity is a stochastic proportion of the order quantity. Many researchers have also considered supply disruption, which can be seen as a special case of the random yield model, where the realized quantity is either 100% or 0%. Manufacturers usually use supplier diversification to reduce the risk and dependencies that arise from reliance on a single supplier.

Gerchak and Parlar [14] studied the benefits and costs of supplier diversification in an economic order quantity (EOQ) setting. Parlar and Wang [25] applied the same analysis to an uncertain demand inventory setting. Anupindi and Akella [2] analyzed how firms allocate order quantities between two unreliable suppliers under continuous demand distribution. Palar and Perry [24] and Gurler and Parlar [15] considered order quantity/reorder-point inventory models in situations involving dual/multi-suppliers and supply disruption risks. Agrawal and Nahmias [1] raised the important trade-off between the risk reduction benefits of ordering from numerous suppliers with uncertain reliability and the fixed order costs associated with such ordering, and developed a model to optimize supplier number. Swaminathan and Shanthikumar [31] analyzed the supply diversification problem studied in Anupindi and Akella [2] to illustrate and explain the difference in policy structure under discrete and continuous demand distributions. Dada et al. [8] considered the problem of a newsvendor served by multiple unreliable suppliers. Babich et al. [5] studied the effects of supply disruption in a supply chain where a retailer faced uncertain demand and sourced from two suppliers. Tomlin [35] investigated how supply yield distribution learning influences both sourcing and inventory strategies in dual-sourcing and single-sourcing models. Wang et al. [38] explored a model in which a firm can source from dual suppliers and/or seek improved supplier reliability. Sawik [27] proposed a stochastic mixed integer programming approach to schedule customer orders and determine single or dual sourcing when supply disruption risk exists. Ju et al. [19] studied the problem of inventory control when the buyer faces two asymmetric supply sources, i.e., an expensive but reliable supplier

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