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Building a mutually beneficial partnership to ensure backup supply ☆

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ABSTRACT

In today's complex global environment, it is very important for a firm to possess backup supply resource when facing unpredictable disruptions from its primary supply resource. To ensure the actual arrival of backup supply in cases of primary supply disruptions, a purchasing firm needs to work with its backup supplier to forge a strong partnership that not only protects itself, but also assures the backup supplier's economic benefit. In this research, we establish the structure of such a partnership based on real business practices. The interactions between the purchasing firm and the backup supplier are examined through a decision-tree approach that takes disruption situations at all levels into consideration. We then design the backup supply contract, find the Nash equilibrium contract parameters, and identify the critical conditions under which such a contractual partnership will be valuable. The contract parameters we find are functions of the moments of the demand distribution, which are independent of specific demand distributions and are easy to be estimated in practice. Our numerical tests support our theoretical results and demonstrate the robustness of the contract with respect to various demand distributions.

1. Introduction

Having a backup or alternative supply resource in place prepares companies for unexpected primary supply disruptions. Numerous earlier success stories have indicated the effectiveness of using backup supply for coping with disastrous events; e.g., Nokia versus Ericson during the 2000 fire [13] and Chiquita versus Dole during 1998s Hurricane Mitch [10]. The importance of backup supply during the tsunami occurred in Japan on March 11, 2011 was witnessed worldwide. Two months after the disaster, Toyota North America, which received up to 15% of its parts from Japan, experienced a shortage of 150 critical parts and was forced to operate at only 30% of its capacity. On the other hand, General Motors, which identified 118 parts that needed to be monitored for shortages because of the tsunami, had resolved the problems with its backup plans and left only five parts on the watch list [9,15].

Backup supply is needed not only in cases of major primary supply breakdowns; it is also essential for purchasing firms to meet changing market demand in the complex global environment, where supply chain disruptions at all levels could happen, e.g., breakdown of an equipment, and shortage of labor during peak time. Large wholesalers such as Staples have adopted the dual sourcing approach for critical and strategic products. Specifically, Staples always keeps multiple suppliers at different geographic locations for notebook and photo paper supplies. Among the multiple suppliers, Staples works closely with two of them and maintains replenishment plans from both suppliers; whenever one supplier encounters disruption or there is a larger than normal order, Staples would call upon the other supplier for extra capacity [35]. Similarly, GE Aviation at Manchester, Connecticut employs two certified suppliers, located at West Hartford, Connecticut (CT) and Long Island, New York (NY), respectively, to perform a plasma spray coating on the Rolls-Royce vane assemblies. GE has contracts with both suppliers, which not only specify the agreed-upon promised turnaround times, but also state that GE can use the NY supplier as a backup to fulfill orders if the CT supplier (the primary source) cannot meet GE's demand on time. In the cases that the NY supplier is used as backup supplier, the contract agrees to compensate it by a premium on a per-lot basis. With such a sourcing strategy in place, the GE facility has been able to maintain continuous operations and to satisfy its customers' order in a timely fashion [6].

Having a backup supply is important; however, establishing a reliable backup supply chain is much more complicated than it appears. Ample literature suggests that a wide range of factors determine various decision-making situations, thereby leading to different action plans and desired outcomes. In this research, we focus on some common challenges in building a backup supply

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chain (e.g., [20,24]). These challenges include preserving a reliable, mutually beneficial relationship for both the buyer and the backup supplier, reserving an appropriate backup capacity, and ensuring backup supply in cases of primary supply disruptions. To combat these challenges, numerous companies develop well-structured partnership to ensure supply availability.

The business practices of Staples, GE and many other companies provide a glimpse of forging a buyer–backup supplier partnership. In this research, we generalize and study the backup supply chain structure based on these real business practices. This paper differentiates from the existing literature in the following five ways:

- Regarding the primary supplier's disruption, unlike many articles that assume the "all-or-nothing" pattern, we consider all levels of disruptions, which are classified into three categories – minor disruption, major disruption and complete shutdown.
- In order to maintain the backup supply partnership, we assume the purchasing firm keeps a small and consistent replenishment plan with the backup supplier during normal situations. Reciprocally, the backup supplier reserves a production capacity for the purchasing firm. Furthermore, we consider a piecewise nonlinear increasing production cost function for the backup supplier to determine available capacity. To our knowledge, our paper is among the first to explicitly model the relationship between limited production capacity and cost in a nonlinear format, as most published articles assume unlimited capacity for the backup supplier.
- In our study, the purchasing firm works with the backup supplier through a revenue-sharing contract to seek emergency capacity in case of primary supply shortfalls. This resembles some spirits of the price-only contracts studied by Sting and Huchzermeier [23] and Xu et al. [32]; but unlike a traditional revenue-sharing contract that requires one major parameter, namely the revenue-sharing fraction, we view and study the buyer's decision as a portfolio comprising of three variables: the reserved order quantity, the revenue-sharing fraction, and the purchase price from the backup supplier. Moreover, the revenue-sharing fraction is split into two tiers in response to the backup supplier's nonlinear, increasing production cost, which is a function of capacity levels.
- In terms of research methods, we adopt a combination of decision-tree approach and Nash game. The decision-tree method allows us to explicitly and clearly capture various decision-making scenarios and to obtain expected functions for subsequent analyses. Unlike most of the existing articles that try to obtain optimal decisions solely from the buyer's standpoint, we believe bilateral decisions in the presence of disruption risks should lead to mutual benefits to both partners. Consequently, we use Nash game to identify equilibrium solutions.
- In the end, we not only identify the buyer and the backup supplier's conditions under which the revenue-sharing contract is feasible, but also find that the equilibrium contract parameters are not influenced by the demand distribution. The closed-form parameters can be calculated with information about the inversed moment, the first moment and the second moment of a demand distribution.

2. Literature review

The importance of dual sourcing for critical and strategic items in a vulnerable and uncertain environment has been recognized for over a decade. A large amount of research interest has emphasized this theme, and numerous results have been presented in the literature, especially in the last 10 years. In this section, we first survey the research efforts of the past decade on dual sourcing under supply disruptions, and then review the contracts that have been studied for supplier–buyer collaborations in a dual-sourcing setting and various modeling approaches to highlight the contributions of this research.

To study different types of dual-sourcing supply chains in the literature, we categorize them by a combination of the following five profiles, which together determine a unique decision-making environment of each supply chain:

- *Product profile*: This profile describes the type and number of products or parts (e.g., single versus multiple) involved in a supply chain. The associated demands of the products are commonly assumed as either constant/fixed, or stochastic/probabilistic.
- *Disruption profile*: This profile contains parameters such as frequency or probability of disruption occurrence, "yield rate" or the percentage of an order that is actually delivered, etc. In most literature, these parameters are either assumed as constants or modeled as probability functions.
- *Supplier profile:* The two suppliers are often differentiated based on their geographic locations (foreign vs. local), wholesale prices (cheaper if more unreliable), capacity (constrained vs. unlimited), production costs, delivery lead time (constant vs. stochastic), reliability (from low, high to perfect), and whether any piece of this information is private or not. The relationship between the two suppliers can be considered as independent, competitive, or cooperative.
- *Buyer profile*: Buyers are different in term of their attitude towards risk; they can be risk neutral or risk averse. Some buyers carry inventory, some don't. Some buyers may consider to exert effort to increase the supplier's reliability (e.g., [30]), or to obtain more information about the supplier's parameters (e.g., [11,32]).
- *Decision horizon*: The length of the planning or decision horizon impacts the modeling approach and the issues to be addressed. The common theme in the existing studies assumes single supply/product cycle with a few exceptions that consider multiple periods or infinite time horizon.

Using the aforementioned five profiles, we have selected representative articles published since 2003 to illustrate the characteristics of different types of dual-sourcing supply chains in the literature. The research outcomes pertinent to single-period decision-making situations are reported and summarized in Table 1, where the empty cells indicate that the selected reference did not consider that factor specifically. It should be noted that because of multiple attributes inherent in each profile, the possible number of decision-making scenarios can be very large. This explains why the research efforts in this field to date have been extensive; it also indicates plenty rooms for future research. At the bottom of Table 1, we include this research to show the specific decision-making condition under investigation.

The research examining dual sourcing under disruptions in multi-period decision horizon has also received some attention, and both make-to-order and make-to-stock systems are considered. In the former, a representative effort is given by Sawik [19], where joint optimal supplier selection and order scheduling decisions that satisfy multiple customer orders over a planning horizon are found by a mixed integer program with conditional value-at-risk as a risk measure. The make-to-stock system under an infinite time horizon has received more attention, as inventory control can be adopted as a tactic to cope with supply disruptions. For example, Tomlin and Snyder [25] proposed a threat advisory