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Coordination in a triple sourcing supply chain using a cooperative mechanism under disruption

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ABSTRACT

In this study, we take into consideration a two-level supply chain consisting of a manufacturer and three suppliers under supply disruption from an unreliable supplier. The paper aims to determine optimal ordering policy for manufacturer as well as optimal pricing and production capacity for two reliable suppliers in situations where there is supply disruption and demand uncertainty for manufacturer. For this purpose, two competitive bi-level models have been developed in which the manufacturer is leader in games and reliable suppliers are followers. In these two models, reliable suppliers determine their optimal prices and production capacities in both competitive and cooperative game, respectively. Finally, in order to improve coordination among manufacturer and reliable suppliers under supply disruption, a cooperative approach among manufacturer and reliable suppliers have been developed. The obtained results indicate that cooperative approach under supply disruption, causes improvement in manufacturer's and reliable suppliers' profits. Other features of models and the optimal policies' structures have been explained through appropriate numerical problems and sensitivity analyses.

1. Introduction

In the last two decades, manufacturers have concentrated more on industry trends such as global sourcing, outsourcing, reducing their inventory level and reliance on their suppliers so that they can expedite their production process, decrease costs, improve efficiency and achieve competitive advantages (Li, Wang, & Cheng, 2010; Narasimhan & Talluri, 2009; Tang, 2006). Following these trends will increase length and complexity of supply chains (Harland, Brenchley, & Walker, 2003; Kleindorfer & Saad, 2005) and consequently make increase in vulnerability of organization from unplanned and unpredictable events that are resulted due to peripheral uncertainties. These events are called disruptions in supply chain literature. A supply chain disruption is unexpected and unpredictable event that interrupts the normal flow of raw materials and final products within the supply chain and finally leads to supply chain risks (Li et al., 2010) due to uncertainties created in supply, demand, cost etc. The organizations affected by such risk, will experience special and unusual situations as compared with their normal business activities (Wagner & Bode, 2006).

In order to reduce their costs of purchasing the raw materials, organizations would rather to choose only one source and try to maintain their mutual relationships with selected supplier (Davarzani, Zegordi, & Norrman, 2011); although by depending merely on one supplier, the manufacturer deals with risks of losing the total or part of the order. For instance, Philips' semi-conductor plant is interrupted by a fire accident for two weeks in 2000. Both Ericson and Nokia Companies had ordered their required components from this supplier. As a result, Erikson suffered about 400 million US $ loss due to its single sourcing policy, but Nokia, on the other hand, could decrease its loss to a minimum degree for their dual sourcing policy (Silbermayr & Minner, 2014). Providing all the orders from one source might incur lower costs, however in case of any disruption for the supplier and the loss of all or part of the orders will certainly bring irreparable damages and losses for the manufacturer such as interrupting production line and losing the market demand (Davarzani et al., 2011). The more dependency of the manufacturer on the supplier, the more break would be caused within the supply chain and more problems would arise in its performance.

Supply disruption is a kind of disruptions which are caused by some interruptive events such as financial restrictions, bankruptcy, human source problems, natural events, political issues, and war. Negative impacts which are resulted from supply disruption can affect performance of an organization; so it is reasonable for the

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organization to consider this fact that its main supplier may not be always available. Actually, single sourcing strategy increases the supply risk which is caused by a disruption. Different factors can lead to the unreliability of suppliers for a buyer. These factors are in fact sources of disruptions in supply chain that are presented as follows:

- Problems due to human resources like human mistakes or strikes in supplier organization, which can lead to delay in supply or imperfect supply of orders to the buyer.
- Problems due to environmental variations, which can make some events like flood, earthquake, and storm. Under such conditions, supplier would be unavailable completely and the buyer loses all orders.
- Problems due to political instability and legal restrictions, which can avoid cooperation of buyer with the supplier or limit their cooperation. Under such conditions, buyer may lose its supplier completely or a part of orders may be supplied for the buyer.
- Problems related to shipping goods from source (supplier) to destination (buyer) such as lack of required equipment to transport parts and issues due to roads of shipping, laws and permissions for shipping, which can result in uncertainty of buyer about receiving orders from the supplier completely (Kleindorfer & Saad, 2005; Vilko & Hallikas, 2012).

Above mentioned factors can result in absolute or partial unreliability of the supplier for a buyer. This fact leads the manager to select more than one source in order to decrease risk of loosing its orders (Kleindorfer & Saad, 2005; Silbermayr & Minner, 2014). One of the sources leads to supply chain disruption is political restriction (Friesz, Lee, & Lin, 2011; Kleindorfer & Saad, 2005). A disruption named sanction is caused by political restrictions which forbid companies in various countries to collaborate and cooperate with each other. In some cases, the sanction disruption can increase the possibility of unpredictable price increases and loosing main supplier. For instance, financial sanctions made interruption for Iranian automotive industry in receiving supplied parts from some unreliable resources (Davarzani et al., 2011; Zegordi & Davarzani, 2012).

In much of the researches performed in this field, one reliable and one unreliable supplier were considered for the buyer; however it seems that in such conditions working with several reliable suppliers would be much more preferable:

When the manufacturer work only with one reliable supplier, in case of the possibility of any disruption event, it is likely to suffer from costs due to the rise of the reliable supplier's price. Because of reducing negative impacts come from disruption, the manufacturer's dependency on reliable supplier is unavoidable. The reliable supplier is aware from the supply disruption and manufacturer's dependency on its. So, when the disruption probability goes up, the reliable supplier increases its price. In this case, selection of two reliable suppliers could decrease the dependency of manufacturer on one supplier and also make the price competition between two reliable suppliers for achieving more shares of manufacturer's orders (Jin & Ryan, 2012; Meena, Sarmah, & Sarkar, 2011). These results lead to reducing power of reliable suppliers in bargaining over price and finally make reduction in their prices. The second status is conceivable when a reliable supplier has insufficient capacity to supply all the manufacturer's orders. In such cases, manufacturer prefers to select two or more reliable suppliers for its orders.

The above considered situations are highly probable in some real cases. For instance, it is very likely that a manufacturer prefers to order its required parts from a global source because of its lower cost and higher quality. But sometimes a global source may not be fully reliable for manufacturer because of some restrictions and probable events which have been mentioned before. In this case the manufacturer may confront with supply risk due to disruptive events. Also, the manufacturer intends to keep working with unreliable global source because of some advantages like as quality. As a result, the manufacturer decides to choose one or more local sources a long with the global source because of their reliabilities. In one hand, selection of two or more reliable local source has much more advantages for manufacturer which have been mentioned before. In other hand, when the manufacturer decides to work with two or more reliable suppliers, occurrence of two different situations is probable: first, it is probable that reliable suppliers compete with each other to gain more orders from manufacturer according to their competitive factors. In this situation, competition among reliable suppliers avoids irregular increasing in selling prices (make reduction in selling prices) and hence is profitable for manufacturer. Second, it is highly probable that reliable suppliers have some information about unreliability of the main supplier of manufacturer. With this account it is also possible that reliable suppliers decide to make coalition and cooperate with each other against the manufacturer to achieve additional benefits from probable supply disruption; because cooperation among reliable suppliers makes increase in their selling prices and hence makes loss and reduces profit for manufacturer. With this account, it is beneficial for manufacturer to apply an effective and useful technique to prevent reliable suppliers from making coalition against itself. As a result, in this article we propose a cooperative contract between manufacturer and reliable suppliers in supply disruption situation.

In this study, a two-level supply chain consisting of a manufacturer and three suppliers have been considered. There is a possibility of disruption for the first supplier with given probability, so the manufacturer has considered two other reliable suppliers for its orders besides the first supplier which become unreliable now. Each of reliable suppliers has a primary capacity, so they will compete or cooperate with each other to gaining much more of the manufacturer's orders and to determine their sales prices and capacities. To extract optimal policies at first, the problems of manufacturer and reliable suppliers have been investigated separately and optimal policy of each member has been elicited by considering fixed policies of the others. Then, optimal ordering policy of manufacturer and optimal policies of reliable suppliers are determined by developing two bi-level models based on Stackelberg game theory. Along with multi sourcing mitigation strategy, a cooperative approach has also been used to improving the coordination among the manufacturer and reliable suppliers.

The remaining of this article is organized as follows:

In Section 2, multi sourcing strategy and coordination under disruption are studied and existing approaches for managing disruption in terms of these two contexts are reviewed. Then contributions of this study in comparison with the others are mentioned. In Section 3, problem of this study is described and then problems of manufacturer and reliable suppliers are formulated based on defined assumptions and notations. The "CmCm", "CmCo" and "CCo" models are investigated in Sections 4–6 respectively. Then computational study, sensitivity analysis and also limitations of the study and some directions for suture researches are illustrated in Section 7. Finally conclusions are mentioned in Section 8 with a brief summary of this study.

2. Literature review

Considering the focus of this paper, the literature review is conducted in terms of two aspects: multi sourcing strategy and coordination as two mitigation strategies for supply disruption management. He, Huang, and Yuan (2015) classified