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Managing global sourcing with disruption risks in an assemble-to-order system

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ABSTRACT

We consider an assemble-to-order (ATO) system that purchases components from both overseas and local suppliers. The overseas suppliers may be disrupted, while the local suppliers are stable. The objective is to study how the ATO system should utilize a flexible local sourcing policy to mitigate overseas disruption risks. We derive optimal sourcing decisions which are determined by local suppliers' cost ratios between pre-purchasing and replenishing and overseas suppliers' disruption probabilities and total procurement cost. Furthermore, we discuss the balance between cost and responsiveness, explore the value of the flexible local sourcing policy and propose a simple and effective heuristic policy.

1. Introduction

Due to the pressure of increasingly intense market competition, global sourcing is no longer just a choice but has already become a necessary strategy for assemble-to-order (ATO) systems (John, 2014; Accenture, 2007; Fu et al., 2006; Hsu et al., 2006). The most obvious driver of global sourcing is cost reduction (Basilio and Keith, 2007). According to an Accenture study of global sourcing projects, the net direct material cost savings for ATO system or manufacturers are between 10% and 20% (Paul, 2007). Another major benefit from global sourcing is acquisition of advanced R & D abilities and high-quality materials (Fu et al., 2006). The two benefits determine that global sourcing is a hybrid strategy that consists of overseas and local sourcing while not absolutely equivalent to overseas sourcing. In developing countries, such as China, India, and Brazil, local sourcing generates low costs while overseas sourcing brings high-quality components. In contrast, in developed countries, such as the USA and the UK, the benefit of the local sourcing is advanced technology while overseas sourcing is for low operating costs. Thus, how to effectively integrate overseas and local sourcing is the ATO systems' main problem when carrying out global sourcing (Yeniyurt et al., 2013).

Overseas sourcing extends supply chains and further makes ATO systems suffer more disruption risks. A recent survey by Deloitte shows that 71% of 600 executives from global manufacturing and retail companies view supply chain risk as a critical aspect when making strategic decisions and 48% of the executives reflect that the disruption events that cause negative results happen more and more frequently over the last three years (Kelly and Siva, 2013). Disruption risks can be classified to three levels according to occurrence probabilities: high-probability disruption events (e.g., stock-outs, yield problems, and logistics provider failure), medium-probability disruption events (e.g., loss of key supplier, severe weather, and labor issues), and low-probability disruption events (e.g., earthquake, volcano eruption, and hurricane) (Kouvelis et al., 2011). Potential disruption risks in overseas sourcing hinder the implementation of global sourcing. Thus, ATO systems must take measures to mitigate different degrees of disruption risks.

Different from overseas suppliers, local suppliers are more stable and can be closely monitored and managed. Due to the assembly

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structure, the supply risk in overseas sourcing has significant impacts on local sourcing (Pan and So, 2010). Thus, ATO systems should carefully manage the local sourcing to respond to possible risks from overseas suppliers. To achieve coordination between overseas sourcing and local sourcing, Lenove cooperates with some local suppliers with more expensive prices instead of some overseas suppliers with cheaper prices and requires local suppliers to provide responsive supply (Accenture, 2013). Then, how should the ATO systems rely on the high responsiveness of local suppliers to mitigate the overseas suppliers' different degrees of disruption risks? This is the main research problem in our paper. Under the support of responsive supply, ATO systems can stock an appropriate amount of local components in advance, and then replenish the shortage components to respond to changes in supply and demand conditions (Fang et al., 2008; Yao et al., 2013). Then, based on this flexible sourcing policy, how should the ATO systems determine optimal procurement quantities for multiple complementary components? What's the value of this flexible sourcing policy?

Motivated by the global sourcing environment discussed above and to answer the proposed questions, we consider an ATO system's global sourcing problem when facing a single-period uncertain demand for a single product. The product consists of multiple components that are purchased from both overseas suppliers and local suppliers. There exist possible disruption risks in overseas sourcing, while there is no supply uncertainty in local sourcing. To cope with the potential disruption risks in overseas sourcing, the ATO system adopts a flexible local sourcing policy. That is, an appropriate amount of local components are purchased (called *pre-purchasing*) at lower prices before the possible disruption events and uncertain demand are realized, and the shortage components are replenished (called *replenishing*) at higher prices after actual demand is realized if overseas suppliers are not disrupted. Toyota operates a representative ATO system that adopts a similar local sourcing policy. According to Barnes et al. (2003), the local suppliers of Toyota are located close to points of delivery and are required to deliver frequently according to the assembly quantity. Similar flexible sourcing policies can also be found in some academic literature, such as Fu et al. (2009), Xiao et al. (2010), and Wu and Zhang (2014).

This paper contributes to the extant literature in the following aspects. First, we investigate the joint sourcing decisions from unreliable overseas suppliers and reliable local suppliers for an ATO system. We focus on how to utilize the local suppliers' high responsiveness to mitigate the overseas suppliers' different degrees of disruption risk. The results show that the ATO system should manage the local suppliers based on their cost ratios between *pre-purchasing* and *replenishing* to achieve a flexible local sourcing policy. In addition, the sourcing decisions should be adjusted according to overseas suppliers' disruption probability and total procurement cost. Second, our results shed lights on the value of the flexible local sourcing policy. The flexible local sourcing can mitigate various degrees of disruption risks and increase the ATO system's profit. Third, we propose a simple heuristic policy which is also based on the responsiveness of local suppliers to approximate the optimal flexible policy. The heuristic policy can achieve most of the improvement brought by the optimal policy and is easier to be carried out.

The remainder of this paper is organized as follows. Section 2 reviews relevant literature. Section 3 explains the problem's formulation and notations. In Section 4, we study the optimal sourcing decisions when market demand is deterministic and stochastic. In Section 5, we discuss the balance between cost and responsiveness, explore the value of the flexible local sourcing policy, and propose a simple heuristic policy. We present this paper's conclusions in Section 6. All proofs are provided in the Appendix.

2. Literature review

Our research falls within the literature on ATO systems. We refer readers to Song and Zipkin (2003) for a comprehensive review of some related research of ATO systems. Because we study a single-period ATO system, the following review focuses on single-period problems. A number of research papers study components' stocking policies for single-period assembly systems. When product price depends on delivery time, Hsu et al. (2006) study optimal stocking quantities of components with constant but different procurement lead times. The required quantity of product can be delivered in multiple partial shipments in this paper. Hsu et al. (2007) extend the model of Hsu et al. (2006) to consider the situation where the required quantity of product can be delivered in only one full shipment. Different from these two papers, Fu et al. (2006) consider components' stocking policy when the assembly capacity is limited and time dependent. Jiang (2015) studies the impact of sequential sourcing on the ATO system's component stocking policy.

All of these papers consider a one-time procurement policy. Our work is more related to a recent body of literature considering the replenishment policy after the uncertain demand is realized. Fang et al. (2008) consider a decentralized ATO system's component procurement problem. The ATO system manages suppliers under a vendor-managed consignment inventory scheme and requires suppliers to replenish the shortage components after uncertain market demand is realized. Fu et al. (2009) extend the model in Hsu et al. (2006) to study the impacts of components' replenishment by expediting on the ATO manufacturer's stocking policy. When assemble-in-advance strategy and emergency replenishment of components are allowed, Xiao et al. (2010) analyze optimal sourcing and assembly decisions for an ATO system with uncertain assembly capacity. Yao et al. (2013) also study ATO systems' component stocking problem when component replenishment is adopted. However, they focus on the impact of two replenishment channels that have different prices and lead times. Different from these papers, we consider a global sourcing environment and components are procured from both overseas and local suppliers. Only local components' replenishment is considered due to the high responsiveness of local suppliers while low responsiveness of overseas suppliers. Thus, we focus on how the ATO system should utilize local suppliers' responsiveness to collaborate the sourcing of overseas and local components.

Our work is also related to the stream of literature on supply disruptions. Snyder et al. (2016) review quantitative models on supply chain disruptions in Operations Research/Management Science literature. There are numerous papers to study how to mitigate supply disruptions in a single-product's sourcing problem. Some papers study different disruption management strategies for firms, such as Tomlin (2009), Tomlin (2006), Hu and Kostamis (2015), Cui et al. (2016), and Zhen et al. (2016). Some other papers focus on the contracting and incentive issues between the buyer and the seller in a decentralized supply chain setting, such as Xia