Contingency Inventory Reservation for Low-Probability High-Impact Events

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ABSTRACT

This article investigates reservation contracts for contingency inventory management between two buyers and a single supplier under a game theoretic framework. Two channel structures are considered in this context. In the first setting, the buyers simultaneously move to offer reservation fees to the supplier, who in turn, decides on the inventory amount she wants to carry for each buyer. In the second setting, the supplier moves first and offers nonrefundable-deductible reservation fees for the buyers, who respond with their respective reservation quantities. By reserving through a shared supplier, the buyers enable a contingency inventory pool which alleviates overage risk for the supplier and enables availability of products after low-probability high-impact events. Conditions for successful implementation of contingency reservation contracts are investigated. The results obtained for both channel structures were contrasted. It is shown that in a market where the buyers have more negotiation power, reservation contracts are more likely to achieve inventory buildup under relatively lower event probabilities.

KEYWORDS

Backup Inventory, Contingency Inventory, Game Theory, Reservation Contracts

1. INTRODUCTION

Firms must take low-probability big-impact events such as natural disasters and supply disruptions into consideration in their supply planning since they might cause crippling and irreversible effects on businesses. The negative effects of such disasters on global companies might be quite damaging for supply chain operations. For example, Toyota suffered from severe parts shortages when the magnitude-9.0 earthquake and tsunami destroyed many factories in northeastern Japan on March 11, 2011. The company’s global production in March 2011 dropped by 29.9% from a year ago, while its sales in Japan tumbled 45% for the month (usatoday.com 2011). During Hurricane Isaac about 1.3 million barrels per day of crude oil production were shut down and about 3 billion cubic feet per day of Gulf natural gas production were stopped according to the Bureau of Safety and Environmental Enforcement. This resulted with about 564,000 customers left without power in Alabama, Florida, Louisiana, and Mississippi (www.eia.gov 2012). In October 2012, Hurricane Sandy damaged the Atlantic coast that left 8 million people without power, thousands of flights were canceled, businesses

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were shut down for days and billions of dollars were lost. 1.5 million businesses located across 19 counties in the tristate region were affected by the Hurricane (dnb.com 2012).

In addition to the negative effects, natural disasters may create opportunities for businesses. Companies that give adequate focus on flexibility in procurement can attain growth and increased profitability in such cases (Singh et al., 2014). For instance, consumables such as flashlights, batteries, portable generators, and other emergency supplies are the most common necessities during and after a hurricane. When Hurricane Frances was about to hit Florida’s Atlantic Coast in 2004, Wal-Mart executives turned that situation into a great opportunity by using the historical shopper data stored during the past hurricane seasons. Their data-driven tool with predictive technology enabled the company to predict the customer’s behavior, identification of top-selling items and their expected demand surge during the hurricane season. By predicting the demand increase, the company was able to replenish the shelves timely for certain products in its stores in the path of a hurricane (www.nytimes.com).

The disruptions in supply chains due to the catastrophic events create opportunities for smaller agile firms to capture market share from larger flexible firms. For instance, when the banana plantations in Central America were destroyed by the Hurricane Mitch, Dole lost 4% of its market share to its much smaller rival Chiquita. While Dole had no alternative supply source, Chiquita was able to source banana just-in-time from as far as Australia turning this disruption into an opportunity (Monllor and Altay, 2016).

The procurement strategies and models for suppliers and buyers are mainly shaped by the demand environment in the supply chain (Gravier and Farris, 2012; Truong, 2016). In this article, we focus on procurement for demand surges that result after low-probability high-impact events. Specifically, we consider a game theoretic analysis of a decision problem of two buyers and a supplier who enter into a contract for contingency stock to be used in case a low-probability high-impact event such as a hurricane or an epidemic occurs. The buyers operate their businesses in independent markets. During the regular season, each buyer procures the same product from their own separate suppliers. Typically, the low-probability event creates a demand surge that cannot be satisfied from the buyers’ nominal inventories. Consequently, the buyers consider reserving backup inventory from a shared supplier so as to pool their overage and underage risks and meet their low-probability demand surges. In this context, our study focuses on the reservation contracts between the buyers and the contingency supplier. In the general setting, the buyers make nonrefundable yet deductible fees to reserve contingency inventory from the supplier. Once the reservation quantities are set, the buyers have the option of exercising their reservations in the event of the low-probability demand surge. If a buyer needs to exercise her reservation, the reservation fee paid upfront is deducted from the supplier’s wholesale price. The fee for a reserved but not exercised unit is not refundable, that is, the supplier retains the reservation fee in return for the overage risk that she faces. In this setting, when a buyer requests more inventory than the supplier’s reserved amount for her, she is charged a surcharge penalty in addition to the wholesale price. The supplier can satisfy a buyer’s demand from the other buyer’s reservation only if the latter one does not experience the low-probability event.

We consider two cases in terms of the leadership roles of the parties in the channel. In the first case, the buyers move first and offer nonrefundable-deductible reservation fees that they are willing to pay for reserving contingency inventory and the supplier follows by deciding on the inventory amounts that she builds for each buyer. In the second case, the supplier moves first and announces her unit reservation fee for the buyers, who respond with their respective reservation quantities. Both cases may emerge depending on the negotiation powers that the parties have in the channel. In both cases, the buyers have the option to exercise their reservations if the demand surge due to the low-probability event occurs.

We analyze the equilibrium reservation outcomes for the two settings described above. Specifically, we investigate how the equilibrium outcomes depend on event probabilities, buyer margins, and supplier’s overage cost. We identify the conditions under which risk pooling via a
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