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Post-disaster grain supply chain resilience with government aid

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ABSTRACT

Assessing the disruption and resilience of the agricultural grain supply chain is critical to ensure grain supply and stabilize grain price in the final market. This research proposes a quantitative model to analyze how a grain processor regains robustness when supply is disrupted by a natural disaster upstream, and how this disruption affects grain retailers downstream. Two supply chain recovery methods, contingent sourcing and government aid, are considered for grain processor recovery. The results show that (1) a processor prefers timely full recovery, and (2) government aid as an intervention means is indispensable but cannot fully replace the backup supplier.

1. Introduction

Risk and uncertainty are ubiquitous in agriculture supply chain (SC). Particularly, when extreme weather events like hail storms, thunderstorms, tornados, hurricanes, and snowstorms impact agriculture, yield of agricultural products is markedly reduced. For example, corn production declined by up to 30% in some growing regions in Jilin Province, northeast China, due to extreme winds and insect infestations earlier in 2012. A drought in Russia in 2010 reduced grain output by about one third, and the per unit area yield of maize in America fell by 12.7% due to a few months of drought in 2012. The Dongting Lake area, located in northern Hunan Province, China, is prone to natural disasters. Floods, droughts, and pest infestations have occurred frequently, adversely affecting grain production (Jaffee et al., 2010; Zhong et al., 2010; Sun, 2013).

Post-disaster agricultural SC disruptions have become a crucial global issue. A most recent natural disaster, Typhoon Haiyan (Yolanda), made companies with agricultural SC located in the disaster region in Philippines face serious risks of disruption. According to Maplecroft estimates, some 120,000 metric tons (MT) of sugar and 131,600 MT of rice were damaged, affecting supply in the "medium term" (Alegado, 2013; Huh and Lall, 2013). Disruption may occur in any links of the SC from upstream to downstream. Six SC disruption modes are identified, including disruptions in supply, disruptions in transportation, disruptions in production facilities (internal), disruptions in communication (or information) flow, disruptions in human resource capacity, and freight breaches. Therein, supply disruption can cut off cash flows and halt the operation of an entire SC (Sheffi et al., 2003; Hou et al., 2010). Since natural disasters are very common upstream in the agricultural SC, this study mainly focuses on supply disruption caused by reduced grain production due to natural disasters.

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Supply disruption because of reduced grain yield inevitably disrupts the grain supply chain (GSC) when no countermeasures are adopted, and eventually increases the market grain price. According to the food price index of the Food and Agriculture Organization of the United Nations, food prices started rising again in June 2010 after the food price crisis of 2007–08, with international prices of maize and wheat roughly doubling by May 2011. Extreme weather events helped raise food prices in 2007–08 and 2010–11, as mentioned by 2011 Global Food Policy Report. Intense and frequent natural disasters such as droughts and floods, resulting from climate change can decrease yield significantly, such that prices and market volatility increase (Torero, 2011). Moreover, since grain is a strategic commodity with special status, increases in grain prices due to disruption of the GSC can induce panic buying and social unrest. Panic buying by government can be seen easily in the world grain market in January, 2011, especially for developing nations and grain importers, like Algeria, Saudi Arabia, and Bangladesh (Evans, 2011). For instance, Bangladesh, one of the world's largest rice importers, raised its import target for the grain to 1,200,000 tonnes, up from an initial estimate of 600,000 tonnes. And Saudi Arabia planned to double the size of its wheat stocks to cover the demand of a year.

To stabilize grain prices on the domestic market, the GSC must recover quickly after supply disruption by natural disasters. As a major member of a GSC, the grain processor connects the grain producer upstream and the grain retailer downstream. Hence, the rapid recovery of the grain processor after natural disasters is extremely important. Mitigation or contingency strategies that enhance general SC resilience, such as multiple sourcing, inventory management, product substitution, and backup suppliers, have been proposed and systematically investigated by several researchers, which can be applied to the GSC resilience (Tang and Tomlin, 2008; Lu et al., 2011; Qi, 2013).

Furthermore, government aid is often used as an effective method for the GSC resilience. In fact, stabilization of grain prices is an important element of food policy in many countries, including those in the developing and developed worlds. Panic buying of governments in the world grain market is mainly to secure the domestic demand if they feel social unrest is looming because of rising domestic food prices. Metrobank in Philippines provided adequate supply of rice and sugar coupled with price caps after Typhoon Haiyan to cushion the pressures of steep increase in the prices of these commodities (Evans, 2011; Alegado, 2013). In China, stabilizing grain prices is an important goal for the Chinese government, and the government really comes into play in the grain market when grain prices are rising (Li and Zhang, 2012). For instance, although international grain prices fluctuated dramatically in 2008, grain prices in China remained stable, almost unaffected by the world food price volatility.

Government may intervene in the GSC and demand market in a public mode mainly by purchasing grains from the market or selling grains to the market. Protective purchase prices and limited sale prices of the main grain varieties are formulated by the government to avoid excessive volatility. When market prices for grains fall to near or below the protective price, the government will purchase grains from the market and stockpile them to restore reasonable market prices. When market prices for grains rise to near or above the limit price, the government will sell its reserves on the market to keep prices acceptable. In China, the government has developed the minimum purchase prices policy for grain, including wheat and rice, since 2004 (Yang et al., 2008).

Raw grains possessed by the government can be sold on the market by public auction, based on the policy for minimum purchase prices for staple grains. The auction base price has a certain markup (mainly including storage cost and minimum profit) on minimum purchase prices. According to China's Department of Agriculture, 34 auctions were held for wheat reserves between November 3, 2006 and July 26, 2007 (Yang et al., 2008). This auction behavior can be interpreted as a support for the resilience of GSC members from disruptions by the government.

This study attempts to investigate the optimal solution for the contingency tactics of GSC when grain processors face shortages in their SC due to natural disasters. It offers simplified models to illustrate the two scenarios of GSC resilience under supply disruption: with or without government aid, and aims to answer the following research questions: (1) What is the optimal recovery strategy for a processor without government aid? (2) With government aid, how does a processor allocate total loss between the two recovery methods? (3) Should a government intervene to help GSC members when they face supply disruption? (4) Can government aid help SC members restore their robustness quickly and thereby their profit? This is one of the first attempts to tackle agricultural SC disruptions and resilience in SC disaster management and related areas.

The remainder of this paper is organized as follows. Section 2 briefly reviews literature. A detailed description of the problem and model assumptions are given in Section 3. In Section 4, models are constructed to analyze the different scenarios in the recovery process. Numerical examples and sensitivity analysis are conducted and the associated results as well as managerial implications are given in Section 5. Concluding remarks and suggestions for future research are given in Section 6. All the proofs for analytical results are in the Appendix A.

2. Literature review

A large body of literature shows risk management for SC disruption in the industrial field. Interested readers may refer to Kleindorfer and Saad (2005) for a thorough reading. This study mainly reviews articles from the following aspects: SC risks and disruptions in agricultural fields; mitigation or contingency strategies for SC resilience; and government aid in the GSC and grain market.

According to Jaffee et al. (2010), the main activities for SC entities in an agricultural SC include supply, farm production, processing, and domestic or international logistics. Farmers and firms in an agricultural SC face risks from multiple sources, summarized as eight types: weather-related risks; natural disasters (including extreme weather events); biological and