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Supplier hoarding, government intervention, and timing for post-disaster crop supply chain recovery

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ABSTRACT

This work presents a multi-methodological approach to address the issue of post-disaster crop supply chain recovery under the influences of government intervention and supplier hoarding intention. A conceptual model which characterizes the antecedents of supplier hoarding intention is proposed, and validated using survey data. Grounded in the empirical study, an analytical model is then proposed for decision analysis of a two-tier crop supply chain recovering from post-disaster supply disruptions. Analytical results indicate that hoarding behavior reduces the time taken by supply chain members for supply recovery; and however, contributes to mixed effects on the expected profits of supply chain members.

1. Introduction

Due to the ubiquity of natural disasters around the world, post-disaster crop supply chain disruptions become a challenging global issue. For example, the great earthquakes recently occurring in Nepal in April and May of 2015 had caused 3.5 million people in urgent need of food assistance due to nation-wide summer crop plantations damaged and subsequent crop supply disruptions, according to the approximation of The Food and Agriculture Organization (FAO) of the United Nations (Prasain, 2015). A severe heat wave hit Russia in 2010, which caused the national grain harvests reduced by one third, and prices risen by 19%. The resulting economic losses were estimated to be US$15 billion; and the knock-on effect was crop export restrictions in Russia, which led to global wheat supply shortage and anomalous price increases (Kolesnikova, 2010; Kramer, 2010). Similarly, a destructive drought lasting couples of months in 2012 devastatingly disordered the domestic crop supply and demand markets in the US, contributing to total agricultural losses of USD 7.62 billion. (Vergara and Zuba, 2012). Roughly 24 million hectares of crop land in China are under drought at various times each year, resulting in an annual reduction in grain production of about 26 million tons (accounting for 5.2% of China's grain production), and subsequent region-wide grain supply disruptions across numerous provinces accounting for 5.2% of China's grain production, Apparently, disaster-induced crop supply disruptions ubiquitously exist, and thus, timely recovery from post-disaster crop supply disruptions becomes a global issue challenging to not only crop supply chain members but also governments around the world.

Due to the urgency for supply chain recovery after a disaster, various governmental instruments have been used to mitigate the impact of crop supply chain disruptions, particularly the loss of farmers (Balis, 2011; Chhotray and Few, 2012; Fernandez-Gimenez et al., 2012; Watts and Bekkerman, 2012; Akter and Mallick, 2013; McGuire and Sperling,

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2013). For instance, the US government funded diverse aid programs for nearly a century, including the new Supplemental Revenue Assistance Payments (SURE) program, which has the greatest outlays (*e.g.*, $2.04 billion in 2008), markedly exceeding the $1.1 billion average in annual disaster payments between 1970 and 2008 (Watts and Bekkerman, 2012). The SURE program provides disaster insurance by guaranteeing revenue to farmers after natural disasters (Watts and Bekkerman, 2012). Furthermore, food-grain price stabilization has been used by governments since 1960s to cope with natural and man-made food crises after disasters (Cummings, 2012). For example, weather-related disasters have resulted in the loss of 50 million tons of grain each year, according to the China Meteorological Administration (Balis, 2011). The Chinese government not only provides farm subsidies (*e.g.*, RMB12.9 billion (US$2 billion) in 2011) to boost agricultural production, it also provides relief to farmers and populations disproportionally impacted to stabilize market prices.

Differing from other industries, crop supply chains have the following operational uncertainties, each of which can lead to challenges and difficulties in managing post-disaster crop supply chains.

First, agricultural production is cyclical and significantly influenced by the natural environment. Unlike manufacturing industries, which can manufacture products all year, agriculture production is typically outdoors and seasonal. Once the crop supply is damaged by a natural disaster (*e.g.*, floods and typhoons), recovery of the supply after the disaster, ranging from waste removal to re-planting is extremely time consuming and carries a certain amount of risk, thus increasing the challenges to crop supply chain recovery.

Second, post-disaster shockwaves influence the logistics and financial flows, ranging from crop farmers to end-customers. These shockwaves are often speedy as most crop products, particularly crops that are used daily, require continuous supply to meet daily demand. From psychological and behavioral perspectives, the behavioral phenomenon of stockpiling crops is usually observed in both the crop supply and the demand markets, resulting from speculations about supply uncertainty. This argument is particularly germane when a crop supply at its origin is markedly reduced after a disaster, causing unusual fluctuations in end-market prices and demand (Gilbert, 2010; Tadesse et al., 2014).

Third, although government intervention for post-disaster agriculture recovery is indispensable, most government aid is allocated directly to farmers for the recovery of disaster-affected areas rather than to crop supply chains for crop logistics recovery. As such, farming recovery can be regarded as a mid-term/long-term supply-oriented agricultural recovery strategy, which may not be applicable for responding rapidly to end-customer needs and alleviating the short-term market volatility during supply chain disruptions. In contrast, post-disaster supply chain recovery is vital to stabilizing market prices and alleviating end-customers' panic when faced with shortages. Furthermore, issues related to crop supply chain recovery after a disaster may become increasingly complex when influenced by governmental instruments. For example, in addition to price regulation, the Chinese government intervenes in grain markets by purchasing grains from markets when market prices fall below a protective level, and selling stockpiled grains back to markets to avoid excessive volatility in grain prices (Yang et al., 2008). During the post-disaster agriculture recovery period, the Chinese government may temporarily act as a "backup" supplier, strategically providing help for crop supply continuity and price stabilization (Jha and Srinivasan, 1999). Therein, solutions for crop supply chain members to efficiently and effectively respond to such government instruments remain unclear.

Considering the importance of addressing such a global issue as crop supply chain recovery from post-disaster supply disruptions, this work proposes a multi-methodological approach to decision analysis for the recovery of a two-tier crop supply chain from post-disaster supply disruptions under the influences of government intervention and supplier behavior uncertainty attributed to hoarding intention. Specifically, this work proposes and empirically tests a conceptual model which characterizes the relationship between stockpile hoarding and its antecedents. Grounded in empirical findings, this work further proposes an analytical model to seek for the optimal solutions for the timing of supply recovery in the two-tier crop supply chain for cases with and without the government aid by selling stockpiled crops to the dyadic supply chain members (*i.e.*, crop distributor and retailer). It is worth mentioning that this work aims at the instrument of selling stockpiled crops which is one type of intervention of the many available to governments. Nevertheless, we speculate that such a short-term government instrument may contribute to not only the direct effect on procurement costs but also the indirect effect on hoarding intentions of crop supply chain members, as characterized in the proposed conceptual model, thus influencing the decisions and performance of a crop supply chain recovering from disaster-induced supply disruptions.

The remainder of this paper is organized as follows. Section 2 reviews literature related to the position and contribution of this work. Section 3 describes the proposed conceptual framework, including hypotheses and test results of an empirical study used to verify the characteristics of supplier intention to hoarding. Grounded in the proposed conceptual framework and validated by test results, Section 4 presents a normative model for decision analyses of crop supply chain recovery from a disaster-induced crop supply chain disruption with and without government aid. Section 5 conducts quantitative analyses to provide additional insights gained from numerical results. Conclusions are finally drawn in Section 6, along with recommendations for future research.

2. Literature review

Post-disaster supply chain recovery, an emerging area of study, copes with supply chain disruptions caused by such contingencies as equipment breakdowns, strikes, terrorism, political instability, and natural disasters (Chopra and Sodi, 2004; Simchi-Levi et al., 2014). Several pioneering researchers provided thorough reviews (Sheffi, 2005; Tang, 2006; Snyder et al., 2010; Schmitt and Snyder, 2012) of supply disruption risks. This work mainly reviews literature in three streams, each

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