



Penalty and financial assistance in a supply chain with supply disruption [☆]



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ABSTRACT

In a supply chain, when the supply is hit by an unexpected disruption, the supplier may face certain financial difficulty to resume normal production, causing a supply shortage as well as a loss to the manufacturer and the entire supply chain. Combining a penalty term in writing contracts with the provision of financial assistance is the “carrot and stick” approach used by a manufacturer to deal with supply disruption. This article investigates how the manufacturer, in a better financial situation, may use ex-ante penalty terms and ex-post financial assistance to compel the supplier to recover its production capability as much as possible. We find that, the MS (integration of financial assistance and the non-delivery penalty) is the best strategy for the manufacturer in most situations, but it is not a win–win strategy. An interesting result contrary to the conventional wisdom, is that the optimal delivery quantity for the supply chain under the centralized decision-making is less than that under the decentralized decision-making.

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1. Introduction

A supply chain could suffer from major supply disruptions caused by fire, earthquake, terrorism, labor strikes, manufacturing quality failures, supplier bankruptcies, and so on. A supply disruption not only directly affects the supplier, but also causes significant loss to the downstream of the supply chain. For example, in February 1997, a fire in a Toyota brake-supplier plant led to a two-week shutdown of 18 Toyota plants across Japan, resulting in losses amounting to US\$195 million [1]. In March 2000, lightning caused a fire that shut down the Philips semiconductor plant in Albuquerque, New Mexico, leading to a shortage of components for both Ericsson and Nokia. As indicated in its 2001 annual report, Ericsson announced a major loss of about \$400 million, which can be directly attributed to the supply interruption [2]. In March 2011, one of the strongest earthquakes hit Japan, triggering a massive 23-foot tsunami and a nuclear crisis, which subsequently led to a

global supply disruption. For instance, the big three Japanese automakers, Toyota, Honda, and Nissan, suspended production at their respective domestic facilities due to earthquake damages and disruptions in the flow of auto parts from their suppliers [3]. Nissan, one of the heavily affected companies, had at least nine of its Japanese vehicle and parts factories and 35 suppliers affected by the disaster [4]. Supply disruptions often cause serious damages to the operational performance and lead to losses of shareholders' wealth and reputation [5]. When backup suppliers are not immediately available, the key factor for the supplier in overcoming supply disruption is to quickly restore its normal production capability. However, in many cases, the disrupted supplier may be unable, or at least reluctant, to do so because of many reasons, such as financial constraints.

In practice, a lot of operational tools can be used to manage disruption risk. As Tomlin and Wang [6] state, there are five major disruption risk management strategies: inventory, supply diversification, backup supply, demand management and supply chain strengthening. They also analyze each strategy's pros and cons and suggest that managers should align the strategy with the operational environment. Except supply chain strengthening that seeks to reduce the likelihood of supplier-related disruption, all other

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four strategies focus on minimizing the negative consequences of supply interruptions.

Besides the above five strategies, demanding a penalty as a type of default clause is another common ex-ante strategy in disruption management. Generally speaking, a default clause clearly states what actions can be taken if a partner fails to fulfill its obligation. In the context of a supply disruption, when the supplier breaches the contract by failing to supply goods or perform a service as promised, the manufacturer can claim a compensation or penalty for the damage under a default clause. The penalty strategy is relatively easy to implement, partly because it does not require coordination with the supplier after a disruption. However, a question naturally arises: Is a penalty term an effective strategy to protect a manufacturer from the losses brought about by a supply disruption?

Based on the information from interviewing industry managers, we learn that, to maintain supply chain partnership, the purpose of penalizing suppliers under a disruption is to push the supplier to restore normal supply as soon as possible, rather than to exploit the supplier via collecting penalty. Indeed, a high penalty could bankrupt the supplier, which would in turn hurt the manufacturer from the perspective of long-term sustainability. To this end, the manufacturer must also consider other rational options aside from a penalty clause.

Strengthening supply chain, one of strategies shown by Tomlin and Wang [6], can include the ex-ante and ex-post approaches. While the ex-ante approach means that supply chain enterprises can cooperate with each other to reduce the frequency and/or severity of supply problems, the ex-post treatment suggests that the cooperation between supply chain partners occurs after a disruption in order to reduce loss by helping the disrupted company recover production. In recent years, the importance of mutual assistance between supply chain enterprises as an attractive ex-post treatment strategy has been recognized. In the case of a supply disruption, reasonable assistance can enhance the sustainability of supply chain with lower costs. One main approach is through financial assistance, which includes loans, donations, and trade credits. Some cases of financial assistance extended to disrupted suppliers are listed below.

- When the Indonesia Rupiah was devalued by more than 50% in 1997, many Indonesian suppliers were unable to pay for the imported components or materials, and hence, were unable to fulfill orders for their customers. Li and Fung (www.lifung.com), the largest trading company in Hong Kong for fashionable goods provided financial assistance such as credit lines, loans, and so on, to these affected suppliers, thus ensuring continued production and delivery [7].
- In 2009, auto-parts maker American Axle & Manufacturing (AAM), the main supplier of General Motors, was severely affected by the decline of the U.S. auto industry and the subsequent reduction in vehicle sales. General Motors expedited a US\$100 million loan to AAM to help the latter avoid bankruptcy [8].
- In 2012, Autodom Ltd., a supplier of parts to local units of Ford, Toyota and General Motors, shut down its plants in two Australian cities because of the falling demand for locally-built vehicles and increasing operation cost. Ford and General Motors agreed to underwrite US\$6.5 million debt for Autodom to evade shutdown [9].

The objective of this research is to investigate the above mentioned complementary strategies to ensure continued production in a supply chain suffering from a supply disruption. The first strategy is the ex-ante penalty strategy (PS) in which the manufacturer determines a penalty term for any future supply shortage

to reduce the shortage loss and compels the supplier to recover production as soon as possible. The second strategy is the ex post financial assistance strategy (FAS), in which the manufacturer may loan money to the supplier who suffers a capital constraint after the disruption. It is also possible to employ a mixed strategy (MS) which integrates both PS and FAS.

To compare the above three strategies, we model a single-period supply chain consisting of a supplier and a manufacturer with demand uncertainty. As part of the procurement contract, the manufacturer can set up a penalty term, preventing the profit loss caused by the supplier's delivery shortage, wherein the penalty level is acceptable to the supplier so as not to drive the supplier into bankruptcy. Once a supply disruption occurs, the supplier exerts efforts to recover his production, measured by the delivery quantity. If the supplier suffers from capital constraint in the process of production recovery because of higher production cost, the manufacturer can offer financial assistance to the supplier by loaning money to the supplier. In the Stackelberg game (see Tang et al. [10]), the manufacturer as the leader decides the interest rate, and then the supplier determines the capital to borrow and the delivery quantity as a response. We study the delivery quantity of the supplier, the penalty and financial decisions of the manufacturer and the strategy preference problem.

We find that, in most situations, the MS is the best and robust strategy for the manufacturer. However, the MS strategy is not necessarily mutual beneficial, because the penalty term can hurt the supplier, who instead prefers the FAS. We also show that contrary to the case without a disruption, the delivery quantity under the centralized decision-making can be less than that under the decentralized decision-making when a disruption occurs. We further demonstrate that, when the supplier is capital-constrained, both the supplier and the manufacturer benefit from the financial assistance. Hence, offering financial assistance leads to a win-win outcome for both supply chain partners.

The rest of the paper is organized as follows. In Section 2, we provide a brief literature review. The model is described in Section 3. In Section 4, we present a benchmark case where the supplier and the manufacturer use a quantity discount contract to coordinate the supply chain. Sections 5 and 6 investigate the PS, MS and FAS, respectively. Sections 7 and 8 analyze the strategy preference of the manufacturer as well as parameter sensitivity, respectively. Section 9 concludes the paper.

2. Literature review

Supply chain disruption has attracted interest from both researchers and practitioners of operations management. Disruption, usually infrequent and temporary, causes a significant change to the system when it occurs. Hendricks and Singhal [5] provide a diverse set of supply disruption examples, proving that ignoring the possibility of supply chain disruptions can have devastating economic consequences. Yu and Qi [11] present a thorough coverage of how disruption management concept is applied and what impact it makes.

Our study is particularly related to studies that focus on supply disruption (for reviews, see Tang [7] and Snyder et al. [12]). Based on a summary of relevant supply chain risk categories done by Heckmann et al. [13], supply disruption is regarded as a type of network risk. As we have mentioned earlier, in practice, various operational tools can be used to leverage supply disruptions, such as multi-sourcing, carrying inventory, alternative supply sources and backup production options, mutual assistance and contract design and coordination.

A large body of literature studies multi-sourcing, carrying inventory and backup production to hedge against supply

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