



Operational causes of bankruptcy propagation in supply chain

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ABSTRACT

With the increasing interdependence among supply chain members, bankruptcy of a supply chain member may be caused by operational decisions of other members. To investigate how bankruptcy occurs and propagates in supply chain networks, we build a multi-agent simulation model for a two-stage supply chain that consists of multiple upstream manufacturers and multiple downstream retailers. Based on the developed simulation model, we study impacts of various operational parameters and decisions, such as horizontal competition among retailers, order allocation strategies of retailers, wholesale price of manufacturers, characteristics of market demand and number of retailers, on bankruptcy propagation. Since many operational decisions of a firm are made under financial constraints, we also investigate the linkage between firm's operational risks and financial decisions (e.g., the maximal risk of cash flow that a member is willing to take, and the up-front payment proportion of retailers in a two-period payment policy). Experimental results reveal that operational interactions between supply chain members and operational decisions made by supply chain members are important causes of bankruptcy propagation, but impacts of these operational parameters and decisions depend on financial decisions. These observations indicate that supply chain members can moderately hedge their operational risk through financial decisions.

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1. Introduction

Corporate bankruptcy occurs when a firm has chronic and serious losses and/or when a firm becomes insolvent with liabilities that are disproportionate to assets. Traditionally, bankruptcy of a firm is attributed to the firm's own poor management and autocratic leadership [19]. With the increasingly intensive interactions among supply chain members, bankruptcy of a supply chain member may cause other member firms to get into financial difficulties. In network economy, this phenomenon is termed bankruptcy propagation or financial contagion [6,16].

An intuitive explanation of bankruptcy propagation is the avalanche of debt chain or credit chain [10,16,23]. The current financial crisis triggered by the 2008 sub-prime crisis is a typical evidence of this viewpoint. Because of the bankruptcy of sub-prime lending institutions, many investment banks (e.g., Lehman Brothers Holdings Inc.) have been filed for bankruptcy. The companies that own Lehman Brothers' securities also suffer big losses on their investments, and more companies are then expected to be bankrupt.

In network economy, companies are not only connected by the capital market, but may also have operational interactions. A supply chain is a network of firms interacting to transform raw material into

finished product for customers [24]. Since interactions among supply chain members on material, information and cash flow are becoming increasingly intensive, financial status of a firm in a supply chain depends not only on its own management, but also on the decisions and management of other supply chain members. Intuitively, one expects that upstream manufacturers will benefit from horizontal competition among downstream retailers. However, as we will show in this paper that, intensive horizontal competition among retailers may cause decreases in profit and liquidity of manufacturers and retailers in the long run. As a consequence, the risk of bankruptcy propagation in the supply chain increases. Despite the fact that bankruptcy propagation frequently appears in the network economy, the problem of how various operational decisions of a supply chain member and interactions among supply chain members affect bankruptcy propagation has drawn little attention in the researches of supply chain management.

For a two-echelon supply chain network that consists of multiple manufacturers and retailers, this paper systematically investigates the impacts of various operational decisions/interactions of/between supply chain members, such as horizontal competition among retailers, order allocation strategies of retailers, wholesale price of manufacturers, production uncertainty of manufacturers, characteristics of market demand and number of retailers, on bankruptcy propagation in supply chain.

Bankruptcy, which refers to an unhealthy financial status, is the result of the operations of all members in the supply chain over multiple periods [37]. Because of the complex linkages among supply chain members and the dynamically uncertain nature of revenues, financial

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status of the supply chain members is hard to be investigated by any analytical supply chain model. Similarly, empirical questionnaire review or case study can hardly relate financial performance of a supply chain member with a specific operation or decision made by a supply chain member. Based on these considerations, this paper investigates financial status of supply chain members through agent-based simulation experiments. Agent-based simulation is an effective approach for its encapsulation of the complex internal behaviors of the members [31] and thus has been extensively used in the field of supply chain modeling (e.g., [27,28,38]).

Main contributions of this paper are three folds. First, an agent-based simulation model is firstly built to investigate the relationship between the operational decisions/interactions and bankruptcy propagation in a supply chain network. Second, through extensive simulation experiments, impacts of various operational parameters and decisions on occurrence and propagation of bankruptcy have been analyzed, which provide a solid foundation for the research of mitigating bankruptcy propagation in supply chain networks. Third, the linkage between firms' operational decisions and financial decisions is analyzed, which suggests hedging supply chain member's operational risk through financial decisions.

The remainder of this paper is organized as follows. In Section 2, we review the literatures related to bankruptcy propagation and its causes. In Section 3, we make a description of the supply chain model. Section 4 clarifies the methodology and development of the simulation model. Simulation results and analyses are presented in Sections 5. Section 6 provides a conclusion remark of this study.

2. Literature review

With the increasing interdependence and interaction among firms, bankruptcy propagation has become an important cause for firms' bankruptcies. Many researchers and practitioners have observed this phenomenon. The previous academic researches about bankruptcy propagation mainly focus on the following three aspects: 1) the mechanisms of financial contagion in financial systems; 2) bankruptcy propagation in production networks owing to financial interactions between general firms; 3) bankruptcy propagation in production networks owing to operational interactions between firms. The next three paragraphs successively review the researches on these three aspects.

The phenomena of bankruptcy propagation were firstly observed in banking system. By modeling financial contagion as an equilibrium phenomenon, Allen and Gale [2] analyzed how bank crisis spreads by contagion, and put forward a theory of "financial contagion" in a network model of the inter-bank market. They emphasized the role of inter-bank credit in determining financial contagion. Rijckeghem and Weder [34] provided empirical evidence in support of the view that spillovers through common bank lenders were important in transmitting currency crises. Dary and Shāna [13] demonstrated that there is a significant relationship between financial contagion and the inflation rate and between financial contagion and financial liquidity. Using a model with banking and insurance sectors, Allen and Carletti [1] argued that credit risk transfer can also lead to financial contagion between the two sectors and increase the risk of crises. These researches focused on the causes of financial contagion among financial institutions.

The research on financial contagion has also been extended from banking system to general inter-firm situation. Based on the background of the slump in Japan in the 1990s, Kiyotaki and Moore [23] examined two mechanisms through which bankruptcy propagation among firms may occur: First, the propagation may be caused by the effects that fluctuations in asset prices have on collateral values; second, the propagation can also be caused by the effects that default on or postponement of debt payments have when there are chains of credit. According to Gatti et al. [18], bankruptcy propagation among

firms can be induced by the indirect interaction among firms that takes place through the endogenous determination of the interest rate on bank loans. That is, bankruptcy of one firm may induce banks restraining the supply of credit and pushing up the interest rate, which may trigger more firms to go bankruptcy. Bradley and Rubach [11] examined the relationship between trade credit and the filing for bankruptcy by 131 US small businesses. They found that 31% of the 131 entrepreneurs consider non-payments of trade credit as the most important cause for their bankruptcy. Boissay [10] also emphasized the role of trade credit in inducing bankruptcy propagation. By developing a theoretical model that firms are linked by trade credit, they found that when customers of a sound firm are financially distressed, then this firm gets into financial difficulties with probability that ranges from 4.1% to 12.8% (depending on the business cycle and the underlying economic scenario). Gatti et al. [16] modeled a network economy with three sectors: downstream firms, upstream firms, and banks. Through agent-based simulations, they found that credit/loan inter-linkages among agents and the financial policies of the banks are important sources of bankruptcy propagation across different sectors. The above research indicated that, the interdependence and interaction between firms are important causes for bankruptcy propagation. However, the above researches mainly attribute bankruptcy propagation to finance-related causes, e.g., bank loans, trade credit and the endogenous determined interest rate.

The effect of operational decisions of a supply chain member or interactions among supply chain members on bankruptcy propagation has rarely been investigated. Among the few researches, Battiston et al. [6] presented a simple model of a production network in which firms are linked by supplier–customer relationship. Through simulation analyses, they identified roles of some factors on bankruptcy propagation, e.g., trade credit, interest rate and costs due to supply failure. However, they ignored the relationship between operational decisions (e.g., inventory decisions, cooperation and competition) and these factors. Similar to Battiston et al. [6], by highly simplifying and abstracting operations of firms and interactions among firms, Gatti et al. [17] examined the impacts of supply chain structures, i.e., static or evolving, on bankruptcy avalanches. Based on the review of 1695 bankruptcy filings between 1978 and 2004 from Bankruptcy DataSource Index, Hertz et al. [22] investigated how financial distress and bankruptcy affect a filing firm's customers and suppliers, and found that distress related to bankruptcy filings is associated with negative and significant stock price effects for suppliers. For a simple three-echelon supply chain that consists of a retailer, a distributor, and a manufacturer, Xu et al. [39] found that demand forecasting methods, market demand characteristics (uncertainty of demand in each period and auto-correlation of demands in consecutive periods) and thus service levels required by the supply chain members, have significant impacts on the occurrence of bankruptcy at each stage of the supply chain. By using the recent 10 years data of bankruptcy in Japan, Fujiwara [15] showed that the causes of bankruptcy propagation (e.g., secondary effect from bankruptcy of customer, failure of business-related firms and failure of accounts receivable) are by no means negligible. These researches have not established the relationship between operational decisions made by supply chain members and bankruptcy propagation appeared in the supply chain.

Many theoretical and practical evidences have proven that business success of a supply chain member depends not only on its own competence, but also on the competence of its partners in the supply chain and on the cooperative interactions between the supply chain members [35]. However, we still know little about how an operational decision of a supply chain member affects the financial status of other members of the supply chain. We also have little knowledge about the effect of operational interactions among supply chain members on bankruptcy propagation. Therefore, there is a gap between supply chain operations and bankruptcy propagation in the research of supply chain management, which is the reason for the present paper.

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