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The effects of a trust mechanism on a dynamic supply chain network

Yunzhang Hou [a], Yu Xiong [b,c,*], Xiaoling Wang [d], Xi Liang [e]

[a] School of Management, Fudan University, Shanghai 200433, China
[b] School of Economics and Business Administration, Chongqing University, Chongqing 400044, China
[c] Norwich Business School, University of East Anglia, Norwich NR4 7TJ, UK
[d] School of Law and Politics, Shanghai Normal University, Shanghai 200234, China
[e] College of Finance & Economics, Chongqing Jiaotong University, Chongqing 400074, China

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ABSTRACT

Recognizing trust as the basis for firm cooperation, we investigate how a trust mechanism affects a supply chain network using a dynamic multi-agent and multi-stage model that incorporates three supplier selection rules: a preferred price rule, a preferred trust rule, and a preferred random rule. We use this model to explore the impact of the three rules on supply chain performance and bankruptcy propagation under the conditions of external disruption, bank rate, and new firms entering the market. Our results identify the preferred trust rule as the supplier selection method that can in most cases best improve the total revenue of the whole supply chain network. In terms of firm bankruptcy, on the other hand, it is the preferred random rule that has the least impact and the preferred price rule that has the most.

1. Introduction

In recent years, supply chain management, with its important competitive advantages for market enterprise, has become the subject of increasing interest to academics, consultants, and business management alike (Croom, Romano, & Giannakis, 2000). At the same time, in the face of rapid technological advancements, the basic supply chain has evolved rapidly into what is now known as a supply chain network. In such a network environment, all firms involved interact intensively, meaning that one firm's operational decisions can cause another firm to get into financial difficulties (Hua, Sun, & Xu, 2011). Being an inherently dynamic (Wieland & Wallenburg, 2011) and complex system (Choi, Dooley, & Rungtusanatham, 2001), however, the supply chain network can also be dramatically affected by external factors like new entrants into the market and government financial policies.

Because a supply chain network is made up of individual firms collaborating to serve end customers, its effectiveness is greatly dependent on trust between the network partners (Vlachos & Bourlakis, 2006). In fact, trust plays a crucial role in the development of any long-term relationship (Morgan & Hunt, 1994). Trust also tends to improve the average cycle time and in-time order fulfillment rate (Lin, Sung, & Lo, 2005) and supply chain financial performance (Zhang & Huo, 2013). Nevertheless, the scientific literature offers few empirical insights into how a trust mechanism affects risk propagation and performance in a dynamic supply chain network. We therefore address this issue by first building a multi-stage supply chain network whose stages each involve several firms and then running simulations using two types of agent models and three supplier selection rules. We also take into account external factors that affect supply chain networks.

The remainder of this paper is organized as follows. Section 2 reviews the related literature, and Section 3 describes the two types of agent model developed. Section 4 reports the simulation and analytical results, after which Section 5 presents the conclusions and suggests directions for future research.

2. Literature review

2.1. Risk in supply chain networks

Over the last few years, the topic of supply chain risk has attracted growing interest among both academics and practitioners, resulting in the publication of numerous articles in international journals and supply chain trade magazines (Bandaly, Shanker, Kahyaoglu, & Satir, 2013; Snyder et al., 2012). The rubrics under which these various papers are classified, however, differs greatly (Bode, Kemmerling, & Wagner, 2013; Klimov & Merkuryev, 2008; Tang, 2006). Tang (2006), for example, divides supply chain risks into "operational" risks, inherent uncertainties, and "disruption" risks, major disruptions caused by natural and man-made disasters. Klimov and Merkuryev (2008), on the other hand, classify supply chain risk into risks generated internally and external risks resulting from such disruptions as earthquakes, floods, terrorist

* Corresponding author at: Norwich Business School, University of East Anglia, Norwich NR4 7TJ, UK. Tel.: +44 (0) 1603597239.
E-mail address: y.xiong@uea.ac.uk (Y. Xiong).

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attacks, economic crises, or workers' strikes. Nevertheless, most of published research is based on a simple supply chain composed of only one supplier and one retailer.

More recently, in the face of a rapidly growing research focus on supply chain networks, some investigators have begun to examine risk control in more complex networks. These studies can be divided into three categories: supply chain network design and planning with different risks (Baghalian, Rezapour, & Farahani, 2013; Cruz & Wakolbinger, 2008; Liu & Cruz, 2012), risk analysis and assessment of supply chain networks (Takata & Yamanaka, 2013; Tuncel & Alpan, 2010; Wu, Dong, Tang, & Chen, 2010), and contract design and coordination of supply chain networks given different risks (Govindan, Popiuc, & Diabat, 2013; Xu, Sun, & Hua, 2010; Zhao, Qu, & Liu, 2008). Yet even recent research, whether based on a risk environment or a stable environment, still tends to focus on static supply chain networks rather than the complex, dynamic networks of reality (Wieland & Wallenburg, 2011), which can be influenced by multiple factors, including firm bankruptcy induced by poor management, new market entrants, and increasing application of e-commerce. Given this complexity, Choi et al. (2001) suggest that supply chain networks are inherently complex adaptive systems (CAS), many of which simply emerge rather than being engendered from the purposeful design of a singular entity.

In any supply chain network, individual entities are linked together by logistics, information, and financial flow and must therefore cooperate and compete with one another. As a result, the interaction among entities in the supply chain is intense, and one firm's decision can cause structural changes in the network that affect both the firm itself and all the other network entities. Hence, a network firm's financial status depends not only on its own management skills but also on the management and operational decisions of linked partners (Hua et al., 2011).

2.2. Bankruptcy in supply chain networks

In the network context, risks evolve and propagate along the entire network, meaning that a firm may lose profit or even go into bankruptcy as a result of making decisions that lead to local instabilities in the network. Once accumulated, these local instabilities are propagated and amplified across the whole supply chain network, potentially generating an eventual avalanche of bankruptcy.

For financial system, the interconnections among financial institutions make potential channels for contagion and amplification of shocks (Glasserman & Young, 2013). One of the first empirical observations of bankruptcy propagation is that by Allen and Gale (2000), who use an equilibrium model to demonstrate how financial distress spreads in a network of interbank relations. Allen and Carletti (2006) then use this same framework to show how an insurance company default can cascade into the banking sector and increase the risk of crises. Elliott, Golub, and Jackson (2013) model the contagions and cascades of defaults in organizations and illustrate how the network propagates uncontinuous changes in asset values. More recent work by Hua et al. (2011) establish an agent-based model to investigate how bankruptcy arises and propagates in supply chain networks. Specifically, they study the effects of operational parameters such as retailer competition and number of retailers on bankruptcy propagation and the relation between a firm's operational risks and financial decisions. To decrease bankruptcy risk in a supply chain network, both Xu et al. (2010) and Sun, Xu, and Hua (2012) examine how the typical supply chain contract, which includes such agreements as information sharing, price discounts, and quantity flexibility, can mitigate bankruptcy propagation along the network. Similarly, Serrano, Oliva, and Kraiselburd (2011), drawing on empirical findings from finance research, build a supply chain model to investigate how risk propagates upstream through payment distortion. They show not only that payment variability can appear even when orders are fixed but that such variability propagates and increases at the upper stages.

The constituent topology of a supply chain network, which emerges when supply chain members decide on their partners, profoundly affects risk propagation. Hence, the relation between propagation and the structure to which it is linked has been the subject of much academic research. Fujiwara (2008), for example, using 10 years of Japanese bankruptcy data, shows that the influence of the "link effect" on bankruptcies in a nationwide economy is so important that it accounts for nearly 20% of all bankruptcy debt. Gatti, Gallegati, Greenwald, Russo, and Stiglitz (2006) employ a static credit network model comprising households, firms, and banks to examine how bank and firm choices of credit supply are interrelated. They then extend this static credit network to an evolving one (Gatti, Gallegati, Greenwald, Russo, & Stiglitz, 2009). Their simulations, all using a model that provides customers with a preferred partner choice rule during supplier selection, demonstrates that business cycles can emerge as a result of the complex interactions of the different financial conditions of the agents involved. Weisbuch and Battiston (2007), in contrast, employ a simple periodic lattice model to investigate how local failures can result in avalanches of bankruptcies. Using simulation analyses, they identify scale-free distributions of production and wealth among firms. Mizgier, Wagner, and Holyst (2012) then extend Weisbuch and Battiston's (2007) framework to establish a dynamic supply chain network in which supply chain members select their partners randomly and firms with more suppliers have more opportunities to switch to a new supplier. These simulations clearly reveal that collective firm bankruptcies are likely to result in self-emergent network structures.

2.3. Trust in a supply chain

As already emphasized, trust plays a crucial role in the development of any long-term relationship (Morgan & Hunt, 1994) and is especially important in strategic partner relationships (Ireland & Webb, 2007). In general, trust is an accumulated product of repeated past interactions among parties through which they come to understand themselves and develop a common knowledge of mutual commitments (Ring & VandeVen, 1994). In the supply chain network context specifically, the effectiveness of collaboration is dependent on a firm's initiatives to build and foster trust with its partners (Vlachos & Bourlakis, 2006), which can improve responsiveness even when suppliers have more power than buyers in the supply chain (Handfield & Bechtel, 2002). For instance, Lin et al.'s (2005) evaluation of the effect of trust mechanisms on supply chain performance clearly shows that trust mechanisms reduce the average cycle time and increase in-time order fulfillment rate, especially when the environment is highly changeable. Kim (2009) also concludes that the trust relationship between firms, whose symmetrical levels emerge from the firms' self-organizing processes, can reduce the variability of inventory levels. Panayides and Lun (2009) provide empirical evidence that trust affects not only supply chain performance but also innovation, and Zhang and Huo (2013) also use empirical research to show that trust with customers/suppliers significantly influences supply chain integration which can improve supply chain financial performance profoundly.

The aforementioned research, especially that of Gatti et al. (2009), also provides clear evidence that the topology of the supply chain network is determined by supplier selection rules, which ultimately influence the risk propagation and aggregate fluctuation of the entire network's output. Nevertheless, despite broad investigation of supplier selection methods and criteria (Govindan, Rajendran, Sarkis, & Murugesan, 2013; Ho, Xu, & Dey, 2010),