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How does the trust affect the topology of supply chain network and its resilience? An agent-based approach

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ABSTRACT

This paper builds a dynamic supply chain network, where firms can select suppliers according to the trust, the selling price or just randomly. Simulation results show that the trust-based rule can significantly increase the aggregated working capital and decrease firm's likelihoods of bankruptcy. Moreover, firms' sizes under trust-based and price-based rules follow power-law distributions. The degree distribution of supply chain network under price-based rule follows a power-law distribution, while those under trust-based and randomly-choosing rules are similar to that of random network. Furthermore, results also indicate that trust-based rule is the most robust one against random and targeted disruptions.

1. Introduction

With the rapid advancement of technology and the further globalization of economy, supply chains become more complex and rapidly evolve into what is now known as supply chain networks (Choi et al., 2001; Pathak et al., 2007; Wu et al. 2017). In supply chain networks, firms are facing the challenges not only from the high demand variability and customized requirements, but also from the influence of operational decisions of their partners' in the supply chain network (Hua et al., 2011). All of these challenges make supply chain networks become more unstable and hence more vulnerable to risks and disruptions (Rajagopal et al., 2017). In practice, any local instability in supply chain can propagate and amplify across the supply chain network, which may result in the significant disruption and avalanche of whole network (Hou et al., 2014; Mensah et al., 2015).

Extant literatures in supply chain risk and disruption mainly focus on the building of efficient supply chains while resilient to disruptions (Kamalahmadi and Parast, 2016), and often adopted risk theory to identify, assess and mitigate risks and bankruptcies caused by disruptions (Fahimnia et al., 2015). However, along with the growing interest of network perspective in supply chain management, there is also a research stream that examines disruption and related supply chain issues from network perspective and show that the topology of a supply network has great impact on its risk and resilience (Zhao et al., 2011; Nair and Vidal, 2011). Thus, it is crucial for firms in global environment to gain more structure information of the supply chain network to mitigate the potential risks (Carnovale et al., 2016).

As we know, collaborative buyer-supplier relationships are fundamentally important for supply chain to increase competitive advantage (Zhang et al., 2011), and the development and maintenance of this relationship is usually depend on the trust among partners (Vlachos and Bourlakis, 2006). The research on buyer-supplier relationships clearly indicates that trusting buyer-supplier

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relationships can improve supply chain performance (Capaldo and Giannoccaro, 2015a), and trust is crucial to build a long-term relationships (Morgan and Hunt, 1994). Then, it is reasonable to believe that trust is also beneficial to maintain the comparatively stable structure of supply chain network. Thus, it is important to understand the relationship between the trust and the network structure of supply chain.

As noted above, a large body of literature has explored the supply chain risk and the positive relationship between trust and supply chain performance, yet we know remarkably little about whether and how the trust affects the interdependence structure of the supply chain and therefore affects the supply chain network's resilience against both random and targeted disruption. To address this gap in literature, we frame the supply chain network as a complex adaptive system (CAS), and explore how the trust among firms affects the topology of supply chain network and their resilience against random failures and targeted attacks. In particular, to describe the adaptability and dynamic behavior of the supply chain network, we use agent-based model (ABM) to analyze the dynamic supply chain network. In addition, for comparison, we also examine the supply chain network under the price-based and randomly-choosing rules, and compare the results with those when the firms in supply chain network choose suppliers according to the trust among them.

Note that the structure of supply chain network comes into being when all firms select their partners (Choi and Hong, 2002). Accordingly, the rules for firms to choose their partners are crucial to the formation of supply chain network. In our agent-based models, we consider three different supplier selection rules: the preferred trust rule (PTR), the preferred price rule (PPR), and the preferred random rule (PRR). Actually, a totally different supply chain structure will appear when firms in supply chain choose their partners by different rule. Based on the proposed supply chain networks, we examine which supplier selection rule can significantly improve the performance of supply chain network, and can be mostly resilient against both random and targeted disruptions. Our simulation results show that PTR is the most effective rule in improving the aggregated working capital of the supply chain. Meanwhile, the degree of supply chain network under PPR follows a power-law distribution, while those under PTR and PRR follow a distribution similar to that of random network. Moreover, the results indicate that the supply chain network when firms engaged in PTR is the mostly resilient against the random and targeted disruptions.

The remainder of this paper is organized as follows. Section 2 reviews the related literatures on the trust, supply chain network and resilience. Section 3 introduces three supplier selection rules and models the supply chain network. Section 4 discusses our simulation results, and in Section 5, we present the conclusions.

2. Literature review

2.1. Supply chain network and risk propagation

In today's business environment, as supply chains become more globalized, both of the length and complexity of their network grow accordingly, which may lead to high level of disruption risk (Choi and Krause, 2006). Extant literatures in supply chain risk mainly focus on the risk identification, assessment and mitigation strategy (Altay and Green, 2006), and primarily regard risk as logistical or operational (Garvey et al., 2015). However, the risk can usually propagate and amplify along the highly interconnected network, which can generate serious problems (e.g., the avalanche of whole network) (Ashayeri et al., 2014). Therefore, it is very crucial to design a resilient supply chain network and consider the structure of supply chain network and the corresponding risk propagation (Garvey et al., 2015; Fattahi et al., 2017). Nair and Vidal (2011) used a multi-agent method to examine the relationship between the topology of supply network and its robustness in the presence of random failure and targeted attack. Garvey et al., (2015) utilized a Bayesian Network approach and established risk propagation model which considers both inter-dependencies among different risks and the supply chain network structure. Different from these studies, some researchers recently proposed various methods to control the risk propagation in supply chain. For example, Han and Shin (2016) developed an evaluation mechanism to assess the structural robustness of supply chain network. Yin et al., (2017) investigated the sourcing policy to mitigate overseas disruption risks in an assemble-to-order system.

In practice, disruption may cause firm bankruptcy directly. More recently, Hua et al. (2011) investigated the impacts of some important factors (such as retailer competition and number of retailers) on the bankruptcy propagation in a static supply chain network. Sun et al. (2012) examined how the typical supply chain contract (e.g. information sharing) can mitigate the bankruptcy propagation along the network. Based on the empirical findings from the finance research, considering the retailer's possibility of bankruptcy risk, Yan and Sun (2013) designed a supply chain financial system and illustrated that an effective financial policy can encourage a capital-constrained retailer to order more. To improve the resilience of supply chain network, Hasani and Khosrojerdi (2016) developed a mixed-integer nonlinear programming model to examine the resilience of supply chain.

The interconnected structure of supply chain network can significantly affect the risk propagation. Recently, Thadakamalla et al. (2004), and Nair and Vidal (2011) showed that the topology of a supply network can greatly affect the resilience of supply chain. Zhao et al.(2011a) proposed a new metric and a rewiring approach to investigate the distribution network and showed that the network topology can affect its robustness considerably. Based on a similar metric, Zhao et al. (2011b) built a network growth model and explored how different network topologies affect the network resilience. Based on a preferred-partner choice rule, Gatti et al. (2008) built a dynamic credit network model and demonstrated that business cycles can emerge as a result of the complex interactions among agents involved. Mizgier et al. (2012) established a dynamic supply chain network in which supply chain members can select their partners randomly. Their results showed that collective bankruptcies can likely result in self-emergent network structures.

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