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A study of contagion in the financial system from the perspective of network analytics

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ABSTRACT

The increase in the frequency and scope of financial crises has made the stability and robustness of the financial system a major concern in the field of finance worldwide. Due to the interconnectedness between institutions, the negative effects of financial crises spread through the financial system in a process referred to as financial contagion. In this study, we focus on a financial system in which large numbers of financial institutions are connected by direct balance sheet linkages through their lending-borrowing relationships. We mainly focus on modeling and analyzing financial contagion from a network analytics perspective. First, we model the financial system and the mechanism of contagion by introducing the concepts of exposure matrix, book value, market value and liquidation cost. Second, we propose a simple contagion algorithm based on this modeling process. Third, we study the effects of the financial system's heterogeneity on the magnitude of financial contagion by applying the proposed algorithm. The level of heterogeneity is measured by the diversification of exposure ratio and the extent of network connectivity. According to the results of our comprehensive numerical simulation, we conclude that an increase in heterogeneity has a significant influence on the stability of the financial system. Our study has significant implications for the practice of financial regulation and surveillance.

1. Introduction

In recent years, the increasing frequency and scope of financial crises has made the stability and robustness of the financial system a major concern for finance managers around the world. One crucial characteristic of these financial crises is the contagion effect (or avalanche effect) of distress and failure, which increases the potential for shocks to spread among a wide range of interconnected financial institutions. Although these institutions are not necessarily large in terms of total assets, the links between them can cause financial failures to spread quickly across the whole financial system through an unexpected domino effect. For example, the default of Lehman Brothers, triggered by the sharp write-downs of assets related to subprime mortgages, led to the 2008 financial crisis, which induced the collapse of the worldwide financial system. This event is widely considered the most serious financial downturn since the Great Depression. Financial contagion can impair the stability and robustness of the whole financial system. Such contagion induces systemic risk, as opposed to the more limited risk of shocks to individual institutions within the system.

Many academics and regulators have made significant efforts to better understand financial contagion since witnessing its effects in the financial crisis. Network analytics theory [1,2] has been intensively used to analyze financial contagion in general. According to this theory, a financial system can be described as a network of claims and obligations that arise through lending or borrowing [3–5]. This network reflects the interconnectedness of the financial system. Indeed, financial integration and technological innovation significantly increase the financial interconnectedness between institutions. Such interconnectedness is initially pursued for the sake of risk sharing, but it also acts as a network of channels for financial contagion. Network analytics theory can thus be considered a powerful, flexible tool to identify and quantify the topology of interconnectedness in a financial system.

Financial crises occurred frequently throughout the twentieth century. However, it is only since the global financial collapse caused by the subprime crisis of 2008–2009 that economists and financial regulators have extensively applied network analytics theory to study contagion in financial systems [6–8]. A large body of literature has since been developed. Theoretical studies

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comprise one stream of research on financial contagion. The seminal study by Allen and Gale [9] initiated this strand of theoretical literature by showing how the network structure (complete or incomplete) of the financial system affects the level of risk-sharing. These pioneering authors point out that a complete network can absorb idiosyncratic shocks, but an incomplete network might allow negative spillovers to spread throughout the system (financial contagion). Since this outstanding work, numerous studies on financial contagion have adopted network or graph models. We can broadly categorize these theoretical studies into two groups. The first group considers the financial system as a random network and emphasizes the importance of a network topology structure, e.g., network connectivity. This group of studies models financial contagion as the result of an initial idiosyncratic shock to one or several financial institutions, which then spreads through the entire network in a cascade manner. This group of studies includes [7,10–13]. The other group of studies considers a deterministic network, and views the financial network as either exogenous or endogenous. Such studies examine the effects of initial defaults as predetermined by network externalities. These studies propose various approaches, including the configuration model [14], the tiered banking network [15] and the nested split graph [16]. The other stream of research on financial contagion involves empirical studies, the number of which has considerably increased in the last decade. One strand of this empirical research is the study of network topology structures and their dynamics during particular time periods—especially before and after economic crises [17–20]. For example, Chinazzi et al. investigate the statistical properties of the International Financial Network (IFN), and examine whether the 2008 financial crisis has resulted in a significant change to the topological properties of the financial system. They find a core-periphery structure to the existing IFN architecture [17]. Another type of empirical study focuses on exploring the financial stability or vulnerability of banking systems at the national level [21–25]. For example, Caccioli et al. use the Austrian interbank network to examine two kinds of contagion mechanisms: counterparty failure risk and overlapping portfolio exposures [21].

Indeed, such studies have sought to analyze a wide range of issues related to financial contagion and financial stability. However, these studies on the nature and causes of financial contagion reflect the uncertainties and conflicting views of various academic experts. For example, in [9,26], the authors argue that as the financial system is becoming more dense and interconnected, the effects of failures by individual institutions on the rest of the system are becoming smaller, as the losses from distressed individual institutions are divided among more creditors. However, Blume et al. [27] and Vivier-Lirimont [28] argue to the contrary, claiming that the frangibility of a financial system increases when the number of an institution's counterparties increases. These conflicting conclusions illustrate the critical need for new understanding and fundamental analyses of financial contagion. Our study responds to this need. We follow the paradigm of network analytics, and focus mainly on modeling and analyzing financial contagion in a financial system in which a large number of financial institutions are connected by direct balance sheet linkages, due to their lending-borrowing relationships.

Financial contagion is conveyed mainly through three mechanisms: (1) correlation risk due to overlapping portfolio exposure; (2) liquidity hoarding risk due to rumor or information asymmetry; and (3) counterparty risk due to direct bilateral exposures. Fig. 1 shows a typical financial system to illustrate these three mechanisms. In this system, all of the institutions (firms A, B, C) are represented by stylized balance sheets. The effect of correlation risk arises as soon as financial institutions hold assets that are somehow correlated. This kind of risk has been widely studied in the financial literature [21,29–31]. Obviously, many financial

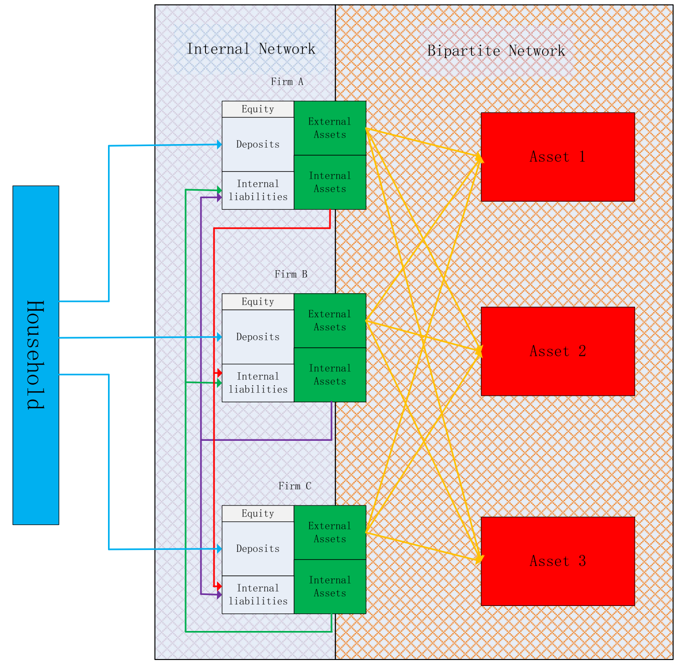

Fig. 1. The financial system.

institutions invest in projects that have correlated returns due to geographical proximity, or because such projects are vulnerable to the same sources of exogenous shocks. Another source of correlation is the exchange of investment projects via derivative contracts. These various correlations among institutions' assets can be viewed as a bipartite network of indirect linkages. During a time of financial distress, the contagion phenomenon may appear as some institutions start to fire-sell their assets due to the liquidity risk, thereby depressing the prices of other assets via correlation. The liquidity hoarding risk arises from the perturbation of investors (e.g., deposit fluctuations) in the form of cutbacks to lending between institutions, which occur as a defensive strategy in response to rumor or information asymmetry [32–34].

The third mechanism of financial contagion is counterparty risk [7,11,13,35,36], which arises via bilateral exposures due to direct balance sheet linkages in the form of lending-borrowing relationships. These lending-borrowing relationships among financial institutions can be viewed as an internal network, such as the interbank network in a banking system. Our study particularly examines this third mechanism, in which the network of bilateral exposures is formed by the cross-holding of claims and obligations that arise through lending-borrowing relationships. In particular, we aim to extend network analytics to the study of financial contagion.

We first model the financial system and the contagion mechanism within this system by introducing the concepts of exposure matrix, book value, market value and liquidation costs. Second, we propose a simple contagion algorithm based on this modeling process. Third, we study the effects of heterogeneity in the financial system on financial contagion, as projected by using this algorithm. The heterogeneity of the system is measured by the diversification of exposure ratio and by network connectivity. Based on the results of a comprehensive numerical simulation, we conclude that the increase in heterogeneity has a significant influence on the stability of the financial system. Our study has significant implications for the practice of financial regulation and surveillance.

The rest of this study is organized as follows: Section 2 presents the modeling process, Section 3 analyzes the effects of