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The effect of the interbank network structure on contagion and common shocks

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ABSTRACT

This paper proposes a dynamic multi-agent model of a banking system with central bank. Banks optimize a portfolio of risky investments and riskless excess reserves according to their risk, return, and liquidity preferences. They are linked via interbank loans and face stochastic deposit supply. Comparing different interbank network structures, it is shown that money-centre networks are more stable than random networks. Evidence is provided that the central bank stabilizes interbank markets in the short run only. Systemic risk via contagion is compared with common shocks and it is shown that both forms of systemic risk require different optimal policy responses.

1. Introduction

The recent financial crisis has shown that systemic risk takes many forms and is highly dynamic. It builds up slowly in normal times, and unwinds rapidly during times of distress. The insolvency of the US investment bank Lehman Brothers in September 2008 marked the tipping point between the build-up and rapid unwinding of systemic risks and led to a freeze in interbank markets. Banks were no longer able to obtain liquidity and engaged in costly fire sales. Central banks were forced to undertake unprecedented non-standard measures to ensure liquidity provision within the banking system.

This paper analyzes the non-trivial network structure of the bilateral interbank loans which form the money market. Interbank networks exhibit what Haldane (2009) describes as a *knife-edge*, or *robust-yet-fragile property*: in normal times the connections between banks lead to an enhanced liquidity allocation and increased risk sharing.[1] In times of crisis, however, the same interconnections can amplify initial shocks such as the insolvency of a large and highly interconnected bank.[2] This implies that there are two different regimes of financial stability: a stable regime in which initial shocks are contained, and a fragile regime in which initial shocks are transmitted via interbank linkages to a substantial part of the financial system. The knife-edge property of interbank markets can be attributed to a counterparty risk externality which is characteristic of over-the-counter markets (e.g. Acharya and Bisin (2010)). When a bank lends to a number of other banks it is oblivious to any links between those banks and might underestimate its portfolio correlation. A similar effect can be termed *correlation externality* and arises when a bank is oblivious to the asset holdings of other banks. The counterparty risk externality can lead to interbank contagion (sometimes called cascading defaults), while the correlation externality can lead to common shocks.[3]

This poses the question of whether there exist network structures that are less prone to systemic risk (caused by either externality) and hence more resilient to financial distress. The massive intervention of central banks at the height of the financial crisis furthermore raises the question of whether central bank interventions

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[1] See for example Allen and Gale (2000) (or Freixas et al. (2000) for a similar setting) who show that highly interconnected banking systems are less prone to bank-runs.

[2] The fragility of an interconnected financial system was analyzed by Gai and Kapadia (2010), who show that the risk of systemic crises is reduced with increasing connectivity on the interbank market. At the same time, however, the magnitude of such a crisis increases.

[3] A common shock can affect banks who have become overly correlated as a consequence of a correlation externality.

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can effectively stabilize interbank markets and ensure banks' liquidity provision. Finally, in order to understand systemic financial fragility, it is necessary to compare the instabilities caused by the counterparty risk externality with instabilities caused by the correlation externality (i.e. to compare the effects of interbank contagion to the effects of common shocks).

This paper addresses the aforementioned questions by developing a simple dynamic model of a banking system that explicitly incorporates an evolving interbank network structure. Banks optimize a portfolio of risky investments and riskless excess reserves. Risky investments are long-term investment projects that fund an unmodelled firm sector while riskless excess reserves are short-term and held at the deposit facility of the central bank.[4] Banks face a stochastic supply of household deposits and stochastic returns from risky investments. This gives rise to liquidity fluctuations and initiates the dynamic formation of an interbank loan network. Banks, furthermore, have access to central bank liquidity if they can provide sufficient collateral.

Three key results are obtained. First, this model is used to compare different possible interbank network structures, and it is shown that in random graphs the relationship between the degree of interconnectivity and financial (in-)stability is non-monotonic. In times of distress, money centre networks (which are typically found in reality) are seen to be more stable than purely random networks. In tranquil times, however, I show that different interbank network structures do not have a substantial effect on financial stability. The key intuition behind this behaviour is a regime switching property of the model financial system. In tranquil times, liquidity demand-driven interbank lending is low and cascading defaults are thus contained. In times of crisis, individual banks suffer larger liquidity fluctuations and engage in higher liquidity-driven interbank lending. This drives the financial system as a whole into a *contagious regime*. When exactly the regime switching behaviour occurs depends on the interbank network structure.

Second, I show that the central bank can stabilize the financial system in the short run. In the long run, however, the system always converges to a steady state which depends, amongst other things, on the interbank network structure. Central bank liquidity provision helps banks to withstand liquidity shocks for a longer time. This, however, allows banks that would otherwise be insolvent to engage in liquidity demand-driven interbank borrowing. The result is that the financial system as a whole is more highly interconnected and more likely to enter the contagious regime.

Third, I show that the introduction of a common shock hitting all banks simultaneously can cause substantial financial fragility but has a less severe impact on the liquidity provision of the interbank market. This finding is of particular importance for policymakers implementing emergency measures in times of a crisis: while interbank contagion requires mainly liquidity provision, a common shock requires banks to be recapitalized.

The remainder of this paper is organized as follows. After this introduction, section two outlines the contribution to the literature. Section 3 describes the dynamic model that has been used to analyze the aforementioned questions. Section 4 will present the main results, Section 5 provides a discussion of further model implications, while sextion six concludes.

2. Relation to the literature

The literature on financial networks has been growing rapidly over the past few years.[5] As a result, this paper relates to various strands of literature. First, it relates to a class of network models using static network structures and fixed balance sheets. In contrast to this literature the present paper models banks that optimize their balance sheet structure in every period and continuously adapt the interbank network structure. Closest to the present paper are the works by Iori et al. (2006) and Nier et al. (2008). In the model of Iori et al. (2006) banks' balance sheets consist of risk-free investments and interbank loans as assets, with deposits, equity and interbank borrowings as liabilities. Banks receive liquidity shocks via deposit fluctuations and pay dividends if possible. Nier et al. (2008) describe the banking system as a random graph where the network structure is determined by the number of banks and the probability that two nodes are connected. The banks' balance sheet consists of external assets investments and interbank assets on the asset side and net worth, deposits, and interbank loans as liabilities. Net worth is assumed to be a fixed fraction of a bank's total assets and deposits are a residual, designed to complete the bank's liabilities side. Idiosyncratic shocks that lead to a bank's default are distributed equally within the interbank market. Both papers assume a risk-free investment opportunity and Nier et al. (2008) further assume deposits to be residual. By contrast, I explicitly allow the possibility of risky investments and deposit fluctuations.

In a recent paper, Bluhm et al. (2012) develop an intertemporal agent-based model of banks with a dynamic interbank network. While Bluhm et al. (2012) focus on the contribution of individual banks to overall systemic risk, I analyze the impact of the interbank network structure on financial stability. Ladley (2011) finds in a *static* network setting that for small shocks, high interconnectivity helps to stabilize the system, while for large shocks high interconnectivity amplifies the initial impact. Such a static approach has been considered by a number of authors, including Gai and Kapadia (2010), Battiston et al. (2012), and, earlier, Eisenberg and Noe (2001). In contrast to this literature, I consider a *dynamic* contagion model where banks optimize their balance sheet structure and as a result the actual interbank network structure.

Second, this paper relates to the empirical literature on the topology of interbank networks by conducting a dynamic analysis of interbank contagion with general interbank network topologies. Such empirical analyses include Blåvarg and Nimander (2002), Boss et al. (2004), van Lelyveld and Liedorp (2006), Degryse and Nguyen (2007), and Becher et al. (2008). These papers show that interbank networks often exhibit a scale-free topology, i.e. they are characterized by a few money centre banks with many interconnections and a large number of small banks with few connections.

Third, this paper contributes to a vast literature on systemic risk. A large part of the literature on systemic risk in interbank markets has focused on the analysis of contagion effects (i.e. studying the counterparty risk externality). Recently, more attention has been given to the correlation externality and the analysis of common shocks as sources of systemic risk. Acharya and Yorulmazer (2008), for example, point out how banks are incentivized to increase the correlation between their investments, and thus the risk of an endogenous common shock, in order to prevent costs arising from potential information spillovers.

Fourth, in addition to the existing literature on interbank networks, this paper introduces a central bank as a key player in the financial system. To motivate central bank interventions, Allen et al. (2009) and Freixas et al. (2010) show that central bank intervention can increase the efficiency of interbank markets. The present model investigates the effects of central bank intervention on contagion and common shocks.

[4] Alternatively, excess reserves could be held in form of highly liquid T-bills.

[5] An overview of the existing literature can be found, for example, in Allen et al. (2010).