Interbank lending and the spread of bank failures: A network model of systemic risk☆

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A B S T R A C T

We model a stylized banking system where banks are characterized by the amount of capital, cash reserves and their exposure to the interbank loan market as borrowers as well as lenders. A network of interbank lending is established that is used as a transmission mechanism for the failure of banks through the system. We trigger a potential banking crisis by exogenously failing a bank and investigate the spread of this failure within the banking system. We find the obvious result that the size of the bank initially failing is the dominant factor whether contagion occurs, but for the extent of its spread the characteristics of the network of interbank loans are most important. These results have implications for the regulation of banking systems that are briefly discussed, most notably that a reliance on balance sheet regulations is not sufficient but must be supplemented by considerations for the structure of financial linkages between banks.

"We [believed] the problem would come from the failure of an individual institution. That was the big mistake. We didn't understand just how entangled things were."
Gordon Brown, former British Prime Minister at the Institute for New Economic Thinking's Bretton Woods Conference on 9 April 2011.

1. Introduction

The current financial crisis has raised questions about the adequacy of financial regulation to ensure the stability of the banking system. A particular feature was the threat of systemic risk, where the failure of one bank spreads to other banks, arising from financial links between them. These financial links, either through interbank loans, payment systems or OTC derivatives positions, have received significant attention in the literature in recent years, although a thorough analysis of their impact on systemic risk is still outstanding. In this paper we seek to develop a model of such financial linkages and investigate how they contribute to the spread of bank failures. This study is the first of its kind that seeks to explicitly evaluate the role of the network structure of interbank loans as well as the balance sheet structure of individual banks in the spread of bank failures. In contrast to previous contributions we do not assume all banks to be identical, have random links with each other or to have interbank loans of equal sizes, but rather allow the characteristics of banks and their interactions to vary in a much more realistic setting that captures more aspects of real banking systems.

Systemic risk is defined by the Bank for International Settlements as "the risk that the failure of a participant to meet its contractual obligations may in turn cause other participants to default with a chain reaction leading to broader financial

difficulties", Bank for International Settlements (1994). A common approach to modeling systemic risk is that of bank runs, where customers loose confidence in a bank and withdraw their deposits. Observing a run on one bank then undermines confidence in other banks which in turn may suffer a bank run, thus spreading the problems beyond the initially affected bank, although no fundamental reason for this development is present. An alternative approach is to assume a common exogenous shock that affects all banks, e.g. a currency crisis, which as a consequence of this common shock experience a large number of failures, see e.g. Kaufman and Scott (2003) and Kaufmann (2005) for a non-technical overview. While such origins of crises are certainly relevant, the focus of this paper will be the spread of failures due to direct and indirect financial linkages between banks as arising from interbank loans or similar financial connections such as OTC derivatives markets.

The following section provides a brief overview of the current research on the relation of systemic risk and interbank loans, together with an outline of the empirical properties of the interbank loan market before we introduce the model investigated developed in Section 3. The variables considered in our subsequent analysis are described in Sections 4 and 5 shows how we derive the main factors that can be identified from those variables in a principal components analysis. The main results of our model are discussed in Section 6 with policy implications of these results being outlined in Section 7. Finally Section 8 concludes our findings and makes numerous suggestions for further research.

2. Literature on the interbank loan market

This section will provide a brief overview of the current state of the literature on systemic risk arising from interbank loans and in the second part outline the main empirical characteristics of banking systems and interbank loans.

2.1. Relevance of interbank loans for systemic risk assessment

Systemic risks are one of the main concerns of central banks and bank regulators, consequently the amount of work conducted in this area is significant; it also serves as the main justification for the tight regulation of bank activities. This section seeks to provide a brief overview of some of the works conducted in this area and from there point out the differences to the model we develop in this paper. A number of contributions seek to provide an overview of different origins and forms of systemic risks and the associated modeling approaches as well as empirical evidence, e.g. Bandt and Hartmann (2000), Kaufman and Scott (2003), or Chan-Lau et al. (2009).

A significant part of the theoretical models developed over the years investigate the impact reduced liquidity has on the spread of bank failures. The idea in such models is that banks suffer losses in the value of their assets due to "fire sales" arising from the liquidations by failing banks. This also reduces the value of the assets of non-failing banks, which can lead to losses exceeding their capital base and they might fail subsequently, see Allen and Gale (2001) and Diamond and Rajan (2005). Another strand of literature models the interbank lending and how it can reduce systemic risk. They do so either by providing incentives to banks to monitor each other's behavior as the exposure to interbank loans makes them susceptible to any other bank failing as in Rochet and Tirole (1996), or as a means to cushion the impact of any withdrawals from depositors as shown by Freixas et al. (2000). An empirical investigation supporting such models has been conducted by Cocco et al. (2009). It has also been shown by Eichberger and Summer (2005) that an increase in capital adequacy can actually increase systemic risks in equilibrium. A common feature of these models is that they are equilibrium models and while interactions with other banks are acknowledged, they are not explicitly modeled and a direct investigation into the impact of interbank loans are not possible, in particular the structure and properties of the network cannot be considered in those models.

More recently models have become popular that explicitly model the financial connections between banks as networks and employ simulation techniques to assess the spread of any bank failures. A general overview of the issues surrounding such modeling techniques is given by Haldane (2009). The range of network models applied is wide; for example in Vivier-Lirimont (2004) we find a contribution that investigates the determination of the optimal network structure of interbank loans from a bank's perspective. While this approach might allow us to explain the existence of specific network structures we observe, it does not directly contribute to our understanding of systemic risk. On the other hand, there exist a range of models that concentrate on the implications of liquidity effects, similar to the equilibrium models discussed in the previous paragraph, see e.g. Cifuentes et al. (2005) and Iori et al. (2006). The difference of these models compared to those mentioned in the previous paragraph is that these models explicitly use the network structure of financial connections to assess the spread of bank failures arising from to liquidity effects.

While the models considered thus far only model the banks themselves in a rudimentary way, other models such as those in Eboli (2007), Gai and Kapadia (2007), Nier et al. (2007), and Battiston et al. (2009), and May and Arinaminpathy (2010) explicitly include the balance sheets of banks and how the failure of a bank spreads through interbank loans in the banking system via losses they incur in their balance sheets. These models make a variety of assumptions on the network structure, properties of the banks and how failures spread. Some common assumptions are an Erdös-Renyi random network of interactions between banks, all banks having the same size, all banks having the same capital base, or all interbank loans to be for an identical amount, thus not taking into account empirical facts about real banking systems as well as the heterogeneity of banks. Furthermore, given the restrictive nature of their assumptions, these contributions do not provide a comprehensive analysis of the determinants of banking crises and their extent, often relying on mean-field approximations to derive results based on a small number of parameters. A common finding in such models is that a higher interconnection