Capital Provision to Reduce Liquidity Defaults and the Role of Central Banks

Extended Abstract

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ABSTRACT

We study to what extent the interbank market and central bank intervention can reduce funding liquidity defaults in banking networks. We build a multi-period agent-based model to simulate the banking network and interbank market for the long term. Based on this model, we define a strategic game in which each systemically important bank faces a decision of whether to lend and to which type of distressed bank to lend. We conduct an empirical analysis based on datasets published by the European Banking Authority. We compute the equilibria of the induced game using Empirical Game-Theoretic Analysis with different equilibrium solvers and analyse bank behaviour at different equilibria. The experimental results show that in the non-cooperative scenario, if all demand banks are solvent, central bank lending can significantly reduce liquidity defaults. Our results also suggest that the central bank can indirectly intervene in the interbank market by coordinating banks through recommendations, thus increasing interbank lending and reducing liquidity defaults, even without central bank lending.

KEYWORDS

Financial Networks, Liquidity Default, Systemic Risk, Empirical Game-Theoretic Analysis

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1 INTRODUCTION

A *liquidity default* refers to a situation in which a financial entity's current cash inflows are less than its cash outflows, and its cash reserves are insufficient to meet this gap. Liquidity defaults caused by *maturity mismatch* can exist independently of solvency defaults. For example, a bank whose total assets exceed its total liabilities may experience a cash shortage at some point and thus face a liquidity default. To solve this problem, this bank can find someone who is not only able to but also willing to lend it cash at the moment and agree to take the cash back later. The *interbank market* is the place in which such borrowing and lending occur. However, this operation may not be attractive for lending banks, especially when they act myopically, as the delayed repayment may lead to declines in their net values in the near future. Regulators can intervene by providing *central bank lending* to the borrowing bank to ensure the repayment of interbank lending, thereby creating positive incentives. In some cases, a small amount of central bank lending can facilitate much interbank lending, which can be more efficient than providing a full bailout. In this paper, we are interested in the extent to which the capital provision by interbank lending can reduce liquidity defaults and whether the central bank can motivate such interbank lending. Our main contributions can be summarised as follows:

(1) we present a multiple-period agent-based model to simulate the interbank market based on real-world data;
(2) we define a lending game to simulate banks' strategic interactions and analyse their strategic choices at equilibria;
(3) we define the central bank intervention and analyse its impact on the efficacy of the interbank market;
(4) we also compare the equilibria computed by different solvers and discuss the robustness of EGTA conclusion to the solver.

2 MODEL

We are given *banks* $N = \{1, \dots, n\}$ and *time steps* $T = \{1, \dots, t_{\max}\}$. Each bank i has a positive amount of *cash* at time step t, denoted by $c_i(t)$. Let $\boldsymbol{c}(t)$ denote the cash vector at t and $\boldsymbol{c}$ the cash vector throughout T. An interbank *liability*, denoted by $l_{ij}(t)$, represents a payment from bank i to bank j with the amount of $l_{ij}(t)$ at t. The liability matrix $\boldsymbol{L}(t)$ contains all the interbank liability data at t, and $\boldsymbol{L}$ contains all interbank liability data throughout T. Bank i's *total liabilities* at t are defined as the sum of its liabilities, i.e., $L_i(t) = \sum_{j \in N} l_{ij}(t)$. A *relative liability*, denoted by $\varphi_{ij}(t)$, represents the proportion of liability of i to j relative to i's total liabilities, i.e.,

$$\varphi_{ij}(t) = \begin{cases} l_{ij}(t)/L_i(t) & \text{if } L_i(t) > 0, \\ 0 & \text{otherwise.} \end{cases}$$

A *clearing vector* $\boldsymbol{\Lambda}(t)$, representing actual payments between banks, is a vector such that $\boldsymbol{\Lambda}(t) = \Psi(\boldsymbol{\Lambda}(t))$ where function Ψ is given by

$$\Psi(\boldsymbol{\Lambda}(t))_i = \begin{cases} L_i(t) & \text{if } c_i(t) + \sum_{j \in N} \varphi_{ji}(t)\Lambda_j(t) \geq L_i(t), \\ c_i(t) + \sum_{j \in N} \varphi_{ji}(t)\Lambda_j(t) & \text{otherwise.} \end{cases}$$

We use the Greatest Clearing Vector Algorithm (GA) [4] to calculate this clearing vector for a given banking network $(N, \boldsymbol{c}(t), \boldsymbol{L}(t))$. Bank i's *value*, denoted by $v_i(t)$, is defined as

$$v_i(t) = c_i(t) + \textstyle\sum_{j \in N} \varphi_{ji}(t)\Lambda_j(t) - L_i(t). \quad (1)$$

A bank is considered in *distress* at t if $v_i(t) < 0$.

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2.1 Interbank Market

We separate banks into three categories: (i) *demand banks* that are in distress at time step t and need to borrow money, given by $N_D(t) = \{i \in N : v_i(t) < 0\}$; (ii) *supply banks* that have positive values at t and can lend cash, given by $N_S(t) = \{j \in N : v_j(t) > 0\}$; and (iii) balanced banks whose values are exactly zero at t.

Demand. For any $i \in N_D(t)$, its *demand* is given by

$$D_i(t) = -v_i(t). \tag{2}$$

Supply. For any $j \in N_S(t)$, its maximal *supply* is the minimum between its cash and value if it does not choose to hoard liquidity,

$$S_j(\boldsymbol{s}(t)) = \begin{cases} \min\{c_j(t), v_j(t)\} & \text{if } s_j(t) \in \{\texttt{solvent}, \texttt{all}\}, \\ 0 & \text{otherwise,} \end{cases} \tag{3}$$

where $s_j(t) \in \{\texttt{none}, \texttt{solvent}, \texttt{all}\}$ denotes j's strategic choice at t. Specifically, $s_j(t) = \texttt{none}$ indicates that j hoards liquidity and does not lend to any banks; $s_j(t) = \texttt{solvent}$ indicates that j only lends to solvent demand banks; and $s_j(t) = \texttt{all}$ indicates that j can lend to all demand banks. The vector $\boldsymbol{s}(t)$ registers this choice for each supply bank at t.

Interest rate. An *interbank lending*, denoted by $\ell_{ji}(\boldsymbol{s}(t))$, indicates how much cash j actually lends to i at t. The *interbank lending matrix* $\boldsymbol{\ell}(\boldsymbol{s}(t))$ contains all interbank lending data at t. For a given $\boldsymbol{\ell}(\boldsymbol{s}(t))$, the *interest rate* offered by a demand bank $i \in N_D(t)$ is

$$r_i(\boldsymbol{s}(t)) = \theta \cdot r_{\min} + (1-\theta) \cdot r_{\max}, \quad \theta = \frac{\sum_{j \in N_S(t)} \ell_{ji}(\boldsymbol{s}(t))}{D_i(t)} \tag{4}$$

where $r_{\min}$ and $r_{\max}$ are the lower and upper limits of interest rates set by the central bank, satisfying $0 < r_{\min} < r_{\max}$ [1].

Interbank lending. For a given banking network $(N, \boldsymbol{c}(t), \boldsymbol{L}(t))$, demand $\boldsymbol{D}(t)$ and supply $\boldsymbol{S}(\boldsymbol{s}(t))$ are determined by (2) and (3). Each demand bank acts in a random order, borrowing from the supply bank with the largest claim on it. The interbank lending amount is the minimum between the demand and the supply. This process repeats until there is no matching demand or supply left. Once the interbank lending matrix $\boldsymbol{\ell}(\boldsymbol{s}(t))$ is determined, the supply banks will transfer cash to the demand banks. These cash transfers will be considered new liabilities and added to the liability matrix at $t+1$, considering interest rates $\boldsymbol{r}(\boldsymbol{s}(t))$ calculated by (4).

2.2 Game Model

In principle, the interbank market can help banks align cash inflows and outflows. However, during a liquidity crisis, supply banks may tend to hoard liquidity rather than lend it out. We construct a game model to investigate whether the central bank can mitigate this problem. We define a *game* $G(t)$ at each time step t as a tuple $(N_S(t), \Delta(t), \boldsymbol{U}(t))$, where $\Delta(t) = \bigtimes_{j \in N_S(t)} \{\texttt{none}, \texttt{solvent}, \texttt{all}\}$ and $\boldsymbol{U}(t)$ denotes the payoff table.

Strategy. At each time step t, each supply bank $j \in N_S(t)$ can choose one *strategy* from the *strategy space* $\{\texttt{none}, \texttt{solvent}, \texttt{all}\}$ to determine its supply amount and counterparty type (see (3)). A *strategy profile* $\boldsymbol{s}(t)$ includes all supply banks' strategies.

Payoff. For a given strategy profile $\boldsymbol{s}(t)$, each supply bank's *payoff* is determined by its value (see (1)) at the next time step, i.e.,

$$u_j(\boldsymbol{s}(t)) = v_j(t+1).$$

For an interbank lending from j to i, j transfers cash of $\ell_{ji}(\boldsymbol{s}(t))$ to i at t and expects to receive a repayment of $\ell_{ji}(\boldsymbol{s}(t)) \cdot (1 + r_i(\boldsymbol{s}(t)))$ at $t+1$. If i can fully repay this new debt, j's value will increase by $\ell_{ji}(\boldsymbol{s}(t)) \cdot r_i(\boldsymbol{s}(t))$ at $t+1$; if i fails to pay, j's value will decrease at $t+1$. This change in value quantifies j's incentive to lend to i. The *payoff table* $\boldsymbol{U}(t)$ contains payoff data for all strategy profiles.

Central bank lending. The central bank can lend to demand banks to increase the incentives of supply banks. Here, we assume that central bank lending is only issued to solvent banks, to incentivise the interbank market. The amount of central bank lending is defined as the opposite of the sum of the demand bank's net assets at t and $t+1$ if this amount is negative; and 0 otherwise.

3 RESULTS OVERVIEW

The data used in our experiments comes from datasets published by the European Banking Authority (EBA) in the EU-wide Transparency Exercise [2]. We consider 6 banks with the largest total assets as *systemically important banks* (SIBs) and assume that only SIBs are able to lend to others in the interbank market. We use a global *cash parameter* β to control the proportion of cash used for interbank liabilities for each bank, and the lower and upper limits of interest rates are set to $r_{\max} = 0.08$ and $r_{\min} = 0.02$.

Liquidity defaults. We first consider the scenario in which all banks are solvent, i.e., we provide banks with additional cash to ensure their solvency. In this context, with central bank lending, the non-cooperative game converges to the equilibrium where the majority of SIBs tend to lend, leading to increased market supply. As a result, there will be no defaults after interbank lending. On the other hand, if there is no central bank lending, the non-cooperative game will turn to a result in which almost all SIBs choose to hoard liquidity, leading to a number of liquidity defaults. However, if the regulator can intervene in the market through centralised coordination, the interbank market can still perform effectively and efficiently, even without central bank lending.

Mixture of liquidity and solvency defaults. We also investigate cases containing both liquidity and solvency defaults, which is more common in reality. In a general non-cooperative game in which some demand banks are insolvent, many SIBs tend to hoard liquidity, even when supported by central bank lending. On the other hand, in the centralised coordination scenario, some SIBs may choose to solely lend to solvent demand banks when the cash parameter β is small, and an increasing number of banks lend to all demand banks with the increase in β.

4 CONCLUSION

In this work, we study to what extent the interbank market can reduce liquidity defaults and how central bank intervention affects market performance. We build a multiple-period agent-based model to simulate the interbank market and formally define a game in which SIBs can strategically choose their actions. We conduct empirical analysis calibrated on datasets published by the EBA. Our results indicate that the interbank market can effectively reduce liquidity defaults in different scenarios, and central bank lending can incentivise interbank lending, especially in the non-cooperative scenario. Furthermore, centralised coordination can also reduce liquidity defaults, even without central bank lending.

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