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Contagion through common borrowers

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ABSTRACT

We propose a model in which banks are exposed to the risk of contagion through their portfolio of loans. We show that a solvency problem in one bank can be transmitted to another if they lend to the same borrower. The novelty is that the channel for the transmission involves banks' monitoring incentives. The intensity with which all banks monitor a common borrower is reduced when one of the banks suffers a solvency shock. The reduced effort intensity affects the borrower's probability of success and creates a contagion (endogenous correlation) from the balance-sheet of the affected bank to the balance-sheet of the other banks lending to the same borrower. Banks hit by a solvency shock have lower incentives to monitor borrowers because less is left after paying depositors. Banks not hit by a solvency shock face borrowers' risks entirely on their own, which increases the expected cost of lending. As a consequence, they respond by reducing the monitoring intensity for the common borrower. Bank equity can mitigate the risk of contagion.

1. Introduction

Since the global financial crises of 2008–2009, the view that the intertwined structure of financial markets plays a central role in propagating financial problems has become conventional wisdom and has motivated policy reforms. An example of a recent policy change motivated by this perspective is the provision of "single counter-party exposure limits" in the Dodd-Frank Act, which attempts to prevent distress at an institution from spreading to the rest of the system by limiting each firm's exposure to any single counter-party. Although recent contributions have shed light on certain sources of financial contagion, the mechanism through which these problems spill over remains, at best, imperfectly understood (e.g., Allen and Carletti, 2013).

Solvency problems can be transmitted from one institution to another through common asset exposures. Existing literature has provided three different explanations for this: fire sales (Cifuentes et al., 2005), common shocks (Wagner, 2010 and Ibragimov et al., 2011), and roll-over risk (Allen et al., 2012 and Oh, 2013). In this paper, we focus on an alternative explanation: banks' monitoring incentives. We analyze whether banks are exposed to systemic risk through their portfolio of loans. Our approach is based on the observation that lending to a common borrower not only allows banks to share the borrower's risk, but also affects banks' incentives to monitor the borrower.

The contribution of this paper is to show a new channel for the transmission of a solvency problem from one bank to another, which involves the banks' incentive to monitor common borrowers. In this economy, banks monitor borrowers in order to increase the project's success probability. The monitoring activity is costly for banks and unobservable, hence generating a moral hazard problem. A solvency shock to one bank undermines all banks' monitoring incentives. In other words, systemic risk not only arises exogenously from banks' exposures to common borrowers but also evolves endogenously, through an incentive channel.

Our theory may be applied to study the syndicated loan market, where syndicates often have multiple lead banks that are involved in the active monitoring of the borrower. Alternatively, our theory is also relevant for the case when a single firm maintains multiple borrowing relationships with different banks (Ongena and Smith, 2000). Recent empirical literature (e.g., Cai et al., 2018 finds that banks interconnected through loan portfolios in the syndicated loan market contribute more to systemic risk; see also Li and Perez-Saiz, 2018). Our results, therefore, provide theoretical elements to better understand these empirical findings.

We present a model in which there are two identical banks. Each bank holds an ongoing investment and one unit of cash as its unique assets. The ongoing investment is risky, and at an interim date, everyone observes a signal regarding its state. When the sig-

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nal is good, the ongoing investment is successful, whereas a poor signal represents a solvency shock for the bank and implies that the ongoing investment is worthless. Both banks use the unit of cash to finance a common borrower's project. The project may face a liquidity shock before its completion. If the liquidity shock occurs, the project needs an additional injection of funds; otherwise, it is inefficiently liquidated. Only banks with good ongoing investments are able to raise funds to rescue the project from liquidation.

We compare the probability of project success in two different situations: when both banks have good ongoing investments (benchmark) and when one of the banks has suffered a solvency shock. We show that the intensity with which each bank monitors the common borrower is reduced when one of the banks suffers a solvency shock, relative to the benchmark. The bank that has suffered the solvency shock has lower incentives to monitor the borrower because less is left after paying depositors. The healthy bank, on the other hand, faces the borrower's liquidity risk entirely on its own, which increases the expected cost of lending. As a consequence, it responds by reducing the monitoring intensity for the common borrower.

Equity plays a special role in our model. In addition to the standard effect that bank equity leads to an increase in monitoring incentives (e.g., Holmstrom and Tirole, 1997), it also mitigates the risk of contagion (similar to the results in Morrison and Walther, 2017 and Agenor, 2018, though different channels). In our framework, a well-capitalized bank is less affected by a solvency shock to a connected bank, relative to a poorly-capitalized bank. The intuition for this result is as follows: for a bank, both its level of equity and health of the other bank, improve its monitoring incentives. Since the monitoring cost is convex, the marginal effect of the other bank's health on the bank's incentives is decreasing in the level bank monitoring and hence, higher levels of bank equity. For a sufficiently high level of bank equity, the other bank's health does not affect a bank's monitoring incentives.

Our results have a number of additional implications. First empirical, banks monitor the borrowers they share with healthy banks more intensely than the borrowers they share with weak banks. This finding implies that the rate of non-performing loans in a single bank should vary across borrowers, depending on the state of other banks funding these borrowers. To the best of our knowledge, this prediction has not been tested yet.

Second regulatory, the results show that multiple-bank lending is a source of contagion across banks. Possible actions could be a more stringent supervision of banks sharing borrowers with weak financial institutions, or higher regulatory provisions for loans granted to borrowers who are shared with weak banks. Choi (2014) shows that heterogeneity across banks is important for regulation of contagion; stronger banks should be supported earlier, as this will improve the overall system stability more. We show that heterogeneity may also be relevant at a more granular level: different loans originated by the same lender will be differently affected, depending on the co-lenders for each loan.

The rest of the paper is organized as follows. In the next section, we present the related literature. In Section 3, we present the set-up of the model. Section 4 contains the derivation of the equilibrium and the main results. Section 5 discusses the implications of the model. Section 6 concludes. Proofs of the main results are in the Appendix.

2. Related literature

This paper contributes to the literature in financial contagion. Pioneering works by Allen and Gale (2000) and Freixas et al. (2000) analyze financial contagion as a function of the structure of interbank liabilities. They suggest that a more interconnected architecture enhances the resilience of the system to the insolvency of any individual bank. The intuition is that in a more densely interconnected financial network, the losses of a distressed bank are divided among more creditors, thereby reducing the impact of negative shocks to the individual institution on the rest of the system.

Others focus on network externalities created from individual bank risk. For instance, Babus (2015) proposes a model where banks share the risk that the failure of one bank propagates to the entire system. Castiglionesi and Navarro (2016) show that an agency problem between bank shareholders and debtholders leads to fragile financial networks. According to Zawadowski (2013) banks that are connected within a network of hedging contracts fail to internalize the negative effect of their own failure. More recently, Acemoglu et al. (2015) show that the extent of financial contagion exhibits a form of phase transition. They find that when negative shocks affecting financial institutions are sufficiently small, a more densely connected financial network enhances financial stability; however, beyond a certain point, dense connections work as a mechanism of contagion. Whereas all of these papers rely on a domino effect as the source of contagion, this paper focuses on common asset exposure as a source of systemic risk.

Common asset exposure as a channel of contagion has also been addressed by the literature in financial contagion. Banks may (privately) optimally choose to make correlated investments for several reasons: it may be due to government distortions (e.g., Acharya and Yorulmazer, 2007, Farhi and Tirole, 2012 and Horvath and Wagner, 2017), or in order to sharpen incentives by exposing themselves to fire sale risk (Morrison and Walther, 2017). Wagner (2010) and Ibragimov et al. (2011) find that diversification through risk sharing among banks is beneficial for individual institutions, but it increases the likelihood of systemic problems as portfolios become more similar. The common asset exposure literature focuses on contagion through asset sales or roll-over risk. Cifuentes et al. (2005) show that when banks are connected via portfolio holdings, a shock to one bank can spread to the other banks through changes in asset prices, which is only possible in traded assets. Allen et al. (2012) find that when investors observe a bad signal regarding the solvency of an interconnected banking system and cannot identify the situation in their own bank, they may not roll-over the debt. Similar to this strand of the literature, the present paper also considers the possibility of contagion arising from common asset exposures. However, in contrast to these papers, we focus on non-traded assets (loans) rather than traded ones. More specifically, we focus on common borrower exposures and the channel of contagion is monitoring incentives of banks. Several theories study the informational nature of contagion, where news regarding one firm reveals information about another, leading to correlated risks (see e.g., Manz, 2010 and Oh, 2013). In contrast to these studies, we present a moral hazard framework in which contagion adversely affects monitoring incentives.

Our paper adds to the emerging literature that highlights the importance of feedback from the real sector as the source of systemic risk in banks. When lenders share common counter-parties (Li and Perez-Saiz, 2018) or when bank loan portfolios are diversified (Silva, 2017, 2018), the system becomes vulnerable to systemic risk. Our model also relies on feedback from the borrower. Different from these papers, we highlight bank monitoring incentives as the channel for transmission of the risk.

This paper also contributes to the literature in multiple-bank lending. This literature shows that banks co-lending to borrowers introduces frictions. Parlour and Rajan (2001), Attar et al. (2018), and Bennardo et al. (2015) find that multiple-bank lending leads to credit rationing and higher interest rates. Carletti et al. (2007) consider the free-riding problem that arises when there are several banks monitoring the same borrower. They find that the attractive-

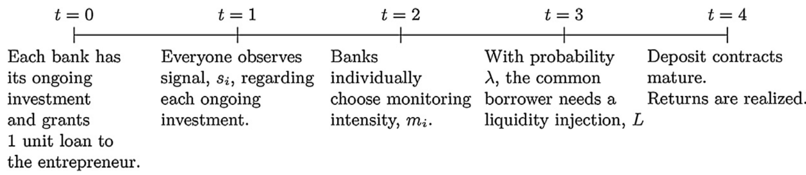

Fig. 1. Timeline.

ness of sharing lending decreases with the amount of bank equity and increases with the cost of monitoring. Our paper contributes to this literature by highlighting a new dark side of multiple-bank lending. Namely, multiple-bank lending induces contagion across financial institutions.

3. Model

We consider an economy with two banks financing a common project and a continuum of identical external investors, who we call depositors; all agents are risk neutral.

Banks are ex-ante identical and indexed by $i \in \{1, 2\}$. Each bank has an ongoing risky investment, I (similar to the legacy loans of Bahaj and Malherbe, 2018), and one unit of cash derived from previous operations. At maturity, the ongoing investment delivers a risky payoff. However, at an interim date, everybody observes a perfectly informative signal, $s_i \in \{g, b\}$, which reveals the state of the ongoing investment of each bank. When $s_i = g$, the bank i's ongoing investment payoff is $r_I I$ at maturity, and when $s_i = b$, the ongoing investment payoff is 0.

Each bank uses the unit of cash to grant a loan to a common penniless borrower who owns a project requiring an upfront investment normalized to 2. The return of the loan is equal to R per unit of investment if the project succeeds, or 0 if it fails. The distribution of such return is affected by banks' monitoring decisions. Each bank chooses the monitoring intensity with which it inspects the borrower's project, $m_i \in [0, 1]$. This choice is not observable. Banks choose the monitoring intensity simultaneously and, given the non-observability of their effort, also non-cooperatively.

The borrower's success probability is increasing in the banks' monitoring efforts. This is a standard assumption in the literature (see Diamond, 1984 for a theoretical treatment and James, 1987 and Lummer and McConnell, 1989 for supporting empirical evidence). The idea is that bank monitoring adds value to borrowers as it resolves agency issues arising between borrowers and lenders.[1] Moreover, banks' efforts are interrelated in the impact on the success probability of the entrepreneur's project. We represent the total monitoring intensity as a function $m_1, m_2 \rightarrow \pi(m_1, m_2)$, where

$$\pi = m_1{}^{\frac{1}{2}} + m_2{}^{\frac{1}{2}} \tag{1}$$

This specification of the monitoring function implies that it is increasing and concave in both arguments.

Monitoring is costly for banks. We model the cost of monitoring as an increasing and convex function of the monitoring intensity: $\frac{cm_i^2}{2}$. Convexity reflects increasing difficulty for the bank to find out more and more about a project.

Similar to Holmstrom and Tirole (1998), we consider that, at an interim date, the project may face a liquidity shock with some probability, λ. If the liquidity shock occurs, continuation can only happen if additional funds, L, are injected into the project; otherwise, the project loses its value. We assume that the expected cost of the liquidity shock, λL, is sufficiently small for bank lending to remain profitable, even if the risk of the shock is taken into account.

A1: $\pi R - 1 - \lambda L > 0$

Additionally, it is assumed that the liquidity shock is sufficiently small such that it is always positive NPV to provide liquidity to the borrower if the shock occurs:

A2: $\pi R - L > 0$

If a bank fails to cover its share of the liquidity needs, it loses its claim to repayment from the borrower, even if the other bank covers the entire liquidity need by itself.

Banks' assets are funded by a combination of equity, E, and debt raised from depositors with the face value, D. Depositors are deep-pocketed investors, without the ability to directly invest in a portfolio of loans and without other investment opportunities. They could provide outside financing to each bank or invest in an alternative project with a rate of return normalized to 1. We assume that the face value of each bank's debt D is larger than the payoff that each bank receives from the common borrower's project, R:

A3: $1 < R < D$

This assumption implies that none of the banks can fully repay initial depositors with the proceeds of the loan granted to the common borrower. What we have in mind with this assumption is that the size of the common borrower loan is small, compared to the size of the existing liabilities of the bank.

Timing. There are five dates, $t = \{0, 1, 2, 3, 4\}$. At $t = 0$, each bank jointly invests its unit of cash in the borrower's project. At $t = 1$, there is a signal, s_i, regarding the quality of each bank's ongoing investment. This signal is observed by all participants, and it perfectly reveals whether the ongoing investment is good or bad, $s_i \in \{g, b\}$. At $t = 2$, each bank simultaneously decides the monitoring intensity with which it will monitor the entrepreneur's project, m_i. At $t = 3$, with probability λ, the entrepreneur's project faces a liquidity shock. If banks cover the liquidity shortage, the returns are realized and distributed at $t = 4$; otherwise, the project ends at this date with a zero liquidation value. Deposit contracts and the ongoing projects mature at the end of $t = 4$. Fig. 1 illustrates this timing.

4. Equilibrium

We look for the subgame perfect Nash equilibrium and solve for the equilibrium backwards. First, we analyze whether or not a bank is able and willing to raise funds at $t = 3$ in order to meet the liquidity needs of the borrower. Then, we derive each bank's choice of monitoring effort at $t = 2$.

4.1. Deposit market at t = 3

In this section, we consider the case when the borrower suffers a liquidity shock, and the banks will need to raise new deposits to fund the borrower's liquidity needs. The amount of deposits that a bank needs to raise depends on whether or not the other bank is contributing to the liquidity needs of the borrower. For tractability, we focus on the symmetric equilibrium, i.e., conditional on being in the same state of the world (good state or bad state), each bank equally contributes to the borrower's liquidity needs. If, however, one bank is in the good state, and the other in the bad state, asym-

[1] For simplicity, we assume that the effect of bank monitoring on borrowers is homogenous; however, it should be noted that heterogeneity may arise across borrowers (see e.g., Diamond, 1991 and Chemmanur and Fulghieri, 1994).

metries may arise. In other words, the level of new deposits that bank i needs to raise depends on the state of the other bank i': when $s_{i'} = g$, $L_i = L/2$, and when $s_{i'} = b$, $L_i = L$.

We denote the minimum interest rate at which new depositors will supply funds as $r_L{}^s$, while the maximum interest rate that the bank is willing to pay for the new deposits is denoted as $r_L{}^d$. The bank raises new deposits in equilibrium if $r_L{}^s \leq r_L{}^d$. The equilibrium is characterised as $\{L_i, r_L\}$, where L_i is the bank's share of the borrower's liquidity need, and $r_L = r_L{}^s$ is endogenously determined.[2] As L_i is pre-determined by $t = 3$ (it depends on the state each bank is in, which is revealed at $t = 1$), we only solve for r_L at $t = 3$, to fully characterize the equilibrium.

4.1.1. Supply of deposits

At $t = 3$, the bank's ability to raise new deposits depends on its own state:

- If the signal of the ongoing investment of bank i is $s_i = b$:
  Then with probability π, the new project succeeds and produces R. Given Assumption *A3*, R is insufficient to repay both existing and new depositors, in full. In this case, new depositors receive their pro-rata share, $\frac{L_i}{D+L_i}R$. With complementary probability $(1-\pi)$, the new project fails, and the bank fully defaults on all of its deposits. Therefore, the expected payoff of the new depositor is $\pi\frac{L_i}{D+L_i}R - L_i < 0$. In other words, when the signal of the ongoing investment is bad ($s_i = b$), time 3 depositors' expected payoff is negative. This implies that even if the bank is willing, it will not be able to raise the deposits to cover the borrower's liquidity needs. This situation is similar to the Myers (1977) debt overhang problem. When a bank suffers a solvency shock, its pre-existing debt prevents it from raising new debt at $t = 3$.
  One may argue that the bank may overcome the overhang problem by giving seniority to the new debt raised at $t = 3$ over pre-existing deposits. However, anticipating this, all pre-existing deposit contracts will include covenants protecting seniority over future deposits raised by banks. This is also in line with what we observe in practice. In the US and many other countries, legislation (the so-called 'depositor preference') prevents issuing securities which are senior to deposits.
- If the signal of the ongoing investment of bank i is $s_i = g$:
  Then with probability π, the project succeeds, and bank i's time 3 depositors will be fully repaid at the promised repayment rate (say r_L). With complementary probability $1-\pi$, the entrepreneur's project fails, and (all) depositors are repaid using only the proceeds of the ongoing investment, $r_I I$. We consider two different cases: i) $\mathbb{1}_I = 1$: $r_I I \geq D + L_i$, the proceeds of the ongoing investment are sufficient to fully repay all deposits (deposits are riskless); ii) $\mathbb{1}_I = 0$: $r_I I < D + L_i$, the proceeds of the ongoing investment are not sufficient to fully repay all deposits (risky deposits). In the latter case, the return from the bank's ongoing project is divided among the existing and new depositors; new depositors receive a pro-rata share, $\frac{L_i}{D+L_i}r_I I$. Given the above considerations, the expected payoff for $t = 3$ depositors of bank i when the signal of the ongoing investment is $s_i = g$ is given by D_i^3 and is equal to:

$$D_i^3 = \pi r_L L_i + (1-\pi)\left[r_L L_i \mathbb{1}_I + r_I I\frac{L_i}{D+L_i}(1-\mathbb{1}_I)\right] - L_i \tag{2}$$

where π is the aggregated monitoring function valued at (m_1, m_2), r_L is the interest rate promised to time 3 depositors, and $\mathbb{1}_I$ is an indicator function taking the value, 1, when $r_I I \geq D + L_i$. Since depositors are willing to invest new funds in the bank as long as they make non-negative profit in expectation, the minimum interest rate at which they will provide funds can be derived by setting Eq. (2) equals to zero.

- $\mathbb{1}_I = 1$: Deposits are riskless and depositors provide the funds, regardless of the size of the liquidity needs. The minimum interest rate that depositors require at $t = 3$, r_L^s, is equal to the opportunity cost of the depositors, i.e., $r_L^s = 1$.
- $\mathbb{1}_I = 0$: Deposits are risky. The minimum interest rate that depositors require at $t = 3$ is:
  $r_L^s = \dfrac{D + L_i - (1-\pi)r_I I}{\pi(D+L_i)}$
  Clearly, in this case, $r_L^s > 1$. Additionally, note that the deposit rate, r_L^s, is increasing in the level of deposit, L_i:

$$\frac{\partial r_L^s}{\partial L_i} = \frac{(1-\pi)r_I I}{\pi(D+L_i)^2} \geq 0 \tag{3}$$

Lemma 1. *Depositors are willing to provide funds to bank i at $t = 3$ only if the signal for the ongoing investment is good (s_i = good). In this case, the required deposit rate is equal to:*

$$r_L{}^s = \begin{cases} 1 & \text{if} \quad r_I I \geq D + L_i \\ \dfrac{D + L_i - (1-\pi)r_I I}{\pi(D+L_i)} & \text{if} \quad r_I I < D + L_i \end{cases} \tag{4}$$

4.1.2. Demand for deposits

At $t = 3$, bank i is willing to raise deposits and provide liquidity to the borrower if its expected payoff is higher than or equal to the expected payoff when it does not provide liquidity. We consider below the bank's incentives to raise new deposits in its two possible states:

- If the signal of the ongoing investment of bank i is $s_i = b$:
  The bank is indifferent between raising new deposits or not. In this case, if the bank does not raise new deposits and fails to provide liquidity to the borrower, then its payoff is 0. On the other hand, if it raises new deposits, and the borrower's loan is rolled over, the bank defaults, as the payoff from the project is insufficient to meet all of the bank's liabilities (due to Assumption, *A3*). Therefore, whether or not the bank raises new deposits, its payoff is 0.
- If the signal of the ongoing investment of bank i is $s_i = g$:
  Raising deposits at $t = 3$ will be an optimal strategy, if and only if,

$$\pi\left[R + r_I I - D - r_L L_i\right] + (1-\pi)\max\left\{0, r_I I - D - r_L L_i\right\} \geq \max\left\{0, r_I I - D\right\} \tag{5}$$

  The LHS is the expected payoff of the bank if it provides liquidity to the borrower. As $s_i = g$, the ongoing project yields $r_I I$. With probability π, the new project succeeds and yields a return, R. The total liability is $D + r_L L_i$. On the other hand, with probability $(1-\pi)$, the new project fails. Note that the bank is protected by limited liability. The RHS is the expected payoff if the bank does not raise new deposits at $t = 3$, and consequently, the new borrower's project fails.
  According to Eq. (5), we consider three situations in order to derive the maximum interest rate that bank i is willing to pay to time 3 depositors:
  - $r_I I > D + r_L L_i$, the proceeds of the ongoing investment are sufficient to cover existing and new deposits. By using this inequality in Eq. (5), raising deposits at $t = 3$ is an optimal strategy for bank i if:
    $r_L \leq \dfrac{\pi R}{L_i}$

[2] Since depositors are deep-pocket investors without opportunity cost, they will deposit in the bank as long as they do not have negative expected return.

Substituting the above inequality in $r_I I > D + r_L L_i$, the relevant parameter space is rewritten as: $r_I I > D + \pi R$.

– $D < r_I I < D + r_L L_i$, the proceeds of the ongoing investment are sufficient to cover existing deposits, but not the sum of the new and existing deposits: in this case, deposits are risky. By using this inequality in Eq. (5), raising deposits at $t = 3$ is an optimal strategy for bank i if:
$$r_L \leq \frac{\pi R - (1-\pi)(r_I I - D)}{\pi L_i}$$
Substituting the above inequality in $D < r_I I < D + r_L L_i$, the relevant parameter space is rewritten as: $D < r_I I < D + \frac{\pi R - (1-\pi)(r_I I - D)}{\pi}$.

– $r_I I < D$, the proceeds of the ongoing investment are insufficient to cover existing deposits: in this case, deposits are risky. By using this inequality in Eq. (5), raising deposits at $t = 3$ is an optimal strategy for bank i, if:
$$r_L \leq \frac{R - (D - r_I I)}{L_i}$$

Lemma 2. *Bank i is willing to raise deposits at $t = 3$ only if the signal for the ongoing investment is good ($s_i = g$). In this case, the deposit rate that the bank is prepared to promise in order to raise the necessary funds is:*

$$r_L{}^d \leq \begin{cases} \dfrac{\pi R}{L_i} & \text{if } r_I I > D + \pi R \\ \dfrac{\pi R - (1-\pi)(r_I I - D)}{\pi L_i} & \text{if } D < r_I I \leq D + \dfrac{\pi R - (1-\pi)(r_I I - D)}{\pi} \\ \dfrac{R - (D - r_I I)}{L_i} & \text{if } r_I I \leq D, \end{cases} \tag{6}$$

and it equals 0; when the signal of the ongoing investment is bad, $s_i = b$.

4.1.3. Equilibrium in the market for deposits

We know from Lemma 1 that when the signal of the ongoing investment is bad, the bank will not be able to raise new deposits. If the signal is good, the bank is able to raise deposits, as long as the interest rate paid to depositors is high enough ($r_L{}^s$ is sufficiently high). On the other hand, we know from Lemma 2 that when the signal of the ongoing investment is good, a bank is willing to raise deposits, as long as the promised repayment is not too high ($r_L{}^d$ is sufficiently low). For any given parameter values, a bank raises new deposits if the minimum interest rate required by depositors, $r_L{}^s$, is lower than the maximum interest rate at which the bank is willing to raise deposits, $r_L{}^d$. Using Eqs. (4) and (6), we get:

- If $D + L_i < r_I I$, deposits are riskless and $r_L{}^s = 1$. As we assume that providing liquidity to the borrower is positive NPV, we have $\frac{\pi R}{L_i} > 1$ (i.e., the demand condition is satisfied for $r_L{}^d = 1$). Therefore, bank i covers the borrower's liquidity needs, and the loan rate is set as $r_L = 1$.
- If $D < r_I I \leq D + r_L L_i$, deposits are risky and $r_L > 1$. Bank i will cover the borrower's liquidity needs if:
$$R > \frac{L_i(\pi D + L_i) + (1-\pi)D(r_I I - D)}{\pi(D + L_i)}$$
- If $r_I I \leq D$, deposits are risky and $r_L > 1$. Bank i will cover the borrower's liquidity needs if:
$$R > \frac{(L_i + \pi D)(D + L_i - r_I I)}{\pi(D + L_i)}$$

This implies that the bank will raise deposits and cover its share of the borrower's liquidity needs, if the size of the liquidity shock is sufficiently small compared to the return of the on-going investment.

4.2. Monitoring incentives at t=2

For the remainder of the text, we focus on the situation where the size of the liquidity shock L is such that a bank is willing to inject liquidity when the borrower suffers a liquidity shock. We show that in this parameter space, a solvency shock to one bank may spread to the other.

We derive the optimal level of monitoring intensity at $t = 2$. In order to simplify the notation and without a loss of generality, we focus our attention on bank 1. Here on, we drop index i from the parameters of the model. Consider the case when the borrower needs a liquidity injection at $t = 3$. Bank 1 is able to raise deposits to meet liquidity needs only if $s_1 = g$. If $s_2 = g$, bank 1 contributes $\frac{L}{2}$, and its expected payoff is $\pi(r_I I + R - (D + r_L L/2)) - cm_1^2$. If, however, $s_2 = b$, bank 1 contributes L at $t = 3$, and its expected payoff is $\pi(r_I I + R - (D + r_L L)) - cm_1^2$. Note that the deposit rate, r_L, depends on the level of deposits and $r_L(L/2) < r_L(L)$. Finally, if bank 1 suffers a solvency shock, i.e., $s_1 = b$, it fails to raise new deposits due to the debt overhang, and its payoff is $-cm_1^2$. Bank 1's expected payoff at $t = 2$, denoted as V_1^2, is summarized below:

$$V_1^2(s_1, s_2) = \begin{cases} \pi[r_I I + R - (D + \lambda r_L(L/2)L/2)] - \dfrac{cm_1^2}{2} & \text{if } s_1 = g \text{ and } s_2 = g \\ \pi[r_I I + R - (D + \lambda r_L(L)L)] - \dfrac{cm_1^2}{2} & \text{if } s_1 = g \text{ and } s_2 = b \\ -\dfrac{cm_1^2}{2} & \text{if } s_1 = b \end{cases} \tag{7}$$

Next, we derive the optimal level of monitoring in two cases: when both banks have good ongoing investments, i.e., $s_i = g$ for all i (the benchmark case), and when bank 2 suffers a negative shock to its ongoing investment i.e., $s_1 = g$ and $s_2 = b$ (the contagion case).

4.2.1. Benchmark: the case without solvency shocks

In order to derive the optimal monitoring intensity in a scenario without solvency shocks, we focus on the first line of Eq. (7). Bank 1's first order condition with respect to the level of monitoring intensity is given by the following equation:

$$\pi_{m_1}[r_I I + R - (D + \lambda r_L(L/2)L/2)] - cm_1 = 0 \tag{8}$$

Therefore, the second best level of monitoring intensity of bank 1, when neither bank has suffered a solvency shock, $m_1^{*benchmark}$, is implicitly given by the solution to Eq. (8). An analog equation can be derived for bank 2. The equilibrium level of monitoring depends on the size of possible the liquidity shock L.

Proposition 1. *The optimal individual level of monitoring intensity when none of the banks has experienced a solvency shock is equal to $m^{*benchmark} > 0$ (from Eq. (8)):*

$$m^{*benchmark} = \left(\frac{\alpha}{2c}\right)^{\frac{2}{3}} \tag{9}$$

where $\alpha = r_I I + R - (D + \lambda r_L(L/2)L/2)$.

4.2.2. Contagion: solvency shock to bank 2

We define contagion as a scenario in which a solvency shock to one bank affects the other bank's incentives and the average quality of its loans. Hence, in this model, there is contagion if a shock to, say bank 2, affects bank 1's incentives and the project's success probability.

In order to derive the optimal monitoring intensity in a scenario with a solvency shock to bank 2, we focus on the second line of Eq.

(7). The first order condition with respect to monitoring intensity of bank 1 is:

$$\pi_{m_1}[r_I I + R - (D + \lambda r_L(L)L)] - cm_1 = 0 \tag{10}$$

The equilibrium level of monitoring of bank 1, m_1^{*shock}, is implicitly given by Eq. (10). As discussed above, bank 2's equilibrium level of monitoring, m_2^{*shock}, is equal to 0.

Proposition 2. *The optimal individual level of monitoring intensity, when only one of the banks has experienced a solvency shock, is equal to 0 for the bank that experienced the shock, and is equal to $m^{*shock} > 0$ for the other bank (from Eq. (10)):*

$$m^{*shock} = \left(\frac{\alpha'}{2c}\right)^{\frac{2}{3}} \tag{11}$$

where $\alpha' = r_I I + R - (D + \lambda r_L(L)L)$.

4.2.3. Comparison

Next, we compare the individual monitoring intensities under the two scenarios described above, and we summarize the result in the following proposition.

Proposition 3. *Individual monitoring intensities are lower for both banks when one of the banks has experienced a solvency shock, i.e., $m_i^{*benchmark} \geq m_i{}^{*shock}$ for $i \in \{1, 2\}$.*

Proof. See the appendix. □

According to Proposition 3, not only the bank which suffers the solvency shock has lower incentives to monitor the borrower, but also the other bank. The reasons, however, differ for each bank. The bank that has suffered the solvency shock will get a negative payoff if it exerts a non-zero level of effort. In other words, monitoring will not be rewarded. By contrast, the other bank will monitor less because it no longer shares the borrower's liquidity risk. If the entrepreneur's project suffers a liquidity shock, the solvent bank has to meet the borrower's entire liquidity need on its own. This imposes an extra cost for the solvent bank, which reacts by reducing its monitoring intensity. Therefore, as a corollary of Proposition 3 we can state the following result.

Corollary 1. *The aggregate equilibrium level of monitoring intensity, and hence, the success probability of the project is lower when one of the banks has experienced a solvency shock, i.e., $\pi^{*benchmark} \geq \pi^{*shock}$ for $i \in \{1, 2\}$.*

Proposition 3 and Corollary 1 make up the formal statement of our main result. The aggregate level of monitoring, and therefore, the project's success probability is lower when one of the banks has experienced a solvency shock. This implies that a bank will see a reduction in its average portfolio quality as a consequence of a solvency shock suffered by another bank with whom it shares borrowers.

4.3. The role of equity

In this section, we analyze whether the level of bank equity plays a role in inhibiting the contagion mechanism pointed out in the previous section. We first state the following result:

Corollary 2. *The optimal individual level of monitoring intensity, m_i, and the project's success probability, π, are increasing in the level of bank equity E_i.*

Proof. See the appendix. □

The result stated in Corollary 2 is consistent with the main results in moral hazard problems: the more skin in the game the agent has, the more effort she will exert in the project (e.g., Holmstrom and Tirole, 1997) The importance of this result here is that higher equity may curb contagion. We state this result below:

Proposition 4. *Bank equity mitigates contagion. The adverse effect of a negative shock to bank 2 on bank 1's monitoring incentives and the project's success probability are decreasing in bank 1's level of equity. Specifically:*

$$\frac{\partial \Delta m_1}{\partial E_1} \leq 0$$

where, $\Delta m_1 = m_1{}^{benchmark} - m_1{}^{shock}$.

Proof. See the appendix. □

The intuition for this result is as follows: from bank i's perspective, the health of the other bank and its own level of equity, E_i, are substitutes in the sense that both lead to stronger monitoring incentives. The cost of monitoring is convex. Therefore, at higher levels of equity (when monitoring is already high), the marginal value of the other bank's health on monitoring incentives is small. As a result, contagion is less damaging if a bank is well capitalized. In fact, for a sufficient level of capitalization, a shock to one bank will not affect the other bank's incentives to monitor the borrower. We state this result below:

Corollary 3. *There exists a threshold $\hat{E}$ such that when a bank's equity is higher than or equal to it, $E \geq \hat{E}$, its monitoring incentives are not affected when the other bank suffers a solvency shock.*

Proof. See the appendix. □

4.4. Robustness: the free-rider problem

The literature in multiple-lending argues that lending to the same borrower may give rise to a free-rider problem among lenders, in the sense that monitoring can be seen as public good. We have in mind the situation in which one bank may find optimal to reduce its contribution to monitoring when the other bank increases it. In terms of our model, considering free-riding implies that $\pi_{m_1 m_2} < 0$. Under this assumption, if a bank suffers a solvency shock and consequently reduces its monitoring intensity, the other bank may compensate for this reduction by increasing its monitoring intensity, which affects some of our results. Specifically, it is no longer true that a bank, i, always exerts lower effort if the other bank, i', suffers a solvency shock. The effect that a free-riding problem has on banks' incentives is opposite to the contagion effect described here. The net effect is an empirical question and depends on the severity of the free-rider problem.

Below we augment our basic model with free-riding between lenders. For tractability, we assume a specific form for the combined monitoring intensity. In particular, the combined monitoring intensity and, therefore, the borrower's probability of success is assumed to be:

$$\pi = m_1{}^{\frac{1}{2}} + m_2{}^{\frac{1}{2}} - \gamma m_1 m_2 \tag{12}$$

where $\gamma \geq 0$. Free-riding is captured by the term $-\gamma m_1 m_2$. The parameter γ represents the severity of the free-rider problem. Notice that $\gamma = 0$ returns us to the baseline case with no free-riding, and $\gamma = 1$ brings us to the specification of Carletti et al. (2007).

Using Eq. (8), we derive the benchmark case (no shock) symmetric equilibrium in which $m_1 = m_2$:

$$m_i^{*benchmark} = \frac{\alpha}{2(c + \gamma\alpha)}^{\frac{2}{3}} \tag{13}$$

where $\alpha = r_I I + R - (D + \lambda r_L L/2)$.

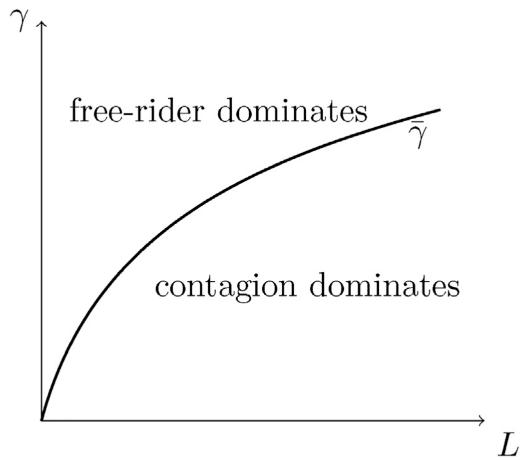

Fig. 2. Contagion vs Free rider problems.

When there is a solvency shock to bank 2 ($s_2 = b$), $m_2 = 0$. Using Eq. (10), we derive the shock case:

$$m_1^{*shock} = \frac{\alpha'}{2c}^{\frac{2}{3}} \tag{14}$$

where $\alpha' = r_l I + R - (D + \lambda r_L L)$.

The contagion effect dominates the free-rider effect if $\Delta m = m_1^{*benchmark} - m_1^{*shock} > 0$, which simplifies as follows:

$$\gamma < \bar{\gamma} \equiv \frac{c(\alpha - \alpha')}{\alpha\alpha'} \tag{15}$$

Fig. 2 illustrates this relationship.

5. Implications

In this section, we discuss the empirical and regulatory implications of the results derived in the previous section.

5.1. Empirical predictions

The results derived in the previous section suggest at least two effects of multiple lending on the credit market.

First, multiple lending allows idiosyncratic risks to become systemic by creating a contagion channel. Banking systems more interconnected through shared loans are systemically riskier. Further, this risk of contagion increases when the shared borrowers are more likely to face liquidity shocks, such as in times of recessions. Cai et al. (2018) find strong empirical support for this prediction (see also Li and Perez-Saiz, 2018). They show that banks more heavily interconnected through syndicated corporate loans contribute more to systemic risk, and the effect is exacerbated during recessions.

Second, contagion via multiple lending creates externalities that undermine the incentives of financial institutions to monitor their borrowers. Banks will exert more monitoring on borrowers that they share with healthy banks. Since monitoring affects borrowers' likelihood of repayment, more monitoring would result in a lower rate of non-performing loans. This implies that the rate of non-performing loans of a single bank should vary across borrowers, depending on the equity level of other banks funding these borrowers. We are not aware of any empirical work that tests this prediction.

5.2. Policy

Bank authorities have been largely concerned about the consequences of systemic risk on the stability of the financial sector. Different policy measures have been taken, aimed at minimizing the individual exposures across banks. Our results suggest, however, that not only are direct links across banks relevant for systemic risk, but also indirect links arising from common borrowers. In particular, this is due to a decrease in banks' monitoring incentives when one of the co-lending banks is hit by a solvency shock. Since a bank's monitoring is unobserved, it is not possible to regulate directly.

There are, however, two possible ways to mitigate the problem. One possible solution could be a more stringent supervision of those banks sharing borrowers with weak financial institutions, or higher regulatory provisions for loans granted to borrowers who borrow from weak banks. The other policy implication comes from the discussion in Section 4.3, which states that a high enough level of equity inhibits the possibility of contagion through the monitoring incentive channel. It should be noted that being better capitalized is not only privately beneficial for a bank, but also socially beneficial in banking systems that are highly intertwined through common borrowers. The social benefit derives from the bank equity's ability to contain spillovers of negative monitoring shocks to connected banks. Given that banks would not internalize this social benefit of equity, the socially optimal level of capital would be higher than the bank's privately optimal level of capital. This suggests that a regulator should step in and curb this source of contagion by setting high enough capital requirements.

6. Conclusions

The intertwined nature of the banking sector has been proffered as an explanation for the spread of risk throughout the system. This view has motivated changes in regulatory frameworks and has opened an important debate regarding the sources of financial contagion.

Our paper contributes to this debate by presenting a new channel through which solvency problems can spread across financial institutions. It shows that multiple-bank lending can lead to contagion. The channel for the transmission involves the monitoring incentives of banks. A solvency shock in one bank undermines the monitoring incentives of all banks financing the same borrower. The bank that has suffered the solvency shock has lower incentives to monitor the borrower because it has less to recover after paying depositors. The bank that has not suffered from the shock has lower incentives to monitor the borrower because it no longer shares the liquidity risk of the borrower with the other bank. As a consequence, the bank that has not suffered the solvency shock reacts by reducing the monitoring intensity for the common borrower.

Our results have a number of implications. First, banks monitor borrowers that they share with healthy banks more intensely. Second, in order to assess the risk of contagion, the regulator should consider the degree of bank interconnectedness arising from loan portfolios. This can be addressed either by exerting more stringent supervision to banks sharing borrowers with weak financial institutions, or by imposing higher regulatory provisions to the loans shared with weak banks. Bank equity mitigates the risk of contagion.

Appendix A.

This appendix contains the proofs of Propositions 3 and 4, and Corollaries 2 and 3.

Proof of Proposition3

In order to compare the equilibrium monitoring intensities in the case of shock and non-shock, we have to compare the optimal level of monitoring implicitly defined by Eqs. (8) and (10). The difference in these equations is given by the term in brackets, so they can be written as:

$$\pi_{m_i}\alpha - cm_i = 0 \tag{16}$$

where α corresponds to $[R-(D+\lambda r_L(L/2)L/2)]$ and $[R-(D+\lambda r_L(L)L)]$ for Eqs. (8) and (10), respectively. By totally differentiating Eq. (16), we get the following:

$$\frac{\partial m_i}{\partial \alpha} = -\frac{\pi_{m_i}}{\pi_{m_i m_i}\alpha - c} \geq 0$$

Notice that $[R-(D+\lambda r_L(L/2)L/2)] > [R-(D+\lambda r_L(L)L)]$. This is true since $L/2 < L$ and $r_L(L/2) < r_L(L)$. Thus, we have that individual monitoring intensities are lower when one of the banks has been hit by a solvency shock.

Proof of Corollary2

To prove this corollary, we write Eq. (8) as a function of equity, E. To do so, we establish the relationship between the face value of debt D and the level of equity E:

$$1 + I = D + E \tag{17}$$

Plugging the value of $D = 1 + I - E$ into Eq. (8), and totally differentiating this equation we get the following:

$$\frac{\partial m_i}{\partial E} = -\frac{\pi_{m_i}}{\pi_{m_i m_i}\alpha - c} \geq 0$$

This implies that individual monitoring intensities are monotonically increasing functions of the level of equity.

Proof of Proposition4

We need to show that the change in the monitoring intensity of bank 1, due to a shock to bank 2, is lower when bank 1 has a higher level of equity:

$$\frac{\partial \Delta m}{\partial E_1} < 0$$

where $\Delta m = m_1{}^{benchmark} - m_1{}^{shock}$.

Taking the difference between Eqs. (8) and (10) and using Eq. (1):

$$\Delta m = \left(\frac{\alpha}{2c}\right)^{\frac{2}{3}} - \left(\frac{\alpha'}{2c}\right)^{\frac{2}{3}}$$

Differentiating with respect to E_1 and re-arranging,

$$\begin{aligned}\frac{\partial \Delta m}{\partial E_1} &= \frac{2}{3}\left(\frac{\alpha}{2c}\right)^{-\frac{1}{3}}\frac{\partial \alpha}{\partial E_1} - \frac{2}{3}\left(\frac{\alpha'}{2c}\right)^{-\frac{1}{3}}\frac{\partial \alpha'}{\partial E_1}\\ &= \frac{2}{3}\left(\frac{\alpha}{2c}\right)^{-\frac{1}{3}} - \frac{2}{3}\left(\frac{\alpha'}{2c}\right)^{-\frac{1}{3}} < 0\end{aligned}$$

The expression is negative since $\alpha > \alpha'$.

Proof of Corollary3

We know from Corollary 2 that individual monitoring intensities are monotonically increasing functions of the level of equity. Furthermore, individual monitoring intensities are bounded by 1, i.e., $m_i \in [0, 1]$, such that $\pi \in [0, 1]$. Therefore, there exists a threshold $\hat{E}$, such that for all $E \geq \hat{E}$, $m_i = 1$, regardless of the behavior of the other bank.

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