Information Contagion and Bank Herding[1]

Viral V. Acharya[2]
London Business School and CEPR

Tanju Yorulmazer[3]
Bank of England

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[2]Contact: Department of Finance, London Business School, Regent's Park, London – NW1 4SA, England. Tel: +44 (0)20 7262 5050 Fax: +44 (0)20 7724 3317 e–mail: vacharya@london.edu. Acharya is also a Research Affiliate of the Centre for Economic Policy Research (CEPR).

[3]Contact: Systemic Risk Reduction Division, Bank of England, Threadneedle Street, London, EC2R 8AH, Tel: +44 (0) 20 7601 3198 Fax: +44 (0) 20 7601 3217 e–mail: Tanju.Yorulmazer@bankofengland.co.uk

Information Contagion and Bank Herding

Abstract

We show that the likelihood of information contagion induces profit-maximizing bank owners to herd with other banks. When bank loan returns have a common systematic factor, the cost of borrowing for a bank increases when there is adverse news on other banks, since such news, in turn, conveys adverse information about the common factor. The increase in a bank's cost of borrowing relative to the situation of good news about other banks is greater when bank loan returns have less commonality (in addition to the systematic risk factor). Hence, banks herd and undertake correlated investments so as to minimize the impact of such information contagion on the expected cost of borrowing. Competitive effects such as superior margins from lending in different industries mitigate herding incentives.

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1 Introduction

In this paper, we show that the likelihood of information contagion can induce even profit-maximizing bank owners to herd with other banks. Banks have an incentive to herd so as to minimize the information spillover from bad news about other banks on their borrowing costs and in turn on their future profits.

In our model, there are two periods and two banks with access to risky loans and deposits that are borrowed from risk-averse depositors. The returns on each bank's loans consist of a systematic component, say a common factor driving loan returns such as an aggregate or an industry cycle, and an idiosyncratic component. The ex-ante structure of each bank's loan returns, specifically their exposure to systematic and idiosyncratic factors, is common knowledge; the ex-post performance of each bank's loan returns is also publicly observed. However, the exact realization of systematic and idiosyncratic components is not observed by the economic agents. Ex ante, banks choose whether to lend to similar industries and thereby maintain a high level of inter-bank correlation, or to lend to different industries. If banks lend to similar industries, their lending margins are eroded relative to the margins they earn upon lending to different industries.

The poor performance of each bank conveys potential bad news about the common factor affecting loan returns. Similarly, the good performance of each bank is good news about the common factor. Depositors rationally update priors about the prospects of their bank based on the information received about not only their bank's returns but also of the other bank. In particular, depositors require a higher promised rate on their deposits if the other bank has performed poorly compared to the state in which both banks have done well. This is an information spillover of one bank's poor performance on the other bank's borrowing costs.[1] Indeed, if the future profitability of loans is low, the bank that performed well may not be able to pay the borrowing rate when one bank performs poorly though it can pay this rate

[1]Empirical evidence on the information spillover from bank failures on other banks' borrowing costs is plenty: Carron (1982) shows that the Franklin National failure in New York (and perhaps also the Herstatt failure in Germany) in mid-1974 led to an increase in the quarterly average spread between US jumbo certificates of deposits (CDs) and 3-month Treasury bills by a factor of at least six. Cooperman, Lee and Wolfe (1992) examine the effect of the 1985 Ohio Deposit Insurance crisis on the pricing of retail six-month CDs for a sample of 69 federally-insured Ohio banks and savings and loans. The results indicate a significant unexpected rise in weekly CD prices for less solvent Ohio depository institutions (lasting approximately seven weeks). Jayanti and Whyte (1996) estimate statistically significant increases in the average CD rates – at constant Treasury bill reference rates – for both UK and Canadian banks after the Continental Illinois failure in the United States in May 1984. Finally, Saunders (1987) acknowledges that the average spread between 3-month Euro-dollar deposits and T-Bills doubled during the Continental Illinois problem in months of April and May 1984. An even stronger effect was visible in the average monthly domestic (US) risk premium, as measured by the difference between 3-month CD rates and 3 month T-Bill rates, which more than tripled during April and May 1984.

when both banks perform well. Hence, we interpret this spillover as an information contagion.

We argue that in order to minimize the impact of such information contagion on profits, banks alter their ex-ante investment choices. The increase in cost of borrowing for a bank when the other bank has performed poorly relative to when this other bank has done well is greater when bank loan returns have less commonality. Formally, let r_i^{HH}, r_i^{HL}, and r_i^{LL} denote, respectively, the costs of borrowing when both banks perform well, only one bank performs well, and both banks perform poorly with $i \in \{s, d\}$ denoting whether banks invested in the same industry or in different industries (with r_s^{HL} not defined in the model as banks are perfectly correlated when they invest in the same industry). Then, it can be shown that (Proposition 1):

$$r_d^{HH} < r_s^{HH} < r_d^{HL} = r_d^{LH} < r_s^{LL} < r_d^{LL}. \tag{1}$$

The intuition for this result is that when banks invest in the same industry, their returns are perfectly correlated and banks' performance will be identical. Hence, observing the other bank's performance will reveal no additional information about a given bank. Thus, when banks invest in the same industry, joint good (poor) performance is not as good (bad) news about the common systematic risk factor as in the case where banks invest in different industries. Given this relationship between costs of borrowing in different future states and under different investment choices, the expected borrowing cost of banks is minimized by investing in the same industry. This result holds as long as depositors are risk-averse.

Counteracting this herding force is the erosion of lending margins from investing in similar industries. As long as the effect of competition on bank margins is not too severe, the above intuition prevails: banks herd, that is, they choose correlated investments, over a robust set of parameter values for the future profitability of corporate sector (Proposition 2). Incentives to herd by lending to a common industry are thus stronger if there is a high concentration amongst banks in lending to that industry, or, if that industry has experienced a positive technology shock reducing the rate at which returns-to-scale diminish. Such herding can lead to productive inefficiency as banks may bypass profitable projects in other industries of the economy.

Section 2 discusses the related literature. Section 3 presents the model. Section 4 analyzes the model and delivers the results on herding. Section 5 discusses the robustness of our results. Section 6 concludes.

2 Related Literature

The empirical studies on bank contagion test whether bad news, such as a bank failure, the announcement of an unexpected increase in loan-loss reserves, bank seasoned stock issue announcements, etc., adversely affect other banks.[2] These studies have found evidence of contagion using a variety of indicators: intertemporal correlation of bank failures (Hasan and Dwyer 1994, Schoenmaker 1996), bank debt risk premiums (Carron, 1982, Saunders, 1987, Cooperman, Lee and Wolfe, 1992, Jayanti and Whyte, 1996), deposit flows (Saunders, 1987, Saunders and Wilson, 1996, Schumacher, 2000), survival times (Calomiris and Mason, 1997, 2003), and stock price reactions (Aharony and Swary, 1983, Swary, 1986, Slovin, Sushka, and Polonchek, 1992, and 1999, and Lang and Stulz (1992), to cite a few). This evidence is consistent with the channel of information spillover across banks that drives our results.

Our model of information contagion is close to the models of Chen (1999) and Kodres and Pritsker (2002). Chen (1999) builds a model with multiple banks with interim revelation of information about the performance of some banks. With Bayesian-updating depositors, a sufficient number of interim bank failures results in pessimistic expectations about the general state of the economy, and leads to runs on the remaining banks. In contrast, in our model the information spillover shows up in increased borrowing rates (and potentially also in bank failures) – an aspect that relates better to the empirical evidence. Kodres and Pritsker (2002) allow for alternative channels for contagion and show that contagion can occur between markets due to cross-market rebalancing even in the absence of correlated information and liquidity shocks. Neither of these papers models the endogenous choice of correlation of banks' investments.

Our paper is closest in spirit to Acharya (2000) who examines the choice of ex-ante inter-bank correlation in response to pecuniary externalities that arise upon bank failures, and Acharya and Yorulmazer (2004, 2005) who investigate a similar problem but in response to "too-many-to-fail" regulatory guarantees. The channel of information spillover that we examine complements these channels.

Finally, our paper is related to the vast literature on herding. In this literature, herding is often an outcome of sequential decisions, with the decision of one agent conveying information about some underlying economic variable to the next set of decision-makers. In Scharfstein and Stein (1990), for example, herding behavior is driven by managerial concerns for reputation ("sharing the blame" when there is joint under-performance) and involves sequential investments. Herding, however, need not always be the outcome of such an informational cascade. It can also arise from a coordination game. In our paper, herding is a simultaneous ex-ante decision of banks to coordinate correlated investments. In this sense, our modelling

[2] If the effect is negative, the empirical literature calls it the "contagion effect." The overall finding is that the contagion effect is stronger for highly leveraged firms (banks being typically more levered than other industries) and is stronger for firms with similar cash flows. If the effect is positive, it is termed the "competitive effect." The intuition is that demand for the surviving competitors' products (deposits, in the case of banks) can increase. Overall, this effect is found to be stronger when the industry is less competitive, that is, more concentrated.

approach is similar to Rajan (1994) who also considers herding based on managerial reputation considerations but models coordination in the announcement of losses by short-termist bank managers. We view our channel of herding under which even profit-maximizing bank owners have incentives to herd as being complementary also to these reputation-based channels.

3 Model

There are two banks in the economy, Bank A and Bank B, and three dates, $t = 0, 1, 2$. The timeline in Figure 1 details the sequence of events in the economy. There is a single consumption good at each date. Each bank can borrow from a continuum of depositors of measure 1. Depositors consume their each-period payoff (say, w). We assume that:

(A1): Depositors have risk-averse time-additive utility $u(w)$, with $u'(w) > 0$, $u''(w) < 0$, $\forall w > 0$. By way of normalization, we assume that $u(0) = 0$, and we denote $u(1)$ by $\overline{u}$.

Depositors have one unit of the consumption good at $t = 0$ and $t = 1$. Bank owners are risk-neutral and also consume their each-period payoff. All agents have access to a storage technology that transforms one unit of the consumption good at date t to one unit at date $t+1$. In each period, that is at date $t = 0$ and $t = 1$, depositors choose to keep their good in storage or to invest it in their bank. We assume that:

(A2): Deposits take the form of a simple debt contract with maturity of one period. In particular, the promised deposit rate is not contingent on realized bank returns, which are assumed to be observable but non-verifiable.

(A3): Banks are monopolists in the deposit markets they operate. This can arise due to the costs associated with changing banks that unsophisticated depositors incur, such as switching and searching costs.[3]

Banks choose to invest the borrowed goods in storage or in a risky asset. The risky asset is to be thought of as a portfolio of loans to firms in the corporate sector. The performance of a bank's loan portfolio is determined by the random output of its borrowers and is denoted by $\widetilde{R}_t$: either the output is high and there is correspondingly a high return on the bank portfolio, denoted by R_t, or the output is low, in which case the return on bank's loan portfolio is low, denoted by L_t. We assume that:

(A4): The low return from the first period investment is equal to 1, that is, $L_0 = 1$. And the low return from the second period investment is equal to 0, that is, $L_1 = 0$.

[3]Data collected on current account switching behavior from the Financial Research Survey of the National Opinion Poll for the UK imply that a representative current account holder would only change banks every 91 years (Gondat-Larralde and Nier, 2006).

Hence, from the depositors' point of view, deposits in the first period are riskless.

The return on bank investments depends on a systematic component, a common factor affecting loan returns, and an idiosyncratic component. We refer to the common factor as the overall state of the economy, which can be $Good(G)$ or $Bad(B)$, recognizing that it represents more broadly any common component of loan returns (such as a sector-specific or a regional component) that is not perfectly observable.[4] The state of the economy is assumed to persist for both periods of the economy. The prior probability that the state is G for the risky asset is p. Even if the overall state of the economy is *Good* (*Bad*), the return can still be low (high) due to the idiosyncratic component. The probability of a high return on bank investments when the state is good is $q \in (1/2, 1)$: when the state is good, it is more likely, although not certain, that the return will be high. The probability that the return is high when the state is *Bad* is $(1 - q)$. Therefore, the probability distributions of returns in different states are symmetric. For simplicity, we also assume that:

(**A5**): Conditional on the state of the economy, the realizations of returns in the first and second period are independent.

Furthermore, we allow the promised returns on bank loans to vary over time.

The possible states at date 1, denoted by j, are given as follows: HH : Both banks had the high return; HL (LH) : Bank A (B) had the high return, while Bank B (A) had the low return; and, LL : Both banks had the low return.

3.1 Correlation of bank returns

Banks can choose the level of correlation between the returns from their respective investments by choosing the composition of loans that compose their respective portfolios. We will refer to this correlation as "inter-bank correlation" and denote it as ρ.[5]

We model banks' choice of correlation in a simple way. There are two possible industries in which banks can invest, denoted as 1 and 2. Bank A (B) can lend to firms A_1 and A_2 (B_1 and B_2) in industries 1 and 2, respectively. If in equilibrium banks choose to lend to firms in the same industry, specifically they either lend to A_1 and B_1, or they lend to A_2 and B_2, then they are assumed to be perfectly correlated ($\rho = 1$). However, if they choose different industries, then their returns are less than perfectly correlated, say independent ($\rho = 0$). Let

[4] This opaqueness about the bank balance-sheet and realized returns is critical to our model. Given that a proportion of bank loans is in fact to small- and medium-sized firms, usually unrated by rating agencies, we believe the assumption that such an unobservable common factor exists is a reasonable one.

[5] In order to focus exclusively on the choice of inter-bank correlation, we abstract from the much-studied issue of the banks' choice of the scale of their loan portfolios and their absolute level of risk. This abstraction is common to several papers in this literature including the ones on herding due to managerial reputation considerations.

$E(\Pi_i)$ be the expected profit for a bank when banks invest in the same industry ($i = s$) or in different industries ($i = d$). Hence, in a Nash equilibrium, if banks invest in the same industry, then they receive $E(\Pi_s)$, whereas if they invest in different industries, that is, in (A_1, B_2) or (A_2, B_1), then they receive $E(\Pi_d)$. In the Nash equilibrium, banks invest in the same industry if $E(\Pi_s) > E(\Pi_d)$, and invest in different industries otherwise. Thus, for the same level of inter-bank correlation, the identity of the industries banks invest in does not matter in terms of bank returns. In other words, while there may be multiple Nash equilibria that correspond to the same level of inter-bank correlation, they are payoff equivalent. In turn, it is sufficient to concentrate analysis on the inter-bank correlation ρ, rather than on the identity of individual industries for banks' choice.

When banks operate in the same industries, they compete with each other for corporate loans and drive each other's profit margins down. We model this in the following simple way:

(**A6**): The return on a bank's investment when the return is high is $(\theta(\rho)R_t)$, where $\theta(\rho)$ captures the effect of competition on bank returns.[6] When $\rho = 0$, banks invest in different industries and do not face any competition, that is, $\theta(0) = 1$. And, when banks invest in the same industry, that is, when $\rho = 1$, $\theta(1) = (1 - \delta)$, where $\delta \in [0, 1)$.

We can provide a micro-foundation for competition in the lending market in the following way. Suppose that when banks operate in different industries, they are monopolists in the markets they operate in, whereas when they operate in the same industry, they compete as Cournot duopolists. We provide a detailed analysis in the Appendix. In this case, we can show that, when the return is high, the profit of each bank when they operate in different industries, that is, when they are monopolists, is equal to 9/4 times the profit of each bank when they invest in the same industry, that is, when they are Cournot duopolists. This, in turn, gives us $\delta = \left(\frac{5(R_t-1)}{9R_t}\right)$.

In our model banks choose which industries to invest in for both of their investments, that is, at $t = 0$ and $t = 1$. Later on we show that it is never optimal to invest in the same industry at $t = 1$.

4 Analysis

While the choice of inter-bank correlation is determined by backwards induction, it is easier for sake of exposition to first examine the investment problem at date 0.

[6] We assume that when the return is low, the investment is liquidated, there is a separate market for liquidating these investments and the liquidation value does not depend on the interbank correlation. Hence, when the return is low, banks get a return of L_t for $\rho \in \{0, 1\}$.

4.1 First investment problem (date 0)

Recall that deposits in this period are riskless. Thus, banks can attract deposits by offering depositors the risk-free rate of 1. However, when the return is low, bank pays all the proceeds back to depositors and makes a profit equal to 0.[7] Thus, the expected payoff to the bank at date 0 from its first-period investment, $E(\pi_{1,i})$, where $i = s$ when they invest in the same industry and $i = d$ when they invest in different industries, is

$$E(\pi_{1,i}) = \alpha_0[\theta(\rho)R_0 - 1], \tag{2}$$

where α_0 is the probability of having the high return from the first investment and is given as: $\alpha_0 = [pq + (1-p)(1-q)]$.

Note that this first-period expected payoff is decreasing in the inter-bank correlation.

4.2 Second investment problem (date 1)

Recall our simplifying assumption that realizations of returns in the first and second periods are independent, conditional on the state of the economy. Since there is a systematic component in the probabilities of returns which persists for both periods, the banks' return from their first investments is relevant information and depositors rationally update their beliefs in response to this information.

However, the extent of information revealed to the depositors depends on whether banks have invested in the same or different industries at $t = 0$. Next, we analyze each case separately. Before doing so, we would like to introduce the following notation. Let $P_i(G|j)$ and $P_i(B|j)$ represent the posterior probabilities of the overall state of the economy being *Good* (G) and *Bad* (B), respectively, when the industries banks invest in at $t = 0$ are denoted by $i \in \{s, d\}$, and the states at $t = 1$ being denoted by $j \in \{HH, HL, LH, LL\}$.

4.2.1 Same industry $(i = s)$ at $t = 0$

Note that when banks invest in the same industry at $t = 0$, their returns are perfectly correlated, that is, either both banks have the high return (HH) or both have the low return (LL). Using this, depositors update the probabilities about the overall state of the economy to obtain

$$P_s(G|HH) = \frac{pq}{pq + (1-p)(1-q)} \quad \text{and} \quad P_s(B|HH) = \frac{(1-p)(1-q)}{pq + (1-p)(1-q)}, \tag{3}$$

$$P_s(G|LL) = \frac{p(1-q)}{p(1-q) + (1-p)q} \quad \text{and} \quad P_s(B|LL) = \frac{(1-p)q}{p(1-q) + (1-p)q}. \tag{4}$$

[7] We assume that $(1-\delta)R_0 > 1$, as otherwise the problem at hand is rendered uninteresting.

Using these posterior probabilities for the state of the economy, depositors calculate the probability of a high return for their bank in the second period, denoted as α_i^j, as

$$\alpha_s^{HH} = \frac{pq^2 + (1-p)(1-q)^2}{pq + (1-p)(1-q)} \quad \text{and} \quad \alpha_s^{LL} = \frac{q(1-q)}{p(1-q) + (1-p)q} \ . \tag{5}$$

By the individual rationality of depositors, we obtain that $r_s^{HH} = u^{-1}(\overline{u}/\alpha_s^{HH})$ and $r_s^{LL} = u^{-1}(\overline{u}/\alpha_s^{LL})$. Note that the borrowing rates (r_i^j), and hence the expected borrowing cost, at $t = 1$ depend on the information revealed by banks' performances from the first period investments, which, in turn, depend on the correlation in banks' investments in the first period. However, the borrowing rates at $t = 1$ do not depend on banks' choice of correlation at $t = 1$. Furthermore, if banks invest in the same industry at $t = 1$, they drive down their returns by (δR_1). Hence, banks never invest in the same industry at $t = 1$.

The payoff to each bank at date 2 from the second-period investment, denoted by $\pi_{2,i}^j$, is thus given by

$$\pi_{2,s}^j = \begin{cases} R_1 - r_s^{HH} & \text{if} \quad j = HH \text{ and } \widetilde{R}_1 = R_1 \quad \text{and} \quad R_1 > r_s^{HH} \\ R_1 - r_s^{LL} & \text{if} \quad j = LL \text{ and } \widetilde{R}_1 = R_1 \quad \text{and} \quad R_1 > r_s^{LL} \\ 0 & \text{otherwise} \end{cases} \ . \tag{6}$$

4.2.2 Different industries ($i = d$) at $t = 0$

With the information of the returns of both banks in the first period, depositors can update the probabilities about the overall state of the economy, to obtain

$$P_d(G|HH) = \frac{pq^2}{pq^2 + (1-p)(1-q)^2} \quad \text{and} \quad P_d(B|HH) = \frac{(1-p)(1-q)^2}{pq^2 + (1-p)(1-q)^2}, \tag{7}$$

$$P_d(G|LL) = \frac{p(1-q)^2}{p(1-q)^2 + (1-p)q^2} \quad \text{and} \quad P_d(B|LL) = \frac{(1-p)q^2}{p(1-q)^2 + (1-p)q^2}, \tag{8}$$

$$P_d(G|HL) = P_d(G|LH) = p \quad \text{and} \quad P_d(B|HL) = P_d(B|LH) = (1-p)\,. \tag{9}$$

Using these posterior probabilities about the state of the economy, depositors can calculate the probability of a high return for their bank in the second period as

$$\alpha_d^{HH} = \frac{pq^3 + (1-p)(1-q)^3}{pq^2 + (1-p)(1-q)^2} \quad \text{and} \quad \alpha_d^{HL} = \alpha_d^{HL} = \alpha_0, \tag{10}$$

$$\alpha_d^{LL} = \frac{pq(1-q)^2 + (1-p)q^2(1-q)}{p(1-q)^2 + (1-p)q^2}. \tag{11}$$

By the individual rationality of depositors, we obtain that $r_d^{HH} = u^{-1}(\overline{u}/\alpha_d^{HH})$, $r_d^{HL} = r_d^{HL} = u^{-1}(\overline{u}/\alpha_d^{HL})$ and $r_d^{LL} = u^{-1}(\overline{u}/\alpha_d^{LL})$. Thus, the payoff to each bank at date 2 from the second period investment, denoted as π_2^{HH}, is given by

$$\pi_d^j(0) = \begin{cases} R_1 - r_d^{HH} & \text{if} \quad j = HH \text{ and } \widetilde{R}_1 = R_1 \quad \text{and} \quad R_1 > r_d^{HH} \\ R_1 - r_d^{HL} & \text{if} \quad j = HL\ (LH) \text{ and } \widetilde{R}_1 = R_1 \quad \text{and} \quad R_1 > r_d^{HL} \\ R_1 - r_d^{LL} & \text{if} \quad j = LL \text{ and } \widetilde{R}_1 = R_1 \quad \text{and} \quad R_1 > r_d^{LL} \\ 0 & \text{otherwise} \end{cases} . \quad (12)$$

Note that if $R_1 < r_s^{HH}$ in equation (6), or $R_1 < r_d^{HH}$ in equation (12), then it is individually rational for depositors not to lend their goods to banks. Storage is preferred to deposits, since the highest return on loans is insufficient to compensate depositors for the risk of bank failure. We consider all such possible cases in our analysis.

4.3 Information Spillover

We can now characterize the spillover from the realization of a return for one bank on the other bank. In particular, the bank that had the high return has a higher cost of borrowing when the other bank has the low return, relative to the state where both banks had the high return (HH).[8] This is a negative spillover resulting from a bank's poor performance. This spillover tends to reduce the profits of banks in states where they have high returns but their peers have low returns. The result is an "information contagion".[9] In fact, if the profitability of the surviving bank's investments (level of promised return on loans R_1) is low enough, the increased borrowing cost can render the surviving bank unviable: depositors "run" on the bank in response to other bank's low return since it is better for them to invest in storage than to lend to their bank. Conversely, the good performance of a bank results in a positive spillover on the other bank by lowering its cost of borrowing.

Proposition 1 (Information Spillover) $\forall\ p \in (0,1)$ *and* $q \in (1/2, 1)$, *we have*

$$r_d^{HH} < r_s^{HH} < r_d^{HL} = r_d^{LH} < r_s^{LL} < r_d^{LL}. \quad (13)$$

[8] Under our assumed two-point return distribution for each bank, the information spillover arises precisely when a bank has the low return. With a continuous return distribution, any combination of realizations of bank profits leads to rational updating by depositorsand the overall spillover remains qualitatively similar. The bank with superior performance always suffers some information spillover due to the relatively inferior performance of the other bank. To summarize, date 1 in our model could simply be considered an "information event" that leads to rational updating by depositors. The resulting revision of borrowing costs would affect bank profits as long as banks require additional financing.

[9] It is plausible that banks increase their lending rates when faced by an increased borrowing cost. However, this would ration those bank borrowers with project returns that are lower than the lending rate offered by the bank. Providing that a bank cannot undo completely the decrease in its profits from increased borrowing rates by increasing its lending rates, this result on information contagion holds. We consider this scenario reasonable, given the typical diminishing returns-to-scale faced by banks on lending side.

Proof: *See Appendix.*

Note that the return depositors demand in state HH (LL) increases (decreases) as the correlation in banks' investments increases. The reason for this is the following: when banks are perfectly correlated, $\rho = 1$, banks' performance will be identical and observing the other bank's performance will reveal no additional information about a given bank.

Proposition 1 suggests that if a period of good news for the banking sector in general is followed by bad news for a few banks, then other banks' profits and values could fall due to an increase in borrowing costs. Much empirical evidence exists to support such rational updating by depositors and the resulting information spillover on bank values and borrowing costs.[10] It is worthwhile to point out that what is crucial for our analysis is that bank profits fall as a result of information updating. While in our model profits fall due to an increase in the cost of borrowing deposits, this could arise more generally due to an increase in the cost of issuing subordinated debt and/or equity. This observation is crucial once the possibility of deposit insurance is considered. We discuss this in more detail in Section 5.

Before exploring the consequences of such information contagion for the endogenous choice of inter-bank correlation at date 0, the following computation of the expected payoff of banks from their second-period investment is required. The ex-ante expected second-period return of bank A (and by symmetry, of bank B) is given by

$$\begin{aligned} E(\pi_{2,i}) \quad = \quad & P_i(R_1, HH)\, [R_1 - r_i^{HH}]^+ + P_i(R_1, HL)\, \left[R_1 - r_i^{HL}\right]^+ + \\ & P_i(R_1, LH)\, \left[R_1 - r_i^{LH}\right]^+ + P_i(R_1, LL)\, [R_1 - r_i^{LL}]^+, \end{aligned} \tag{14}$$

where the expressions $P_i(R_1, HH)$, $P_i(R_1, HL)$, $P_i(R_1, LH)$ and $P_i(R_1, LL)$ represent, respectively, the joint probabilities of having the high return from the second investment and having states HH, HL, LH and LL from the first investments, when banks invest in the same ($i = s$) and different industries ($i = d$) at $t = 0$.

4.4 Choice of Inter-Bank Correlation

In this section, we show that under some conditions banks choose to be perfectly correlated at date 0 in response to the anticipated information spillover at date 1.

[10] See footnote 1 and the references in Section 2. In addition, Rajan (1994) examines the effects of an announcement on December 15, 1989, that Bank of New England was hurt from the poor performance of the real estate sector and that it would boost its reserves to cover bad loans. He documents significant negative abnormal returns (-2.4%) for all banks, and that the effect was stronger for banks with headquarters in New England (-8%). Both of these features are consistent with the analysis of our model. He also documents significant negative abnormal returns for the real estate firms in general, whereas the negative effect is stronger for real estate firms with holdings in New England. This suggests that the information revealed by the announcement was rationally taken into account by investors in their updating process.

Note that, at $t = 1$, banks always choose to invest in different industries. Hence, the objective of each bank is to choose whether to invest in same ($i = s$) or different ($i = d$) industries at $t = 0$ to maximize

$$\max_{i \in \{s,d\}} E(\pi_{1,i}) + E(\pi_{2,i}).$$

This choice implies inter-bank correlation $\rho = 1$ for $i = s$ and $\rho = 0$ for $i = d$ for the first period investment. Note that $E(\pi_{1,i})$ equals $[\alpha_0 \ (\theta(\rho)R_0 - r_0)]$ and $E(\pi_{2,i})$ is given by equation (14). This maximization yields the following result on ex-ante herding by banks.

Proposition 2 *If banks are not viable in state HH when they invest in the same industry, that is, for $R_1 < r_s^{HH}$, banks invest in different industries. In all other cases, there exist threshold values of δ such that, when δ is above that threshold, banks invest in different industries and when δ is below that threshold, banks invest in the same industry.*

Proof: *See Appendix.*

If competition amongst banks in lending to a common set of industries does not erode their lending margins too rapidly, then herding occurs over a robust set of parameter values. While the proof of this proposition can be found in the Appendix, we provide an intuitive explanation of our result based on the special case where $\delta = 0$, that is, when competition does not have any effect on bank loan returns, and where banks are viable in all states at $t = 1$, that is, $R_1 \geq r_d^{LL}$.

Since there is no competition in this special case, $E(\pi_{1,i})$ is independent of ρ. Thus, banks concentrate on the second-period profits and choose to be perfectly correlated provided $E(\pi_{2,s}) > E(\pi_{2,d})$. Next, we show that for the economy studied thus far, this condition always holds. In particular, the expected cost of attracting depositors in the second period is minimized when banks are perfectly correlated.

The expected second-period profit, given in equation (14), is effectively the expected return on bank loans minus the expected borrowing cost in the second period. Note that whether banks invest in the same or different industries, the probability of having the high return R_1 from the second investment is given as

$$P_i(R_1) = P_i(R_1, HH) + P_i(R_1, HL) + P_i(R_1, LH) + P_i(R_1, LL) = \alpha_0. \tag{15}$$

Thus, inter-bank correlation affects bank profits only through the expected borrowing cost. For sake of argument, suppose that depositors are risk-neutral with the utility function $u(w) = w$. In this case, we can calculate the expected borrowing cost $E(r_i)$ as

$$E(r_i) = \sum_j P_i(R_1, j) \cdot (1/\alpha_i^j), \tag{16}$$

where $\alpha_i^j = P_i(R_1|j) = \frac{P_i(R_1,j)}{P_i(j)}$ represents the conditional probability of having the high return R_1 from the second investment in state $j \in \{HH, HL, LH, LL\}$. Using the conditional probabilities α_i^j, we can show that

$$E(r_i) = \sum_j P_i(R_1, j) \left(\frac{P_i(j)}{P_i(R_1, j)} \right) = P_i(HH) + P_i(HL) + P_i(LH) + P_i(LL). \tag{17}$$

Furthermore, we have

$$P_d(HH) + P_d(HL) = P_d(H) = P_s(HH) = P_s(H). \tag{18}$$

Also note that we have $P_s(R_1, HH) = P_d(R_1, HH) + P_d(R_1, HL)$. Thus, when depositors are risk-neutral, by equation (18), the expected borrowing cost at $t = 1$ when a bank has the high return (H) from the first investment is the same when they invest in the same or in different industries. In other words, the probability distribution f_d^H that assigns probability $\left(\frac{P_d(R_1,HH)}{P_s(R_1,HH)}\right)$ to $r_d^{HH} = \left(1/\alpha_d^{HH}\right)$ and probability $\left(\frac{P_d(R_1,HL)}{P_s(R_1,HH)}\right)$ to $r_d^{HL} = \left(1/\alpha_d^{HL}\right)$ can be shown to be a mean-preserving spread of the probability distribution f_s^H that assigns probability 1 $\left(= \frac{P_s(R_1,HH)}{P_s(R_1,HH)}\right)$ to $r_s^{HH} = \left(1/\alpha_s^{HH}\right)$.

Now, consider the risk-aversion of depositors. If depositors are risk-averse, then $v(= u^{-1})$ is a convex function and we obtain

$$E(r_i) = \sum_j P_i(R_1, j) \cdot v(\overline{u}/\alpha_i^j). \tag{19}$$

Thus, by second-order stochastic dominance and the convexity of v, we have

$$P_d(R_1, HH) \cdot v(\overline{u}/\alpha_d^{HH}) + P_d(R_1, HL) \cdot v(\overline{u}/\alpha_d^{HL}) > P_s(R_1, HH) \cdot v(\overline{u}/\alpha_s^{HH}). \tag{20}$$

The same result can be shown to hold for the case of low returns. Hence, as long as depositors are risk-averse (Assumption 1), expected borrowing cost is higher when banks invest in different industries. Thus, in the special case of no competition ($\delta = 0$), banks herd and invest in the same industry.

In the general case where competition among banks reduce their profit margins, the benefit of lower expected borrowing costs from investing in the same industry can be eroded by lower profit margins. Hence, there is a critical level of δ, denoted by δ^*, such that when competition reduces profit margins severely, that is, when $\delta > \delta^*$, banks invest in different industries whereas when competition is not very severe, that is, when $\delta \leqslant \delta^*$, banks herd.

Hence, incentives to herd by lending to a common industry are stronger if there is a high concentration amongst banks in lending to that industry, or, if that industry has experienced a positive technology shock reducing the rate at which returns-to-scale diminish. In turn, such herding can lead to productive inefficiency as banks may bypass profitable projects in other industries of the economy.

5 Robustness

In this section, we discuss the robustness of our results to relaxing various assumptions, considering deposit insurance and uninsured bank funding, and allowing for alternative ways of bank herding such as creating inter-bank linkages and making syndicated loans.

Deposit insurance and uninsured bank funding: If banks are funded only by insured deposits, then their cost of borrowing would be rendered insensitive to fluctuations in banks' health. In turn, information spillover of the sort we described would be irrelevant. Formally, suppose a proportion $y \in [0,1]$ of bank deposits are insured and the rest are uninsured deposits. Then, if the bank performs well, depositors receive the promised return of r, whereas if the bank performs poorly, depositors receive y units from the deposit insurance fund. It is straightforward to show that as the proportion of insured deposits y increases, the sensitivity of the promised deposit rate r to the probability of success α decreases. This, in turn, weakens the effect of information spillover.

The provision of deposit insurance is only partial in most countries. Some countries do not have deposit insurance (e.g., Australia, New Zealand, and Malaysia) while the coverage is limited in almost all countries that have insurance schemes (e.g., in the U.S., deposits are insured up to \$100000, and in the U.K., up to £20,000).[11] As long as deposits are not fully insured and banks do access sizable quantities of uninsured deposits and other uninsured forms of capital (such as subordinated debt), our results continue to hold. For example, in the U.S., the proportion of funding that is FDIC-insured is only 31% and 62% for large and small banks, respectively, illustrating the importance of uninsured forms of bank funding.[12] Increasingly, banks have employed uninsured subordinated debt as a form of funding whose interest rates respond to information pertaining to the bank's health. Empirical studies have documented a significant correlation between bank-specific risks and secondary-market subordinated debt spreads, especially in the post-FDICIA period in the U.S. starting in

[11] As Jayanti and Whyte (1996) note in their study of UK and Canadian banks after the Continental Illinois failure: " In reality, however, deposit insurance schemes vary across countries in terms of, inter alia, the extent of coverage (maximum amount per deposit or per customer), scope of coverage (whether foreign banks and foreign offices of domestic banks are covered), the types of deposits covered (whether residents' and non-residents' deposits and foreign currency deposits are covered), and premium structure (flat premium or risk-based premium). Furthermore, absence of an explicit deposit insurance scheme may result in a contagion effect... In all the countries where deposit insurance is in existence, ceilings on the amount of deposits insured are imposed... Thus, although the presence of deposit insurance reduces fear of loss by insured depositors, the uninsured depositors may still incur losses in the event of a bank failure. The market's perception of the extent to which uninsured depositors are likely to suffer losses may significantly influence the market reaction [to bank failures]."

[12] See, for example, the presentation by George Pennacchi, University of Illinois at Urbana Champagne, at www.business.uiuc.edu/gpennacc/f461n02.ppt.

1991.[13] Recognition of such risk-sensitive marginal sources of bank funding implies that poor performance of a bank affects other banks' cost of borrowing even in the presence of partial deposit insurance.

Alternative ways of herding: While lending to similar industries is one way for banks to increase the correlation in their returns, there are also other approaches that may not lead to erosion of profit margins as in the case of lending. First, banks could bet on systematic risk factors such as interest-rate risk through choosing from a range of products such as mortgages and interest-rate derivatives. That is, banks could specialize within a class of risk exposures to achieve a trade off between incentives to correlate and to differentiate. Second, banks can lend to similar set of customers and get exposed to similar risks without erosion of profit margins by participating in syndicated loans to common set of borrowers.[14]

Bankruptcy and flight to quality: In this model, we assumed that the low return from the first period investment is equal to 1, that is, $L_0 = 1$. Hence, banks do not fail at $t = 1$ and always have the chance to make the second period investment. In an unabridged version of this paper, we relax this assumption and allow for lower values for L_0 so that banks can go bankrupt at $t = 1$, in which case, they are closed and cannot do the second period investment. In that case, depositors of the failed bank can migrate to the surviving bank, if there is any. This increases the benefit for banks from surviving when other banks fail and, in turn, strengthens incentives for differentiation.

Origins of banking crises: The literature on the origins of banking crises provide strong empirical evidence for the fact that bank failures result from shocks to the asset side of banks' balance sheet, which is consistent with the predictions of our model. In many instances, bank failures are related to the current condition of the economy or the particular sectors banks operate in, which affect the asset side of banks' balance sheet. Gorton (1988) conducts an empirical analysis using US data from the late 19th and early 20th century and finds a close relation between the occurrence of banking panics and the overall state of the economy. Calomiris and Gorton (1991) use a larger set of data and find similar evidence. Furthermore, consistent with the predictions of our model, we observe from the empirical literature that

[13] See, for example, Covitz, Hancock and Kwast (2004) for the period 1985-1987 and Jagtiani, Kaufman, and Lemieux (2000), DeYoung et al. (2001), Hancock and Kwast (2001), and Morgan and Stiroh (2001) for the post-FDICIA period. Moreover, the National Depositor Preference Act of 1993 lowered the liquidation standing of bank subordinated debt, which had a positive effect on the subordinated debt market's sensitivity to bank-specific risks. Furthermore, Morgan and Stiroh (1999), using data for the 1993-98 period, found that the relationship between issuance bond spreads and bond ratings was about the same for banks as it was for other corporate firms.

[14] See Jain and Gupta (1987) for a discussion of the role of syndicated loans for bank herding during the emergining market debt crisis in the early 1980s.

bank failures and periods of tranquillity cluster over time. Grossman (1993), Hasan and Dwyer (1994) and Schoenmaker (1996) analyze data from the US Free Banking Era (1837-1863) and provide evidence of intertemporal clustering of bank failures.

6 Conclusion

This paper showed that the likelihood of information contagion can induce profit-maximizing bank owners to herd with other banks. Our model provides a way to jointly study various aspects of systemic risk, the risk that banks may fail together. While most studies of systemic risk and financial fragility are concerned with the ex-post effects of bank failures and losses, our paper demonstrates that analyzing the ex-ante response of banks to these effects may be important. The extent of herding can be considered the ex-ante aspect of systemic risk: It affects the likelihood of joint failure of banks, but also affects and is affected by the extent of information contagion, which can be considered the ex-post aspect of systemic risk. The lack of exhaustive empirical evidence on the extent of bank herding, its causes, and the nature of its variation over the business cycle suggests that further investigation of these issues is warranted to improve our understanding of systemic risk in financial sectors. We view our channel of herding under which even profit-maximizing bank owners have incentives to herd as being complementary to other herding channels. Differentiating between these various channels of herding (reputational, regulatory or information-based) is an open theoretical and empirical question for future research.

A Proofs

Modelling competition in the lending market: Here, we provide one possible way of modelling competition in the lending market: When banks operate in different industries, they are monopolists in the markets they operate in, whereas when they operate in the same industry, they compete as Cournot duopolists.

Let $P = a - bQ$ define the inverse demand function for bank loans in each industry, where $a > 0$ and $b > 0$. Note that the deposits are riskless for the first period investment so that the cost of borrowing is given as $r_0 = 1$. Banks are monopolists when they operate in different industries. In this case, banks' problem is to choose the units of loans to supply, denoted by x, to maximize total profits, that is,

$$\underset{x \geqslant 0}{Max} \quad P(x)x - x.$$

This gives us the quantity supplied by the monopolist bank $x_m = \left(\frac{a-1}{2b}\right)$. The resulting price is $P_m = \left(\frac{a+1}{2}\right)$. And the monopolist bank makes a profit of $\Pi^m = \left(\frac{(a-1)^2}{4b}\right)$.

When banks operate in the same industry, they compete as Cournot duopolists. Let x_a and x_b be the quantities Bank A and Bank B supply, respectively. We can write Bank A's problem as

$$\underset{x_a \geqslant 0}{Max} \quad P(x)x_a - x_a,$$

where $x = (x_a + x_b)$ is the total quantity of loans supplied by Bank A and Bank B. We can write Bank B's maximization problem in a similar way. Solving these two problems simultaneously gives us $x_a^* = x_b^* = \left(\frac{a-1}{3b}\right)$. The resulting price is $P_c = \left(\frac{a+2}{3}\right)$. And each bank makes a profit of $\Pi^c = \left(\frac{(a-1)^2}{9b}\right)$.

Hence, $\frac{\Pi^c}{\Pi^m} = 4/9$. Note that in the specification we use, when the return is high, $\Pi^m = (R_0 - 1)$ and $\Pi^c = ((1-\delta)R_0 - 1)$. And, this gives us $\delta = \left(\frac{5(R_0-1)}{9R_0}\right)$.

Proof of Proposition 1: We prove the whole proposition in four steps: we show (i) $\alpha_s^{HH} > \alpha_d^{HL}$, (ii) $\alpha_s^{LL} < \alpha_d^{HL}$, (iii) $\alpha_s^{HH} < \alpha_d^{HH}$ and (iv) $\alpha_d^{LL} < \alpha_s^{LL}$. Since $u' > 0$, we have $(u^{-1})' > 0$. Hence, showing that these four cases hold is sufficient to prove the Proposition.

(i) We need to show

$$\begin{aligned}
&\frac{pq^2 + (1-p)(1-q)^2}{pq + (1-p)(1-q)} > pq + (1-p)(1-q) \Longleftrightarrow \\
&pq^2 + (1-p)(1-q)^2 > p^2q^2 + 2pq(1-p)(1-q) + (1-p)^2(1-q)^2 \Longleftrightarrow \\
&0 < p(1-p)q^2 - 2pq(1-p)(1-q) + p(1-p)(1-q)^2 \Longleftrightarrow \\
&q^2 - 2q(1-q) + (1-q)^2 > 0 \Longleftrightarrow (2q-1)^2 > 0,
\end{aligned}$$

which is always satisfied.

(ii) We need to show

$$\frac{q(1-q)}{p(1-q) + (1-p)q} < pq + (1-p)(1-q) \Longleftrightarrow \tag{21}$$

$$1 < p^2 + p(1-p)\left[\frac{(1-q)}{q} + \frac{q}{(1-q)}\right] + (1-p)^2. \tag{22}$$

Note that the right-hand side is increasing in q, for $q \geqslant 1/2$. Hence right-hand assumes its minimum value of $(p-(1-p))^2 = 1$ when $q = 1/2$. This gives us the desired result.

(iii) We need to show

$$\frac{pq^2 + (1-p)(1-q)^2}{pq + (1-p)(1-q)} < \frac{pq^3 + (1-p)(1-q)^3}{pq^2 + (1-p)(1-q)^2}. \tag{23}$$

Dividing the numerator and the denominator of the right-hand side by q, we get

$$\frac{pq^2 + (1-p)(1-q)^2}{pq + (1-p)(1-q)} < \frac{pq^2 + (1-p)(1-q)^2 \left(\frac{1-q}{q}\right)}{pq + (1-p)(1-q)\left(\frac{1-q}{q}\right)}. \tag{24}$$

We can write the above condition as

$$\frac{e+f}{c+d} < \frac{e+fz}{c+dz}, \tag{25}$$

where $e = pq^2$, $f = (1-p)(1-q)^2$, $c = pq$, $d = (1-p)(1-q)$ and $z = \left(\frac{1-q}{q}\right)$. The above condition boils down to

$$\frac{e+f}{c+d} < \frac{e+fz}{c+dz} \Longleftrightarrow fc < ed \Longleftrightarrow (1-q) < q. \tag{26}$$

which is satisfied when $q > 1/2$.

(iv) We need to show

$$\begin{aligned}
\frac{q(1-q)}{p(1-q)+(1-p)q} &> \frac{pq(1-q)^2 + (1-p)q^2(1-q)}{p(1-q)^2 + (1-p)q^2} \Longleftrightarrow \\
\frac{1}{p(1-q)+(1-p)q} &> \frac{p(1-q)+(1-p)q}{p(1-q)^2+(1-p)q^2} \Longleftrightarrow \\
p(1-q)^2 + (1-p)q^2 &> p^2(1-q)^2 + 2pq(1-p)(1-q) + (1-p)^2q^2 \Longleftrightarrow \\
0 &< p(1-q)^2(1-p) - 2pq(1-p)(1-q) + (1-p)pq^2 \Longleftrightarrow \\
(1-q)^2 - 2q(1-q) + q^2 &= (q-(1-q))^2 = (2q-1)^2 > 0,
\end{aligned}$$

which is always satisfied.

These four steps complete the proof. $\diamondsuit$

Proof of Proposition 2: Note that depending on R_1, banks may or may not be viable in some states in the second period. Below, we prove each case separately.

Case 1: $R_1 \geq r_d^{LL}$: We first analyze the case where banks are viable in all states. To start with, we assume that competition does not affect banks' profit margins, that is, $\delta = 0$ and $\theta(\rho) = 1$ for all $\rho \in \{0, 1\}$. We have expected second period profit given as:

$$\begin{aligned}
E(\pi_i) &= P_i(R_1, HH)\,[R_1 - r_i^{HH}] + P_i(R_1, HL)\,\left[R_1 - r_i^{HL}\right] + \qquad (27)\\
&\quad P_i(R_1, LH)\,\left[R_1 - r_i^{LH}\right] + P_i(R_1, LL)\,[R_1 - r_i^{LL}], \qquad (28)
\end{aligned}$$

which can also be written as:

$$E(\pi_i) = \underbrace{R_1 \cdot \overbrace{[P_i(R_1,HH) + 2P_i(R_1,HL) + P_i(R_1,LL)]}^{=P_i(R_1)}}_{\text{expected return from second investment}} - \tag{29}$$

$$\underbrace{\left[P_i(R_1,HH)\ \left(r_i^{HH}\right) + 2P_i(R_1,HL)\ \left(r_i^{HL}\right) + P_i(R_1,LL)\ \left(r_i^{LL}\right)\right]}_{=E(r_i)=\text{expected cost of borrowing}}. \tag{30}$$

where the expressions for probabilities $P_i(R_1,HH)$, $P_i(R_1,HL)$, $P_i(R_1,LH)$ and $P_i(R_1,LL)$ are given as:

$$P_d(R_1,HH) = pq^3 + (1-p)(1-q)^3, \tag{31}$$

$$P_d(R_1,HL) = P_d(R_1,LH) = pq^2(1-q) + (1-p)q(1-q)^2, \tag{32}$$

$$P_d(R_1,LL) = pq(1-q)^2 + (1-p)(1-q)q^2, \tag{33}$$

$$P_s(R_1,HH) = pq^2 + (1-p)(1-q)^2, \tag{34}$$

$$P_s(R_1,HL) = P_s(R_1,LH) = 0, \tag{35}$$

$$P_s(R_1,LL) = pq(1-q) + (1-p)(1-q)q. \tag{36}$$

Using the joint probabilities above, we can find the probabilities $P_i(R_1,H)$ and $P_i(R_1,L)$ for individual banks as follows:

$$P_d(R_1,H) = P_d(R_1,HH) + P_d(R_1,HL) = pq^2 + (1-p)(1-q)^2 = P_s(R_1,HH) = P_s(R_1,H), \tag{37}$$

$$P_d(R_1,L) = P_d(R_1,LH) + P_d(R_1,LL) = q(1-q) = P_s(R_1,LL) = P_s(R_1,L), \tag{38}$$

where $P_i(R_1,H)$ and $P_i(R_1,L)$ represent the probability of having the high return R_1 from the second investment and having the high (H) and low (L) return from the first investment, respectively. Note that these probabilities are independent of the inter-bank correlation ρ.

We can also show that $P_s(R_1) = P_d(R_1) = pq + (1-p)(1-q) = \alpha_0$. As a result, in this case, the inter-bank correlation can affect banks' profits only through the expected cost of borrowing. We have the expected borrowing cost $E(r_i)$ given as:

$$E(r_i) = P_i(R_1,HH)\ \left(r_i^{HH}\right) + 2P_i(R_1,HL)\ \left(r_i^{HL}\right) + P_i(R_1,LL)\ \left(r_i^{LL}\right). \tag{39}$$

For the moment, suppose that depositors are risk neutral with the utility function $u(w) = w$. Then, we would have $r_i^j = 1/\alpha_i^j$, where $\alpha_i^j = P_i(R_1|j) = \frac{P_i(R_1,j)}{P_i(j)}$. In that case, that is, when depositors have the utility function $u(w) = w$, we have[15]

$$E(r_i) = \sum_j P_i(R_1, j) \left(\frac{P_i(j)}{P_i(R_1, j)} \right) = P_i(HH) + P_i(HL) + P_i(LH) + P_i(LL) = 1. \quad (40)$$

We have

$$\begin{aligned} E(r_d) &= P_d(HH) + P_d(HL) + P_d(LH) + P_d(LL), & (41) \\ E(r_s) &= P_s(HH) + P_s(LL), & (42) \end{aligned}$$

since $P_s(HL) = P_s(LH) = 0$.

Furthermore, we have

$$P_d(HH) + P_d(HL) = P_d(H) = \alpha_0 = P_s(HH) = P_s(H). \quad (43)$$

Note that by equation (37), we have

$$P_s(R_1, HH) = P_d(R_1, HH) + P_d(R_1, HL). \quad (44)$$

Hence, the probability distribution f_d^H that assigns probability $\left(\frac{P_d(R_1,HH)}{P_s(R_1,HH)}\right)$ to $r_d^{HH} = \left(1/\alpha_d^{HH}\right)$ and probability $\left(\frac{P_d(R_1,HL)}{P_s(R_1,HH)}\right)$ to $r_d^{HL} = \left(1/\alpha_d^{HL}\right)$ can be shown to be a mean-preserving spread of the probability distribution f_s^H that assigns probability 1 $\left(= \frac{P_s(R_1,HH)}{P_s(R_1,HH)}\right)$ to $r_s^{HH} = \left(1/\alpha_s^{HH}\right)$.

Now, let $v = u^{-1}$. By risk aversion of depositors, v is a convex function and we have

$$\begin{aligned} E(r_d) = {} & P_d(R_1, HH) \cdot v(\overline{u}/\alpha_d^{HH}) + P_d(R_1, HL) \cdot v(\overline{u}/\alpha_d^{HL}) + \\ & P_d(R_1, LH) \cdot v(\overline{u}/\alpha_d^{LH}) + P_d(R_1, LL) \cdot v(\overline{u}/\alpha_d^{LL}). \end{aligned} \quad (45)$$

$$E(r_s) = P_s(R_1, HH) \cdot v(\overline{u}/\alpha_s^{HH}) + P_s(R_1, LL) \cdot v(\overline{u}/\alpha_s^{LL}). \quad (46)$$

Thus, by second order stochastic dominance ($SOSD$) and the convexity of v, we have

$$P_d(R_1, HH) \cdot v(\overline{u}/\alpha_d^{HH}) + P_d(R_1, HL) \cdot v(\overline{u}/\alpha_d^{HL}) > P_s(R_1, HH) \cdot v(\overline{u}/\alpha_s^{HH}). \quad (47)$$

The same result can be shown to hold for the case of low returns. We have

$$P_d(LH) + P_d(LL) = P_d(L) = p(1-q) + (1-p)q = P_s(LL) = P_s(L).$$

[15] Note that, banks promise depositors returns such that depositors in expected terms receive their reservation utility of $u(1)$. Hence, with $u(w) = w$, regardless of the inter-bank correlation ρ, the expected borrowing cost for each bank would be equal to 1.

Note that by equation (38), we have

$$P_s(R_1, LL) = P_d(R_1, LH) + P_d(R_1, LL). \tag{48}$$

Hence, the probability distribution f_d^L that assigns probability $\left(\frac{P_d(R_1,LH)}{P_s(R_1,LL)}\right)$ to $r_d^{LH} = \left(1/\alpha_d^{LH}\right)$ and probability $\left(\frac{P_d(R_1,LL)}{P_s(R_1,LL)}\right)$ to $r_d^{LL} = \left(1/\alpha_d^{LL}\right)$ is a mean-preserving spread of the probability distribution f_s^L that assigns probability 1 $\left(= \frac{P_s(R_1,LL)}{P_s(R_1,LL)}\right)$ to $r_s^{LL} = \left(1/\alpha_s^{LL}\right)$.

Thus, by $SOSD$ and the convexity of v, we have

$$P_d(R_1, LH) \cdot v(\overline{u}/\alpha_d^{LH}) + P_d(R_1, LL) \cdot v(\overline{u}/\alpha_d^{LL}) > P_s(R_1, LL) \cdot v(\overline{u}/\alpha_s^{LL}). \tag{49}$$

By combining inequalities in the expressions (47) and (49), we get $E(r_d) > E(r_s)$.

Thus, if $R_1 \geq r_d^{LL}$ and $\delta = 0$, then $E(\Pi_s) > E(\Pi_d)$ and banks choose to invest in the same industry at $t = 0$, resulting in $\rho = 1$ for the first period investment.

Now we look at the general case where $\theta(\rho) = 1 - \delta\rho$, and $\delta > 0$. Using equations (2) and (14), we get:

$$\begin{aligned} E(\Pi_s) &= \alpha_0[(1-\delta)R_0 - 1] + \alpha_1 R_1 - E(r_s) && (50) \\ E(\Pi_d) &= \alpha_0[R_0 - 1] + \alpha_1 R_1 - E(r_d). && (51) \end{aligned}$$

Hence, we have

$$\Delta(\delta) = E(\Pi_d) - E(\Pi_s) = \alpha_0[\delta R_0] - [E(r_d) - E(r_s)]. \tag{52}$$

We already showed that for $R_1 > r_d^{LL}$, we have $E(r_d) > E(r_s)$. Hence, for $\delta = 0$, $\Delta < 0$. And note that Δ is increasing in δ since $\frac{\partial \Delta}{\partial \delta} = \alpha_0 R_0 > 0$. Hence, there exists a critical level of δ, given by

$$\delta_1^* = \frac{E(r_d) - E(r_s)}{\alpha_0 R_0}, \tag{53}$$

such that, for $\delta < \delta_1^*$, banks invest in the same industry and for $\delta \geqslant \delta_1^*$, they invest in different industries.

Case 2: $r_s^{LL} \leqslant R_1 < r_d^{LL}$: Note that in this case, banks are not viable in state LL when they invest in different industries. Hence, $E(\Pi_s)$ is the same as in Case 1 and is given in equation (50) while $E(\Pi_d)$ is different from the Case 1. In particular, we have

$$E(\Pi_d) = \alpha_0[R_0 - 1] + \alpha_1 R_1 - E(r_d) - P_d(R_1, LL)(R_1 - r_d^{LL}), \tag{54}$$

where $E(r_d)$ and $E(r_s)$ are given in equations (45) and (46), respectively. Thus, we have

$$\Delta(\delta) = \alpha_0[\delta R_0] - [E(r_d) - E(r_s)] - P_d(R_1, LL)(R_1 - r_d^{LL}). \tag{55}$$

Note that Δ is increasing in δ. Hence, for $\delta < \delta_2^*$, where

$$\delta_2^* = \frac{E(r_d) - E(r_s) + P_d(R_1, LL)(R_1 - r_d^{LL})}{\alpha_0 R_0}, \tag{56}$$

banks invest in the same industry and for $\delta \geqslant \delta_2^*$, they invest in different industries.

Case 3: $r_d^{HL} \leqslant R_1 < r_s^{LL}$: In this case, banks, when they invest in the same industry, are viable in state HH but are not viable in state LL. Hence, we have

$$E(\Pi_s) = \alpha_0[(1-\delta)R_0 - 1] + \alpha_1 R_1 - E(r_s) - P_s(R_1, LL)(R_1 - r_s^{LL}). \tag{57}$$

And, when banks invest in different industries banks are viable at HL (therefore at state LH) but not viable at state LL. We have

$$E(\Pi_d) = \alpha_0[R_0 - 1] + \alpha_1 R_1 - E(r_d) - P_d(R_1, LL)(R_1 - r_d^{LL}). \tag{58}$$

Hence, we have

$$\Delta(\delta) = \alpha_0[\delta R_0] - [E(r_d) - E(r_s)] - P_d(R_1, LL)(R_1 - r_d^{LL}) + P_s(R_1, LL)(R_1 - r_s^{LL}). \tag{59}$$

Note that Δ is increasing in δ. Hence, for $\delta < \delta_3^*$, where

$$\delta_3^* = \frac{E(r_d) - E(r_s) + P_d(R_1, LL)(R_1 - r_d^{LL}) - P_s(R_1, LL)(R_1 - r_s^{LL})}{\alpha_0 R_0}, \tag{60}$$

banks invest in the same industry and for $\delta \geqslant \delta_3^*$, they invest in different industries.

Case 4: $r_s^{HH} \leqslant R_1 < r_d^{HL}$: We have

$$\begin{aligned} E(\Pi_d) &= \alpha_0[R_0 - 1] + P_d(R_1, HH)(R_1 - r_d^{HH}), & (61)\\ E(\Pi_s) &= \alpha_0[(1-\delta)R_0 - 1] + P_s(R_1, HH)\left[R_1 - r_s^{HH}\right] & (62)\end{aligned}$$

Hence, we have

$$\Delta(\delta) = \delta\left[\alpha_0 R_0\right] + P_d(R_1, HH)(R_1 - r_d^{HH}) - P_s(R_1, HH)\left[R_1 - r_s^{HH}\right]. \tag{63}$$

Note that Δ is increasing in δ. Hence, for $\delta < \delta_4^*$, where

$$\delta_4^* = \frac{P_s(R_1, HH)\left[R_1 - r_s^{HH}\right] - P_d(R_1, HH)(R_1 - r_d^{HH})}{\alpha_0 R_0}, \tag{64}$$

banks invest in the same industry and for $\delta \geqslant \delta_4^*$, they invest in different industries.

Case 5: $R_1 < r_s^{HH}$: In this case banks are not viable in the second period when they invest in the same industry. Banks may or may not be viable in state LL when they invest in different industries but this does not change our result in this case. Formally, we have

$$E(\Pi_s) = \alpha_0[(1-\delta)R_0 - 1] \quad (65)$$

$$E(\Pi_d) \geqslant \alpha_0[R_0 - 1]. \quad (66)$$

Note that by investing in the same industry, banks erode their first period profits by (δR_0). Hence, they invest in different industries.

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t = 0

- Nature chooses the state (*Good* or *Bad*), but it is not known to banks and depositors.
- Banks borrow deposits at r_0.
- Banks choose which industries to lend to resulting in the inter-bank correlation ρ.

t = 1

- Returns from the first investments are realized.

States

HH

- Both banks had the high return.
- Banks borrow deposits at lower rates, that is, $r^{HH} < r_0$.

HL

- Bank *A* had the high return and Bank *B* had the low return.
- Negative spillover from Bank *B* to Bank *A* through borrowing rate: Bank *A* borrows at $r_0 > r^{HH}$.

LH

- Symmetric to *HL*.

LL

- Both banks had the low return.
- Borrowing rates go up, that is, $r^{LL} > r_0$.

Figure 1: Timeline of the model.