Bank Information Sharing and Asset Marketability*

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August 2020

Abstract

We provide a novel explanation for why banks voluntarily disclose borrowers' credit history. Such disclosure reduces information asymmetry on banks' loan quality, which benefits banks with less costly asset sales in case of liquidity shocks, or with more profitable securitization. Credit information sharing arises endogenously when the benefits dominate the cost of losing market power in loan origination. We show that banks have incentives to truthfully disclose borrowers' credit history, even if such information is not verifiable. We also provide an original rationale for promoting public credit registries.

JEL Classification: G21.

Keywords: Information Sharing, Market Liquidity, Adverse Selection.

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*We thank Thorsten Beck, Allen Berger, Christoph Bertsch, Sudipto Dasgupta, Hans Degryse, Xavier Freixas, Chong Huang, Artashes Karapetyan, Michal Kowalik, Vasso Ioannidou, Jordan Martel, Marco Pagano, Ettore Panetti, Francesc Rodriguez Tous, Kasper Roszbach, Linus Siming, Quentin Vandeweyer, Cindy Vojtech, and Lucy White for insightful comments. We are also grateful to conference participants at IBEFA (Portland), FIRS (Hong Kong), AEA (Chicago), Lisbon Game Theory meeting, London Financial Intermediation Theory workshop, Atlanta Fed workshop on "The role of liquidity in the financial system", 9th Swiss Winter Conference in Lenzerheide, Cass Business School workshop on "Financial System Architecture and Stability", 1st Dolomite Winter Conference in Brunico, CICF (Guangzhou), 27th Finance Forum (Madrid), and seminar attendants at Hong Kong University, Riksbank, Tilburg University, University of Bristol, University of Gothenburg, University of Lancaster, University of Warwick for useful comments. Zhao Li and Kebin Ma acknowledge financial support from National Natural Science Foundation of China (Ref. No. 71803024). Any remaining errors are our own.

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1 Introduction

Banks provide the service of liquidity transformation by borrowing short-term and lending long-term. The funding liquidity risk is a natural by-product of the banks' *raison d'être* (Diamond and Dybvig, 1983). The existence of funding liquidity risk creates the need for liquidity management, in particular, making banks desire to maintain the marketability of their assets. This paper argues that maintaining asset marketability can be a reason why banks share their borrowers' credit information. When banks have to sell their assets, either directly or securitized, asymmetric information about asset qualities can make such asset sales costly. Sharing credit information allows banks to reduce the information asymmetry, which in turn reduces the cost of asset sales. The benefit of information sharing, however, has to be traded off with its potential cost. In letting other banks learn the creditworthiness of its borrowers, an incumbent bank can sacrifice its market power as an information monopoly.[1] Our paper provides a thorough analysis of this trade-off.

Our theory of bank information sharing is motivated by observations of the U.S. consumer credit markets (such as markets for mortgages and credit cards). These markets are competitive and contestable. At the same time, banks are able to sell loans originated in these markets. We believe that the two features can be linked and both related to the U.S. credit information sharing system, where a borrower's credit history is recorded by credit bureaus (such as Equifax, Experian, and TransUnion), summarized by a FICO score, and made accessible to all lenders. On the one hand, the shared information on the borrower's credit history reduces the asymmetric information about the borrower's creditworthiness. This enables banks to compete for the borrower with whom they have no previous lending relationship. On the other hand, the resulting loan is more marketable because the shared credit information signals the borrower's creditworthiness so that potential buyers of the loan are less concerned about adverse selection. In sum, the shared credit information both intensifies competition in loan origination and promotes bank asset marketability.

For the main part of our paper, we focus on the traditional originate-to-hold banking business model and examine how funding liquidity risks motivate credit information

[1] The concern for primary loan market competition due to credit information sharing is empirically documented in Liberti et al. (2018) for the credit market of equipment finance in the U.S.

sharing. The bank in our model has two features. First, it has private information about its borrowers, in the form of their types (intrinsic creditworthiness) and credit histories (repayment records). Second, the bank faces the funding liquidity risk of potential runs. Upon creditor runs, the bank will need to liquidate its loans to meet the liquidity need. When the loan quality is unknown to outsiders, the price of the loan in the secondary market can be lower than its fundamental value due to adverse selection. This may cause a bank with high-quality loans to fail, which destroys value from both a private and a social point of view. Credit information sharing provides a way to mitigate adverse selection and to avoid costly asset liquidation.

Our main analysis focuses on bank sharing borrowers' credit histories and unfolds in three steps.[2] First, we show that sharing verifiable credit history can boost the price of the loan in the secondary market. This is a non-trivial result because information sharing has two countervailing effects. On the one hand, the shared credit history mitigates the adverse selection problem in the secondary loan market, which can boost the loan price. On the other hand, the shared credit history also intensifies competition in the primary loan market, which lowers the face value of the loan and tends to reduce its price. We show that the former effect always dominates. We then establish conditions under which credit information sharing is efficient: under such conditions, the shared credit history sufficiently boosts the loan price so that the bank can survive runs.

Second, we show that a bank voluntarily commits to sharing its borrower's verifiable credit history when the benefit of higher asset marketability exceeds the cost of losing market power in loan origination. Naturally, the conditions for the bank to find credit information sharing privately profitable are (at least weakly) stricter than the conditions under which information sharing is socially efficient.

Third, we relax the traditional assumption in the literature that a borrower's credit history, once shared, is verifiable.[3] With unverifiable credit history, the bank may overstate

[2]In the banking literature, the borrower's type can be considered to be soft information which is difficult to communicate to third parties, whereas credit history can be considered to be hard information that can be shared with outsiders. We also analyze an illustrative, albeit unrealistic, setting where the bank can share verifiable information about the borrower's type and show that information sharing endogenously arises in the same fashion.

[3]Besides being restrictive from a theoretical point of view, such an assumption does not always hold empirically either. For example, Giannetti et al. (2017) show that banks manipulate the internal credit

the borrower's past credit performances to obtain a higher price when the loan is on sale. Nevertheless, we show that the bank still has incentives to truthfully reveal its borrower's previous default, when the truthful disclosure allows the bank to extract more rent from the borrower. Guaranteeing truth-telling imposes an additional incentive constraint and tightens the conditions under which information sharing endogenously emerges.[4]

Since the bank does not always find it profitable to share its borrowers' credit history even when that is socially efficient, our model provides a novel rationale to promote public credit registries.[5] In particular, when the borrower's credit history is verifiable, requiring banks to share the information improves efficiency. More interestingly, even if credit history is not verifiable, a public registry can still improve efficiency: while a bank can find it privately unprofitable to share its borrowers' credit history, the bank will truthfully disclose such information once it is obliged to do so.

Since banks have been transforming their business from the traditional originate-to-hold model to the originate-to-distribute model, we also analyze the role of information sharing in the new business model. Central to the originate-to-distribute model is the securitization of assets, which, admittedly, has at least two benefits in terms of reducing funding liquidity risks. First, securitized banks do not necessarily finance themselves using short-term debt, which directly mitigates the liquidity risk. Second, securitization also creates information-insensitive securities such as low-risk senior debt claims, which makes the asymmetric information about asset qualities appear to be less relevant. However, the originate-to-distribute model does not undermine the benefits of credit information sharing in maintaining asset marketability. To show this, we extend our main model to allow for securitization. We show that the lack of information on the underlying loan quality entails higher private credit enhancement for the resulting senior securities to be attractive to targeted investors. Thus, banks still have incentives to share credit information to mitigate

ratings of their borrowers before reporting them to the Argentinian credit registry.

[4]An alternative and established way to sustain truth-telling is to consider a dynamic game where the incumbent bank has some reputation at stake. We show that truth-telling can also be sustained in equilibrium in a static game.

[5]The literature (e.g., World Bank, 2012) refers to credit reporting institutions that are privately owned and operated as credit bureaus, and those that are managed by bank supervisors or central banks as public credit registries. While the reporting to the private credit bureaus is voluntary, the reporting to the public credit registries is compulsory. We adopt the same terminologies in this paper.

information asymmetry so as to reduce the cost of providing private credit enhancement.

Our theory that credit information sharing helps promote securitization highlights one possible drive for the development of asset-backed security markets in the U.S., which also seems to have inspired European regulators. In their effort to revive securitization markets in the post-crisis Europe, the European Central Bank and the Bank of England have jointly pointed out that "credit registers could improve the availability and quality of information that could, in principle, also benefit securitization markets by allowing investors to build more accurate models of default and recovery rates" (BoE and ECB, 2014).[6]

It is important to notice that credit information sharing schemes differ from alternative forms of credit information disclosure such as credit ratings. Credit ratings do not replace bank credit information sharing but rather build on it. In its rating criteria for U.S. residential mortgage-backed securities, Standard and Poor's (2018) makes it clear that "... the CLTV ratio and the FICO score are two of the most important measures of credit risk in residential mortgages ... the FICO score helps indicate the relative likelihood that the borrower will make the required payments based on past payment history."[7] Credit ratings also differ from credit information sharing because ratings are often an equilibrium outcome of strategic interactions between the rating agencies and the rated institutions (e.g., Bolton et al., 2012). By contrast, it is plausible to assume that individual borrowers have little strategic interaction with credit bureaus to affect their FICO scores. In our model, the intricate strategic choice lies with the bank, whose decision to participate in a credit information sharing scheme can be viewed from the perspective of the Bayesian persuasion literature pioneered by Kamenica and Gentzkow (2011). That is, the bank uses its borrowers' credit histories as a noisy signal for its asset quality to persuade asset buyers to make higher bids.[8]

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[6] According to the proposal, the credit registers should provide information both to primary-market lenders as well as to secondary-market investors. This is true for credit information such as the FICO score in the U.S. markets. Our model incorporates this feature.

[7] Borrowers' credit histories are also a key input for ratings of the other two rating agencies. Fitch Ratings (2017) states that "Credit or FICO score remains a key driver of default in Fitch's model, as the data continue to show a strong relationship to default risk ... a higher borrower FICO score, which indicates a sound repayment history of debt obligations, results in a lower PD assumption." Moody's (2018) similarly reports that "The first step in the MILAN approach is to calculate the loan's benchmark PD. The benchmark PD for a loan is based on the borrower's FICO score and the borrower's combined loan-to-value (CLTV)".

[8] Another application of Bayesian persuasion in finance is analyzed by Goldstein and Leitner (2018).

Throughout the paper, we allow for the possibility for the bank to use its capital structure to signal its loan quality. Indeed, in the originate-to-hold business model, the bank may, in principle, signal its loan quality to creditors with its choice of deposit rates. In the originate-to-distribute model, the bank may, in principle, signal its loan quality to buyers of asset-backed securities by choosing the size of the senior tranche. We show, however, that capital structure cannot signal the bank's loan quality. The shared credit information, by contrast, directly produces an informative signal about the loan quality.

We contribute to the literature on bank credit information sharing in three ways. First, different from existing theories that emphasize the role of information sharing in reducing the credit risk of bank loans, we show that credit information sharing can be driven by banks' need for asset marketability. Second, we relax the common assumption of verifiable credit history and show that truthful information sharing can still be sustained. Finally, we highlight a novel rationale and efficiency gains for establishing public credit registries.

This paper is organized as follows. The remainder of the introduction reviews the literature. Section 2 presents our model in the context of a traditional originate-to-hold banking sector. Section 3 derives the conditions under which information sharing arises endogenously and provides a rationale for promoting public credit registries. Section 4 extends our model to incorporate the originate-to-distribute banking model and shows how credit information sharing facilitates securitization. Section 5 concludes. The Appendix collects the main proofs, and the Online Appendix reports the remaining proof and discusses robustness checks.

Related literature. The theoretical literature has mostly explained the existence of bank information sharing by focusing on credit risks in primary loan markets. In their seminal paper, Pagano and Jappelli (1993) rationalize information sharing as a mechanism to reduce adverse selection in loan origination. That is, exchanging credit information about borrowers allows banks to better screen borrowers and reduces loan defaults. Information sharing can also mitigate borrowers' moral hazard problems (Padilla and Pagano, 1997 and 2000). Instead, we see information sharing as stemming not only from frictions in the primary loan market but also from frictions in the secondary market. Our conjecture

The authors study how a similar engagement can explain banks' commitment to disclose the results of stress tests.

that information sharing is driven by asset marketability is novel and complementary to existing theories.

Another strand of the literature argues that information sharing allows the incumbent bank to extract more monopolistic rent. When competition for borrowers occurs in two periods, inviting competitors to enter in the second period by sharing information can dampen the competition in the first period (Bouckaert and Degryse, 2004; Gehrig and Stenbacka 2007). Sharing information about a borrower's past defaults also deters the entry of competitors, which allows the incumbent bank to capture the borrower (Bouckaert and Degryse, 2004). This mechanism is also present in our model, and it is instrumental in sustaining truth-telling when the borrower's credit history is not verifiable.[9]

The inability to commit to entering exclusive contracts can also induce agents to reveal private information, for sharing such information could mitigate the inefficiencies generated by non-exclusive contracting. Bennardo et al. (2015) show that sharing information via credit reporting systems mitigates the banks' incentives to over-lend. Leitner (2012) shows that agents can avoid excessive defaults by voluntarily reporting trades to a central mechanism, such as a clearing house.

Our paper is also related to the broader literature on (non-financial) firms' voluntary information disclosure.[10] Along that strand of literature, our paper is particularly linked to the recent work of Yang (2020), on studying how information disclosure affects asset prices. While Yang (2020) suggests firms' voluntary disclosure resulting in greater price informativeness which feeds back to real efficiency, we focus on how the disclosure of borrower's credit history makes the asset price less distorted by adverse selection.

Empirical studies on information sharing have mostly focused on the impact of credit registries on banks' credit risk exposures and firms' access to bank financing. For example, Djankov, McLiesh, and Shleifer (2007) show that private credit increases after the introduction of credit registries. Brown et al. (2009) show that information sharing improves credit availability and reduces the cost of credit to firms. Houston et al. (2010) find that

[9] Information sharing also affects banks' lending strategies. For example, information sharing can induce the acquisition of soft information (Karapetyan and Stacescu, 2014a) and complement collateralization (Karapetyan and Stacescu, 2014b).

[10] The literature studies how the decision on sharing information such as production cost and demand depends on the nature of product market competition. See Vives (2008) for a survey.

information sharing is associated with lower bank insolvency risks and a lower likelihood of financial crises. Doblas-Madrid and Minetti (2013) provide evidence that information sharing reduces contract delinquencies.

2 The Model

We consider a four-period economy with dates $t = 0, 1, 2, 3, 4$. The economy is populated by the following agents: two banks (an incumbent bank and an entrant bank), a borrower, and many depositors, as well as potential buyers of bank assets. All agents are risk-neutral. The gross return on the risk-free asset is equal to r_f.

The borrower needs a loan of unit size at $t = 2$. The loan pays off at $t = 4$, and its return depends on the type of the borrower. The borrower can be either safe (H-type) or risky (L-type). The common prior on the borrower's type is that $\Pr(H) = \alpha$ and $\Pr(L) = 1 - \alpha$. A safe borrower generates a payoff $R > r_f$ with certainty, whereas a risky borrower generates a payoff that depends on an aggregate state $s \in \{G, B\}$, which is realized at $t = 3$ and is publicly observable. A risky borrower generates the same payoff R as a safe borrower in the good state G, but only a zero payoff in the bad state B. The probabilities of the two states are $\Pr(G) = \pi$ and $\Pr(B) = 1 - \pi$, respectively. One can interpret the H-type being a prime mortgage borrower and the L-type being a subprime borrower. While both can pay back their loans in a housing boom ($s = G$), the subprime borrowers will default in a sluggish housing market ($s = B$).

The incumbent bank has an established lending relationship with the borrower from $t = 0$ and privately observes at $t = 1$ both the borrower's type and credit history. We denote a credit history with a default record by D, and a credit history with no previous default by $\overline{D}$. While the safe borrower has a credit history $\overline{D}$ with probability 1, the risky borrower has a credit history $\overline{D}$ with probability δ and a credit history D with probability $1 - \delta$. For example, one may interpret the default as a late repayment on the borrower's credit card debt. While the safe type never misses a repayment, the risky type incurs a late repayment with probability $1 - \delta$.[11]

[11] Note that the realization of the aggregate state s is assumed to be independent of the borrower's credit history which captures an idiosyncratic risk. In the example of mortgage loans, the probability of a

We model credit information sharing as a unilateral decision of the incumbent bank at $t = 0$.[12] We denote the information sharing regime by $i \in \{N, S\}$, where N refers to the regime without information sharing, and S refers to the regime with information sharing. When $i = S$, the incumbent bank makes a public announcement at $t = 1$ about the borrower's credit information. We will take a step-by-step approach on what kind of information the incumbent bank can share. We start by analyzing the simplest scenario where the information on the borrower's type can be shared and is verifiable. This allows us to illustrate the main mechanism of our model. For the main part of our analysis, we consider a setting where the borrower's credit history can be shared and is verifiable. As a final step, we relax the assumption on the verifiability of the credit history and allow for the possibility that the incumbent bank can overstate the borrower's past loan performance.

The entrant bank has no existing lending relationship with the borrower. It observes no information about the borrower's type or credit history unless the incumbent bank decides to share such information. At $t = 2$, the entrant bank can compete for the borrower by offering competitive loan rates, but has to pay a fixed cost c to initiate the new lending relationship. Such a cost instead represents a sunk cost for the incumbent bank.[13]

The bank that wins the loan market competition will finance itself solely by deposits. We assume that the winning bank has the market power to set the deposit rate, and that depositors demand to earn return r_f in expectation. Bank deposits are assumed to be fairly priced, so that deposit rates reflect the bank's riskiness. This allows us to abstract from the risk-shifting incentives induced by equity holders' limited liability.[14] Like the entrant bank, depositors have no private information about the borrower and learn the borrower's type or credit history only if the incumbent bank shares such information. In case the incumbent bank wins the loan market competition, the depositors may also infer

housing market boom is independent of the borrower's repayment record on, for example, his credit card debt.

[12]The approach is in line with the literature on firms' voluntary information disclosure, e.g., Vives (1984) and Yang (2020). We also discuss in the Online Appendix the case where information sharing can emerge as mutual agreement among banks.

[13]The fixed cost c can be interpreted as the cost that the entrant bank has to bear to establish new branches, to hire and train new staff, or to comply to any financial regulations. Alternatively, it can represent the borrower's switching cost that is borne by the entrant bank.

[14]When deposits are insured and subsidized, the incumbent bank's incentives to share credit information would be lower. In the Online Appendix, we show however that it is still possible to derive conditions under which voluntary information sharing will endogenously emerge.

the borrower's type from the deposit rate offered by the incumbent bank.

To capture the funding liquidity risk, we assume that the incumbent bank faces runs at $t = 3$ with a probability ρ.[15] We assume the risk of runs to be independent of the borrower's credit risk and the aggregate state s.[16] When runs happen, all depositors withdraw their funds, and the incumbent bank has to raise liquidity to meet the depositors' withdrawals.[17]

Upon runs, the bank can sell its loan in a competitive secondary market. We assume that the loan is indivisible and that the bank has to sell it as a whole. Buyers in the secondary loan market demand to break even in expectation. They observe the state s that is realized in $t = 3$ but do not have private information on the borrower. Therefore, while they condition their bids on the state, they can condition their bids on the borrower's type or credit history only if the incumbent bank shared such information.

The incumbent bank is assumed to have private information on whether it faces runs or not. Therefore, the loan can be on sale for two reasons: either due to funding liquidity needs, in which case an H-type loan may be on sale, or due to a strategic sale for arbitrage, in which case only an L-type loan will be on sale. The possibility of a strategic asset sale leads to adverse selection in the secondary market. An H-type loan will be underpriced, so that the incumbent bank which holds an H-type loan can fail due to illiquidity. In the case of a bank failure, we assume that bankruptcy costs result in a zero salvage value.

We make the following two parametric assumptions:

$$c + r_f < R; \tag{1}$$

$$c + r_f > \frac{r_f}{\pi}. \tag{2}$$

Assumption (1) states that the entrant bank finds it profitable to lend to an H-type borrower. Assumption (2) states that the cost of entry is relatively high given the default

[15]The entrant bank is assumed to face no liquidity risk. The incumbent bank, however, can manage the liquidity risk by sharing information on the borrower. The model setup is symmetric in this respect.

[16]In a global games-based model, bank runs occur if and only if the bank's fundamentals are lower than a threshold. In such a setting, the threshold usually decreases in the liquidation value of banks' assets, so that credit information sharing should still reduce the risk of runs when the shared information mitigates adverse selection and boosts the secondary-market price of the bank's loan on sale.

[17]One can think that bank run is triggered by a sun-spot event as in Diamond and Dybvig (1983). It is also an equilibrium feature of global-games-based bank run models with arbitrarily precise private signals that all depositors will run on the bank when a run happens.

risk of an L-type borrower.[18] Assumptions (1) and (2) jointly imply

$$R > \frac{r_f}{\pi}. \quad (3)$$

That is, both the L- and H-type loans have positive NPVs, so that the incumbent bank finds it profitable to lend to the borrower independent of the borrower's type.[19]

The sequence of events is summarized below. The timing captures the fact that information sharing is a long-term decision (commitment), whereas the competition in the loan market and the liquidity risk are relatively short-term concerns.[20]

t = 0	t = 1	t = 2	t = 3	t = 4
1. The incumbent bank inherits a lending relationship from the past. 2. The incumbent bank decides whether to engage in credit information sharing.	1. The borrower's type and credit history is realized. 2. The information is privately observed by the incumbent bank. 3. The incumbent bank announces the borrower's type or credit history if it chose to share such information in the previous stage.	1. The incumbent bank and entrant bank compete to finance the borrower by offering loan rates. 2. The winning bank finances itself using fairly priced deposits and extends the loan to the borrower.	1. State s is realized and is publicly observed. 2. The incumbent bank's liquidity risk is realized and is privately observed by the bank. 3. The secondary loan market opens where the asset buyers bid competitively.	The bank loan pays off.

3 Equilibrium Information Sharing

In this section, we derive conditions under which information sharing arises endogenously. Note that once the incumbent bank has chosen an information sharing regime $i \in \{N, S\}$, we face a well-defined game g_i that can be solved backward. Therefore, we can determine the incumbent bank's payoffs in each self-contained game g_i. The incumbent bank chooses at $t = 0$ the information sharing regime that delivers the highest expected payoff.

We analyze the incumbent bank's incentive to share information on the borrower's *verifiable type* (Section 3.1), on the borrower's *verifiable credit history* (Section 3.2), and on the borrower's *non-verifiable credit history* (Section 3.3). We also provide a novel

[18] Assumption (2) guarantees a unique equilibrium of our model. Indeed, it avoids the existence of an equilibrium where the entrant bank finances the loan if the borrower is an H-type, while the incumbent bank finances the loan if the borrower is an L-type.

[19] If the inequality does not hold, the incumbent bank will only finance the H-type borrower, and the incumbent bank's lending decision fully reveals the borrower's type.

[20] Note that it is necessary to assume that the information sharing decision ($t = 0$) is made *before* the incumbent bank acquires the borrower's information ($t = 1$). Otherwise, the information sharing decision itself may serve as a signaling device of the incumbent bank.

rationale for the establishment of public credit registries (Section 3.4).

3.1 Sharing borrower type

To illustrate the main mechanism of our model, we start by considering the simplest setting, where the incumbent bank can share verifiable information on the borrower's type.

Let us first examine the case where the incumbent bank operates under the regime $i = S$ and the shared information reveals the borrower being the L-type. The game $g_S(L)$ features complete information, and we solve for its subgame perfect equilibrium (SPE) by backward induction. First, we determine the secondary-market price for an L-type loan in state G and B, respectively. Second, we compute the deposit rate at which depositors are willing to supply their funds to the banks, given that the shared information identifies the borrower as the L-type. Finally, we determine the equilibrium loan rate to the borrower.

Since the L-type succeeds in state G but defaults in state B, the loan price on the secondary market will be state-dependent. Let $P_S^B(L)$ and $P_S^G(L)$ be the price of the L-type loan under the regime $i = S$ in state B and G, respectively. Asset buyers' competitive bidding leads to following secondary-market prices:

$$P_S^B(L) = 0 \quad \text{and} \quad P_S^G(L) = R_S^*(L),$$

where $R_S^*(L)$ denotes the equilibrium loan rate for the L-type under the regime $i = S$.

Depositors know that they will be repaid only in the favorable state G, which occurs with a probability π. Let $r_S^I(H)$ and $r_S^E(H)$ denote the deposit rates that the incumbent bank and the entrant bank, respectively, need to offer. Depositors would accept rates

$$r_S^I(L) = r_S^E(L) = \frac{r_f}{\pi} > r_f.$$

Expecting to recoup its investment only when $s = G$, the entrant bank can break even by offering a loan rate

$$R_S^E(L) = \frac{c + r_f}{\pi},$$

so that its expected payoff equals its cost of lending: $\pi \cdot \left[R_S^E(L) - r_S^E(L)\right] + (1 - \pi) \cdot 0 = c.$

The equilibrium loan rate $R_S^*(L)$ depends on the value of the return R. If $R \geq (c+r_f)/\pi$, the incumbent bank has to match the entrant bank's loan rate, making $R_S^*(L) = R_S^E(L)$. If $R < (c+r_f)/\pi$, the entrant bank will not find it profitable to bid for the borrower, and the equilibrium loan rate will hit the corner solution of $R_S^*(L) = R$. Therefore, we have

$$R_S^*(L) = \min\left\{R, \frac{c+r_f}{\pi}\right\}.$$

By lending to an L-type borrower, the incumbent bank makes an expected profit

$$\Pi_S(L) = \pi \cdot \left[R_S^*(L) - r_S^I(L)\right].$$

We now solve analogously the complete-information game $g_S(H)$ where the shared information reveals the borrower as an H-type. Since the safe type never defaults, the price of the loan will always equal its face value, i.e., $P_S^B(H) = P_S^G(H) = R_S^*(H)$, where $R_S^*(H)$ denotes the equilibrium loan rate for the H-type. Depositors perceive lending to a bank that finances an H-type loan safe, and are willing to accept the risk-free rate, $r_S^I(H) = r_S^E(H) = r_f$. The entrant bank can break even by offering a loan rate $R_S^E(H) = c + r_f$, and the equilibrium loan rate for the H-type borrower can be written as $R_S^*(H) = \min\{R, c + r_f\}$. By lending to an H-type borrower, the incumbent bank's profit is

$$\Pi_S(H) = R_S^*(H) - r_S^I(H).$$

When the information sharing decision is made at $t = 0$, the type of the borrower is unknown. The incumbent bank makes the following expected profit by committing to sharing the borrower's type:[21]

$$V_S^{Type} = \alpha\Pi_S(H) + (1-\alpha)\Pi_S(L) = \alpha R_S^*(H) + (1-\alpha)\pi R_S^*(L) - r_f. \tag{4}$$

[21] We use Π to denote the incumbent bank' expected profit at $t = 2$, i.e., the expected payoff *after* the bank receives the information about the borrower's type and credit history. We denote with V the bank's expected profit at $t = 0$, i.e., the expected payoff *before* the bank receives any information on the borrower. When calculating the bank's expected profit at $t = 0$, we suppress the incumbent bank's payoff from the existing lending, i.e., the borrower's repayment at $t = 1$. Since such repayment does not change across information sharing regimes, suppressing it will not affect our analysis.

We now turn to the case where the bank does not share any information. The game g_N features incomplete information. All outsiders (the entrant bank, depositors, and asset buyers) need to form beliefs about the quality of the borrower, and we solve the game backward using the concept of perfect Bayesian equilibrium (PBE). As we will establish, the game has a unique pooling equilibrium where the incumbent bank lends to both the H- and L-type borrowers at the same loan rate and finances itself at a deposit rate independent of the type of its loan. We characterize the pooling equilibrium in the following paragraphs.[22]

The secondary loan market now features adverse selection. With no information on the borrower's type and a belief that both types of borrowers are financed, asset buyers hold the prior that the loan is an H-type with a probability α. In state B, the incumbent bank will sell an H-type loan only if hit by the liquidity shock, but will always sell an L-type loan to arbitrage with its private information. Taking into account the incumbent bank's strategic asset sale, the asset buyers' break-even price in state B when purchasing a loan with unknown quality can be written as

$$P_N^B = \frac{\alpha\rho}{(1-\alpha)+\alpha\rho} R_N^*,$$

where R_N^* denotes the pooling equilibrium loan rate under the regime $i = N$. By contrast, the asset buyers know that both the H- and L-type borrowers can repay the loan in state G, so that $P_N^G = R_N^*$.

Suppose $P_N^B < r_f$ (i.e., the loan price is lower than the risk-free rate in state B). Then, depositors at the incumbent bank understand that their claims are risky in state B. The incumbent bank can repay its deposits only if it holds an H-type loan *and* experiences no run. Therefore, the incumbent bank needs to offer a deposit rate

$$r_N^I = \frac{r_f}{\pi + (1-\pi)\alpha(1-\rho)}.$$

On the other hand, since the entrant bank is assumed to face no liquidity risk, the depositors

[22] We refer to Appendix A.1 for the formal definition of the PBE adopted in game g_N and for the proof of equilibrium uniqueness.

are willing to accept a deposit rate

$$r_N^E = \frac{r_f}{\pi + (1-\pi)\alpha}.$$

Given the funding cost r_N^E and a belief that both H- and L-type borrowers participate in the market, the entrant bank will offer a loan rate

$$R_N^E = \frac{c + r_f}{\alpha + (1-\alpha)\pi},$$

so that it breaks even, $\alpha\left(R_N^E - r_N^E\right) + (1-\alpha)\pi\left(R_N^E - r_N^E\right) = c$. Again, taking into account the possibility of $R_N^E > R$, the equilibrium loan rate R_N^* can be written as

$$R_N^* = \min\left\{R, \frac{c + r_f}{\alpha + (1-\alpha)\pi}\right\}.$$

The following Lemma establishes that when $P_N^B < r_f$, the game g_N has a unique pooling PBE where the incumbent bank lending to the borrower regardless of the type. As a result, the secondary loan market features adverse selection on the equilibrium path, and the bank fails in state B even when holding an H-type loan.

Lemma 1 *When $P_N^B < r_f$, the game g_N features a unique PBE, where the incumbent bank offers to the borrower a pooling loan rate $R_N^* = \min\left\{R, R_N^E\right\}$, regardless of the borrower's type or credit history. Here $R_N^E = \frac{c+r_f}{\alpha+(1-\alpha)\pi}$ is the entrant bank's break-even rate when lending to a borrower of unknown type and credit history. The incumbent bank offers a deposit rate $r_N^I = \frac{r_f}{\pi+(1-\pi)\alpha(1-\rho)}$ that allows depositors to break even. The incumbent bank sells its H-type loan only if hit by the liquidity shock in state B. Upon the loan sale, buyers offer state-contingent prices $P_N^G = R_N^*$ and $P_N^B = \frac{\alpha\rho}{(1-\alpha)+\alpha\rho} R_N^*$.*

Proof. See Appendix A.1. ■

Since the incumbent bank raises funding after having learned the type of its borrower, the bank can, in principle, use the deposit rate r_N^I to signal its loan quality. Given the cash flow of the bank, r_N^I determines the debt repayment and the market value of equity at the same time. Therefore, the choice r_N^I can be seen as a choice of the bank's capital structure. The proof of Lemma 1 establishes that, when the incumbent bank signals only using the capital structure, no separating equilibrium can be sustained. Intuitively, the L-type bank can benefit from mimicking the H-type and setting the same deposit rate, which is always lower than its own cost of funding in a separating equilibrium.

By sharing no credit information, the incumbent bank makes an expected profit

$$V_N = \pi \left(R_N^* - r_N^I\right) + (1-\pi)\alpha(1-\rho)\left(R_N^* - r_N^I\right) = [\pi + (1-\pi)\alpha(1-\rho)] \cdot R_N^* - r_f. \quad (5)$$

Comparing expressions (4) and (5) leads to the following proposition.

Proposition 1 *There exists a critical probability of runs $\hat{\rho}$, such that, when $\rho > \hat{\rho}$ and $P_N^B < r_f$, the incumbent bank prefers sharing the information on borrowers' type to no information sharing.*

Proof. See Appendix A.2. ■

This proposition can be easily verified when all equilibrium loan rates take the corner solution, or when all take interior solutions. Indeed, in these two cases, sharing borrower's type dominates no information sharing independent of ρ, since the shared information only increases the bank's asset marketability but does not reduce the bank's market power. Consider first the all-corner-solution case, where $R_S^*(L) = R_S^*(H) = R_N^* = R$. We have

$$V_S^{Type} = [\alpha + (1-\alpha)\pi]R - r_f > V_N = [\pi + (1-\pi)\alpha(1-\rho)]R - r_f.$$

The difference in payoffs, $V_S^{Type} - V_N = (1-\pi)\alpha\rho \cdot R > 0$, captures that, by sharing the borrower's type, an H-type bank avoids the failure when facing a run in state B. On the other hand, when the equilibrium loan rates equal to the entrant bank's break-even rates, we have $V_S^{Type} = c > V_N$. Indeed, this is a scenario where the primary market is contestable, independent of whether the entrant knows the borrower's type. As a result, the incumbent bank always makes a profit of c, equal to the entrant bank's entry cost.

The trade-off between asset marketability and the loan market power emerges in the intermediate cases. On the one hand, the shared information increases the price of an H-type loan from $P_N^B < r_f$ to $P_S^B(H) > r_f$, saving the incumbent bank from runs in state B. On the other hand, the incumbent bank suffers the loss of market power, as the equilibrium loan rate reduces from R_N^* to $R_S^*(H)$. The benefit of enhanced asset marketability is most prominent when the risk of runs is high, $\rho > \hat{\rho}$, in which case the incumbent bank finds sharing the borrower's type optimal.

3.2 Sharing verifiable credit history

We now analyze the more realistic scenario in which only the borrower's credit history can be communicated to third parties.[23] Clearly, when the incumbent bank does not share information on the borrower credit history, we have again the game g_N, whose PBE is characterized in Lemma 1.

Consider the case in which the incumbent bank discloses a credit history of no default (i.e., a $\overline{D}$-history). This announcement only partially reveals the borrower's type, as the borrower can still be either an H- or L-type. The game $g_S(\overline{D})$, thus, features incomplete information. Parallel to Lemma 1, Lemma 2 characterizes the unique pooling PBE.[24]

Lemma 2 *When $P_S^B(\overline{D}) > r_f$, the game $g_S(\overline{D})$ features a unique PBE, where the incumbent bank offers to the borrower who has no previous default a loan rate $R_S^*(\overline{D}) = \min\left\{R, R_S^E(\overline{D})\right\}$, regardless of the borrower's type. Here $R_S^E(\overline{D}) = \frac{\alpha+(1-\alpha)\delta}{\alpha+(1-\alpha)\delta\pi}(c + r_f)$ is the entrant bank's break-even rate of lending to a borrower with a $\overline{D}$-history. The incumbent bank offers a risk-free deposit rate $r_S^I(\overline{D}) = r_f$ and sells an H-type loan only if experiencing runs in state B. Upon the loan sale, asset buyers offer state-contingent prices $P_S^G(\overline{D}) = R_S^*(\overline{D})$ and $P_S^B(\overline{D}) = \frac{\alpha\rho}{(1-\alpha)\delta+\alpha\rho} R_S^*(\overline{D})$.*

Lemma 2 shows that there exists a set of parameters in which the unique pure-strategy PBE involves the incumbent bank financing the loan regardless of the borrower's type. Moreover, on the equilibrium path, the incumbent bank can survive a run even in state B. Similar to the case without credit information sharing, the incumbent bank cannot signal its type using only its capital structure. Nevertheless, a credit history of no previous default serves as an informative signal of the loan quality.

[23] The incumbent bank also obtains higher rents by sharing the borrower's credit history than by sharing the borrower's type. We provide the full calculation in the Online Appendix.

[24] The complete proof, which closely resembles that of Lemma 1, is reported in the Online Appendix.

When the incumbent bank announces that the borrower has previously defaulted (i.e., a D-history), the shared information fully reveals the borrower as an L-type. The game $g_S(D)$, therefore, features complete information and can be solved with SPE — by the same analysis as in the case where the incumbent bank announces the borrower being an L-type (see Section 3.1). Lemma 3 characterizes the unique SPE of the game $g_S(D)$. On the equilibrium path, the incumbent bank that lends to the borrower of a D-history will fail when the state B occurs.

Lemma 3 *When the borrower has a credit history of previous default, the game $g_S(D)$ has a unique SPE, where the incumbent bank offers to the borrower a loan rate $R_S^*(D) = \min\left\{R, R_S^E(D)\right\}$. Here $R_S^E(D) = (c + r_f)/\pi$ is the entrant bank's break-even rate when lending to a borrower who has previously defaulted. The incumbent bank offers a deposit rate $r_S^I(D) = r_f/\pi$ that allows depositors to break even. The incumbent bank always sells the loan whether it experiences runs or not. Upon the loan sale, asset buyers offer state-contingent prices $P_S^G(D) = R_S^*(D)$ and $P_S^B(D) = 0$.*

We can rank the equilibrium loan rates in Lemma 1, 2 and 3, as follows:

$$R_S^*(\overline{D}) \leq R_N^* \leq R_S^*(D). \tag{6}$$

The equalities hold only when the equilibrium loan rates hit the corner solution R (i.e., the entrant bank does not find it profitable to bid for the borrower). Intuitively, the borrower with a default (D-history) is identified as an L-type and charged the highest loan rate accordingly. On the other hand, the borrower with no previous default ($\overline{D}$-history) is more likely to be an H-type. Correspondingly, the loan rate drops. When no information is shared, the equilibrium loan rate will be set according to the prior probabilities of the borrower's types, resulting in the intermediate loan rate R_N^*.

Depending on how the project income R relates to the ranking of the equilibrium loan rates in inequalities (6), we have the following four cases $j = 0, 1, 2, 3$:

- Case 0: $R \in \mathbb{R}_0 \equiv \left[c + r_f, R_S^E(\overline{D})\right)$, thus $R_S^*(\overline{D}) = R_N^* = R_S^*(D) = R$.

- Case 1: $R \in \mathbb{R}_1 \equiv \left[R_S^E(\overline{D}), R_N^E\right)$, thus $R_S^*(\overline{D}) = R_S^E(\overline{D})$ and $R_N^* = R_S^*(D) = R$.

- Case 2: $R \in \mathbb{R}_2 \equiv \left[R_N^E, R_S^E(D)\right)$, thus $R_S^*(\overline{D}) = R_S^E(\overline{D})$, $R_N^* = R_N^E$ and $R_S^*(D) = R$.

- Case 3: $R \in \mathbb{R}_3 \equiv \left[R_S^E(D), +\infty\right)$, thus $R_S^*(\overline{D}) = R_S^E(\overline{D})$, $R_N^* = R_N^E$ and $R_S^*(D) = R_S^E(D)$.

Note that we index each case with the number of interior solutions (i.e., the equilibrium loan rate equals the entrant bank's break-even rate). Each case shows a different degree of loan market contestability. The higher R, the more contestable the primary loan market. In Case 0, the project payoff R is so low that the entrant bank finds it unprofitable to enter the market even if the borrower has no previous default. In Case 3, by contrast, R is so high that the entrant bank competes even for the borrower who previously defaulted. The four mutually exclusive cases are illustrated in Figure 1.

[Insert Figure 1 here]

The benefit of sharing credit history: avoiding inefficient liquidation.

Information sharing is beneficial in each of the four cases. That is, there exists a set of parameters where the incumbent bank holding a loan with a $\overline{D}$-history survives a run in state B when sharing the credit history, and fails otherwise.

Similar to Section 3.1, when the incumbent bank discloses the borrower having no previous default, the perceived loan quality becomes higher, which mitigates adverse selection and boosts the secondary-market loan price. However, once it is known that the borrower has no previous default, the incumbent bank may only charge a loan rate lower than the one under no information sharing. As the loan on sale has a lower face value, information sharing *may* result in a lower loan price. The following lemma shows that the former effect dominates, so that credit information sharing *always* increases the price of a loan with a $\overline{D}$-history in state B.

Lemma 4 *The equilibrium prices of the loan on sale are such that $P_S^B(\overline{D}) > P_N^B$. There exists a range of parameters such that $P_S^B(\overline{D}) > r_f > P_N^B$. For those parameteris, the incumbent bank holding a loan of a $\overline{D}$-history can survive a run in state B, while the bank fails without information sharing.*

Proof. See Appendix A.3. ■

To provide the intuition, we discuss here Case 2, a core case upon which the complete proof builds. Recall that in Case 2 the equilibrium loan rates are $R_N^* = R_N^E$ and $R_S^*(\overline{D}) = R_S^E(\overline{D})$. Substituting them into the expressions that characterize the equilibrium prices P_N^B and $P_S^B(\overline{D})$, as given in Lemma 1 and 2 respectively, we have

$$\frac{P_N^B}{P_S^B(\overline{D})} = \underbrace{\frac{(1-\alpha)\delta + \alpha\rho}{(1-\alpha) + \alpha\rho}}_{(A)} \cdot \underbrace{\frac{\alpha + (1-\alpha)\delta\pi}{(\alpha + (1-\alpha)\pi)\,(\alpha + (1-\alpha)\delta)}}_{(B)}.$$

The ratio between P_N^B and $P_S^B(\overline{D})$ can be decomposed into the product of two elements. Expression (A) is the ratio of the expected loan quality in the secondary market under no information sharing to that conditional on a shared $\overline{D}$-history.[25] This ratio is smaller than 1, implying an improvement in the perceived loan quality conditional on the borrower having no previous default. Expression (B) is the ratio of the primary market loan rate R_N^* to $R_S^*(\overline{D})$. This ratio is greater than 1, reflecting the intensified competition from the entrant bank due to a decline in the perceived credit risk conditional on a shared $\overline{D}$-history.

Note that $P_N^B/P_S^B(\overline{D}) = 1$ when $\rho = 1$ and $\pi = 0$ *simultaneously* hold. This is, in fact, the case where the primary and secondary loan markets have the same level of information asymmetry. To see why, note that while the information asymmetry about the borrower's type exists in both the primary and secondary markets, these two markets differ in two aspects. First, the strategic asset sale by the incumbent bank is only relevant in the secondary market. This difference vanishes as ρ approaches 1, since it is then sure that the incumbent bank is selling the loan not for strategic reasons but because of runs. Second, the uncertainty about the aggregate state s exists only in the primary market, whereas it has been resolved when the secondary market opens. This difference disappears when π approaches 0.[26] Therefore, when $\rho = 1$ and $\pi = 0$, the impact of information sharing is symmetric across the primary and secondary markets, resulting in $P_N^B/P_S^B(\overline{D}) = 1$.

The price ratio $P_N^B/P_S^B(\overline{D})$ is smaller than 1 when either $\rho < 1$, or $\pi > 0$, or both. To see this, notice that expression (A) increases in ρ. Intuitively, as the probability of a run decreases from 1, it becomes more likely that the loan is on sale for strategic reasons. As

[25] The expected quality is defined as the probability that the loan is granted to an H-type borrower.

[26] On the other hand, if $\pi = 1$, there will be no longer a difference between the H- and L- type borrowers, as both are guaranteed to succeed.

a result, the adverse selection in the secondary market is aggravated, and the gap in the expected qualities widens across the two information sharing regimes. On the other hand, expression (B) decreases in π. Intuitively, as π increases, the difference between the H- and L-type borrowers diminishes. The credit history becomes less relevant as a signal, and the gap between the two equilibrium loan rates narrows. Whenever $\rho < 1$, or $\pi > 0$, or both, information sharing's positive impact of reducing adverse selection in the secondary market dominates its negative effect of decreasing the loan rate in the primary market.

Once it is established $P_S^B(\overline{D}) > P_N^B$, a continuity argument ensures that there must exist a set of parameters where the risk-free rate r_f lies between the two prices. We denote by $\mathbb{F}_j$ the set of parameters where inequalities $P_S^B(\overline{D}) > r_f > P_N^B$ hold in case $j = 0, 1, 2, 3$. We establish the non-emptiness of the sets $\Psi_j \equiv \mathbb{R}_j \bigcap \mathbb{F}_j$ in the following Lemma.

Lemma 5 *When π exceeds a unique $\hat{\pi} \in (0, 1)$, there exists a non-empty set of parameters Ψ_j in Case $j = 0, 1, 2, 3$, where $P_S^B(\overline{D}) > r_f > P_N^B$ so that sharing the borrower's credit history saves the incumbent with a $\overline{D}$-loan from runs. We have:*

- $\Psi_0 \equiv \mathbb{R}_0 \bigcap \mathbb{F}_0$ *with* $\mathbb{F}_0 \equiv \{(c, R) | \underline{R} < R < \overline{R}\}$.
- $\Psi_1 \equiv \mathbb{R}_1 \bigcap \mathbb{F}_1$ *with* $\mathbb{F}_1 \equiv \{(c, R) | R < \overline{R} \text{ and } c > \underline{c}\}$.
- $\Psi_2 \equiv \mathbb{R}_2 \bigcap \mathbb{F}_2$ *with* $\mathbb{F}_2 \equiv \{(c, R) | \underline{c} < c < \overline{c}\}$.
- $\Psi_3 \equiv \mathbb{R}_3 \bigcap \mathbb{F}_3$ *with* $\mathbb{F}_3 \equiv \mathbb{F}_2$.

Proof. See Appendix A.4 ■

Figure 2 gives the graphic representation of the sets Ψ_j.[27] We provide the expressions for the cutoff values (i.e., $\underline{c}, \overline{c}, \underline{R}, \overline{R}$, and $\hat{\pi}$) in Appendix A.4.[28]

[Insert Figure 2 here]

The sets $\Psi_j, j = 0, 1, 2, 3$, represent the range of parameters where sharing the borrower's credit history is efficient. Moreover, these sets contain all parameters for which

[27]Notice that the expressions for P_N^B and $P_S^B(\overline{D})$ are the same in Case 2 and Case 3. This is because the payoff of the loan, R, is sufficiently high that the entrant bank competes with the incumbent bank both for a loan of unknown credit history and for a loan with a $\overline{D}$-history. Therefore, we have $\mathbb{F}_3 = \mathbb{F}_2$.

[28]The condition $\pi > \hat{\pi}$ in Lemma 5 is immaterial. It only reduces the number of cases to be analyzed.

information sharing can endogenously emerge. For all other parametric combinations, information sharing only triggers competition from the entrant bank. Therefore, we will focus our analysis on the sets Ψ_j.

The incumbent bank's decision on sharing credit history.

We are now in a position to determine whether the incumbent bank voluntarily chooses to share the borrower's credit history at $t = 0$. Let us denote with V_S the incumbent bank's expected profit when sharing the borrower's credit history. We denote by φ_j the set of parameters where $V_S > V_N$ in Case $j = 0, 1, 2, 3$. The next proposition establishes the non-emptiness of the sets φ_j.

Proposition 2 *The incumbent bank voluntarily shares its borrower's credit history in region $\varphi_j = \Psi_j$ for Case $j = 0, 3$, and in region $\varphi_j \subseteq \Psi_j$ for Case $j = 1, 2$. We have $\varphi_j = \Psi_j$ for Case $j = 1, 2$, if and only if $\rho > \overline{\rho} \equiv (1-\alpha)(1-\delta)$. Otherwise, the incumbent bank discloses its borrower's credit history whenever sharing such information is efficient.*

Proof. See Appendix A.5. ■

To illustrate the intuition, we decompose the difference between the incumbent bank's expected profits in the two information sharing regimes as follows:

$$V_S - V_N = \underbrace{[\alpha + (1-\alpha)\delta\pi](R_S^*(\overline{D}) - R_N^*)}_{(1)} + \underbrace{(1-\alpha)(1-\delta)\pi(R_S^*(D) - R_N^*)}_{(2)} + \underbrace{\alpha(1-\pi)\rho R_N^*}_{(3)}.$$

Term (1) represents the *competition* effect: disclosing the borrower's credit history $\overline{D}$ encourages the entrant bank to compete for the borrower. It is non-positive because $R_S^*(\overline{D}) \leq R_N^*$. Term (2) is understood in the literature as the *capturing* effect: disclosing the default history of a borrower can deter entry, so that the incumbent bank can capture such borrower and charge a higher loan rate. It is non-negative because $R_S^*(D) \geq R_N^*$. Finally, Term (3) is positive and denotes the new effect that our model features. We refer to it as the *asset marketability* effect. Revealing the borrower as having no previous default reduces the adverse selection in the secondary market.

The incumbent bank voluntarily engages in information sharing if and only if $V_S - V_N > 0$. In Case 0 and Case 3, the incumbent bank faces no cost of sharing information, and credit information sharing always dominates, so that $\varphi_j = \Psi_j$ for $j = 0, 3$. Indeed, in Case 0, the entrant bank never competes for the borrower, i.e., $R_S^*(\overline{D}) = R_N^* = R_S^*(D) = R$. As a result, $V_S - V_N$ is given only by the asset marketability effect. In Case 3, the entrant bank always competes for the borrower. The incumbent bank avoids inefficient liquidation under information sharing regime, but only earns an expected profit equal to the entrant bank's entry cost, that is $V_S = c$. Whereas without information sharing, the incumbent bank fails in state B when experiencing a run — even if the bank holds an H-type loan. As a result, the expected profit under no information sharing is $V_N = c - \alpha(1-\pi)\rho R_N^* < V_S$, with the expression $\alpha(1-\pi)\rho R_N^*$ reflecting the expected liquidation loss.

The incumbent bank does incur a cost for sharing the borrower's credit history in Case 1 and Case 2, as reflected by $R_S^*(\overline{D}) < R_N^*$. When the probability of runs is sufficiently small ($\rho < \overline{\rho}$) the cost of information sharing dominates its benefits. As a result, the set of parameters where information sharing is privately optimal is a subset of the set where information sharing is efficient. That is, $\varphi_j \subset \Psi_j$ for $j = 1, 2$. The sets φ_j would still be non-empty for $\rho \in (0, \overline{\rho})$ though. For example, near the lower bound of Case 1 (R marginally higher than $R_S^E(\overline{D})$), the competition effect is close to zero; the capturing effect is zero, but the asset marketability effect remains $\alpha(1-\pi)\rho R$, which makes $V_S > V_N$. Similarly, near the upper bound of Case 2 (R marginally lower than $R_S^E(D)$), one can verify that the competition and capturing effects mostly cancel, so that $V_S > V_N$ is again driven by the asset marketability effect. Finally, when the probability of a run is sufficiently high ($\rho \geq \overline{\rho}$), the benefits from information sharing will dominate the cost, such that $\varphi_j = \Psi_j$ also for $j = 1, 2$. Figure 3 summarizes the results graphically.

[Insert Figure 3 here]

Our results can be understood from the perspective of the Bayesian persuasion literature. The incumbent bank can be considered as a persuader and the asset buyers as (homogenous) receivers. By choosing the information sharing regime, the incumbent bank commits to a test on its loan quality. Without information sharing, the asset buyers bid a price $P_N^B < r_f$ in regions φ, so that inefficient liquidation can happen to a bank with an H-type loan. The incumbent bank can increase its expected payoff by generating a binary signal $x \in \{\overline{D}, D\}$. Consequently, the buyers' beliefs about the loan quality improve when the signal is $\overline{D}$ and deteriorate otherwise. Given the posterior beliefs, the secondary-market loan prices in state B are such that $P_S^B(D) < P_N^B < r_f < P_S^B(\overline{D})$. The incumbent bank will receive a zero payoff in region φ, both under the no information sharing regime and when information sharing generates a signal D. However, when the information sharing generates a signal $\overline{D}$, the incumbent bank boosts the loan price in the secondary market and avoids the inefficient liquidation of the H-type loan. As a result, the incumbent bank has incentives to persuade the buyers.[29]

3.3 Sharing unverifiable credit history

When the reported borrower's credit history is not verifiable, the incumbent bank may have incentives to overstate the borrower's past credit performance to boost the loan price.[30] We focus on the possibility of misrepresenting a borrower who has previously defaulted as one with no default history.[31] Since a pre-requisite for the incumbent bank to manipulate the shared credit history is that the bank has chosen the information sharing regime in the first place, we restrict our analysis to regions φ_j, $j = 0, 1, 2, 3$, as defined in Section 3.2.

The incumbent bank faces two considerations when it decides whether to mis-report a D-history. On the one hand, by overstating the past credit performance, the bank will be able to boost the secondary-market loan price and to survive a run in state B. Therefore, the expected gain from lying is $(1-\pi)P_S^B\left(\overline{D}\right)$. On the other hand, upon the (false) announcement of a $\overline{D}$-history, the entrant bank will compete more fiercely for the borrower so that the incumbent bank may only charge a lower rate in the primary loan market. Therefore, the expected cost from lying is $\pi\left[R_S^*(D) - R_S^*(\overline{D})\right]$.

[29] As Kamenica and Gentzkow (2011) points out, Bayesian rationality only requires receivers' posterior beliefs Bayes plausible in equilibrium. Our model satisfies this requirement, because $Pr(H|\overline{D})Pr(\overline{D}) + Pr(H|D)Pr(D) = \alpha$ and $Pr(L|\overline{D})Pr(\overline{D}) + Pr(L|D)Pr(D) = 1-\alpha$.

[30] Information manipulation can also occur in more subtle ways. For examples, banks in Japan are observed to ever-green their 'zombie' borrowers, and Spanish banks kept on lending to real estate firms that were likely to be in distress after the housing market crash. Notice that such countries are characterized by relatively low competition in the credit market. As we will show in this section, this is consistent with our model's prediction that banks operating in competitive markets have stronger incentives to truthfully reveal their borrowers' credit information.

[31] We assume that the incumbent bank cannot falsely claim a borrower to have a default record. This is because the borrower would have the incentives and means to correct it. For example, borrowers can access their own credit records and correct such inaccuracies under Fair Credit Act in the U.S. A purposeful false report can result in a legal dispute.

A necessary condition for the incumbent bank to truthfully reveal the borrower's past default is that $R_S^*(D) > R_S^*(\overline{D})$. Otherwise, the incumbent bank will only have incentives to lie. By implication, the incumbent bank will never have the incentive to truthfully reveal the borrower's credit history in region φ_0 where $R_S^*(D) = R_S^*(\overline{D})$.

In the other regions (i.e., φ_1, φ_2 and φ_3) the loan market is more contestable and $R_S^*(D) > R_S^*(\overline{D})$. However, even if the incumbent bank has incentives to truthfully communicate the credit history ex post, it is possible that the bank is unwilling to share such information ex ante. For truthful information sharing to be voluntary, the set of parameters that guarantees truth-telling has to overlap with the set of parameters that makes information sharing ex-ante profitable. In other words, the ex-ante incentive constraint for voluntary information sharing has to be simultaneously satisfied with the ex-post incentive constraint for truth-telling.

We show that the incumbent bank's incentive to truthfully disclose the borrower's credit history is positively related to the contestability of the primary loan market. Truth-telling cannot be sustained in region φ_1. In this case, the loan rate $R_S^*(D)$ is bounded above by the relatively low return R, so that the expected loss of lying is limited and the expected gain dominates. In regions φ_2 and φ_3, the return R becomes larger and the expected loss of lying can dominate the benefit. Truthful reporting then becomes sustainable.

Proposition 3 *The incumbent bank truthfully discloses the borrower's credit history only if $R_S^*(D) > R_S^*(\overline{D})$. Truthful communication of credit history cannot be sustained in regions φ_0 and φ_1, and it is sustainable in the whole region φ_3. In region φ_2, there exists a set of parameters $\varphi_2' \subseteq \varphi_2$ where truth-telling is sustainable. Furthermore, there exists a unique $\underline{\rho} \in (0, \overline{\rho})$ such that $\varphi_2' = \varphi_2$ when $\rho < \underline{\rho}$.*

Proof. See Appendix A.6 ■

The results on truthful disclosure are illustrated in Figure 4. As compared to Figure 3, it highlights a dark-blue area corresponding to the set of parameters in which truth-telling can be sustained. Truth-telling cannot be sustained in Case 0 and Case 1, but can be sustained in Case 3 whenever the bank finds it profitable to share information at $t = 0$. In Case 2, we depict a scenario where $\underline{\rho} < \rho < \overline{\rho}$, so that truth-telling is sustained only in a subset of φ_2. In Figure 4, this subset is depicted by the area above the line R_T, the cutoff value above which truthful information sharing can be sustained.

[Insert Figure 4 here]

3.4 Private credit bureaus v.s. public credit registries

From our discussion in Section 3.2, it should be clear that the incumbent bank's private decision on information sharing is not always socially efficient. Proposition 2 establishes that, when $\rho < \overline{\rho}$, there exist regions in both Case 1 and 2 where the incumbent bank chooses not to engage in information sharing — even though doing so can save the bank from runs in state B.[32] That is, the incumbent bank finds it too costly to give up being an information monopoly in all states, to benefit from the boosted asset marketability only with a small probability.

The imperfectly aligned incentives leave scope for policy intervention. We now consider the efficiency and feasibility of establishing a public credit registry, in which a regulator commands the incumbent bank to share its borrower's credit history. Compared to a private institution, the regulator is concerned with the inefficient liquidation of the incumbent bank but not its loss of monopolistic rent.[33] Such a loss only constitutes a transfer from the incumbent bank to the borrower and is therefore efficiency neutral. This point can be illustrated by comparing Figure 3 and 4. Within the regions Ψ_1 and Ψ_2 where information sharing can save the incumbent bank from illiquidity, the incumbent bank finds it too costly to share the borrower's credit history in the area between R_1 and R_2.[34] When the shared credit history is verifiable, imposing a public credit registry improves efficiency.

When the shared credit history is not verifiable, policies that demand the disclosure of such information also needs to make sure that the bank truthfully reports to the public

[32]On the other hand, when $\rho \geq \overline{\rho}$, the private decision on information sharing is also socially efficient in regions Ψ_1 and Ψ_2. The private decision is always efficient in regions Ψ_0 and Ψ_3. Furthermore, even if it is feasible to share borrower's type, as assumed in Section 3.1, the inefficiency will remain. According to Proposition 1 the incumbent bank finds it profitable to share information only if $\rho > \hat{\rho}$. When $\rho < \hat{\rho}$, we have an inefficient decision similar to the case of sharing information on the borrower's credit history.

[33]Historically, governments' goal in creating public credit registries has been to improve SMEs' access to financing in primary loan markets. Our theory shows that an overlooked benefit of information sharing is the development of secondary markets.

[34]The definitions of R_1 and R_2 can be found in the legend to Figure 4 and the proof of Proposition 2.

credit registry. Imposing a public registry would only improve efficiency in regions where the incumbent bank finds it ex ante unprofitable to share the borrower's credit history but ex post has incentives to truthfully disclose such information. We show that a public registry can improve efficiency subject to the incumbent bank's ex-post incentive compatibility constraint for truth-telling. The set of parameters where a public registry generates an efficiency gain with non-verifiable credit history is illustrated in Figure 5. In particular, it is represented by the area below R_2 (so that the bank finds it too costly to share information ex ante) and above R_T (so that ex post there is incentive for truthful disclosure). Such a region is non-empty when $\rho < \underline{\rho}$.

[Insert Figure 5 here]

The following corollary summarizes the policy implications of our model.

Corollary 1 *A public registry can improve efficiency only if $\rho < \overline{\rho}$.*

- *When the credit history is verifiable, the public registry improves efficiency in region $\{(c, R)|R_1 < R < R_2\} \cap \Psi_j \neq \varnothing$, $j = \{1, 2\}$.*
- *When the credit history is not verifiable, the public registry improves efficiency if and only if $\rho < \underline{\rho} < \overline{\rho}$. In particular, there exists a unique $\underline{\rho}' \in (0, \underline{\rho})$, such that efficiency gain is only obtained in region $\{(c, R)|R_T < R < R_2\} \cap \Psi_2 \neq \varnothing$ when $\rho \in [\underline{\rho}', \underline{\rho})$. There is also efficiency gain in region $\{(c, R)|R_T < R < R_2\} \cap \Psi_1 \neq \varnothing$ when $\rho < \underline{\rho}'$.*

Proof. See Appendix A.7 ■

4 Securitization and Bank Information Sharing

One way for a bank to reduce its liquidity risk is to securitize and sell its loans. We illustrate in this section that even if the incumbent bank fully finances its loan portfolio by securitization, sharing borrowers' credit history is still beneficial since it reduces the cost of providing credit enhancement.[35]

[35] It is not our intention to claim that information sharing is the main reason for the explosion of the markets for asset-backed securities. It is ultimately an empirical question to what extent information sharing has fueled such market expansion.

To study the securitization of a loan portfolio, we modify our model in two ways. First, we introduce a portfolio-level risk factor, so that there can still be asymmetric information about the quality of the loan portfolio. We maintain the assumption that H-type borrowers are risk-free (generating R with certainty) and that the L-type borrowers are risky (having no default history with probability δ and repaying only in the aggregate state G that happens with probability π). The bank lends to a continuum of borrowers of mass 1. The portfolio-level risk factor affects the quality of the bank's unit loan portfolio. In particular, the fraction of H-type borrowers (α) is uncertain: the fraction can be α_H or $\alpha_L < \alpha_H$, with a prior $Prob(\alpha = \alpha_H) = \gamma$.[36] We assume that the previous defaults are independently and identically distributed in the portfolio of a continuum of loans, and that the aggregate state s and portfolio quality α are independent of each other.

Second, we introduce investors with heterogeneous preferences, because otherwise, there will be no need to tranche the cash flow of the loan portfolio to design different securities. For simplicity, we assume that the economy is populated by two types of investors: an investor who is infinitely risk averse and therefore demands risk-free securities, and a risk-neutral investor who can hold risky claims.[37] We model securitization as the bank financing its loans with funding raised from issuing both risk-free debt claims and risky (external) equity claims. The bank makes take-it-or-leave-it offers to the investors and back both types of claims with the cash flow of the loan portfolio.[38]

We assume that both investors have e units of wealth ($e > 1$) to be allocated between the claims issued by the bank and outside investment opportunities. While the risk-averse investor has access to the risk-free asset that has return r_f, the risk-neutral investor has access to a scalable, risky investment project that features decreasing returns to scale. Suppose the risk-neutral investor invests $I \in (0, e)$ in the outside opportunity. We denote by $y(I)$ the expected *marginal* return of capital and require $y'(I) < 0$, $\lim_{I \to 0} y(I) = +\infty$, and

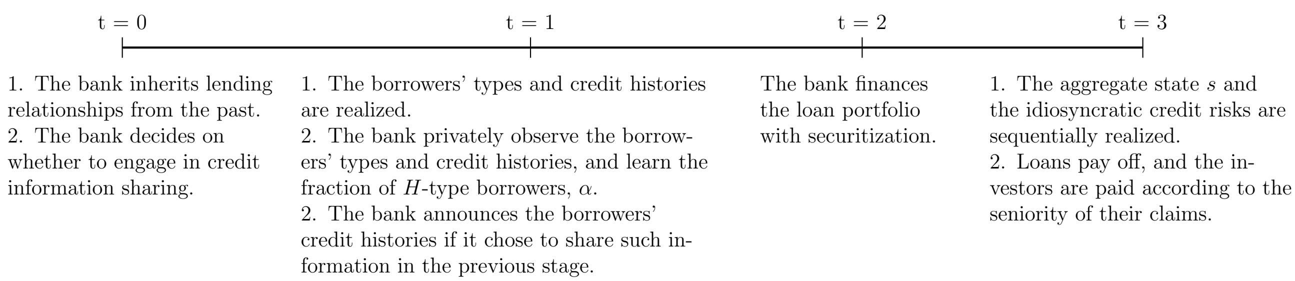
[36] The difference between the portfolio-level risk α and the aggregate risk s is that the bank privately learns the realization α but has no private information about s.

[37] While heterogeneous preferences provide the very basis for designing different securities (Allen and Gale, 1988), for model tractability, it is often assumed that certain agents are infinitely risk averse (Gennaioli, Shleifer and Vishny, 2012, 2013) or prefer extreme safety (Stein, 2012). The assumption of infinite risk aversion can be relaxed, and our result holds as long as some investors are sufficiently risk averse.

[38] This modified setup models the endogenous capital structure more explicitly and shows again that a bank cannot signal its asset quality solely by its capital structure.

$\lim_{I \to e} y(I) \geq r_f$. The last limiting condition implies that it is more costly for the bank to raising funding with equity than with risk-free debt.

As in our main model, the bank learns its borrowers' verifiable repayment history and can commit to sharing such information with outsiders, including the two investors. The bank's decision on information sharing is assumed to take place before the realization of the loan portfolio quality (α) and the aggregate state s. The bank raises funding via securitization before the aggregate state s is realized. The timeline of the modified model is as follows.



We illustrate the benefit of information sharing in securitization when the loan market is not contestable, $R_N^* = R_S^*(D) = R_S^*(\overline{D}) = R$ (i.e., Case 0 analyzed in Section 3). By focusing on this case, we silence the competition in loan origination and highlight the benefit of information sharing. In this case, the cash flow of the loan portfolio $\widetilde{CF}$ is independent of whether the bank shares credit information or not. We have

$$\widetilde{CF} = \begin{cases} R & \text{if } s = G \\ \alpha_L R & \text{if } s = B \text{ and } \alpha = \alpha_L \\ \alpha_H R & \text{if } s = B \text{ and } \alpha = \alpha_H, \end{cases}$$

with the expected cash flow $E\big(\widetilde{CF}\big) = \pi R + (1-\pi)\big[\gamma \alpha_H R + (1-\gamma)\alpha_L R\big]$.

Finally, for simplicity, we assume $\alpha_L R < r_f < \alpha_H R$. The inequalities indicate that the bank can finance its loan portfolio of quality α_H using only risk-free debt, but will need to provide the credit enhancement of an equity tranche to finance a loan portfolio of quality α_L. The parametric assumption can be relaxed and will not qualitatively affect any results.

4.1 Costly securitization without information sharing

Suppose that, without information sharing, banks are in a pooling equilibrium. That is, a bank with α_H fraction of H-type loans cannot be distinguished from a bank with α_L fraction of H-type loans. Then, a bank can issue risk-free debt with a face value of at most $d_N = \alpha_L R$, which allows the bank to raise an amount $b_N = \alpha_L R / r_f$ from the risk-averse investor.[39] The remaining amount $1 - b_N$ has to be raised from the risk-neutral investor in the form of equity. To attract the risk-neutral investor, the return on the equity tranche must exceed that on the investor's outside investment opportunity. In particular, receiving ω_N share of the securitized bank, the risk-neutral investor has a participation constraint

$$\frac{\omega_N \cdot E_{\alpha,s}\left[\max\left(\widetilde{CF} - d_N, 0\right)\right]}{1 - b_N} \geq y\left(e - (1 - b_N)\right),$$

where $y\left(e - (1 - b_N)\right)$ represents the minimum return that the bank needs to offer to attract equity financing. With the expected equity value $E_{\alpha,s}\left[\max\left(\widetilde{CF} - d_N, 0\right)\right]$ equal to $\gamma\left[\pi(R - d_N) + (1 - \pi)(\alpha_H R - d_N)\right] + (1 - \gamma)\left[\pi(R - d_N) + (1 - \pi)(\alpha_L R - d_N)\right] = \pi(R - d_N) + (1 - \pi)\gamma(\alpha_H R - d_N)$, the participation constraint implies the size of equity tranche must be sufficiently high:

$$\omega_N \geq \frac{1 - b_N}{\pi(R - d_N) + (1 - \pi)\gamma(\alpha_H R - d_N)} \cdot y\left(e - (1 - b_N)\right).$$

The financing of the loan portfolio is feasible (i.e., $\omega_N < 1$) if investors' wealth e is sufficiently large. When both types of investors' participation constraints bind, the bank reaches its maximum payoff:

$$V_N^{SEC} = (1 - \omega_N) \cdot E_{\alpha,s}\left[\max\left(\widetilde{CF} - d_N, 0\right)\right] = E\big(\widetilde{CF}\big) - \underbrace{\Big[b_N \cdot r_f + (1 - b_N) \cdot y\big(e - (1 - b_N)\big)\Big]}_{\text{the bank's weighted average cost of funding}}.$$

The expression is rather intuitive: the payoff to the bank is the expected cash flow of its loan portfolio net of its average cost of funding. Specifically, a b_N fraction of funding is raised from the risk-averse debt holder at the risk-free rate r_f; and a $1 - b_N$ fraction of funding is raised from the risk-neutral equity holder at a cost of equity $y\left(e - (1 - b_N)\right)$.

[39] Indeed, without any information on the quality of the loan portfolio, the infinitely risk-averse investor would view the loan portfolio as if it is of quality α_L.

We show that tranching and securitization indeed do not eliminate asymmetric information about asset qualities, and that banks cannot use capital structure as a signal of its asset quality in securitization. Parallel to Lemma 1, no separating equilibrium can be sustained. Nevertheless, a pooling equilibrium in which the H-quality bank exhausts its risk-free debt capacity does not always exist either. This is because a reduction in debt liabilities also makes more cash flow available to equity holders and may reduce the cost of equity. However, when γ is sufficiently high, the punishment for the H-quality bank to deviate (and to be mistaken for an L-quality bank) is strong enough to sustain a pooling equilibrium.

Lemma 6 *No separating equilibrium exists in the case of no credit information sharing. If $\gamma > \alpha_L/[\pi(1-\alpha_L)+(1-\pi)(\alpha_H-\alpha_L)+\alpha_L]$, a pooling equilibrium exists, where both the H- and L-quality banks finance the loan portfolio by issuing an ω_N fraction of equity and risk-free debt with face value d_N.*

Proof. See Appendix A.8. ■

The lack of information revelation in the pooling equilibrium, and the resulting costly credit enhancement, leaves room for information sharing to increase the value of the securitized bank.

4.2 Credit information sharing facilitates securitization

We now turn to the case where the bank shares the repayment history of its borrowers. Since the previous defaults are assumed to be *i.i.d* in the portfolio of a continuum of loans, the bank will have exactly $\alpha+(1-\alpha)\delta$ fraction of borrowers who have no previous defaults and $(1-\alpha)(1-\delta)$ fraction of borrowers who have previously defaulted. This fraction of default can be interpreted as the *average* FICO score of the loan portfolio. Given that δ is common knowledge, investors can calculate the fraction of H-type borrowers in the loan portfolio based on the shared information. In other words, sharing borrowers' credit history results in a complete revelation of the quality of the bank's loan portfolio.

When the shared credit history reveals $\alpha = \alpha_H$, the bank can finance the loan portfolio solely using risk-free debt, given our parametric assumption $r_f < \alpha_H R$. When the shared credit history reveals $\alpha = \alpha_L$, however, the bank can only issue risk-free debt with face value $d_S(L) = \alpha_L R$ and raise $b_S(L) = \alpha_L R/r_f$ from the risk-averse investor. Since the infinitely risk-averse investor only values the worst-case scenario, we have $d_S(L) = d_N$ and $b_S(L) = b_N$. Similar to the case without information sharing, it can be calculated that the bank needs to issue $\omega_S(L)$ fraction of equity to the risk-neutral investor:[40]

$$\omega_S(L) \geq \frac{1 - b_S(L)}{\pi[R - d_S(L)]} \cdot y\left(e - (1 - b_S(L))\right).$$

Under information sharing, the bank's maximum expected payoff is as follows:

$$V_S^{SEC} = E\big(\widetilde{CF}\big) - \underbrace{\Big\{\gamma \cdot r_f + (1-\gamma) \cdot \Big[b_S(L) \cdot r_f + (1 - b_S(L)) \cdot y\left(e - (1 - b_S(L))\right)\Big]\Big\}}_{\text{the bank's } \textit{expected} \text{ weighted average cost of funding}}.$$

While the expected cash flow of the portfolio remains the same, the bank's expected average cost of funding drops when it shares information. Indeed, this payoff is higher than that without information:

$$V_S^{SEC} - V_N^{SEC} = \gamma\big(1 - b_S(L)\big)\Big[y\Big(e - \big(1 - b_S(L)\big)\Big) - r_f\Big] > 0,$$

with the difference completely due to the reduction in the cost of funding. Specifically, the cost of funding remains the same as compared to the no information sharing case when $\alpha = \alpha_L$ is revealed, but the bank no long needs to provide the credit enhancement of an equity tranche when $\alpha = \alpha_H$. As the amount $1 - b_S(L)$ is now raised with risk-free debt, the cost of funding drops from the equity holders' required return $y(e - (1 - b_S(L)))$ to r_f. When the bank commits to information sharing before knowing its portfolio quality, the expected cost of funding will decrease.

Proposition 4 *The value of the bank with a fully securitized loan portfolio increases when the bank shares the repayment history of its borrowers.*

The analysis shows that information sharing dominates also in the context of securitized banking, when the loan market is not contestable. The results would carry over to the rest

[40] Notice that $\omega_S(L) > \omega_N$. This is because, compared to the case without information, the equity holder needs to contribute the same amount of capital, $1 - b_S(L) = 1 - b_N$, but there is no upside given that the shared information reveals $\alpha = \alpha_L$. To compensate the equity holder, the share must increase.

of the cases if the entrant bank finances itself using deposits. In those cases, the trade-off between the cost of facing intensified competition and the benefit of improved asset marketability will re-emerge, in the same fashion as analyzed in Section 3.

5 Conclusions

This paper formally analyzes the conjecture that banks share their borrowers' credit history to maintain the market liquidity of their assets. Information asymmetry in the secondary markets make asset sale costly; and high-quality assets can be priced below their fundamental value. This basic observation implies that banks may find it beneficial to disclose their borrowers' credit information to reduce the information asymmetry about their loan quality. Indeed, we show that credit information sharing can make banks more resilient to funding liquidity risks in the traditional originate-to-hold model, and can facilitate securitization in the originate-to-distribute model.

Our model forcefully provides a novel rationale for the establishment of public credit registries. Banks do not fully internalize the benefit of asset marketability when liquidity risk is small. Banks then may not find it privately profitable to share ex-ante its credit information even when this is socially efficient. Moreover, we show that a public credit registry may induce banks to reveal truthfully ex-post their credit information, even if banks would not establish a registry in the first place.

Our theoretical exposition also generates new testable hypotheses. The model implies that information sharing will facilitate banks' liquidity management and loan sales. Under the presumption that borrower's credit history is the bank's private information, the model suggests that an information sharing system can be more easily established and will work more effectively in countries with a competitive banking sector, and in credit market segments where competition is strong.

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Appendix A.1 Proof of Lemma 1

When the incumbent bank does not share any information, the game features incomplete information. Therefore, we apply the solution concept of PBE.

Definition. *A pure-strategy pooling PBE of the game g_N is characterized as follows. (i) An equilibrium strategy profile. Based on its knowledge of the borrower's type, the incumbent bank at $t = 2$ sets a loan rate R_N^I for the borrower and offers a take-it-or-leave-it deposit rate r_N^I to depositors. When having financed the borrower, the incumbent bank decides at $t = 3$ whether to sell the loan, according to the loan quality, the state s, and its own liquidity position. The entrant bank offers a competing loan rate R^E without knowing the borrower's type or credit history. Depositors choose to provide funding or not based on the offered deposit rate. Asset buyers bid P_N^G in state G and P_N^B in state B to purchase any loan on sale. (ii) A system of beliefs. The entrant bank holds the prior belief about the borrower's type. The depositors Bayesian update their beliefs according to the deposit rate offered by the incumbent bank. The asset buyers Bayesian update their beliefs according to the aggregate state s and observation of asset sale. (iii) The strategy profile in (i) is sequential rational given the beliefs in (ii).*

We show that the unique pure-strategy equilibrium is a pooling equilibrium, as the incumbent bank offers a unified loan rate $R_N^I \in [r_f, R]$ and a unified deposit rate $r_N^I \in [r_f, r_f/\pi]$, independent of the type of borrower it finances.[41] We first establish that the strategy profile and belief system described in Lemma 1 indeed constitute a PBE (Part I). We then prove that no other pure-strategy PBE exists (Part II). We assume that the depositors have an off-equilibrium belief worse than the prior. This includes the standard assumption that when an off-equilibrium action is observed, the players have the worst belief about the loan quality.

Part I: The existence of a pure-strategy pooling PBE.

[41] Notice that the incumbent bank holds private information about the borrower's type as well as the credit history. Note that the borrower's type is more relevant than the credit history. Therefore, without losing generality, we consider the incumbent bank directly conditions its loan rates on the true types.

To establish the equilibrium described in Lemma 1, we solve the game backwards.

Step 1. We start by analyzing the secondary loan market in the state G and B respectively. In state G, the incumbent bank sells its loan only when facing a run, and in that case sells its loan regardless of the borrower's type. The asset buyers, therefore, hold the prior belief . Moreover, both types of borrowers will repay R_N^* in state G. As a result, asset buyers' competitive bidding leads to $P_N^G = R_N^*$.

In state B, the incumbent bank always sells its L-type loan and sells an H-type loan only if facing a run. The asset buyers Bayesian update their belief accordingly:

$$Prob(H|\text{loan sale}) = \frac{Pr(\text{run})Pr(H)}{Pr(\text{run})Pr(H) + Pr(L)} = \frac{\alpha\rho}{\alpha\rho + (1-\alpha)}.$$

Since only the H-type borrower will replay R_N^* in state B, the asset buyers face a break-even condition $\frac{\alpha\rho}{\alpha\rho+(1-\alpha)}\left(R_N^* - P_N^B\right) + \frac{1-\alpha}{\alpha\rho+(1-\alpha)}\left(0 - P_N^B\right) = 0$, which implies

$$P_N^B = \frac{\alpha\rho}{(1-\alpha)+\alpha\rho} R_N^* < R_N^*. \tag{7}$$

It is straightforward to verify that the incumbent bank's equilibrium strategy is sequentially rational given the asset buyers' beliefs and bids.

Step 2: We now move to the stage where the incumbent bank raises its funding. The strategic interaction between the incumbent bank and its depositors can be considered as a signaling game. The incumbent bank (sender) has private information about its loan quality and offers a deposit rate (a message) to the depositors (receivers). The depositors may infer the bank's loan type when deciding on accepting the bank's offer or not.

We first analyze depositors' belief and strategy on the equilibrium path described by Lemma 1. As the incumbent bank offers a pooling deposit rate r_N^I, the depositors' belief about the bank's loan quality remains the same as the prior. Moreover, under the condition $P_N^B < r_f$, the incumbent bank cannot raise enough liquidity from the loan sale when a run happens. Thus, while depositors anticipate the bank to fully repay its debt in state G, they expect the bank to survive in state B only when it holds an H-type of loan *and* faces no run. Given depositors' belief about the loan quality, the minimum rate that they are willing to accept equals $r_N^I = r_f/[\pi + (1-\pi)\alpha(1-\rho)]$, which allows them to break even given the subsequent equilibrium strategies of the incumbent bank and asset buyers.

The incumbent bank's equilibrium deposit rate r_N^I can be sustained by the depositors' worse-than-prior off-equilibrium beliefs: $Pr(H|r^I \neq r_N^I) < \alpha$ and $Pr(L|r^I \neq r_N^I) > 1-\alpha$. The depositors' break-even rate can be computed as $\hat{r} = \frac{r_f}{\pi+(1-\pi)Pr(H|r^I \neq r_N^I)(1-\rho)} > r_N^I$.

Given the depositors' break-even rate, it is indeed sequentially rational for the incumbent bank to offer the pooling deposit rate r_N^I. In particular, when the incumbent bank wins an H-type loan, it earns an expected profit $\Pi_N(H) = [\pi+(1-\pi)(1-\rho)](R_N^* - r_N^I) > 0$, by offering the equilibrium deposit rate r_N^I.[42] Suppose, instead, the incumbent bank deviates by offering a deposit rate $r^I \neq r_N^I$. Then its expected profit is $\hat{\Pi}_N(H) = 0 < \Pi_N(H)$ if $r^I < \hat{r}$, and $\hat{\Pi}_N(H) = [\pi + (1-\pi)(1-\rho)](R_N^* - \hat{r}) < \Pi_N(H)$ if $r^I > \hat{r}$. Thus, the incumbent bank has no profitable deviation when holding an H-type loan. Similarly, when the incumbent bank wins an L-type loan, it earns an expected profit $\Pi_N(L) = \pi(R_N^* - r_N^I) > 0$, by offering the equilibrium rate r_N^I. While its expected profit from deviation is $\hat{\Pi}_N(L) = 0 < \Pi_N(L)$ if $r^I < \hat{r}$, and $\hat{\Pi}_N(L) = \pi(R_N^* - \hat{r}) < \Pi_N(L)$ if $r^I > \hat{r}$. Therefore, the incumbent bank has no profitable deviation when holding an L-type loan either. In fact, the worse-than-prior off-equilibrium belief is a necessary and sufficient condition for r_N^I to be part of the PBE.[43]

Step 3: We now analyze the primary loan market competition. Given the entrant bank's belief $Prob(H) = \alpha$ and $Prob(L) = 1-\alpha$, the minimum loan rate that satisfies the entrant bank's participation constraint is $R_N^E = (c + r_f)/[\alpha + (1-\alpha)\pi]$. Otherwise, the entrant bank will be better off holding the risk-free asset.

We now show that, given the subsequent equilibrium strategies characterized in *Step 1* and *2*, the incumbent bank's equilibrium strategy in the primary loan market is to offer a pooling rate $R_N^* = \min\{R, R_N^E\}$ regardless of the type of the borrower.

First, consider the interior solution $R_N^* = R_N^E < R$.[44] For an H-type borrower, the incumbent bank earns an expected profit $\Pi_N(H) = [\pi + (1-\pi)(1-\rho)](R_N^E - r_N^I) > 0$ by

[42] When $R_N^* = R$, the inequality $R_N^* > r_N^I$ is guaranteed by condition (3). When $R_N^* = R_N^E = \frac{c+r_f}{\alpha+(1-\alpha)\pi}$, the inequality is guaranteed by assumption (2).

[43] The worse-than-prior off-equilibrium belief is also a necessary condition. If the off-equilibrium beliefs are more optimistic than the prior, the incumbent bank will also have incentives to deviate from offering r_N^I. Therefore, a pooling equilibrium that features the deposit rate r_N^I must be associated with worse-than-prior off-equilibrium beliefs.

[44] We assume the borrower sticks to the incumbent bank when there is a tie in competing loan rates.

offering $R_N^* = R_N^E$. The inequality is guaranteed by Assumption (2). Indeed, we have

$$c > \frac{1-\pi}{\pi} r_f \Rightarrow c > \frac{\alpha(1-\pi)\rho}{\pi + (1-\pi)\alpha(1-\rho)} r_f \Leftrightarrow \frac{c + r_f}{\alpha + (1-\alpha)\pi} > \frac{r_f}{\pi + (1-\pi)\alpha(1-\rho)}.$$

The incumbent bank has no profitable deviation. If the bank deviates by charging a loan rate $R^I(H) > R_N^E$, it will lose the loan competition and realizes a zero profit. If the bank deviates by charging a loan rate $R^I(H) < R_N^E$, it still wins the H-type borrower but earns an expected profit lower than $\Pi_N(H)$. For an L-type loan, the incumbent bank earns an expected profit $\Pi_N(L) = \pi(R_N^E - r_N^I) > 0$ by offering the equilibrium rate R_N^E, and has no profitable deviation either. If the bank deviates by charging a loan rate $R^I(L) > R_N^E$, it will lose the loan competition and realizes a zero profit. If the bank deviates by charging a loan rate $R^I(L) < R_N^E$, it still wins the L-type borrower but earns an expected profit lower than $\Pi_N(L)$.

Consider now the corner solution $R_N^* = R < R_N^E$. The incumbent bank charges a loan rate R independent of the borrower's type, and earns $\Pi_N(L) = \pi(R - r_N^I)$ and $\Pi_N(H) = [\pi + (1-\pi)(1-\rho)](R - r_N^I)$ on the L- and H-type borrower, respectively. Both $\Pi_N(H)$ and $\Pi_N(L)$ are guaranteed to be positive by condition (3). Similar to the case of interior solution, one can verify the incumbent bank has no profitable deviation for either type.

Lastly, we show that, given its belief about the loan quality and the incumbent bank's strategy R_N^*, the entrant bank has no profitable deviation either. Consider first the interior case $R^E = R_N^E < R$. By offering a slightly higher loan rate $R_N^E + \varepsilon$, the entrant bank loses the loan market competition regardless of the borrower's type and receives a zero profit. By offering a slightly lower loan rate $R^E = R_N^E - \varepsilon$, the entrant bank wins the borrower but would be better off in expectation by investing in the risk-free asset. Indeed, we have $[\alpha + (1-\alpha)\pi](R_N^E - \varepsilon) - (c + r_f) = -[\alpha + (1-\alpha)\pi]\varepsilon < 0$. Consider next the corner case where $R_N^E \geq R$. The entrant bank will not be able to attract any borrower by offering a loan rate higher than R. If the entrant bank offers a rate lower than R, it wins the borrower regardless of its type but receives a negative expected profit.

To summarize, we have established that the strategy profile and belief system described in Lemma 1 is indeed a pure-strategy PBE.

Part II: The uniqueness of the pure-strategy pooling PBE.

We now show that there exists no separating equilibrium or another pooling equilibrium other than the one described in Lemma 1. We consider all possible strategy profiles from the primary loan market competition and prove by contradiction that none of them can be part of a PBE. With R^E denoting the loan rate offered by the entrant bank, we denote $R^I(\theta)$ and $r^I(\theta)$ be the loan rate and deposit rate offered by the incumbent bank on a θ-type borrower, $\theta \in \{H, L\}$. We have the following four alternatives scenarios.

Scenario 1: Assume $R^E < \min\{R^I(H), R^I(L)\}$, so that the incumbent bank loses the loan market competition irrespective of the borrower's type. Suppose that these loan rates had indeed been a part of a PBE. Then the incumbent bank offering a deposit rate to raise funding will be off the equilibrium path. We now show this cannot be a PBE, because the incumbent bank has profitable deviations for any off-equilibrium belief of the outsiders.

For the sake of the argument, consider the most pessimistic beliefs of depositors and asset buyers that the incumbent bank must have financed an L-type loan. Given the belief, the asset buyers will offer a price equal to 0 in state B, and the depositors will accept a rate r_f/π to break even. We now turn to the loan market competition. When the entrant bank wins the loan competition irrespective of the borrower's type, R^E must satisfy

$$R^E \geq \frac{c + r_f}{\alpha + (1 - \alpha)\pi}$$

so that the entrant bank's participation constraint is satisfied. The incumbent bank has profitable deviation. Consider the L-type borrower. By undercutting R^E, that is offering a rate $R^I(L) = R^E$, the incumbent bank earns an expected profit

$$\pi \left(\frac{c + r_f}{\alpha + (1 - \alpha)\pi} - \frac{r_f}{\pi} \right),$$

which is positive because of Assumption (2). It is straightforward to see that profitable deviation also exists for an H-type borrower and for any more optimistic off-equilibrium beliefs of the outsiders. Therefore, $R^E < \min\{R^I(H), R^I(L)\}$ cannot be part of a PBE.

Scenario 2: Assume $R^I(H) \leq R^E < R^I(L)$, so that the incumbent bank only wins the H-type borrower. Suppose these loan rates had indeed been a part of a PBE and that the incumbent bank offers a rate $r^I(H)$ to depositors. The depositors' on-equilibrium belief will be $Pr(H|r^I(H)) = 1$. Furthermore, the depositors expect asset buyers to Bayesian update their beliefs about the incumbent bank's loan quality according to the equilibrium strategy and to purchase the incumbent bank's asset on sale at a price $P^G = P^B = R^I(H) > r_f$. Therefore, it is sequentially rational for the depositors to provide financing for $r^I(H) = r_f$.

We now analyze the primary loan market competition. In a separating equilibrium where the entrant bank only finances the L-type, its participation constraint requires $R^E \geq (c + r_f)/\pi$. Given its funding cost r_f, the incumbent bank can profitably deviates by increasing $R^I(H)$ until it reaches R^E for the H-type, and by decreasing $R^I(L)$ until R^E for the L-type. Consequently, $R^I(H) \leq R^E < R^I(L)$ cannot be part of a PBE either.

Scenario 3: Assume $R^I(L) \leq R^E < R^I(H)$, so that the incumbent bank only wins the L-type borrower. Suppose these loan rates had indeed been a part of a PBE. Similar to Scenario 2, the depositors would hold an on-the-equilibrium-pathbelief $Pr(L|r^I(L)) = 1$. Depositors also expect the asset buyers to offer $P^G = R^I(L) > r_f$ and $P^B = 0$ for the incumbent bank's asset on sale in state G and B, respectively. Therefore, it is sequentially rational for the depositors to provide financing for $r^I(L) = r_f/\pi$.

In this separating equilibrium where the entrant bank wins the H-type borrower, the bank's participation constraint requires $R^E \geq c + r_f$. The incumbent bank can profitably deviate by increasing $R^I(L)$ until R^E for the L-type, since

$$\pi\left(R^E - \frac{r_f}{\pi}\right) - \pi\left(R^I(L) - \frac{r_f}{\pi}\right) = \pi\left(R^E - R^I(L)\right) \geq 0,$$

and by decreasing $R^I(H)$ until R^E for the H-type, because $c + r_f - r_f/\pi > 0$ under Assumption (2). Thus, we establish that $R^I(L) \leq R^E < R^I(H)$ cannot be part of a PBE.

Scenario 4: Assume $\max\{R^I(H), R^I(L)\} \leq R^E$, so that the incumbent bank still wins the loan market competition regardless of the borrower's type. But instead of a pooling equilibrium as described in Lemma 1, there is a separating PBE where either $R^I(H) \neq R^I(L)$, or $r^I(H) \neq r^I(L)$, or both. We prove by contradiction that these rates cannot be part of a PBE because the incumbent bank will have incentives to deviate. In particular, an incumbent bank with an L-type loan will mimic a bank with an H-type loan.

Suppose the incumbent bank offers separating deposit rates $r^I(H) \neq r^I(L)$ in equilibrium. The depositors' beliefs on the equilibrium path will be $Pr\left(H|r^I(H)\right) = 1$ and $Pr\left(L|r^I(L)\right) = 1$, and they will provide funding for deposit rates $r^I(L) \geq r_f/\pi$ and $r^I(H) \geq r_f/[\pi + (1-\pi)(1-\rho)]$. As a result, the incumbent bank can profitably deviate by offering $r^I(L) = r^I(H) = r_f/[\pi + (1-\pi)(1-\rho)]$. That is, to secure a lower cost of funding, the incumbent bank would always claim having lend to an H-type borrower given the depositors' beliefs on the equilibrium path. Therefore, offering separating deposit rates must not be a part of PBE.

Now suppose separating loan rates $R^I(H) \neq R^I(L)$ had indeed been a part of a PBE. Note that the incumbent bank's funding cost for a loan will be r_N^I according to our previous discussion. Moreover, recall that the entrant bank's minimum profitable loan rate is R_N^E, so we must have $R^E \geq R_N^E$. Given such competing loan rate R^E and funding cost r_N^I, the incumbent bank has profitable deviations by increasing both $R^I(H)$ and $R^I(L)$ up to R^E if $\max\{R^I(H), R^I(L)\} < R^E$ or increasing the lowest until R^E if $\max\{R^I(H), R^I(L)\} = R^E$, because $R^E - r_N^I \geq \min\{R, R_N^E\} - r_N^I > 0$. Consequently, offering the above separating loan rates can not be a sequential rational action for the incumbent bank.

In sum, we establish a unique pure-strategy pooling PBE as described in Lemma 1.

Appendix A.2 Proof of Proposition 1

Depending on the value of R, we have four cases (with the index number of each case representing the number of the interior solutions).

Case 0: $R \in [0, c + r_f)$ so that $R_S^*(H) = R_N^* = R_S^*(L) = R$;

Case 1: $R \in \left[c + r_f, \frac{c+r_f}{\alpha+(1-\alpha)\pi}\right)$ so that $R_S^*(H) = c + r_f$ and $R_N^* = R_S^*(L) = R$;

Case 2: $R \in \left[\frac{c+r_f}{\alpha+(1-\alpha)\pi}, \frac{c+r_f}{\pi}\right)$ so that $R_S^*(H) = c + r_f$, $R_N^* = \frac{c+r_f}{\alpha+(1-\alpha)\pi}$ and $R_S^*(L) = R$;

Case 3: $R \in \left[\frac{c+r_f}{\pi}, \infty\right)$ so that $R_S^*(H) = c + r_f$, $R_N^* = \frac{c+r_f}{\alpha+(1-\alpha)\pi}$ and $R_S^*(L) = \frac{c+r_f}{\pi}$.

For Case 0 and 3, we have shown in the text that $V_S^{Type} > V_N$ for any $\rho > 0$. It remains to show that in Case 1 and 2 there exists a $\hat{\rho} \in (0, 1)$ such that $V_S^{Type} > V_N$ for $\rho > \hat{\rho}$.

Consider Case 1. At $t = 0$, the incumbent bank's expected profit V_N can be written as

$$V_N = [\pi + (1-\pi)\alpha(1-\rho)]\, R - r_f,$$

which decreases in ρ, and we have $\lim_{\rho\to 0} V_N = [\pi + (1-\pi)\alpha] R - r_f$ and $\lim_{\rho\to 1} V_N = \pi R - r_f$ at the boundaries. On the other hand, the expected profits V_S^{Type} can be written as

$$V_S^{Type} = \alpha(c + r_f) + (1-\alpha)\pi R - r_f = \pi R + \alpha[(c + r_f) - \pi R] - r_f.$$

The last expression is strictly smaller than $[\pi + (1-\pi)\alpha] R - r_f$ because under Case 1 we have $R > c + r_f$, and it is greater than $\pi R - r_f$ because $\pi R < (r_f + c)$. Since V_N is continuous in ρ, there must exist a $\hat{\rho}_1 \in (0,1)$ such that $V_S^{Type} > V_N$ for $\rho > \hat{\rho}_1$.

Consider Case 2. The expected payoff V_N becomes

$$V_N = \frac{\pi + (1-\pi)\alpha(1-\rho)}{\alpha + (1-\alpha)\pi}(c + r_f) - r_f,$$

which still decreases in ρ, with $\lim_{\rho\to 0} V_N = c$ and $\lim_{\rho\to 1} V_N = \frac{\pi(c+r_f)}{\alpha+(1-\alpha)\pi} - r_f$ at the boundaries. On the other hand, the expression of V_S^{Type} remains the same as in Case 1, that is

$$V_S^{Type} = \alpha(c + r_f) + (1-\alpha)\pi R - r_f < c$$

because $\pi R < (c + r_f)$ also holds in Case 2. Meanwhile, we know

$$V_S^{Type} > \alpha(c + r_f) + (1-\alpha)\pi \frac{c + r_f}{\alpha + (1-\alpha)\pi} - r_f = \left[\alpha + \frac{(1-\alpha)\pi}{\alpha + (1-\alpha)\pi}\right](c + r_f) - r_f,$$

where the inequality holds because under Case 2 we have $R > \frac{c+r_f}{\alpha+(1-\alpha)\pi}$. The last expression is greater than the lower bound of V_N because $\alpha(1-\alpha)\pi/[\alpha+(1-\alpha)\pi] > \pi/[\alpha+(1-\alpha)\pi]$. Since V_N is continuous in ρ, there must exist a $\hat{\rho}_2 \in (0,1)$ such that $V_S^{Type} > V_N$ for $\rho > \hat{\rho}_2$. Letting $\hat{\rho} \le \min\{\hat{\rho}_1, \hat{\rho}_2\}$, we have proven Proposition 1.

Appendix A.3 Proof of Lemma 4

The equilibrium prices of the loan on sale in the secondary market are $P_N^B = \frac{\alpha\rho}{(1-\alpha)+\alpha\rho} R_N^*$ and $P_S^B(\overline{D}) = \frac{\alpha\rho}{(1-\alpha)\delta+\alpha\rho} R_S^*(\overline{D})$, where R_N^* and $R_S^*(\overline{D})$ are the equilibrium loan rates without and with information sharing, respectively.

Consider Case 0. The return R is so low that the entrant bank does not compete for any loan even if the incumbent bank shared a $\overline{D}$ credit history of the borrower. The incumbent bank extracts the entire payoff of the loan irrespective of the information sharing regime, that is $R_S^*(\overline{D}) = R_N^* = R$. Consequently, $P_S^B(\overline{D}) > P_N^B$.

Consider Case 2 (for the easy of exposition it is convenient to prove this case first). The value of R is sufficiently high that the entrant bank competes both under information sharing (when the borrower has no previous default) and under no information sharing. The equilibrium loan rates are therefore

$$R_N^* = R_N^E = \frac{c + r_f}{\alpha + (1-\alpha)\pi} > \frac{\alpha + (1-\alpha)\delta}{\alpha + (1-\alpha)\pi\delta}(c + r_f) = R_S^E(\overline{D}) = R_S^*(\overline{D}).$$

We want to show that

$$P_N^B = \frac{\alpha\rho}{(1-\alpha) + \alpha\rho}\frac{c + r_f}{\alpha + (1-\alpha)\pi} < \frac{\alpha\rho}{(1-\alpha)\delta + \alpha\rho}\frac{\alpha + (1-\alpha)\delta}{\alpha + (1-\alpha)\pi\delta}(c + r_f) = P_S^B(\overline{D}),$$

which can be rewritten as

$$\frac{\alpha\rho + (1-\alpha)\delta}{\alpha\rho + (1-\alpha)}\frac{\alpha + (1-\alpha)\pi\delta}{[\alpha + (1-\alpha)\delta][\alpha + (1-\alpha)\pi]} < 1. \tag{8}$$

To show that the inequality (8) holds, notice that the ratio $\frac{(1-\alpha)\delta + \alpha\rho}{(1-\alpha) + \alpha\rho}$ increases in ρ. So its maximum value is reached when $\rho = 1$ and equals $\alpha + (1-\alpha)\delta$. Therefore, an upper bound of the LHS of (8) can be written as

$$[\alpha + (1-\alpha)\delta]\frac{\alpha + (1-\alpha)\pi\delta}{[\alpha + (1-\alpha)\delta][\alpha + (1-\alpha)\pi]} = \frac{\alpha + (1-\alpha)\pi\delta}{\alpha + (1-\alpha)\pi}.$$

The expression is smaller than 1 for $\forall\delta \in (0, 1)$. Therefore, we prove that $P_S^B(\overline{D}) > P_N^B$.

Consider Case 1. The entrant bank only competes for the borrower with a revealed $\overline{D}$-history, such that $R_S^*(\overline{D}) = R_S^E(\overline{D})$ remains true in equilibrium. With no information sharing, however, the incumbent bank can charge to the borrower the entire project return by setting $R_N^* = R$. Thus, the loss in information rent from primary loan market competition is smaller than that in Case 2, and $P_S^B(\overline{D}) > P_N^B$ also holds in Case 1.

Consider Case 3. The loan payoff R is sufficiently high that the entrant bank competes even when the loan is granted to a borrower with a default credit history D. The relevant equilibrium loan rates R_N^* and $R_S^*(\overline{D})$ are the same as in Case 2 and the same analysis applies. Therefore, $P_S^B(\overline{D}) > P_N^B$ also holds in Case 3.

Appendix A.4 Proof of Lemma 5

Given $P_S^B(\overline{D}) > P_N^B$, by continuity, when r_f is located between the two prices, the incumbent bank survives a run in state B when the loan has a revealed credit history $\overline{D}$ and it fails when sharing no information. We now characterize the regions $\mathbb{F}_j$, with $j = 0, 1, 2, 3$, where the inequality $P_S^B(\overline{D}) > r_f > P_N^B$ holds.

In Case 0, we have $R_N^* = R_S^*(\overline{D}) = R$, so that the inequality can be written as

$$\frac{\alpha\rho}{(1-\alpha)\delta + \alpha\rho} R > r_f > \frac{\alpha\rho}{(1-\alpha) + \alpha\rho} R$$

which is satisfied for any $\delta \in (0, 1)$. The nonempty set $\mathbb{F}_0$ is characterized by the boundaries $\underline{R}$ and $\overline{R}$ as defined as follows

$$R > \frac{\alpha\rho + (1-\alpha)\delta}{\alpha\rho} r_f \equiv \underline{R} \quad \text{and} \quad R < \frac{\alpha\rho + (1-\alpha)}{\alpha\rho} r_f \equiv \overline{R}.$$

Set Ψ_0 is non-empty, since $\mathbb{R}_0$ is delineated by $c + r_f$ and $R_S^E(\overline{D})$.

In Case 1, we have $R_S^*(\overline{D}) = R_S^E(\overline{D})$ and $R_N^* = R$, so that the inequality becomes

$$\frac{\alpha\rho}{(1-\alpha)\delta + \alpha\rho} \frac{\alpha + (1-\alpha)\delta}{\alpha + (1-\alpha)\delta\pi} (c + r_f) > r_f > \frac{\alpha\rho}{(1-\alpha) + \alpha\rho} R.$$

The nonempty set $\mathbb{F}_1$ is characterized by boundaries $\underline{R}$ and $\underline{c} < c + r_f$, with $\underline{c}$ defined as

$$c > \left[\frac{\alpha\rho + (1-\alpha)\delta}{\alpha\rho} \frac{\alpha + (1-\alpha)\delta\pi}{\alpha + (1-\alpha)\delta} - 1 \right] r_f \equiv \underline{c}. \tag{9}$$

The set Ψ_1 is non-empty, since $\mathbb{R}_1$ is delineated by $R_S^E(\overline{D})$ and R_N^E.

In Case 2, we have $R_S^*(\overline{D}) = R_S^E(\overline{D})$ and $R_N^* = R_N^E$ so that the inequality becomes

$$\frac{\alpha\rho}{(1-\alpha)\delta + \alpha\rho} \frac{\alpha + (1-\alpha)\delta}{\alpha + (1-\alpha)\delta\pi} (c + r_f) > r_f > \frac{\alpha\rho}{(1-\alpha) + \alpha\rho} \frac{c + r_f}{\alpha + (1-\alpha)\pi}.$$

The nonempty set $\mathbb{F}_2$ is characterized by boundaries $\underline{c}$ and $\overline{c} > c + r_f$, with $\overline{c}$ defined as

$$c < \left[(\alpha + (1-\alpha)\pi) \frac{\alpha\rho + (1-\alpha)}{\alpha\rho} - 1 \right] r_f \equiv \overline{c}. \tag{10}$$

The set Ψ_2 is non-empty, since $\mathbb{R}_2$ is delineated by R_N^E and $R_S^E(D)$.

In Case 3, the relevant equilibrium loan rates $R_S^*(\overline{D})$ and R_N^* are the same as in Case 2. Therefore we obtain the same cutoff values as in (9) and (10), so that the non-emptiness of $\mathbb{F}_3$ and Ψ_3 follow.

Finally, we now show that when

$$\pi > \hat{\pi} \equiv \frac{-\alpha + \sqrt{\alpha^2 + 4\alpha(1-\alpha)\delta}}{2(1-\alpha)\delta} \in (0,1)$$

the inequalities $(1-\pi)r_f/\pi < \underline{c}$ and $r_f/\pi < \underline{R}$ hold. That is, our parametric assumptions (1) and (2) are non-binding. To see so, notice that the former inequality implies the latter. Further notice that $\underline{c}$ decreases in ρ. A sufficient condition for $(1-\pi)r_f/\pi < \underline{c}$ is therefore

$$\frac{1-\pi}{\pi} r_f < \left[\frac{\alpha + (1-\alpha)\delta\pi}{\alpha} - 1 \right] r_f,$$

which gives a quadratic equation for the critical $\hat{\pi}$.

Appendix A.5 Proof of Proposition 2

We determine the incumbent bank's expected profits V_i in each information sharing regime $i = \{N, S\}$. By sharing no information, the incumbent bank earns an expected profit $V_N = [\Pr(G) + \Pr(B)\Pr(H)\Pr(\text{no run})](R_N^* - r_N^I)$, where the equilibrium deposit rate r_N^I is given in Lemma 1. To facilitate comparison, we re-write V_N as

$$V_N = [\alpha + (1-\alpha)\delta\pi]R_N^* + (1-\alpha)(1-\delta)\pi R_N^* - \alpha(1-\pi)\rho R_N^* - r_f.$$

When participating in information sharing, the incumbent bank earns an expected profit

$$V_S = \Pr(\overline{D}) \cdot \left[\Pr(H|\overline{D})\Pi_S(H,\overline{D}) + \Pr(L|\overline{D})\Pi_S(L,\overline{D}) \right] + \Pr(D) \cdot \Pi_S(D). \tag{11}$$

$\Pi_S(D)$ represents the expected profit of financing an L-type borrower with a default credit history D, whereas $\Pi_S(H,\overline{D})$ and $\Pi_S(L,\overline{D})$ are the expected profits of financing an H-type and an L-type borrower, respectively, when the borrower generates a credit history $\overline{D}$. We have $\Pi_S(H,\overline{D}) = [\Pr(G) + \Pr(B)\Pr(\text{no run})]R^*_S(\overline{D}) + \Pr(B)\Pr(\text{run})P^B_S(\overline{D}) - r_f$, because the incumbent bank is risk-free and holds an H-type loan to maturity if no bank run occurs. Similarly, we have $\Pi_S(L,\overline{D}) = \Pr(G)R^*_S(\overline{D}) + \Pr(B)P^B_S(\overline{D}) - r_f$, because the incumbent bank would sell its L-type loan even without facing a run. Finally, a borrower that generates a default credit history D must be an L-type. The deposit rate will be $r^I_S(D) = r_f/\pi$, financing such a loan yields $\Pi_S(D) = \Pr(G)[R^*_S(D) - r^I_S(D)] = \Pr(G)R^*_S(D) - r_f$.

With $\Pr(D) = (1-\alpha)(1-\delta)$, $\Pr(\overline{D}) = 1 - \Pr(D) = \alpha + (1-\alpha)\delta$, and $\Pr(H|\overline{D})$ being the posterior probability for a loan that has a credit history $\overline{D}$ to be an H-type, we insert the expressions of $\Pi^H_S(\overline{D})$, $\Pi^L_S(\overline{D})$ and $\Pi^L_S(D)$ into equation (11) to obtain

$$V_S = [\alpha + (1-\alpha)\delta\pi]R^*_S(\overline{D}) + (1-\alpha)(1-\delta)\pi R^*_S(D) - r_f.$$

The difference between the expected profits in the two regimes can be rewritten as

$$V_S - V_N = [\alpha + (1-\alpha)\delta\pi](R^*_S(\overline{D}) - R^*_N) + (1-\alpha)(1-\delta)\pi(R^*_S(D) - R^*_N) + \alpha(1-\pi)\rho R^*_N.$$

We now evaluate the difference $V_S - V_N$ in each region Ψ_j with $j = 0, 1, 2, 3$. We indicate with φ_j the set of parameters that satisfy $V_S - V_N > 0$ in Case j.

Consider Case 0. We have $R^*_S(\overline{D}) = R^*_N = R^*_S(D) = R$, and $V_S - V_N = \alpha(1-\pi)\rho R > 0$. Therefore, $V_S > V_N$ always holds in region Ψ_0, so that $\varphi_0 = \Psi_0$.

Consider Case 1. We have $R^*_S(\overline{D}) = \frac{\alpha+(1-\alpha)\delta}{\alpha+(1-\alpha)\delta\pi}(c + r_f)$ and $R^*_N = R^*_S(D) = R$. We then have $V_S - V_N = [\alpha + (1-\alpha)\delta](c + r_f) - [(1-\alpha)\delta\pi + \alpha - \alpha(1-\pi)\rho] R$. Notice that $(1-\alpha)\delta\pi + \alpha - \alpha(1-\pi)\rho > 0$, so that $V_S - V_N > 0$ if and only if

$$R < \frac{\alpha + (1-\alpha)\delta}{\alpha - \alpha(1-\pi)\rho + (1-\alpha)\delta\pi}(c + r_f) \equiv R_1.$$

Notice that, given the definition of Ψ_1, $R_1 > R^E_S(\overline{D})$ always holds so that φ_1 is non-empty for $\forall \rho \in (0,1)$. On the other hand, φ_1 may not coincide with Ψ_1. Therefore, we have

$$\varphi_1 = \Psi_1 \bigcap \{R | R < R_1\} \subseteq \Psi_1.$$

Recall that the upper bound for R that defines Case 1 is given by R_N^E. If $R_1 > R_N^E$, the condition $V_S > V_N$ is satisfied in the entire region Ψ_1. This is true if and only if

$$R_1 = \frac{\alpha + (1-\alpha)\delta}{\alpha - \alpha(1-\pi)\rho + (1-\alpha)\delta\pi}(c + r_f) > \frac{1}{\alpha + (1-\alpha)\pi}(c + r_f) = R_N^E,$$

which implies $\rho > (1-\alpha)(1-\delta) \equiv \overline{\rho}$. Therefore, whenever the last inequality holds, φ_1 coincides with Ψ_1. Otherwise, we have $\varphi_1 \subset \Psi_1$. Notice that, given the definition of Ψ_1, φ_1 is always non-empty for $\forall \rho \in (0,1)$.

Consider Case 2. We have $R_S^*(\overline{D}) = \frac{\alpha+(1-\alpha)\delta}{\alpha+(1-\alpha)\delta\pi}(c + r_f)$, $R_N^* = \frac{1}{\alpha+(1-\alpha)\pi}(c + r_f)$ and $R_S^*(D) = R$, therefore

$$V_S - V_N = \left[\alpha + (1-\alpha)\delta - 1 + \frac{\alpha(1-\pi)\rho}{\alpha + (1-\alpha)\pi}\right](c + r_f) + (1-\alpha)(1-\delta)\pi R.$$

The condition $V_S - V_N > 0$ holds if and only if

$$R > \left[1 - \frac{1-\pi}{(1-\delta)} \frac{\alpha\rho}{(1-\alpha)[\alpha + (1-\alpha)\pi]}\right] \frac{(c + r_f)}{\pi} \equiv R_2.$$

Notice that, given the definition of Ψ_2, $R_2 < R_S^E(D)$ always holds so that φ_2 is non-empty for $\forall \rho \in (0,1)$. On the other hand, φ_2 may not coincide with Ψ_2. Therefore, we have

$$\varphi_2 = \Psi_2 \bigcap \{R | R > R_2\} \subseteq \Psi_2.$$

The lower bound for R that defines Case 2 is given again by R_N^E. If $R_2 < R_N^E$, $V_S > V_N$ is satisfied in the entire region Ψ_2. That is, if

$$R_2 = \left[1 - \frac{1-\pi}{(1-\delta)} \frac{\alpha\rho}{(1-\alpha)[\alpha + (1-\alpha)\pi]}\right] \frac{(c + r_f)}{\pi} < \frac{c + r_f}{\alpha + (1-\alpha)\pi} = R_N^E$$

which again implies $\rho > (1-\alpha)(1-\delta) = \overline{\rho}$ and $\varphi_2 = \Psi_2$. Otherwise, we have $\varphi_2 \subset \Psi_2$.

Consider Case 3. We have $R_S^*(\overline{D}) = \frac{\alpha+(1-\alpha)\delta}{\alpha+(1-\alpha)\delta\pi}(c+r_f)$, $R_N^* = \frac{1}{\alpha+(1-\alpha)\pi}(c+r_f)$ and $R_S^*(D) = \frac{1}{\pi}(c+r_f)$. It is straightforward to verify that $V_S = c$ and $V_N = c - \alpha(1-\pi)\rho\frac{c+r_f}{\alpha+(1-\alpha)\pi}$. Therefore difference in expected profits is strictly positive

$$V_S - V_N = \alpha(1-\pi)\rho\frac{c+r_f}{\alpha+(1-\alpha)\pi} > 0,$$

so that $V_S > V_N$ is satisfied in the entire region Ψ_3. Therefore $\varphi_3 = \Psi_3$.

Appendix A.6 Proof of Proposition 3

Suppose that all outsiders believe that the incumbent bank truthfully reveals the borrower's credit history. Given that the borrower has previously defaulted, we check if the incumbent bank can profitably deviates by announcing a false credit history $\overline{D}$. The incumbent bank does not fail in state B by misreporting the credit history, since it can sell the loan for $P_S^B(\overline{D}) > r_f$. Thus, we have $r_S(D) = r_f/\pi$ and $r_S(\overline{D}) = r_f$ in region $\varphi_j, j = 0,1,2,3$

We first compute the incumbent bank's expected profit at $t=1$ when truthfully reporting a loan with credit history D. That is,

$$\Pi_S(D|D) = \pi\left[R_S^*(D) - r_S(D)\right] = \pi R_S^*(D) - r_f. \tag{12}$$

The expected profit of reporting the false $\overline{D}$-history can be written as

$$\Pi_S(\overline{D}|D) = \pi R_S^*(\overline{D}) + (1-\pi)P_S^B(\overline{D}) - r_S(\overline{D}) = \pi R_S^*(\overline{D}) + \frac{(1-\pi)\cdot\alpha\rho}{(1-\alpha)\delta+\alpha\rho}R_S^*(\overline{D}) - r_f.$$

Consider Case 0, where $R_S^*(D) = R_S^*(\overline{D}) = R$. We have

$$\Pi_S(D|D) = \pi R - r_f \quad \text{and} \quad \Pi_S(\overline{D}|D) = \pi R + \frac{(1-\pi)\cdot\alpha\rho}{\alpha\rho+(1-\alpha)\delta}R - r_f,$$

so that the incumbent bank finds it profitable to misreport the borrower's credit history. In this case, outsiders' belief cannot be rationalized and truthful information sharing cannot be sustained as a PBE in region φ_0.

Consider Case 1, where $R_S^*(D) = R$ and $R_S^*(\overline{D}) = \frac{\alpha+(1-\alpha)\delta}{\alpha+(1-\alpha)\delta\pi}(c+r_f)$. While truthfully reporting default gives the same expected profit as in Case 0. The expected profit from deviation becomes

$$\Pi_S(\overline{D}|D) = \frac{\alpha\rho + (1-\alpha)\delta\pi}{\alpha\rho + (1-\alpha)\delta}\frac{\alpha + (1-\alpha)\delta}{\alpha + (1-\alpha)\delta\pi}(c + r_f) - r_f. \tag{13}$$

Then the ex-post incentive compatibility constraint to tell the truth is

$$\Pi_S(D|D) - \Pi_S(\overline{D}|D) = \pi R - \frac{\alpha\rho + (1-\alpha)\delta\pi}{\alpha\rho + (1-\alpha)\delta}\frac{\alpha + (1-\alpha)\delta}{\alpha + (1-\alpha)\delta\pi}(c + r_f) > 0,$$

which can be re-arranged as

$$R > \frac{1}{\pi}\left[\frac{\alpha\rho + (1-\alpha)\delta\pi}{\alpha\rho + (1-\alpha)\delta}\frac{\alpha + (1-\alpha)\delta}{\alpha + (1-\alpha)\delta\pi}\right](c + r_f) \equiv R_T. \tag{14}$$

Ex-ante information sharing is chosen in Case 1 when $R < R_1$ (recall the proof of Proposition 2). It can be verified that

$$\frac{1}{R_1} - \frac{1}{R_T} = \frac{1}{\alpha + (1-\alpha)\delta}\frac{\alpha^2(1-\rho)\rho(1-\pi)}{\alpha\rho + (1-\alpha)\delta\pi}\frac{1}{(c + r_f)} > 0$$

Consequently, $R_1 < R_T$ and there exists no R such that the incumbent bank will ex-ante participate in information sharing scheme and ex-post report the true default credit history. Again, the belief of outsiders cannot be rationalized and truthful information sharing cannot be sustained as a PBE in region φ_1.

Consider Case 2. Since $R^*_S(D)$ and $R^*_S(\overline{D})$ remain the same as in Case 1, truthful reporting leads to the same expected profit as (12), and deviation leads to the same expected profit as in (13). Therefore, the incentive compatibility constraint for truth-telling is the same as in (14). On the other hand, information sharing is ex-ante chosen in Case 2 when $R > R_2$ (recall proof of Proposition 2). Since $R_2 < R^E_S(D)$ and $R_T < R^E_S(D)$, there always exist a set of parameters (just below $R^E_S(D)$) such that the incumbent bank truthfully share the borrower's credit history in φ_2.

Furthermore, we establish a set of parameters in which, whenever it is ex-ante optimal for the incumbent bank to share information, it is also ex-post incentive compatible to disclose the true credit history, i.e. $R_2 > R_T$. This implies the following restriction

$$F(\rho) \equiv 1 - \frac{1-\pi}{1-\delta} \frac{\alpha\rho}{(1-\alpha)[\alpha+(1-\alpha)\pi]} - \frac{\alpha\rho+(1-\alpha)\delta\pi}{\alpha\rho+(1-\alpha)\delta} \frac{\alpha+(1-\alpha)\delta}{\alpha+(1-\alpha)\delta\pi} > 0. \tag{15}$$

Note that $R_2(\rho) = R_T(\rho)$ when $F(\rho) = 0$. It can be verified that

$$F'(\rho) = -\frac{1-\pi}{1-\delta} \frac{\alpha}{(1-\alpha)[\alpha+(1-\alpha)\pi]} - \frac{\alpha(1-\alpha)\delta(1-\pi)}{[\alpha\rho+(1-\alpha)\delta]^2} \frac{\alpha+(1-\alpha)\delta}{\alpha+(1-\alpha)\delta\pi} < 0.$$

Moreover, by taking the limits, we have

$$\lim_{\rho\to 0} F(\rho) = 1 - \frac{\alpha\pi+(1-\alpha)\delta\pi}{\alpha+(1-\alpha)\delta\pi} > 0 \quad \text{and} \quad \lim_{\rho\to 1} F(\rho) = -\frac{1-\pi}{1-\delta} \frac{\alpha}{(1-\alpha)[\alpha+(1-\alpha)\pi]} < 0.$$

Thus, there exists a unique $\underline{\rho} \in (0,1)$ such that $F(\underline{\rho}) = 0$ and inequality (15) holds for $\forall \rho \in (0, \underline{\rho})$. In this case, truth-telling can be sustained as a PBE in the whole region of φ_2. In fact, it can also be shown that $F(\overline{\rho}) < 0$ such that $\underline{\rho} < \overline{\rho}$.

Consider Case 3, where $R_S^*(D) = (c + r_f)/\pi$. Reporting the true default history leads to an expected profit $\Pi_S(D|D) = c$. The expected profit of misreporting the credit history is the same as in (13). We have $\Pi_S(\overline{D}|D) < c = \Pi_S(D|D)$ because

$$\frac{\alpha\rho+(1-\alpha)\delta\pi}{\alpha\rho+(1-\alpha)\delta} \frac{\alpha+(1-\alpha)\delta}{\alpha+(1-\alpha)\delta\pi} < 1$$

As a result, truthful information sharing can be sustained as a PBE in the region φ_3.

Appendix A.7 Proof of Corollary 1

Note that R_T increases in ρ, with

$$\lim_{\rho\to 0} R_T(\rho) = \frac{\alpha+(1-\alpha)\delta}{\alpha+(1-\alpha)\delta\pi}(c + r_f) < R_N^E, \quad \text{and} \quad \lim_{\rho\to 1} R_T(\rho) = R_S^E(D) > R_N^E.$$

Thus, we establish a unique $\underline{\rho}' \in (0, \underline{\rho})$ that makes $R_T(\underline{\rho}') = R_N^E$. Further recall that, by definition, $\overline{\rho}$ satisfies $R_2(\overline{\rho}) = R_N^E$, and $\underline{\rho}$ satisfies $R_2(\underline{\rho}) = R_T(\underline{\rho})$. Given that R_2 decreases in ρ and $\underline{\rho} < \overline{\rho}$, we have $R_T(\underline{\rho}) = R_2(\underline{\rho}) > R_2(\overline{\rho}) = R_N^E = R_T(\underline{\rho}')$. Since R_T increases in ρ, we have $\underline{\rho}' < \underline{\rho}$. The rest of the corollary follows.

Appendix A.8 Proof of Lemma 6

We show that the bank cannot signal the quality of its portfolio (α_L or α_H) using its capital structure. It takes three steps to establish the result.

Step 1: No separating SPE under the least costly capital structure.

First, we examine whether a separating equilibrium is automatically achieved when the H-type chooses a capital structure that is not distorted and minimizes its cost of funding. Suppose that there exists a separating equilibrium, where

- the H-type bank finances its loan portfolio using only risk-free debt, and
- the L-type bank raises $b_L = \alpha_L R / r_f$ units of funding via risk-free debt of face value $d_L = \alpha_L R$, and $\omega_L = \frac{1-b_L}{\pi(R-d_L)} \cdot y\left(e - (1-b_L)\right)$ fraction of shares in exchange of $1 - b_L$ units of funding from the risk-neutral investors.

We show that the L-type has incentives to deviate by mimicking the H-type. By playing the on-the-equilibrium-path strategy, an L-type bank makes an expected profit

$$\Pi_N^S(L) = [\pi R + (1-\pi)\alpha_L R] - [b_L \cdot r_f + (1-b_L) \cdot y\left(e - (1-b_L)\right)], \tag{16}$$

which is the expected cash flow of the bank's portfolio net off its average cost of funding.

When the L-type mimics the H-type by issuing only debt. The risk-averse investors will mistake the L-type for the H-type and incorrectly perceive the debt instrument to be risk-free. This leads to the following expected profit for the L-type bank:

$$\widehat{\Pi}_N^{S1}(L) = \pi(R - r_f) + (1-\pi) \cdot \max\left(\alpha_L R - r_f, 0\right) = \pi(R - r_f). \tag{17}$$

It is straightforward to verify that $\widehat{\Pi}_N^{S1}(L) > \Pi_N^S(L)$. Intuitively, the L-type bank benefits from reduced cost of funding at the cost of the risk-averse investors who mistakenly believe that they have purchased risk-free securities. Thus, it is not incentive compatible for the L-type to stick to the strategy under consideration, and such a separating equilibrium cannot be sustained.

Step 2: No separating SPE under more costly capital structure choice.

We now examine whether the H-type bank can distinguish itself from an L-type bank by choosing a more costly capital structure and issuing a positive amount of equity to external equity holders. Suppose that there exists a separating equilibrium, where

- the H-type bank finances its loan portfolio by issuing $b'_N = \alpha' R/r_f$ units of debt with face value $d'_N = \alpha' R$. Here $\alpha' \in (\alpha_L, r_f/R)$ so that the debt is risk-free but less than what the L-type would issue. At the mean while, the H-type bank issues $\omega' = \frac{1-b'_N}{\pi(R-d'_N)+(1-\pi)(\alpha_H R-d'_N)} \cdot y(e-(1-b'_N))$ fraction of shares to obtain $d'_N = 1-\alpha' R/r_f$ units of funding from the risk-neutral investors.

- the L-type bank still raises b_L via risk-free debt of face value d_L, and ω_L fraction of shares in exchange of $1 - b_L$ units of funding from the risk-neutral investors.

We show again that the L-type bank has incentives to deviate and mimick the H-type. Notice that in the the separating equilibrium, the L-type earns the same expected profit $\Pi^S_N(L)$ as in the last case. By mimicking the H-type, on the other hand, leads to the following expected payoff:

$$\begin{aligned}\widehat{\Pi}^{S2}_N(L) &= (1-\omega')\left[\pi(R-d'_N) + (1-\pi)\max(\alpha_L R - d'_N, 0)\right] \\ &= \left[\pi R + (1-\pi)\alpha' R\right] - \left[b'_N \cdot r_f + (1-b'_N) \cdot \frac{\pi(R-d'_N)}{\pi(R-d'_N)+(1-\pi)(\alpha_H R - d'_N)} \cdot y(e-(1-b'_N))\right],\end{aligned}$$

with the fraction smaller than 1 reflecting the over-valuation of the bank's equity. Similar to the first case analyzed, we have

$$\widehat{\Pi}^{S2}_N(L) > \pi R + (1-\pi)\alpha' R - [b'_N r_f + (1-b'_N) y(e-(1-b'_N))] > \pi R + (1-\pi)\alpha' R - [b'_N r_f + (1-b'_N) y(e-(1-b_L))] > \Pi^S_N(L).$$

The L-type bank still benefits from mimicking the H because it reduces the cost of funding. As a result, no such separating equilibrium can be sustained.

Step 3: The existence of a pure-strategy pooling PBE.

Finally, we establish the existence of a pooling equilibrium where both types choose the same capital structure and outsiders' beliefs remain the same as the prior. In particular, we establish a pooling equilibrium where both types of banks raise $b^P_N = \alpha_L R/r_f$ units of funding via risk-free debt of face value $d^P_N = \alpha_L R$, and

$$\omega^P_N = \frac{1-b^P_N}{\pi\left(R-d^P_N\right) + \gamma(1-\pi)(\alpha_H R - d^P_N)} \cdot y(e-(1-b^P_N))$$

fraction of shares in exchange of $1 - b_N^P$ units of funding from the risk-neutral investors. Given an equilibrium is pooling, the aforementioned equilibrium also maximizes banks' payoffs. We also assume that any deviation from the pooling equilibrium results in the belief that the bank is the L-type.

To establish the pooling equilibrium, we need to check neither type has incentives to deviate. We start with the L-type and note that the bank's expected payoff from the pooling equilibrium is

$$\begin{aligned}\Pi_N^P(L) &= (1-\omega_N^P)\pi(R-d_N^P)\\ &= [\pi R + (1-\pi)\alpha_L R] - \left[b_N^P \cdot r_f + \left(1-b_N^P\right)\frac{\pi(R-d_N^P)}{\pi(R-d_N^P)+\gamma(1-\pi)(\alpha_H R - d_N^P)} \cdot y\left(e-(1-b_N^P)\right)\right].\end{aligned}$$

The bank cannot achieve a higher expected payoff by issuing more debt, because then the risk-averse investors will not participate. Therefore, we consider only the deviation where the bank issues debt with face value $\hat{d}_N^P < \alpha_L R$ to raise $\hat{b}_N^P = \hat{d}_N^P / r_f$ amount of funding via risk-free debt. In this case, the bank needs to issue $\widehat{\omega}_N^P$ fraction of equity, with

$$\widehat{\omega}_N^P = \frac{1-\hat{b}_N^P}{\pi(R-\hat{d}_N^P)+(1-\pi)(\alpha_L R - \hat{d}_N^P)} \cdot y(e-(1-\hat{b}_N^P)).$$

This results in the following payoff

$$\widehat{\Pi}_N^P(L) = (1-\widehat{\omega}_N^P)\left[\pi\left(R-\hat{d}_N^P\right)+(1-\pi)\left(\alpha_L R-\hat{d}_N^P\right)\right] = \left[\pi R + (1-\pi)\alpha_L R\right] - \left[\hat{b}_N^P \cdot r_f + (1-\hat{b}_N^P)\cdot\ y\left(e-(1-\hat{b}_N^P)\right)\right].$$

Since $\hat{b}_N^P < b_N^P$ and $y(e-(1-\hat{b}_N^P)) > y(e-(1-b_N^P))$, we obtain $\widehat{\Pi}_N^P(L) < \Pi_N^P(L)$. Therefore, the L-type bank will not deviate from the pooling equilibrium.

We now turn to the H-type and note that the bank's expected payoff in the pooling equilibrium is

$$\begin{aligned}\Pi_N^P(H) &= (1-\omega_N^P)\left[\pi(R-d_N^P)+(1-\pi)(\alpha_H R - d_N^P)\right]\\ &= [\pi R + (1-\pi)\alpha_H R] - \left[b_N^P \cdot r_f + (1-b_N^P)\cdot\frac{\pi(R-d_N^P)+(1-\pi)(\alpha_H R-d_N^P)}{\pi(R-d_N^P)+(1-\pi)\gamma(\alpha_H R - d_N^P)} \cdot y(e-(1-b_N^P))\right],\end{aligned}$$

where the fraction exceeds 1 and reflects the under-valuation of the H-type bank's equity.

By deviating from the pooling equilibrium, the H-type bank will expect a payoff

$$\widehat{\Pi}_N^P(H) = (1 - \widehat{\omega}_N^P)\left[\pi(R - \hat{d}_N^P) + (1-\pi)(\alpha_H R - \hat{d}_N^P)\right]$$
$$= [\pi R + (1-\pi)\alpha_H R] - \left[\hat{b}_N^P \cdot r_f + (1 - \hat{b}_N^P) \cdot \frac{\pi(R - \hat{d}_N^P) + (1-\pi)(\alpha_H R - \hat{d}_N^P)}{\pi(R - \hat{d}_N^P) + (1-\pi)(\alpha_L R - \hat{d}_N^P)} \cdot y(e - (1 - \hat{b}_N^P))\right].$$

The deviation *may* increase the payoff of the bank because it makes more cash flow available to equity holders and *may* thereby reduce the cost of equity. A sufficient condition for $\widehat{\Pi}_N^P(H) < \Pi_N^P(H)$ is that

$$\frac{\pi(R - d_N^P) + (1-\pi)(\alpha_H R - d_N^P)}{\pi(R - d_N^P) + (1-\pi)\gamma(\alpha_H R - d_N^P)} < \frac{\pi(R - \hat{d}_N^P) + (1-\pi)(\alpha_H R - \hat{d}_N^P)}{\pi(R - \hat{d}_N^P) + (1-\pi)(\alpha_L R - \hat{d}_N^P)},$$

which, in turn, is guaranteed by

$$\gamma > \frac{\alpha_L}{\pi(1-\alpha_L) + (1-\pi)(\alpha_H - \alpha_L) + \alpha_L}.$$

Intuitively, when γ is sufficiently high, the H-type bank is severely penalized for being perceived as the other type, so that the cost from deviation is a dominant concern.

Figure 1: Equilibrium loan rates: interior and corner solutions

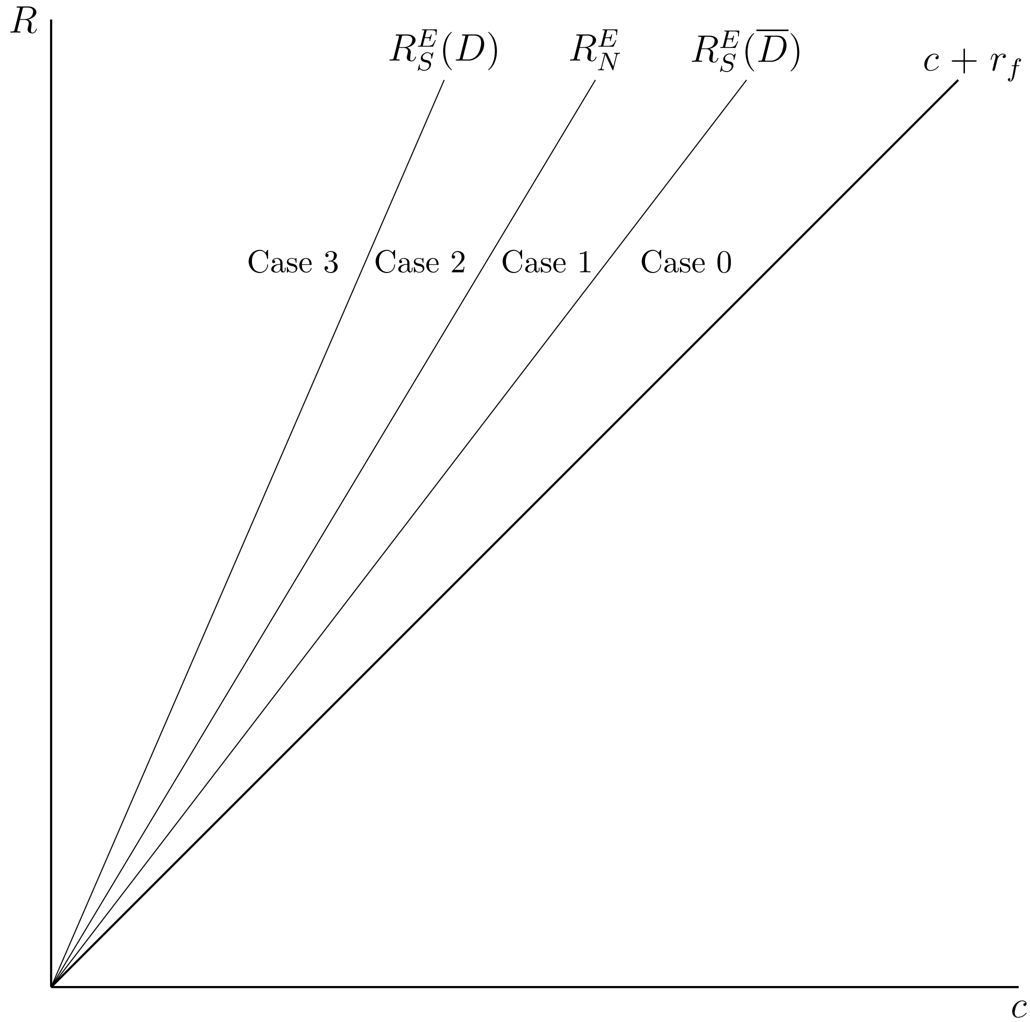
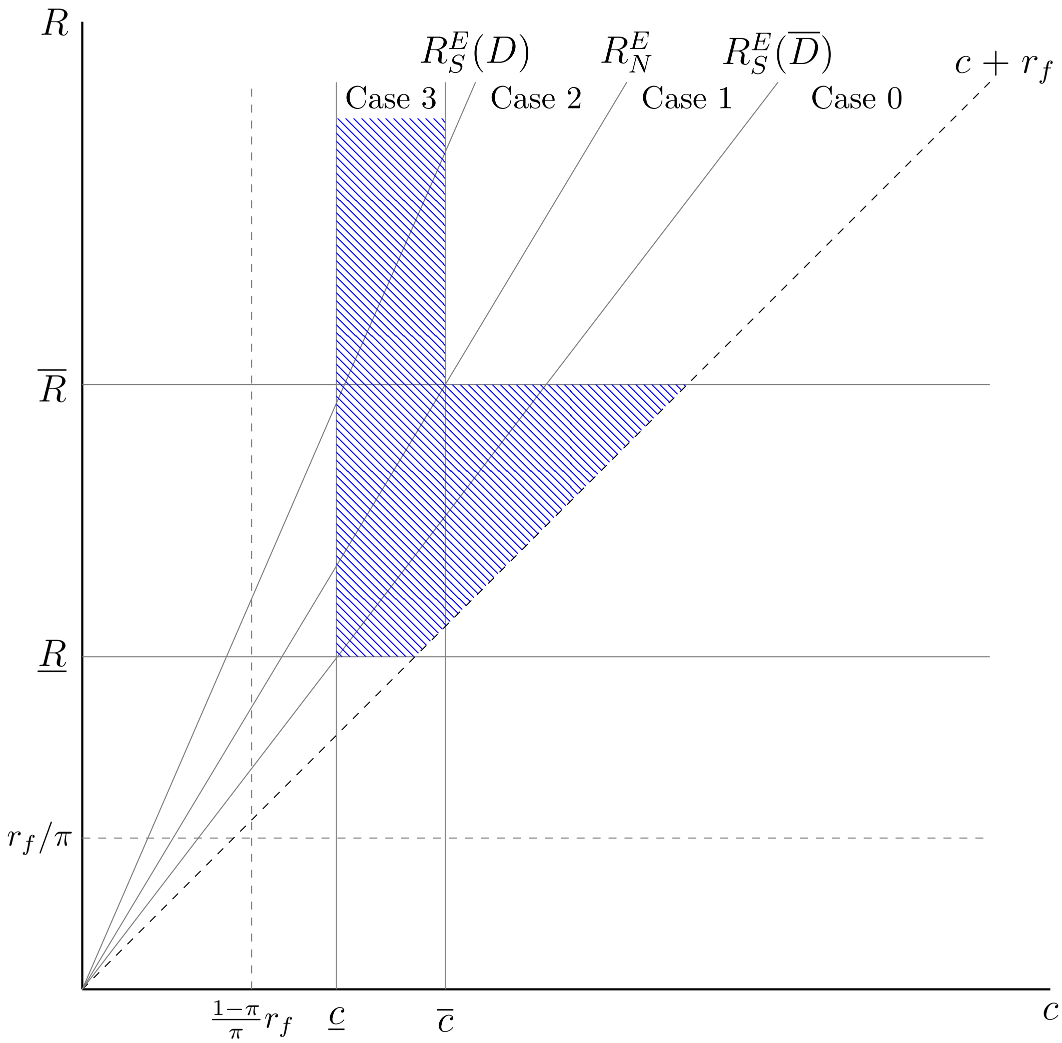
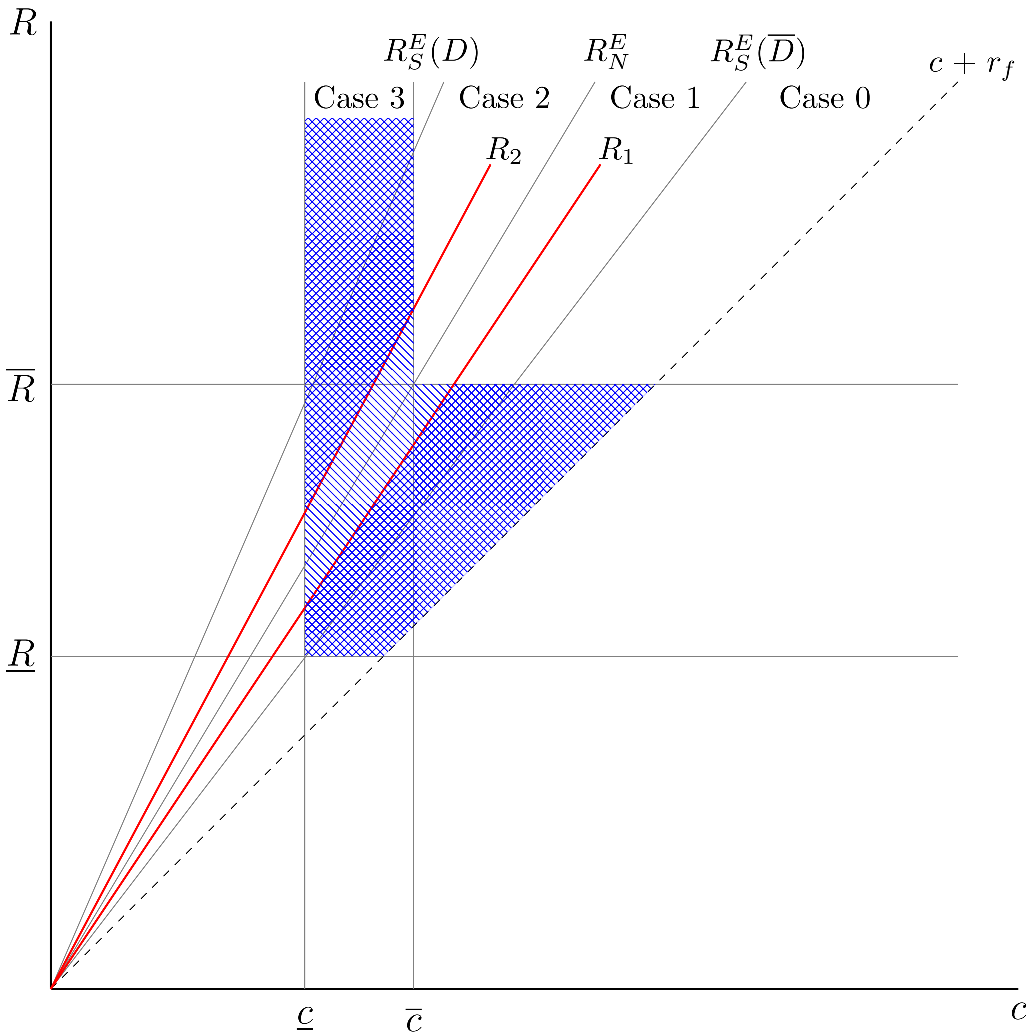


Figure 2: Regions where information sharing can save the incumbent bank from illiquidity



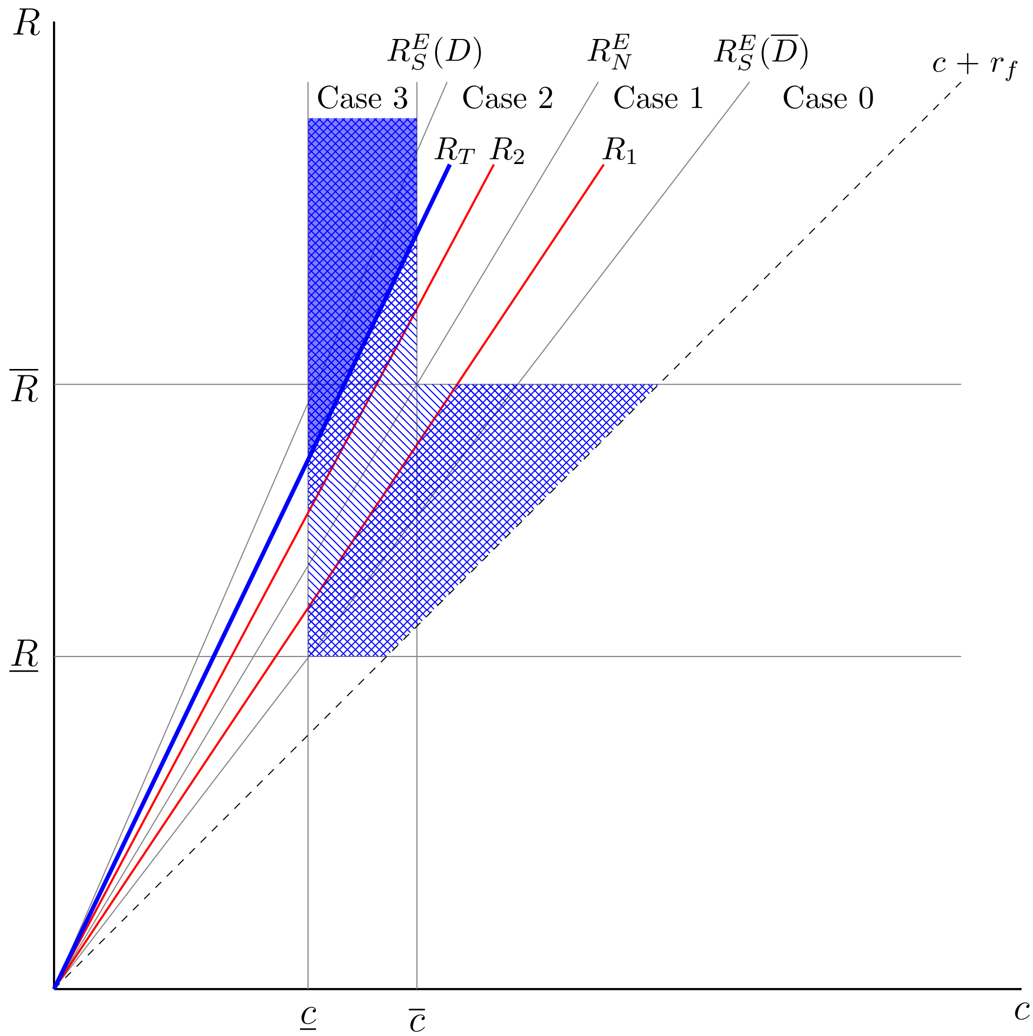
The region where information sharing can save the incumbent bank from illiquidity is indicated by the single-shaded area. The definitions of $\underline{c}$, $\bar{c}$, $\underline{R}$, and $\overline{R}$ can be found in Appendix A.4. The dashed lines indicate the parametric assumption (1)-(3). In particular, condition (1) is indicated by the region above the dashed line $R = c + r_f$; condition (2) is indicated by the region to the right of the dashed line $c = \frac{1-\pi}{\pi} r_f$; and condition (3) is indicated by the region above the dashed line $R = r_f/\pi$. When $\pi > \hat{\pi}$, $r_f/\pi < \underline{R}$ and $\frac{1-\pi}{\pi} r_f < \underline{c}$.

Figure 3: Regions where information sharing leads to a greater value for the incumbent bank



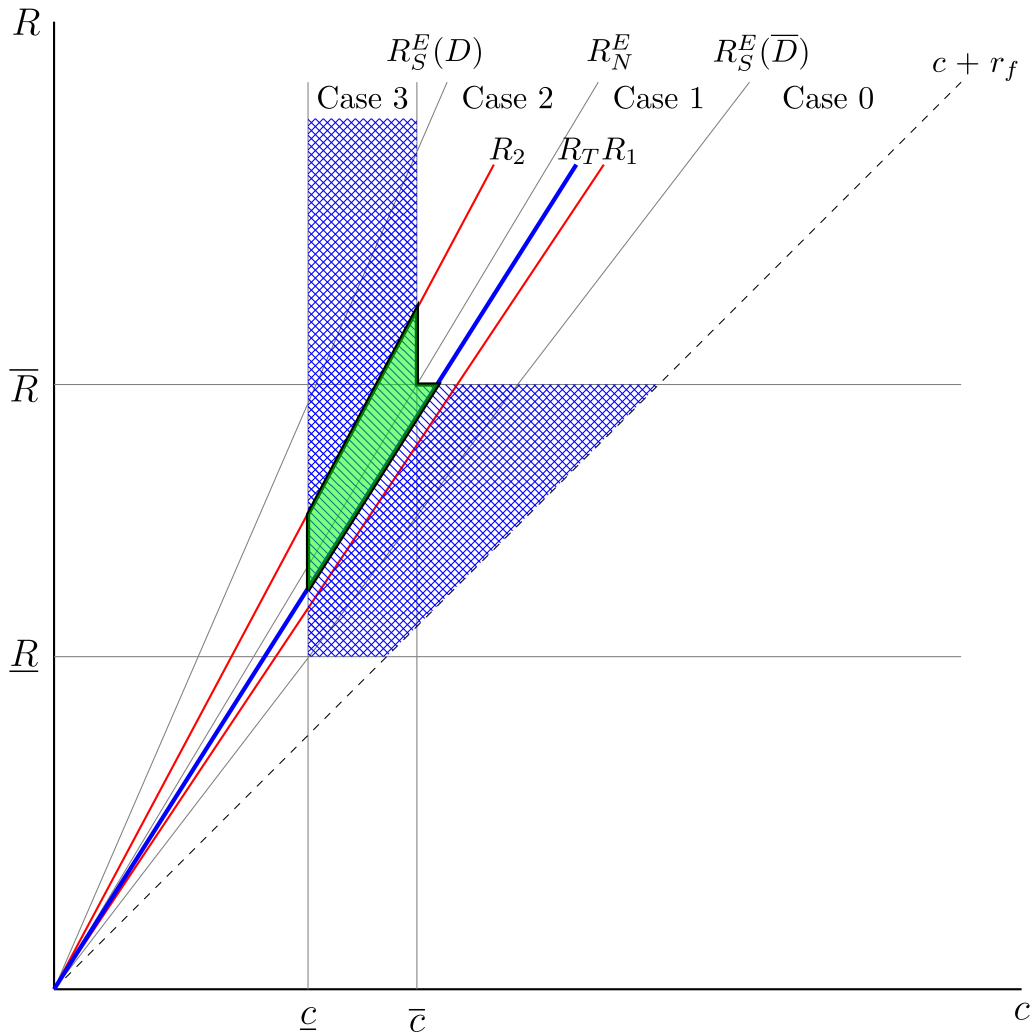
The region where information sharing leads to a greater value for the incumbent bank is indicated by the double-shaded area. Red line R_1 in Case 1 depicts the cutoff value *below* which information sharing increases the value of the incumbent bank, whereas red line R_2 in Case 2 depicts the cutoff value *above* which information sharing increases the value of the incumbent bank. We show a situation where $\rho < \overline{\rho}$, so that voluntary information sharing arises in a subset of Ψ_1 and Ψ_2. Graphically, the double-shaded area is smaller than the single-shaded area. In Case 0 and 3, voluntary information sharing arises in the entire region Ψ_0 and Ψ_3, so that the double-shaded area coincides with the single-shaded area. The definitions of R_1 and R_2 can be found in Appendix A.5.

Figure 4: Regions where truthful information sharing can be sustained in a perfect Bayesian equilibrium



Blue line R_T depicts the cutoff value *above* which truthful information sharing can be sustained in a perfect Bayesian equilibrium. The definitions of R_T can be found in Appendix A.6. The region where truth-telling can be sustained is indicated by the dark-blue area. We show a situation where $\underline{\rho} < \rho < \overline{\rho}$, so that truth-telling can be sustained in a subset of φ_2 in Case 2. In Case 0 and Case 1 there is no dark-blue area depicted since truth-telling is not sustainable under these two cases. The dark-blue area is then smaller than the double-shaded area. In Case 3 truth-telling is always sustained in the entire region φ_3 therefore the dark-blue area coincides with the double-shaded area.

Figure 5: Regions where a public registry can improve allocation



The region where a public registry can improve efficiency, subject to the truth-telling constraint, is indicated by the green area. The existence of the region is guaranteed when $\rho < \underline{\rho} < \overline{\rho}$. We show a situation where R_T is to the right of R_N^E, which is guaranteed for ρ that is sufficiently small ($\rho < \underline{\rho}'$). A public registry needs to be imposed, because the green region is beneath R_2 and the incumbent bank finds it unprofitable to share the borrower's credit history. The public registry can be sustained because the green region is above R_T, so that the bank has incentive to truthfully disclose the borrower's credit history, once sharing such information.