Bank Runs, Bank Competition and Opacity*

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Abstract

We model the opacity and deposit rate choices of banks that imperfectly compete for uninsured deposits, are subject to runs, and face a threat of entry. We show how shocks that increase bank competition or bank transparency increase deposit rates, costly withdrawals, and thus bank fragility. Therefore, perfect competition is not socially optimal. We also propose a theory of bank opacity. The cost of opacity is more withdrawals from a solvent bank, lowering bank profits. The benefit of opacity is to deter the entry of a competitor, increasing future bank profits. The excessive opacity of incumbent banks rationalizes transparency regulation.

Keywords: Competition, entry, opacity, bank run, fragility, global games, competition policy, transparency regulation.

JEL classifications: G01, G21, G28.

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1 Introduction

Bank runs are a recurrent phenomenon and pose a threat to economic activity and future economic growth.[1] It is therefore critical to understand how developments in the financial system affect bank fragility. We study two such developments: changes in bank competition and in bank opacity. The competitive landscape has significantly changed in recent decades due to both regulation and technology.[2] The transparency of banks has also significantly evolved due to the availability of more complex and more opaque assets, new accounting standards, and regulations mandating minimum transparency.[3] The principal goal of this paper is to shed light on how bank runs, bank competition, and bank opacity interact and shape outcomes of the financial system. In doing so, we obtain both positive and normative implications about the opacity choices, funding costs, competitive structure, and the fragility of banks.

We obtain two main sets of results. First, we microfound the competition-fragility and transparency-fragility views of banking, whereby higher competition or greater transparency raise deposit rates, withdrawal incentives, and bank fragility. We emphasize deposit rates changes and show that an intermediate level of bank competition is socially optimal. Second, we propose a novel theory of bank opacity. Greater opacity induces more costly mistakes in both withdrawal and entry choices. Withdrawals from a solvent bank lead to costly liquidation and lower current bank profits, while opacity can deter entry from a potential competitor and raises future profits of imperfectly competitive incumbent banks. We identify wedges between the private and social incentives for opacity and establish a role for transparency

[1] Bank runs and panics have occurred throughout history (e.g., **?**). Recent evidence of bank runs include **?**, **?**, **?**, **?**. See **?** for runs on uninsured deposits of U.S. commercial banks. See also **?** for runs on repo, **?** for runs on asset-backed commercial paper, and **?** for runs on money market mutual funds.

[2] The arrival of FinTechs and platform-based competitors (BigTechs) has increased contestability in recent years. The rise of shadow banks over the last two decades has also increased competition (e.g., for wholesale funding). Earlier structural changes to competition in the U.S. arose from the elimination of restrictions to intrastate and interstate banking (e.g., **?**).

[3] For evidence about the importance of opacity in the banking industry, see **?**.

regulation.

In Section 2 we start our analysis with a parsimonious one-period bank-run model. To make risky investments, banks imperfectly compete for uninsured deposits[4] from investors (?).[5] At an initial date, banks choose deposit rates and the level of opacity. When banks choose more opacity (e.g., via investing in more complex and opaque assets or by adopting less transparent accounting styles), the precision of the private signal about the realized investment return that outsiders receive is noisier (?). Each investor chooses at which bank to deposit and delegates the withdrawal decision at an interim date to a fund manager (?).[6] To serve withdrawals, banks liquidate investment at a cost. We use global-games methods to pin down a unique equilibrium in which a bank fails whenever the return on its investment is below an (endogenous) threshold.[7]

We characterize the equilibrium deposit rate and opacity. When choosing its deposit rate, a bank trades off a higher market share with lower profits per unit of deposits. Higher rates decrease profits because of higher funding costs and a heightened strategic complementarity of withdrawal decisions due to a larger negative impact on the residual funds of the bank.[8] When choosing its opacity, a bank takes into account that higher opacity reduces the sensitivity of withdrawals with respect to the realized investment return.[9] As a result, there are more withdrawals from a solvent bank, causing costly liquidation of investment and lowering bank profits. There are also fewer withdrawals from an eventually insolvent bank, reducing the

[4]Bank debt is assumed to be demandable. Demandability arises endogenously with liquidity needs (?) or as a commitment device to overcome an agency conflict (??). Accordingly, uninsured deposits refer to any short-term or demandable debt instrument, which includes uninsured retail deposits and wholesale funding. Three quarters of U.S. commercial bank funding are deposits and in the largest commercial banks, half of which are uninsured (?).

[5]In Section 4.3 we show that our results generalize to other forms of imperfect competition.

[6]In Section 4.1 we study the case in which investors directly decide on withdrawals.

[7]Global games were pioneered by ?. The more recent literature and developments are reviewed in ? and ?.

[8]Our focus on the impact of heightened strategic complementarity for bank fragility is closely related to ?, who examines a setup with exogenous deposit rates.

[9]This implication is supported by evidence for uninsured deposits of U.S. banks (?).

expected returns to investors and, thus, the amount of bank funding. Taken together, banks choose to be as transparent as possible in our baseline one-period model.

We derive three main implications of this model, emphasizing the role of endogenous deposit rates. First, we microfound the competition-fragility view of banking. Exogenously higher competition (e.g., more banks) increases deposit rates, which raises the strategic complementarity in withdrawal decisions and bank fragility. This view is consistent with the competition-instability view of banking but highlights liability-side risks arising from changes in withdrawal incentives.[10]

Second, we show how certain exogenous reductions to bank profitability can improve bank stability. On the one hand, lower transparency reduces banks profits for the reasons already explained and, hence, the incentives of banks to compete for funding. This results in lower deposit rates and thus lower bank fragility—the transparency-fragility view of banking. On the other hand, a non-pecuniary lending cost shock reduces expected bank profits without directly affecting investment profitability. Thus, banks have lower incentives to compete for funding, which again reduces the deposit rate and bank fragility. Interestingly, the opposite result arises in models of risk-taking on the bank's asset side (e.g., **?** or **?**): lower profitability either increases risk-taking or lowers effort, raising the risk of bank failure. Thus, the effect of changes in bank profitability depends on the source of risk that determines bank failure (asset or liability side risk).

Third, we derive regulatory implications for competition policy. To maximize utilitarian welfare, an intermediate number of banks is socially optimal. Intuitively, the regulator increases the number of banks until the marginal benefit of higher competition in terms of higher net lending equals the marginal cost of competition in terms of higher costly liquidation of investment and bank fragility induced by higher

[10]Evidence consistent with the competition-instability view includes **?**, **?**, and **?**. See also the review by **?** and the literature therein. Consistent with our model's implications, **?** document that lower competition increases deposit inflows into banks and improves their profitability.

deposit rates.[11] In sum, perfect competition among banks is not socially desirable.

In Section 3, we allow for entry of a competitor and derive a novel theory of bank opacity. In contrast to our previous result, an incumbent bank chooses an interior opacity level. The (private) benefit of opacity is to deter entry, increasing the incumbent's charter value via lower future competition, higher market share, and higher profits.[12] The cost of opacity is the mistakes in withdrawal choices described in the one-period model. In sum, we identify a trade-off: banks prefer not to provide precise information to competitors but such opacity leads to costly creditor withdrawals.

In our extended two-period setting, banks choose their deposit rates and opacity at the beginning of each period. The main novel ingredient is that a new bank—a potential entrant—chooses in period 1 whether to enter and operate in period 2. We model entry as a two-stage process. First, the entrant chooses whether to pay an information cost to receive signals about the market, including a noisy private signal about the current investment return (as do fund managers or investors). Since investment returns are persistent, this signal is informative about expected profits in period 2 upon entry. Second, the entrant chooses whether to pay an investment cost to build up capacity to operate in period 2. In order to enter, the entrant has to pay both the information and the investment cost. In sum, the competitive structure in period 2 depends on both entry and whether the incumbent bank exits upon failure.

To characterize entry decisions, deposit rates, opacity, and fragility, we work backwards. For a given number of banks in period 2, the equilibrium is as in the one-period model. The equilibrium in period 1 differs as the incumbent internalizes how its choices affect (i) the chances for future profits (the charter value effect) and (ii) the incentives to enter that affect future competition and profitability (a novel mechanism). The entry decision is influenced by the incumbent's opacity choice

[11] Given the Salop model of imperfect competition, we define net lending as the lending volume of all banks net of the transport costs of all investors.

[12] For evidence on opacity deterring entry, see **?** and **?**, for example.

in period 1. For intermediate investment and information costs, entry occurs only if the incumbent is transparent enough. Incumbent opacity distorts the entrant's investment decisions as the entrant incurs type I and II errors (building up capacity when doing so is not profitable and not building up capacity when it would have been profitable). This lowers the incentives to acquire information and can effectively deter the entrant. These incentives for deterrence are particularly relevant in setups like ours where, due to market power, entry strongly affects the incumbent's profits.

We next derive implications for transparency regulation. Policies to ensure a minimum level of transparency include changes in accounting rules, the pillar 3 of Basel regulation, and the implementation of bank stress tests. We describe a wedge between the private and social incentives for opacity, partly due to their impact on entry. While the incumbent has incentives to deter entry in order to preserve a higher market share, the regulator recognizes that the redistribution of market share from the incumbent to the entrant is not a social cost. When competition upon entry is fierce, the incumbent chooses to be opaque, but the regulator imposes full transparency. Intuitively, the regulator fosters the competitor's entry to increase net lending in the economy and to preserve the gains from intermediation upon the incumbent's failure.

Our final step is to explore the robustness of our results in Section 4. We first consider withdrawal decisions taken directly by investors, relaxing the assumption of delegation to fund managers. We determine conditions under which the same results as in our baseline model arise. We next allow for the underlying investment return to incorporate an idiosyncratic component and for several incumbent banks. We show how the level of competition is a relevant determinant for bank opacity choices: incumbent banks are opaque when competition is low but are transparent in a highly competitive banking sector.[13] Finally, we change the imperfect competition setup for funding from Salop to Cournot and show how our main results hold.

[13] Consistent with our model's implication, **?** document that regulatory shocks that increase bank competition (branch deregulation) leads to an increase in bank transparency.

Related literature. Our paper is related to several literatures. The first covers runs on financial intermediaries (**??**).[14] Using the global-games approach to uniquely pin down the run probability (**??**), we examine the impact of competition and opacity on fragility. We share with **?** that both deposit rates and the run probability are endogenous. Our contribution is to study (i) bank opacity choices and their impact on bank competition and fragility; and (ii) how imperfect competition and entry in the funding market shape the fragility and opacity of banks.[15] We also describe a simple setup in which the fund-manager approach of **?** yields the same outcome as investors directly deciding on withdrawals as, for example, in **?**.

A long-standing literature studies how bank failure is determined by bank competition, focusing on the asset side of banks—see **?** for a recent review. **?**, **?**, and **?**, among others, show how higher competition increases bank incentives to take risk, resulting in a more probable bank failure. This result reverses when the risk choice arises from a moral hazard problem of the entrepreneur, so higher competition results in lower loan rates and safer entrepreneurs (**?**).[16] Focusing on the liability side of banks, we endogenize deposit rates in a global-games bank-run model. Higher competition increases deposit rates and withdrawal incentives, making banks more prone to runs.[17] We also contribute to this literature by exploring the link between bank competition and bank opacity. We show that higher opacity reduces future competition and lower current competition increases opacity.

A third literature studies the transparency of banks subject to runs. Bank transparency can help external financiers discipline bank managers (e.g., **?**). We abstract from such agency problems and focus on the role of transparency for the

[14]**?** document how the demand for uninsured deposits depend on bank distress. Using a structural approach, they show how multiple equilibria can exist in the U.S. banking sector.

[15]Recent work on bank runs in a global-games setup includes **?**, **?**, **?**, **?**, **?**, and **?**.

[16]**?** show that a non-monotonic relation between bank competition and stability arises when loan defaults are imperfectly correlated. **?** study credit market competition when banks face essential runs as in, e.g., **?**.

[17]**?** also study competition for deposits but focus on sunspots.

probability of a run. We share this focus with **?**, who examine the optimal disclosure policy of a regulator who learns about the heterogeneous quality of banks at the debt rollover stage.[18] There are two main differences. First, we study the opacity choice of banks at the funding stage when information between the bank and outsiders is symmetric. Second, we study imperfect competition and entry and how it shapes the fragility and opacity of banks.[19]

At a technical level, our modeling of bank opacity choice is related to a literature on information choice in global coordination games pioneered by **?**. They show that the information choices of investors inherit the strategic motive of an underlying beauty contest, which can result in multiple equilibria. For regime change games, **?** and **?** study private information acquisition. While we share with these papers how more opaque private information affects coordination, there are two main differences. First, these papers study the information choice of investors, while we examine the information choice of banks. Second, the cost of more precise private information is endogenous in our model: it induces entry and higher future bank competition.[20]

[18] See also **?** for a review about the benefits and costs of disclosure.

[19] In our model, bank opacity choices are not driven by asymmetric information about asset quality at the funding stage or the fear of asymmetric information at the rollover stage. A literature starting with **?** emphasizes the role of opacity for secondary market liquidity.

[20] Transparency has been defined as the precision of private signals in currency attacks in **?**. See also **?** and **?**. However, these papers do not study the private opacity choices or its effect on deposit rates.

2 A model of competition, runs, and opacity

We first develop a one-period model in which banks choose their opacity and deposit rates. This model combines bank runs, as in ?, with imperfect competition for funding among banks, as in ?. We model opacity as the precision of private information, as in ?.

There are three dates $t = 0, 1, 2$, no discounting, and universal risk neutrality. There are three types of agents: banks, investors, and fund managers. At date 0, each of the $N \geqslant 1$ banks has access to a risky investment technology with gross return R drawn at date 1. Its uniform common prior at date 0 is

$$R \sim \mathcal{U}\left[\underline{R}, \overline{R}\right] = \mathcal{U}\left[R_0 - \frac{\alpha}{2}, R_0 + \frac{\alpha}{2}\right], \tag{1}$$

where $\alpha > 0$ measures investment risk and $R_0 \geqslant \frac{\alpha}{2}$ the expected return.

At date 0, a unit mass of atomistic investors with a unit endowment each are symmetrically located on a unit-sized circle (Figure 1). Investors have a cost $\mu > 0$ per unit of distance to a bank. Apart from the traditional cost of travelling to banks, the cost can capture heterogeneity in investor taste with respect to the bundles of services offered by banks or the relationships investors formed with banks in funding markets.[21] We refer to μ as transport cost for short.[22] Investors are indifferent between consumption at date 1 and 2 and cannot directly invest in the risky technology.

At date 0 banks are equidistantly located on the circle and compete for debt funding from investors. Bank $j = 1, ..., N$ chooses opacity δ^j (described below) and the face value of debt D^j. We call this face value the (gross) deposit rate promised to investors. The transport cost is low enough such that the funding market is covered if at least 2 banks are active. Debt can be withdrawn at either date 1 or 2. Its face

[21] **?** document the relevance of relationships in funding markets.

[22] In Section 4.3 we study an alternative setup in which banks imperfectly compete as in Cournot.

value is independent of the withdrawal date. Bank choices are observable.

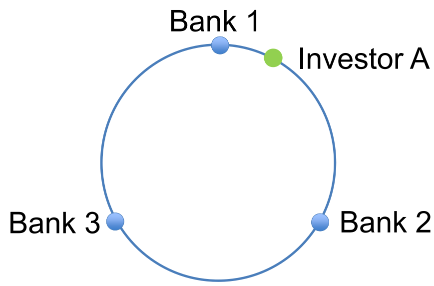

Figure 1: Location of banks on the Salop circle (for $N = 3$). Investor A has a lower transport cost to bank 1 than to bank 2.

At date 0, penniless banks are entirely funded with debt, h^j, and invest all funds in the risky technology, $I^j = h^j$. Liquidation at date 1 yields a fraction $0 < \psi < 1$ of the realized return at date 2, so the per-unit liquidation cost is $z \equiv \frac{1}{\psi} - 1 > 0$. Banks are protected by limited liability and maximize expected profits at date 2.

Investors delegate the rollover decision at date 1 to a group of atomistic fund managers $i \in [0, 1]$.[23] Each fund manager specializes in one of the banks. If a proportion $w^j \in [0, 1]$ withdraws (or refuses to roll over), bank j liquidates some investment to serve these withdrawals. Bank j fails at date 1 and is closed early if it cannot serve interim withdrawals, $w^j D^j h^j > \psi R I^j$, which determines an illiquidity threshold $R_{IL} \equiv \frac{wD}{\psi}$. Upon early closure, all investors receive an equal share of the liquidation value of investment. Otherwise, the bank's residual investment value is $RI^j - \frac{w^j D^j h^j}{\psi}$ at date 2. Bank j fails at date 2 if it cannot serve residual withdrawals $(1 - w^j)D^j h^j$:

$$R - \frac{w^j D^j}{\psi} < (1 - w^j)D^j. \tag{2}$$

We assume zero recovery upon bank failure at date 2 for simplicity.

Following **?**, we assume that the simultaneous rollover decisions are governed by the compensation of fund managers. If the bank fails, a manager's relative compensa-

[23] See Section 4.1 for an extension with investors deciding on withdrawals.

tion from withdrawing is a benefit $b > 0$. Otherwise, the relative compensation from withdrawing is a cost $c > 0$.[24] The conservatism ratio $\gamma \equiv \frac{b}{b+c} \in (0, 1)$ summarizes these parameters, where greater conservativeness (higher γ) makes fund managers more reluctant to roll over debt.[25] This specification ensures global strategic complementarity in rollover decisions (**??**).

We assume incomplete information about the investment return at date 1 to ensure a unique equilibrium. In addition to the common prior in (1), each fund manager i receives a noisy private signal about the return (**?**):

$$x_i^j = R + \epsilon_i^j, \quad \epsilon_i^j \sim \mathcal{U}\left[-\frac{\delta^j}{2}, \frac{\delta^j}{2}\right], \tag{3}$$

where the idiosyncratic noise ϵ_i^j is independent of the investment return R and i.i.d. across fund managers. The idiosyncratic noise is uniformly distributed with zero mean and width $\delta^j \in [\underline{\delta}, \bar{\delta}]$, where $0 < \underline{\delta} < \bar{\delta}$ are bounds and $\underline{\delta} \to 0$.

Each bank chooses the opacity of its assets δ^j at date 0. Higher opacity implies that fund managers receive more dispersed private signals. Examples for a bank's opacity choice include investing in more complex assets or assets without quoted market prices (e.g., Level 2 and 3 assets under IFRS 13 accounting rules), lending based on soft rather than hard information about borrowers, or the choice of accounting procedures and styles, including the adoption of voluntary accounting standards.

$t = 0$	$t = 1$	$t = 2$
1. Banks compete for funding	1. Private signals	1. Investment matures
2. Investors deposit at a bank	2. Withdrawals	2. Banks repay or default
3. Banks invest	3. Consumption	3. Consumption

Table 1: Timeline.

[24] As an example, assume the cost of withdrawal is c; the benefit from getting the money back or withdrawing when the bank fails is $b + c$; the payoff for rolling over when the bank fails is zero.

[25] Reviewing debt markets during the financial crisis, **?** argues that investor conservatism was an important determinant of short-term lending behavior. See also **?**.

We next solve for the equilibrium, focusing on symmetric equilibrium in pure and threshold strategies. We pin down under what conditions debt is rolled over and determine the expected return to investors and expected bank profits. We then characterize the equilibrium choices of opacity and deposit rates and study comparative statics with respect to the degree of competition and changes in bank profitability and transparency. We also derive implications for competition policy.

2.1 Rollover of debt

Dropping the bank index j for expositional simplicity, we consider the debt rollover game between fund managers at date 1. In particular, we analyze how the opacity level δ and face value of debt D of a given bank affect withdrawal decisions.

Proposition 1. ***Bank failure***. *If $\alpha \geqslant \underline{\alpha}$, then there exist unique thresholds of bank failure, $R^* \equiv (1+\gamma z)D$, and of the signal, $x^* \equiv R^* + \left(\gamma - \frac{1}{2}\right)\delta$, in the rollover stage at date 1. Fund manager i rolls over debt if and only if $x_i \geqslant x^*$ and the bank fails if and only if $R < R^*$. The withdrawal proportion for a realized investment return is*

$$w^*(R) = \begin{cases} 1 & R \leqslant R^* - (1-\gamma)\delta \equiv \underset{\sim}{R} \\ \gamma + \frac{R^*-R}{\delta} \quad \text{if} & R \in \left(\underset{\sim}{R}, \widetilde{R}\right) \\ 0 & R \geqslant R^* + \gamma\delta \equiv \widetilde{R} \end{cases} \tag{4}$$

Proof. See Appendix A. ■

Opacity δ affects both the signal threshold x^* and the withdrawal proportion $w^*(R)$. In our model, withdrawals are less sensitive to realized investment returns for a more opaque bank (Figure 2). **?** provide evidence consistent with this implication. Greater opacity implies more partial runs when the bank survives, $R \geqslant R^*$. As we show below, this induces costly liquidation of investment and reduces expected bank profits. Moreover, when the bank fails, $R < R^*$, there are fewer partial runs. The direct effect on expected profits is zero by limited liability. However, greater opacity reduces the expected return offered to investors, as we show below, and therefore affects the bank's competitiveness in the funding market.

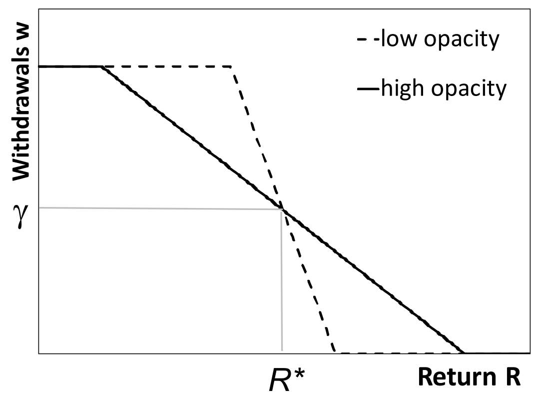

Figure 2: Opacity and withdrawals. The withdrawal proportion depends on the realized investment return for high (bold line) and low (dashed line) levels of opacity. Opacity reduces the sensitivity of withdrawals to the realized investment return. This implication of our model is consistent with evidence documented in **?**.

A higher face value of debt D increases the failure threshold, $\frac{dR^*}{dD} > 0$, because withdrawals have a larger negative impact on a bank's available resources, which raises the degree of strategic complementarity in withdrawal decisions (**?**).

Finally, we mention two technical aspects of the analysis. First, our choice of a uniform distribution simplifies the analysis as it implies that opacity does not directly affect bank failure, $\frac{\partial R^*}{\partial \delta} = 0$. This approach isolates the effect of opacity on fragility via deposit rates, $\frac{\partial R^*}{\partial D}\frac{dD^*}{d\delta} \neq 0$. Second, the sufficient condition $\alpha \geqslant \underline{\alpha}$ ensures that the variance of the investment return is high enough relative to opacity. It ensures that the posterior about the investment return given the equilibrium signal threshold x^* is uniform (see Appendix A for details). This condition is reminiscent of the standard uniqueness condition in global-games models of precise enough private information relative to public information (e.g., **?**).

2.2 Funding market outcomes

We turn to the funding market at date 0. Using the prior of the investment return in (1), the expected return to investors ρ for a given face value D and opacity δ is

$$\rho(D,\delta) \equiv \int_{\underline{R}}^{R_{IL}} \psi R \,\frac{dR}{\alpha} + \int_{R_{IL}}^{R^*} D w(R)\,\frac{dR}{\alpha} + \int_{R^*}^{\overline{R}} D\,\frac{dR}{\alpha}, \tag{5}$$

where the first term is the liquidation proceeds upon early closure of the bank at date 1;[26] the second term is the proceeds from withdrawing from the bank at date 1 when it is liquid but fails at date 2; and the third term is the face value of debt received when the bank survives at date 2 (which is independent of the withdrawal decision).

Opacity leads to the type II error of not withdrawing from a failing bank, which reduces the expected returns to investors, $\frac{d\rho}{d\delta} < 0$, as shown in Appendix B. Opacity drives the withdrawal volume $w(R)$ of the second term, while the first and third term are independent of opacity.[27] For intermediate returns, $R_{IL} \leqslant R \leqslant R^*$, the bank is liquid at date 1 but insolvent at date 2. Thus, investors receive the face value D only upon interim withdrawals, which occur with probability $w(R)$. Since opacity reduces the sensitivity of withdrawals to the investment return (Proposition 1), more opacity induces fewer withdrawals, which reduces the expected return to investors.

We turn to analyzing the expected bank profits per unit of funding π. For low investment returns, $R < R^*$, the bank fails and obtains zero profits by limited liability. Otherwise, per-unit profits are the return net of withdrawal costs. For returns $R^* \leqslant R < \widetilde{R}$, some withdrawals occur at date 1 even if the banker is solvent at date 2. Due to opacity, some fund managers receive a low signal and withdraw—a partial run. That is, opacity leads to the type I error of withdrawing from a solvent bank. For high returns, $R \geqslant \widetilde{R}$, there are no withdrawals. A lower bound on

[26] Using the equilibrium at the rollover stage, the illiquidity threshold becomes $R_{IL} = R^* - \frac{\gamma^2 \delta z D}{\psi\delta + D}$.

[27] The effect of opacity on the illiquidity threshold R_{IL} washes out by continuity.

investment risk, $\alpha > \underset{\sim}{\alpha} \equiv \max_\delta \frac{\gamma\delta(R_0-\gamma\delta)}{(1+\gamma z)\rho-\frac{\gamma\delta}{2}}$, ensures that no withdrawals occur at the highest return, $\widetilde{R} < \overline{R}$, which we assume henceforth. Since the withdrawals w at date 1 cost $\frac{wD}{\psi}$ due to partial liquidation, bank profits (per unit of funding) for a realized return R is

$$E(R) \equiv \max\left\{0, R - D\big(1 + zw^*(R)\big)\right\}, \tag{6}$$

which is zero at the failure threshold, $E(R^*) \equiv 0$ (see Figure 3).

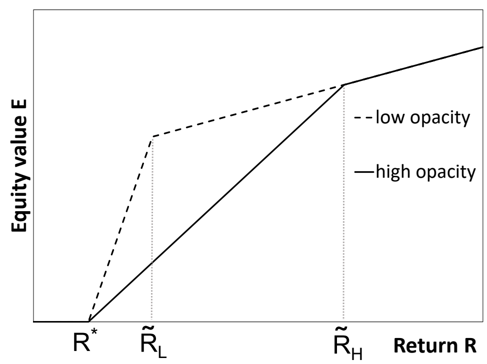

Figure 3: Bank profits (per unit of funding) at date 2 depend on the realized investment return R and the level of opacity δ: high (bold line) and low (dashed line).

Integrating bank profits over all investment returns for which the bank survives and using the prior about returns in (1) yields the expected per-unit profits:

$$\pi(D,\delta) \equiv \int_{R*}^{\overline{R}} E(R)\frac{1}{\alpha}dR = \frac{1}{\alpha}\left[(\overline{R} - R^*)\left(\frac{\overline{R} + R^*}{2} - D\right) - \frac{\gamma^2\delta z D}{2}\right], \tag{7}$$

where the first term is the surplus from investment net of funding costs conditional on bank survival and the second term is the cost of opacity due to a partial run on a solvent bank and the induced costly liquidation of investment. More opacity reduces the expected profits, $\frac{d\pi}{d\delta} < 0$, due to more costly liquidation by a solvent bank.

Equipped with the per-unit expected profits $\pi(D,\delta)$ and the expected return to investors $\rho(D,\delta)$, we solve for the funding market equilibrium at date 0. Bank j chooses opacity δ^j and the face value of debt D^j to maximize expected profits, taken as given the choices of competing banks (D^{-j}, δ^{-j}):

$$\max_{D^j,\delta^j} \quad \Pi(D^j,\delta^j) \equiv h(D^j,\delta^j)\ \pi(D^j,\delta^j). \tag{8}$$

We can now characterize bank choices at date 0 and the funding market outcome.

Proposition 2. ***Bank choices.*** *Banks are as transparent as possible, $\delta^j = \delta^* = \underline{\delta}$. Consider $N \geqslant 2$. If the consequences of rollover risk are large enough, $z\gamma \geqslant 1$, then the face value of debt, $D^j = D^*$, is uniquely and implicitly pinned down by*

$$\frac{d\Pi}{dD} = \frac{dh}{dD}\pi\bigg|_{(D^*,\underline{\delta})} + h\,\frac{d\pi}{dD}\bigg|_{(D^*,\underline{\delta})} = 0. \tag{9}$$

For $N \to \infty$, $D^* \to D^*_{max} \equiv \frac{\overline{R}}{\kappa(1+z\gamma)}$ and $R^* \to R^*_{max} \equiv \frac{\overline{R}}{\kappa}$, where $\kappa \equiv 2-\psi-(1-\psi)\gamma$.

Proof. See Appendix B, which also states the outcomes for monopoly ($N = 1$). ■

In this baseline setup, opacity entails only costs for the bank. The lower sensitivity of withdrawals to the realized investment return leads to (i) costly withdrawals on a solvent bank, reducing expected profits π; and (ii) lower interim withdrawals from a bank that fails at date 2, reducing the expected return to investors ρ and thus funding volume for the bank h. Hence, the banks chooses to be as transparent as possible. Once opacity also has a benefit—e.g., by deterring entry and reducing future competition (studied in the next section)—an interior opacity choice can arise.

When offering a face value of debt, each bank trades off attracting a higher volume of funding due to higher deposit rates, $\frac{dh}{dD} = \frac{dh}{d\rho}\frac{d\rho}{dD} > 0$, with a higher funding cost that reduces the expected profits per unit of funding, $\frac{d\pi}{dD} < 0$. This trade-off pins down the deposit rate D^*. In symmetric equilibrium for $N \geqslant 2$, each bank sets the same deposit rate, $D^j = D^*$, and attracts an equal amount of funding, $h^j = h^* = \frac{1}{N}$.[28]

A bank only raises the deposit rate when it increases the expected return to

[28] Our assumption of a low transport cost ensures that the market is covered for at least two banks.

investors, so $\frac{d\rho}{dD} > 0$ must hold in equilibrium. This condition places an upper bound on fragility, $R^* < R^*_{max}$, and on the deposit rate, $D^* < D^*_{max}$. Intuitively, a higher deposit rate does not increase the expected return to investors if it creates too many withdrawals and fragility. As the number of banks reaches the perfect-competition benchmark, $N \to \infty$, we have $D^* \to D^*_{max}$, where D^*_{max} maximizes the expected return to investors, $\frac{d\rho}{dD} \to 0$.[29] We maintain throughout the sufficient condition $z\gamma \geqslant 1$ that ensures $\frac{d^2\pi}{dD^2} \leqslant 0$ and thus a concave objective function Π and a maximum.

Let $\Pi^*(N, R_0) = \Pi(D^*, \delta^*)$ denote expected bank profits evaluated at the optimal choices of the deposit rate and opacity. This value function depends on the number of active banks, N, and the expected investment return, R_0. We will use this function in Section 3. In Appendix B, we also consider the case of a monopolist, $N = 1$, and derive the associated value function $\Pi^*(1, R_0)$.

2.3 Comparative statics

Turning to comparative statics, we consider (a) changes in the degree of competition (measured either by the number of banks N or the transport cost μ); (b) changes in transparency measured by changes in $\underline{\delta}$;[30] and (c) a change in per-unit profits via a non-pecuniary per-unit cost of lending $\lambda > 0$, such as variable operational costs. For part (c), expected bank profits change to $\Pi_\lambda = h(\pi - \lambda)$.

Proposition 3. ***Comparative statics.***

(a) Higher competition increases the deposit rate and bank fragility. The result holds for two measures of bank competition: the number of banks, $\frac{dD^*}{dN} > 0$ and $\frac{dR^*}{dN} > 0$, and the transport cost, $\frac{dD^*}{d\mu} < 0$ and $\frac{dR^*}{d\mu} < 0$.

[29] In this limit, we have $R^*_{max} < \overline{R}$ and banks make positive expected profits.

[30] For this comparative static, we abstract from $\underline{\delta} \to 0$ that is otherwise considered throughout.

(b) An exogenous increase in transparency (lower $\underline{\delta}$) results in higher deposit rates, $\frac{dD^*}{d\underline{\delta}} < 0$, and higher bank fragility, $\frac{dR^*}{d\underline{\delta}} < 0$.

(c) With a non-pecuniary per-unit cost of lending λ, the deposit rate is lower, $D^*_\lambda < D^*$, which reduces bank fragility, $R^*_\lambda < R^*$.

Proof. See Appendix B. ■

The first result offers a micro-foundation of the competition-fragility view of banking. A higher number of banks induces banks to compete more fiercely for funding and, in equilibrium, results in higher deposit rates. Higher deposit rates, in turn, lead to higher bank fragility (Proposition 1), as shown in Figure 4. The same qualitative results obtain when transport costs decrease, which can be seen as an alternative measure of higher competition. The proposed competition-fragility view of banking belongs to the broader competition-instability view of banking but highlights that greater competition can introduce fragility on a bank's liability side.

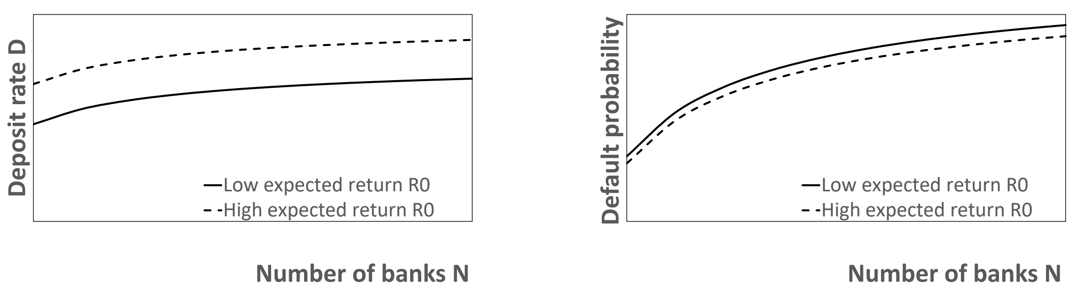

Figure 4: Competition-fragility view of banking: the deposit rate D^* and the probability of bank failure $\Pr\{R < R^*\}$ increase in the degree of competition N.

The second result offers a transparency-fragility view of banking. In our setup, more transparent banks are more profitable, leading to fiercer competition for funding and higher deposit rates. As a result, the fragility of the banking sector increases. This result shows how a less profitable banking system can be more stable (less fragile).

In a related fashion, the third results considers a non-pecuniary cost of lending that exogenously reduces bank profitability without affecting investment returns. Thus, the incentives of banks to compete for funding are again reduced. Hence, higher non-pecuniary lending costs reduce the deposit rate, which in turn reduces strategic complementarity in withdrawal decisions and bank fragility. Both the second and the third result highlight the importance of endogenous deposit rates.

These results that link lower bank profitability to lower fragility sharply contrast with models of risk-taking on the asset side via a moral hazard problem (e.g., **?**). The opposite result arises in those environments because lower expected profits increase the incentives for lower effort or higher risk-taking and, thus, reduce bank stability. Thus, our result highlights the importance of whether the source of bank instability arises from its asset side (e.g., via risk-taking) or its liability side (via a fragile funding structure and runs).[31]

Several testable implications arise from the analysis so far. First, consider shocks to the competitive structure of the financial system, for example, those due to deregulation in the United States in the 1980s and 1990s that heightened bank competition (e.g., **?**) or (local) changes due to bank mergers (e.g., **?**). Our model implies that uninsured deposit rates increase and, therefore, measures of bank fragility increase. Second, the transmission of shocks to fragility depends on the competitive structure. For example, Figure 4 shows how the change in default probabilities after a shock to asset profitability depends on the level of competition, which affects the endogenous reaction of deposit rates to shocks and, in doing so, affects withdrawal incentives. In sum, the level of competition can be fundamental in assessing the overall effect of various shocks to financial fragility. Finally, our model implies that shocks that increase the transparency of the banking sector lead to an increase in both deposit rates and bank fragility.

[31] Our results are related to those in **?**, who show how higher competition leads to less profitable but safer banks. We share the focus on how other players' actions determine bank stability (creditors in funding markets in our model and firms in lending markets in theirs).

2.4 Regulatory implications

We next turn to regulatory implications in the one-period setup. We consider competition policy, i.e., a regulator who sets the number of banks in the economy, N.

A regulator takes as given the incomplete information and the privately-optimal choices of opacity and deposit rates given regulation. That is, banks choose $\delta^* = \underline{\delta}$ and $D^*(\underline{\delta}, N)$. The regulator maximizes utilitarian welfare that comprises expected bank profits and the expected return to investors minus transport costs.[32] We interpret the per-unit liquidation cost z as a social cost (e.g., redeployment of resources to a worse user; **?**). For $N \geqslant 2$, total transport costs are $TC = \frac{\mu}{4N}$ and decrease in the number of banks at a diminishing rate, $\frac{dTC}{dN} < 0$ and $\frac{d^2TC}{dN^2} > 0$.[33]

For $N \geqslant 2$, banks raise a unit mass of deposits, $\sum_{j=1}^{N} h_j = 1$. The regulator takes into account that, from a social perspective, there are no market-stealing incentives as the market for funding is covered. Thus, welfare can be expressed as

$$W \equiv \pi(D^*, \delta^*) + \rho(D^*, \delta^*) - TC. \tag{10}$$

Proposition 4. ***Competition policy.*** *The socially optimal number of banks is interior, $N^* < \infty$. It equalizes the marginal benefits and costs of more banks:*

$$\frac{dW}{dN} = -(1-\psi)R^* \frac{1}{\alpha} \frac{dR^*}{dN} + \frac{\mu}{4N^2} = 0. \tag{11}$$

Proof. See Appendix C. ■

A larger number of banks is associated with a trade-off. Its benefit is lower

[32]For the welfare analysis of the Rochet-Vives model, we follow the approach in **?** and mute the impact of fund managers' payoffs on welfare. That is, we set $b \to 0$ and $c \to 0$ at a rate that preserves the positive implications of this approach, where $\frac{b}{b+c} \to \gamma$ remains constant.

[33]Investors with a distance $d_k \in \left[0, \frac{1}{2N}\right]$ on either side of a given bank's position deposit with this bank because it is the closest. Hence, total transport costs are $TC = \mu \cdot 2N \int_0^{\frac{1}{2N}} d_k \, dd_k = \frac{\mu}{4N}$.

transport costs, $-\frac{dTC}{dN} = \frac{\mu}{4N^2} > 0$. Its costs arise from fiercer competition for funding that results in a higher deposit rate, $\frac{dD*}{dN} > 0$. For vanishing private noise, the deposit rate itself is merely a transfer between banks and investors when the bank survives at date 2.[34] Hence, the deposit rate does not directly affect welfare but a higher deposit rate increases fragility, $\frac{dR*}{dN} > 0$, and the expected costs of liquidation of investment, $(1-\psi)R^*$, that occur with probability $\frac{1}{\alpha}$.[35]

3 Entry and deterrence: A theory of bank opacity

In this section, we include a key element of competition: the entry of a competitor. This setup identifies a (private) benefit of opacity—the deterrence of entry—that gives rise to a novel theory of bank opacity as well as rationalizes transparency regulation.

There are two periods $T = 1, 2$ and each of which resembles the model in Section 2. The investment return has persistence and follows $R_T = R_{T-1} + \eta_T$, where $R_0 > \alpha$, η_T is independently and identically uniformly distributed, $\eta_T \sim U[-\frac{\alpha}{2}, \frac{\alpha}{2}]$, and independent of R_T and over time.[36] We assume R_{T-1} is publicly observed at date 0 of period T, so the common prior at date 0 is

$$R_T \big| R_{T-1} \sim U\left[R_{T-1} - \frac{\alpha}{2}, R_{T-1} + \frac{\alpha}{2}\right]. \tag{12}$$

At date 0 bank j chooses opacity δ_T^j and face value D_T^j for that period. The balance sheet identity is $I_T^j = h_T^j$. The outside option of investors is normalized to zero.

In period 1, there is a single incumbent bank. (For multiple incumbent banks, see Section 4.2.) The incumbent bank I maximizes the sum of expected profits in each

[34] This result arises because the type I and type II errors of not withdrawing from a failing bank and some withdrawals from a solvent bank are vanishing in the limit of $\underline{\delta} \to 0$.

[35] A similar trade-off would occur if we used a Cournot model of imperfect competition, where the trade-off would be between bank fragility and loan quantity (instead of total transport costs).

[36] For idiosyncratic investment risk, see Section 4.2.

period. If it fails in period 1, it exits and is inactive in period 2. A potential entrant E can operate in period 2 only. We assume that (a) investors live for one period and are replaced with new investors with the same endowments; and (b) banks consume their profits at the end of each period. When both banks are active in period 2, they are equidistantly located on the circle.

In period 1, after the incumbent bank chooses its levels of opacity, δ_1, and deposit rate, D_1, at date 0, the entrant observes the opacity of the incumbent bank and decides whether to follow the market and acquire information. Not following the market implies no entry and an outside option normalized to zero. Following the market entails an information cost $C > 0$ that captures resources and time (e.g., of bank executives) devoted to study the market.[37] If the entrant follows the market, it receives two pieces of information. First, at date 1 (simultaneous to the rollover decisions of fund managers), the entrant receives a private signal about the investment return. Paralleling the signals received by fund managers, it also depends on opacity:

$$x_E = R_1 + \epsilon_E, \quad \epsilon_E \sim \mathcal{U}\left[-\frac{\delta_1}{2}, \frac{\delta_1}{2}\right], \tag{13}$$

where ϵ_E is independent of R_1.[38] In sum, the incumbent bank's opacity choice affects the precision of private information of both fund managers and the entrant.

Second, at date 2 the entrant observes whether the incumbent fails, $R_1 < R_1^*$.[39] Based on these pieces of information, the entrant decides whether to pay a fixed cost $F > 0$ of building up capacity that allows it to operate in period 2. Our assumption

[37]This setup is equivalent to assuming that underlying economic conditions are such (e.g., a low enough expected investment return R_0) that an uninformed entrant (who has not acquired information) would not find it profitable to incur the investment cost F to enter the market.

[38]We consider a symmetric information structure for private signals. Our results qualitatively generalize to an entrant's signal of the form $x_E = R_1 + \chi\epsilon_E$ for $0 < \chi < \infty$. For example, $\chi < 1$ would capture that the entrant is better informed than the creditors of the incumbent bank.

[39]Our results are qualitatively unchanged if the entrant also observes the source of the incumbent's failure. The entrant would learn that $R_1 < R_{1,IL}$ when the bank fails due to illiquidity at date 1 or $R_{1,IL} \leqslant R_1 < R_1^*$ when it fails due to insolvency at date 2. The threshold equilibrium and some appropriate bounds on the fixed cost F generalize to this alternative setting. See Proposition 5.

that the fixed cost is paid before the realized investment return R_1 is publicly observed in period 2 captures various costly decisions banks have to make before they can effectively operate in a given market (e.g., the creation of relevant capacities by hiring specialized human capital, building offices, etc.).

In sum, entry has two stages: an information stage in which the entrant chooses whether to acquire information about the market at cost C and an investment stage in which the entrant decides whether to build capacity at cost F based on the information received. The number of active banks in period 2 thus depends on entry and exit, $N_2 = \mathbf{1}\Big\{R_1 \geqslant R_1^*\Big\} + \mathbf{1}\Big\{\text{E enters}\Big\}$, where $\mathbf{1}\{\cdot\}$ is the indicator function.

As in our previous analysis, we study perfect Bayesian equilibrium and focus on symmetric equilibrium in pure strategies and threshold strategies. Generalizing previous results, the failure threshold of the investment return is $R_T^* \equiv (1 + \gamma z)D_T$ and the signal threshold is $x_T^* \equiv R_T^* + \left(\gamma - \frac{1}{2}\right)\delta_T$. The withdrawal proportion is $w_T^* = w^*(R_T)$. Table 2 summarizes the timeline of events in period 1.

$t = 0$	$t = 1$	$t = 2$
1. Banks compete for funding	1. Private signals	1. Investment matures
2. Investors deposit at a bank	2. Withdrawals	2. Banks repay or default
3. Entrant may follow the market	3. Consumption	3. Entrant may build capacity
4. Banks invest		4. Consumption

Table 2: Timeline (Period 1).

3.1 Entry

In this subsection we characterize the entrant's decisions to acquire information and to invest (to build up capacity), and we describe how these decisions depend on the incumbent's opacity choice. We show how higher incumbent opacity can deter the entrant, reducing the incentives of the entrant to acquire information.

We proceed backwards and start with the entrant's investment decision upon having followed the market. At date 2, the entrant forms a posterior $g(R_1|x_E, \delta_1)$ that depends on its two pieces of information and the incumbent's opacity. Knowledge about the current return R_1 helps the entrant form expectations about the future return R_2 and thus future expected profits, $\Pi_2^*(N_2, R_1)$, as defined in Section 2.

Consider first the failure of the incumbent, $R_1 < R_1^*$. When the entrant invests, it is the monopolist in period 2, $N_2 = 1$. Thus, the value of investment (before the fixed cost F) as of date 2 in period 1 is

$$V(x_E, \delta_1) = \int_{\underline{R}_1}^{R_1^*} \Pi_2^*(1, R_1)\, g(R_1|x_E, \delta_1)\, dR_1. \tag{14}$$

Consider next the survival of the incumbent, $R_1 \geqslant R_1^*$. Upon entry, $N_2 = 2$ banks are active and the gross value of investment for the entrant in this case is

$$V(x_E, \delta_1) \equiv \int_{R_1^*}^{\overline{R}_1} \Pi_2^*(2, R_1)\, g(R_1|x_E, \delta_1)\, dR_1. \tag{15}$$

We state our main result on the entrant's investment choice at date 2.

Proposition 5. ***Entry: Investment.*** *When the incumbent I survives, $R_1 \geqslant R_1^*$, there exist bounds $\underline{F} < \overline{F}$. For $F \in (\underline{F}, \overline{F})$, the entrant invests if and only if $x_E \geqslant x_E^*$, where the threshold solves $V(x_E^*, \delta_1) \equiv F$. Investment occurs always (never) if $F \leqslant \underline{F}$ ($F \geqslant \overline{F}$). The case of I failing is analogous with bounds $\underset{\sim}{F} < \widetilde{F}$ and a threshold x_E^{**}.*

Proof. See Appendix D. ■

We now explain these bounds on the investment cost. At the lower bounds, $\underset{\sim}{F}$ and $\underline{F}$, the entrant is indifferent about investment after inferring the lowest possible return ($R_1 = \underline{R}_1$ and $R_1 = R_1^*$, respectively). Hence, the entrant always invests (i.e., for each possible signal) when F is lower than the respective threshold. Similarly, at the upper bounds, $\widetilde{F}$ and $\overline{F}$, the entrant is indifferent after inferring the highest possible return ($R_1 = R_1^*$ or $R_1 = \overline{R}_1$) and never invests when F exceeds the upper bound. For intermediate investment costs, we define threshold investment returns, $\breve{R}_1$ and $\widehat{R}_1$, such that the entrant is indifferent about investing if it observed R_1 without noise:

$$\Pi_2^*(1, \breve{R}_1) \equiv F \equiv \Pi_2^*(2, \widehat{R_1}). \tag{16}$$

Under perfect information, the entrant invests at date 2 of period 1 if and only if $R_1 \geqslant \widehat{R}_1$ when the incumbent survives, and if and only if $R_1 \geqslant \breve{R}_1$ when it fails.

Having characterized the investment decisions at date 2, we turn to the entrant's choice to follow the market at date 0 and its dependence on the incumbent's opacity. The entrant acquires information whenever the profits from following the market and subsequent investment exceeds the information cost, $\Pi_E \equiv \Pi_E^M + \Pi_E^D \geqslant C$, where these profits arise when being a monopolist, Π_E^M, and being a duopolist, Π_E^D:

$$\begin{aligned} \Pi_E^M &\equiv \int_{\underline{R}_1}^{R_1^*} \Big[\Pi_2^*(1, R_1) - F\Big] \mathbf{1}\Big\{\text{E enters}\Big\} \frac{1}{\alpha} dR_1, \\ \Pi_E^D &\equiv \int_{R_1^*}^{\overline{R}_1} \Big[\Pi_2^*(2, R_1) - F\Big] \mathbf{1}\Big\{\text{E enters}\Big\} \frac{1}{\alpha} dR_1. \end{aligned}$$

For intermediate investment costs, the probability of investment q is[40]

$$q(R_1) = \Pr\{x_E \geqslant x_E^* | R_1\} = \begin{cases} 1 & R_1 \geqslant x_E^* + \frac{\delta_1}{2} \\ \frac{1}{2} - \frac{x_E^* - R_1}{\delta_1} \quad \text{if} & R_1 \in \left[x_E^* - \frac{\delta_1}{2}, x_E^* + \frac{\delta_1}{2}\right]. \\ 0 & R_1 \leqslant x_E^* - \frac{\delta_1}{2} \end{cases} \tag{17}$$

For expositional simplicity, we focus on intermediate investment costs, $\underline{F} < F < \overline{F}$ and $\underset{\sim}{F} < F < \widetilde{F}$.[41] This allows us to decompose the entrant's expected profits into a perfect-information benchmark and the costs of making mistakes due to an imprecise

[40] We define $q = 1$ if F is below the relevant lower bound and $q = 0$ if above the upper bound.

[41] In the other cases, the investment decisions are trivial (i.e. always invest or never invest).

signal x_E. These mistakes are a type I error of investing when doing so is unprofitable and a type II error of not investing when doing so is profitable:

$$\Pi_E^M \equiv \underbrace{\int_{\check{R}_1}^{R_1^*} \left[\Pi_2^*(1,R_1) - F\right] \frac{dR_1}{\alpha}}_{\text{perfect information}} - \underbrace{\int_{x_E^* - \frac{\delta_1}{2}}^{\check{R}_1} q\left[F - \Pi_2^*(1,R_1)\right] \frac{dR_1}{\alpha}}_{\text{type I error}} - \underbrace{\int_{\check{R}_1}^{x_E^* + \frac{\delta_1}{2}} (1-q)\left[\Pi_2^*(1,R_1) - F\right] \frac{dR_1}{\alpha}}_{\text{type II error}},$$

$$\Pi_E^D \equiv \underbrace{\int_{\hat{R}_1}^{\overline{R}_1} \left[\Pi_2^*(2,R_1) - F\right] \frac{dR_1}{\alpha}}_{\text{perfect information}} - \underbrace{\int_{x_E^* - \frac{\delta_1}{2}}^{\hat{R}_1} q\left[F - \Pi_2^*(2,R_1)\right] \frac{dR_1}{\alpha}}_{\text{type I error}} - \underbrace{\int_{\hat{R}_1}^{x_E^* + \frac{\delta_1}{2}} (1-q)\left[\Pi_2^*(2,R_1) - F\right] \frac{dR_1}{\alpha}}_{\text{type II error}}.$$

This decomposition clarifies how the entrant's expected profits depend on the incumbent's opacity choice, $\Pi_E = \Pi_E(\delta_1)$. The main intuition is that opacity induces the entrant to make type I and type II errors, which reduces its expected profits conditional on acquiring information. Let $\underset{\sim}{C} \equiv \min_\delta \Pi_E(\delta)$ and $\widetilde{C} \equiv \max_\delta \Pi_E(\delta)$ denote the bounds on these expected profits, where $\widetilde{C} = \Pi_E(0)$ arises in the limit of $\underline{\delta} \to 0$. In words, the expected profits of the entrant is highest when the incumbent is fully transparent because the entrant then makes no mistakes in its investment choice. Since these mistakes are costly, we have the ordering $\widetilde{C} \geqslant \underset{\sim}{C}$.

We can now state our main result on the information choice of the entrant.

Proposition 6. ***Entry: Information acquisition.*** *The entrant follows the market when $C < \underset{\sim}{C}$ and does not follow when $C \geqslant \widetilde{C}$. For an intermediate range of costs, $\underset{\sim}{C} \leqslant C < \widetilde{C}$, the entrant follows the market if and only if $\Pi_E(\delta_1) \geqslant C$.*

Proof. The proof derives from the discussion in the main text. ■

We next discuss the existence of an intermediate range of information costs, $\underset{\sim}{C} < \widetilde{C}$. The fixed investment cost of building up capacity F determines whether an intermediate range of information costs exists. When $F \notin \left(\underline{F}, \overline{F}\right)$ and $F \notin \left(\underset{\sim}{F}, \widetilde{F}\right)$, the choice to acquire information is independent of the private signal x_E and, therefore, of the incumbent's choice of opacity, resulting in $\underset{\sim}{C} = \widetilde{C}$. However, as long as F lies in at least one of the intermediate ranges above, the choice to invest at date 2 depends on the entrant's signal and thus the incumbent's opacity choice, resulting in $\underset{\sim}{C} < \widetilde{C}$. In this case, there is scope for the incumbent to deter the entrant, which constitutes a benefit of opacity. We henceforth assume that the fixed cost F lies in at least one of these intervals, so an intermediate information cost range exists.

We introduce some useful notation. Let $Q = \mathbf{1}\Big\{\Pi_E \geqslant C\Big\}$ denote the entrant's information choice at date 0. Let δ_D denote the deterrence level of opacity, which is the smallest level for which the entrant does not follow the market, $\Pi_E(\delta_D) \leqslant C$.

3.2 Incumbent bank choices of opacity and deposit rates

Having described entry, we turn to the choices of the incumbent bank. When maximizing the sum of expected profits in both periods, Π_I, the incumbent takes into account how its choices of opacity and the deposit rate in period 1 affect its failure probability and its charter value (expected profits in period 2), which is is higher without entry. The incumbent receives the charter value only when surviving, $R_1 \geqslant R_1^*$.

Since entry occurs only when the entrant follows the market, $Q = 1$, and invests, with probability $q(R_1)$, the incumbent's problem in period 1 can be written as

$$\max_{D_1,\delta_1} \Pi_I = \Pi_1 + \int_{R_1^*}^{\overline{R}_1} \Big(\Pi_2^*(1, R_1) - Qq(R_1)\big[\Pi_2^*(1, R_1) - \Pi_2^*(2, R_1)\big]\Big)\frac{1}{\alpha}dR_1. \tag{18}$$

The expected profits of the incumbent has two parts. The first part, $\Pi_1 = h_1\pi_1$, is the expected profits in period 1, just as in the one-period problem. The second part is the expected charter value of the incumbent bank. This formulation explicitly shows the cost of entry for the incumbent. Entry exacerbates competition in period 2, which reduces the incumbent's charter value due to lower future market shares and higher future deposit rates and bank fragility, so $\Pi_2^*(1, R_1) > \Pi_2^*(2, R_1)$.

The problem in (18) illustrates the opacity trade-off the incumbent bank faces in period 1. On the one hand—and as in the one-period model—higher opacity lowers profits in period 1. Recall that higher opacity results in a costly partial run on a solvent bank in period 1, $\frac{d\pi_1}{d\delta_1} < 0$, and not withdrawing from a failing bank reduces the expected return to investors and thus funding volume, $\frac{dh_1}{d\delta_1} < 0$. On the other hand, greater opacity can also deter entry, $Q = 0$, lowering competition in period 2 and raising future profits of the incumbent bank, $\Pi_2^*(N_2, R_1)$, and its charter value.

We obtain the following result on the incumbent's opacity choice in period 1.

Proposition 7. ***Bank opacity and deterrence.*** *Suppose* $\underset{\sim}{C} < C < \widetilde{C}$. *For* $\mu \leqslant \overline{\mu}$, *the incumbent uses opacity to deter entry,* $\delta_1^* = \delta_D$. *For* $\mu < \mu^P$, *the incumbent prefers deterrence over minimum opacity,* $\Pi_I(\delta_D) > \Pi_I(\underline{\delta})$, *and hence chooses* $\delta_1^* > \underline{\delta}$.

Proof. See Appendix E. ■

Following the previous argument, the incumbent bank has more incentives to be opaque than in the model without entry. The main condition for this result is a low enough transport cost μ.[42] The economic intuition is as follows. The incumbent enjoys a higher charter value when remaining a monopolist than when becoming a duopolist. This is for three reasons: future deposit rates D_2^* and future fragility R_2^* are lower as a monopolist and the market share is higher. All three forces reduce the incumbent's charter value upon entry, resulting in a benefit of opacity from deterrence. This reduction in charter value is higher when transport costs are lower (as the entrant is more competitive). On the other hand, the cost of opacity in period 1, which arises from the type I and II errors in withdrawal decisions, is lower for a lower transport cost. Since the deposit rate D_1^* is low, these errors are not very costly to the incumbent and are lower the lower the transport cost. In sum, the benefit of opacity via deterrence outweighs its costs for low transport costs.

[42]The other condition is an interior information cost, whereby the incumbent bank's opacity choice affects the entry choice of entrant. When the entry decision cannot be affected, the incumbent has nothing to gain from opacity and thus chooses minimum opacity, $\delta_1^* = \underline{\delta}$ when $C \notin (\underset{\sim}{C}, \widetilde{C})$.

It is direct to show that the incumbent offers a lower deposit rate D_1^* than in the one-period model. Because of positive expected profits in period 2, the incumbent has incentives to be solvent more often. It internalizes that a lower deposit rate reduces its fragility in period 1, $\frac{dR_1^*}{dD_1} > 0$, increasing the probability of survival and keeping the charter value. This result is in line with the charter value literature whereby higher charter value results in safer banks (**??**).[43]

3.3 Regulatory implications

We turn to implications for transparency regulation in the model with endogenous entry. We study the regulator's choice of the incumbent bank's opacity, δ_1^R.[44] The regulator maximizes utilitarian welfare W over both periods, stated in Appendix F. Welfare comprises (i) the sum of expected bank profits net of information and investment costs of the entrant and (ii) the expected returns to investors net of transport costs. We interpret the (opportunity) costs of information, C, and of investment, F, as social costs. While these assumptions make entry less desirable socially, we show that there are still incentives for the regulator to increase transparency.

Proposition 8. ***Transparency regulation.*** *Suppose $\underset{\sim}{C} < C < \widetilde{C}$. For intermediate transport costs, $\mu^S < \mu < \mu^P$, the regulator chooses higher transparency than the incumbent bank, $\delta_1^R < \delta_1^*$.*

Proof. See Appendix F. ■

The private and social incentives for opacity (and thus deterrence) differ in three ways. First, and as in the one-period model, the regulator includes the expected

[43]In **?** and **?**, the bank loses the entire charter value. In our model, by contrast, the incumbent only loses the charter value at the margin but keeps it for high returns. This result arises because the realized return in period 1 determines both (i) bank failure in period 1 and (ii) the expected return in period 2 (and thus the charter value).

[44]Since the regulator can set upper and lower bounds on bank opacity, it effectively picks δ_1.

return to investors and transport costs in its objective function. Greater transparency (i) increases the expected return to investors in period 1 and (ii) facilitates entry that lowers expected transport costs in period 2. Second, when the incumbent fails, $R_1 < R_1^*$, the social surplus from intermediation is only realized upon entry. This social benefit of entry is not internalized by the incumbent. Third, the incumbent loses market share upon entry but the regulator internalizes that this is only a redistribution from the incumbent to the entrant and does not constitute a social cost. Finally, entry leads to fiercer competition and higher fragility in period 2, which is a social cost of transparency. But it is also a private cost and fully internalized by the incumbent.

Taking all these effects into account, the private benefits of opacity and deterrence exceed the social benefits, which rationalizes a role for transparency regulation. We conclude that, for intermediate transport costs, the regulator imposes higher transparency than what is chosen by the bank (i.e., a minimum transparency level).

4 Extensions

4.1 Investor withdrawal incentives

To determine withdrawal incentives, we have so far followed the **?** approach, whereby the withdrawal decision is delegated from investors to fund managers. In this extension we relax this assumption and study the withdrawal incentives of investors who directly decide on withdrawals. In particular, we describe a tractable and plausible banking setup and show that the implications for fragility are the same as in the main text.

We make two additional assumptions relative to the main text. First, only a fraction $\overline{W} < 1$ of investors decide to withdraw or roll over their deposits at date 1, where $\overline{W}$ is low enough to rule out illiquidity and early closure of the bank. See, for example, **?** for a similar assumption in the context of runs on mutual funds. Rationales for this assumption include investor inattention or some investors not receiving a signal and rolling over based on a favorable prior (high enough R_0). Additional interpretations arise in the context of banking: some investors could also hold insured (retail) deposits or long-term debt, so there may not be an incentive or possibility to withdraw. For ease of exposition (e.g., to avoid the complications of different pricing of debt claims), we assume in this extension that a fraction of investors $1 - \overline{W}$ does not withdraw at date 1 and that a given investor does not know at date 0 whether an investor can withdraw at date 1. These assumptions can be relaxed in a more general model with different pricing of debt claims.

Second, we assume that investors consume at date 2 and can store their resources between date 1 and date 2 at a proportional cost $\phi \in (0, 1)$. Possible interpretations are that (i) investors require a fraction of the resources for storage and safe-keeping (e.g., to protect from theft); (ii) a fee or penalty is associated with early withdrawals; or (iii) there is a (time and resource) cost to opening an account with another intermediary.

Under these two assumptions, we can state an equivalence result between this setup in which investors directly decide on withdrawals and our main analysis.

Proposition 9. ***Investor withdrawal incentives.*** *The bank failure threshold is given by* $R^* = [1 + z(1 - \phi)]D$ *and the results from the main text apply for* $\gamma = 1 - \phi$.

Proof. See Appendix G. ■

Intuitively, investors trade off two forces when deciding whether to withdraw at date 1. If the bank fails at date 2, withdrawing yields the face value D that is worth $(1 - \phi)D$ at date 2, while not withdrawing yields zero due to insolvency. If the bank does not fail at date 2, rolling over yields the net benefit of ϕD (saving the storage costs). Thus, the bank is more fragile for smaller storage costs, $\frac{dR^*}{d\phi} < 0$.

As a concluding remark, we note that a key ingredient for the equivalence result is the debt-like nature of claims on banks.[45] Arguably, this is a realistic characterization of the banking sector, which has many debt-like liabilities such as deposits.

4.2 Idiosyncratic risk

We have focused on aggregate investment risk so far. In this extension, we allow for idiosyncratic investment risk among several incumbent banks in the two-period model studied in Section 3.[46] This approach allows us to (i) show how our main economic intuitions extend to setups in which the default of banks is also determined by an idiosyncratic component; and (ii) show the relevance of the intensity of competition (the number of incumbent banks) for our results.

Specifically, we study an economy with $j = 1, ..., N$ incumbent banks and the following investment return specification. Bank j's investment return in period T is

$$R_{Tj} = R_T + \eta_{Tj}, \tag{19}$$

where the $\eta_{Tj} \sim \mathcal{U}[-\frac{\alpha}{2}, \frac{\alpha}{2}]$ is the idiosyncratic risk component and i.i.d. across incumbent banks and independent over time, and R_T is the aggregate risk component:

$$R_2 = R_1 = R_0 + \Theta, \tag{20}$$

where R_0 is known and Θ is an aggregate shock that takes the value $\theta > 0$ with probability $p \in (0, 1)$ or zero. The aggregate risk component Θ is independent of the idiosyncratic components η_{Tj}. Nobody knows the realized aggregate risk at date 0 of period 1. To ease the exposition, we assume $\theta = \alpha$, so the support of the aggregate

[45] If investors had a claim that gives them an equal share of bank proceeds at date 2, then the bank failure threshold would be more convoluted.

[46] The one-period model in Section 2 effectively yields the same results with idiosyncratic risk.

investment returns under a positive or a negative shock are just not overlapping. As in the main model, fund managers and the entrant receive a private signal about a bank's investment return, $x^i_{Tj} = R_{Tj} + \epsilon^i_{Tj}$, where $\epsilon^i_{Tj} \sim \mathcal{U}\left[-\frac{\delta^j}{2}, \frac{\delta^j}{2}\right]$ are i.i.d. and independent of the aggregate and idiosyncratic components of investment risk.

Upon following the market, the entrant receives a signal x_E from one incumbent bank at random, indexed by $j = J$. It uses this signal to update its beliefs about aggregate risk Θ that affects the entrant's future investment return and expected profits.[47] We assume that the entrant observes the number of surviving incumbent banks, $n \leqslant N$, at date 2. Let $p' \equiv \Pr\{\Theta = \theta | x_E, n\}$ denote the entrant's posterior.

Since the information cost C is sunk at date 2, the entrant invests whenever it expects to recover at least the investment cost F:

$$p'\,\Pi^*_2(n+1, R_0+\theta) + (1-p')\Pi^*_2(n+1, R_0) \geqslant F, \tag{21}$$

for any n. Recall that, conditional on entry, the number of active banks in period 2 is $N_2 = n+1$. We assume the boundary conditions $\Pi^*_2(N+1, R_0) < F < \Pi^*_2(1, R_0+\theta)$, so ranges of the investment cost F exist such that the investment decision is non-trivial for at least one value of n: $\Pi^*_2(n+1, R_0) < F < \Pi^*_2(n+1, R_0+\theta)$.[48]

We are ready to state the main result about entry under idiosyncratic risk.

Proposition 10. ***Information acquisition by the entrant (idiosyncratic risk).*** *The entrant acquires information whenever $\Pi_E(\delta_J) \geqslant C$. Since $\frac{d\Pi_E}{d\delta_J} < 0$, there can only exist a unique deterrence level of opacity δ_D defined by $\Pi_E(\delta_D) \equiv C$.*

Proof. See Appendix H. ■

[47]Note that the entrant only wishes to learn about the realization of the aggregate component of investment risk Θ but not about the incumbent bank's idiosyncratic component η_{1J}, because only the former enters the entrant's investment return in period 2.

[48]The equivalent assumption in the main text is $F \in (\underline{F}, \overline{F})$, or $F \in \left(\underset{\sim}{F}, \tilde{F}\right)$, or both.

For a given level of opacity δ_J, the entrant infers the aggregate risk component perfectly when the signal is very low (so $\Theta = 0$ and $p' = 0$) or very high (so $\Theta = \theta$ and $p' = 1$). In these cases, the entrant makes no mistakes: it invests if and only if it is profitable to do so. For intermediate signals, however, the entrant does not perfectly learn the realized aggregate risk, $p' \in (0, 1)$. Thus, it makes costly mistakes by sometimes investing when it is not profitable ($\Theta = 0$) and sometimes not investing when it would have been profitable to do so ($\Theta = \theta$).

As opacity δ_J increases, this intermediate range of signals expands (on both ends). Thus, the entrant makes more costly mistakes, which reduces its expected profits of following the market, $\frac{d\Pi_E}{d\delta_J} < 0$. Hence, for intermediate information costs, a unique deterrence level δ_D exists.

We turn to the choices of incumbent banks at date 0. As in the main model, they consider the impact of their choices on both current profits and charter value. Incumbent banks use the prior about the aggregate investment return, p. The realization of Θ affects the (conditional) distribution of the bank-specific investment return, $R_{1j}|\Theta$, and the (conditional) distribution of the number of surviving incumbent banks, $f_\Theta(n) \sim B(N, s_\Theta)$. The latter is binomial with N incumbent banks and individual probability of survival $s_\Theta \equiv \Pr\{R_{1j} \geqslant R_1^*|\Theta\}$, where R_1^* is the failure threshold in the symmetric equilibrium. Taken together, an incumbent bank's problem in period 1 is

$$\begin{aligned}\max_{D_{1j},\delta_{1j}} \Pi^j \quad = \quad & \Pi_1^j + p \int_{R_1^*}^{R_0+\theta+\frac{\alpha}{2}} \sum_{k=0}^{N-1} f_\theta(k) \left[e\Pi_2^*(k+1, R_0+\theta) + (1-e)\Pi_2^*(k+2, R_0+\theta)\right] \frac{dR_1}{\alpha} \\ & +(1-p) \int_{R_1^*}^{R_0+\frac{\alpha}{2}} \sum_{k=0}^{N-1} f_0(k) \left[e\Pi_2^*(k+1, R_0) + (1-e)\Pi_2^*(k+2, R_0)\right] \frac{dR_1}{\alpha} \qquad (22)\end{aligned}$$

where e is the probability of the entrant entering in period 1 (following the market and investing) and k is an index of *other* incumbent banks who survive period 1.

We next state results about opacity choice and deterrence under idiosyncratic risk. We focus on two extreme cases: monopoly and perfect competition.

Proposition 11. ***Incumbent bank opacity choice and competition.*** *For $N \to \infty$, each incumbent bank chooses maximum transparency, $\delta^*_{1j} = \underline{\delta}$. For $N = 1$ and μ low enough, the incumbent chooses positive opacity, $\delta^*_1 = \delta_D$, and deters the entrant.*

When the number of incumbent banks is high, future expected profits are low. As a result, the probability of entry is low and the benefit to an incumbent of deterring the potential entrant is small. As a result, the incumbent bank chooses to be transparent as the cost of opacity exceed the benefits (which vanish in the limit of perfect competition, $N \to \infty$). When the incumbent bank is a monopolist, we obtain a result very similar to the main model. For low enough transport cost, future competition upon entry is fierce and substantially reduces incumbent bank charter value, inducing the incumbent to be opaque in order to deter the entrant.

Taken together, the results of our main section can generalize to a model with idiosyncratic risk and several incumbent banks. These results also highlight the intensity of competition as a key determinant of bank opacity. Consistent with this implication, **?** document that regulatory shocks that increase bank competition (branch deregulation) leads to an increase in bank transparency.

4.3 Cournot competition

We have studied imperfect competition for funding as in **?**. In this extension, we show that our main results extend to other imperfect competition setups such as the Cournot model. Thus, our main conclusions hold when we change from a setup of imperfect competition in prices and heterogeneous bank characteristics (Salop) to a setup in which homogeneous banks compete in quantities (Cournot).[49]

[49]**?** show that the Cournot model is analogous to a setup in which banks first commit to quantities (e.g., branches) and then compete via deposit rates as in Bertrand.

To illustrate this point, consider an increasing and weakly convex inverse demand function for bank deposits $\rho(H)$, where $h_j \geqslant 0$ are bank j's deposits and $H = \sum_{j=1}^{N} h_j$ are total deposits. Hence, banks have to offer higher expected returns to investors, ρ, in order to raise more deposits. Bank j decides how many deposits h^j and the opacity level δ^j to offer in period 0. Following the same argument as in Proposition 2, banks choose minimum opacity, $\delta_j^* = \underline{\delta}$. Thus, bank j's problem reduces to

$$\max_{h_j} h_j \, \pi(\rho(H)). \tag{23}$$

The first-order condition, $\pi + h_j \frac{d\pi}{dD} \frac{dD}{d\rho} \frac{d\rho}{dH} = 0$, specifies a profit maximum, where $D(\rho)$ solves Equation (5). One can show that, in the symmetric equilibrium, $h_j^* = h^*$, higher competition increases total deposits, $\frac{dH^*}{dN} > 0$. Given the increasing inverse demand, higher competition increases the expected return to investors, $\frac{d\rho^*}{dN} > 0$, and the deposit rate, $\frac{dD^*}{dN} > 0$, which in turn increases fragility, $\frac{dR^*}{dN} > 0$.

Figure 5 shows how our main results are robust to Cournot competition. Higher competition leads to higher deposit rates and higher default probability. Moreover, the level of competition is a key factor in determining how shocks affect fragility. For example, a shock to investment returns has a higher impact on deposit rates in more competitive markets (higher pass-through), resulting in a greater effect on fragility.

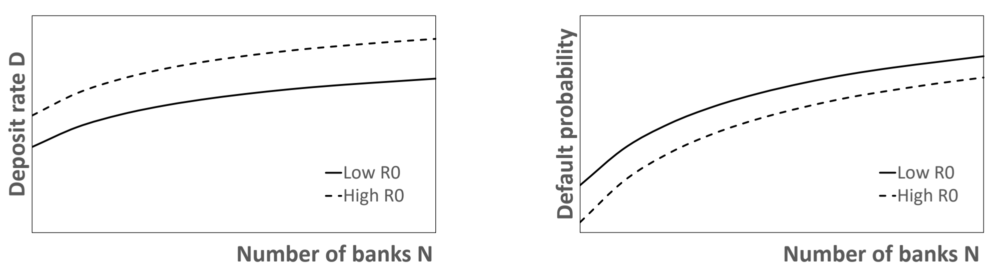

Figure 5: Competition-fragility view: the deposit rate D^* and the probability of bank failure $\Pr\{R < R^*\}$ increase in the degree of competition N (for Cournot competition).

5 Conclusion

This paper presents a tractable model in which imperfectly competitive banks choose their opacity levels and deposit rates that in turn determine the probability of a bank run and the entry choice of a competitor. Using this model, we evaluate how different recent developments in the banking industry, such as changes in competitive intensity or opacity, affect bank fragility, the competitive structure, and welfare. We also derive implications for competition policy and the regulation of bank transparency that arise because of a wedge between the social and private incentives for bank opacity.

We offer a parsimonious micro-founded setup in which banks have intermediation rents due to imperfect competition and show how higher bank competition and higher bank transparency result in higher deposit rates. Higher rates then increase strategic complementarities in withdrawal decisions, raising the probability of a bank run. We also propose a theory of bank opacity. On the one hand, opacity increases partial runs on a solvent bank, lowering expected bank profits as well as the expected return to investors. Hence, banks have an incentive to be transparent. On the other hand, opacity reduces the incentives of a potential entrant to enter which raises incumbent bank profits via lower future competitive intensity, lower future fragility, and higher future market share. When competition is low banks are prone to be opaque, while a regulator chooses higher levels of bank transparency.

Our paper shows how competition in the banking sector and bank opacity are key determinants for deposit rates and bank fragility. We also highlight how both competition and opacity are interlinked. Bank opacity choices affect future competition in the industry through their effect on entry and exit, while current competition affects bank opacity choices through an effect on deterrence incentives. Regarding testable implications, our model suggests that shocks that increase bank competition lead to higher bank transparency, deposit rates, and fragility. Moreover, shocks that increase transparency lead to higher entry, deposit rates, and fragility.

A Proof of Proposition 1

Figure 6 shows the dominance regions if the investment return R were common knowledge. When no funding is withdrawn, $w = 0$, the bank fails when the return is below $\breve{R} \equiv D$, the face value of debt. When all funding is withdrawn, $w = 1$, the bank does not fail when the return exceeds $\widehat{R} \equiv \frac{D}{\psi} > \breve{R}$.

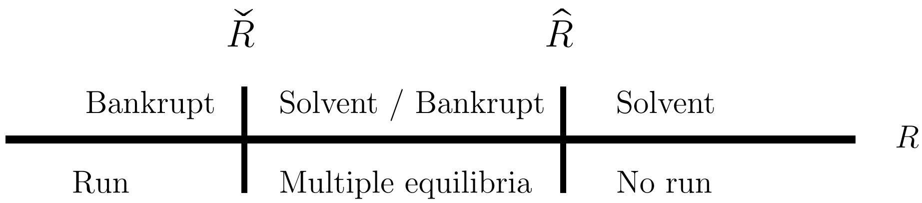

Figure 6: Tripartite classification of investment return (complete information)

Turning to the equilibrium when information about the investment return is incomplete, we solve for the signal and return thresholds (x^*, R^*). Since the insolvency condition is less restrictive than the illiquidity condition, the former is used (**?**). Thus, a **critical mass condition** states that the bank fails at R^*:

$$R^* = [1 + zw(R^*)]\, D, \tag{24}$$

where the face value is chosen at date 0 and the withdrawal proportion at date 1 is

$$w(R) = \Pr\{x_i < x^* | R\} = \begin{cases} 1 & R \leqslant \underset{\sim}{R} = x^* - \frac{\delta}{2} \\ \frac{x^* - R + \delta/2}{\delta} & \text{if} \quad R \in \left(\underset{\sim}{R}, \widetilde{R}\right) \\ 0 & R \geqslant \widetilde{R} = x^* + \frac{\delta}{2} \end{cases}$$

due to the distribution of ϵ_i. The posterior distribution is $R|x_i \sim \mathcal{U}\left[x_i - \frac{\delta}{2}, x_i + \frac{\delta}{2}\right]$ for signals $\underline{R} + \frac{\delta}{2} \equiv \underline{x_i} \leqslant x_i \leqslant \overline{x_i} \equiv \overline{R} - \frac{\delta}{2}$ by Bayesian updating. We study these signals first and 'extreme signals' at the end of this proof. A manager who receives $x_i = x^*$ is indifferent between rolling over and withdrawing (**indifference condition**):

$$c \Pr\{R > R^* | x_i = x^*\} = b \Pr\{R < R^* | x_i = x^*\}. \tag{25}$$

Using the posterior distribution of $R|x^*$, the indifference condition can be expressed as $\gamma = \frac{x^* - R^* + \frac{\delta}{2}}{\delta}$. This result implies the stated failure threshold R^* and signal threshold x^*. Inserting x^* into $\widetilde{R}$ and $\underset{\sim}{R}$ yields the bounds of $w^*(R)$ stated in the main text.

In equilibrium, the threshold fund manager receives the signal $x_i = x^*$ and is indifferent between rolling over and withdrawing funding. Both the conditional probability of bank survival of the threshold manager and the withdrawal proportion at the failure threshold are equal to the conservatism ratio, $\Pr\{R > R^*|x_i = x^*\} = \gamma = w(R = R^*)$. When fund managers are more conservative, the threshold manager requires a higher conditional survival probability and fund managers are more inclined to withdraw, $\frac{\partial w(R)}{\partial \gamma} \geqslant 0$, resulting in a higher failure threshold, $\frac{\partial R^*}{\partial \gamma} > 0$.

Finally, we consider extremely low and high signals, $x_i \leqslant \underline{x_i}$ and $x_i \geqslant \overline{x_i}$. These imply that the posterior distribution becomes non-uniform since the boundary of the signal is close to the boundary of the investment return. We impose sufficient conditions for our focus on the uniform part of the posterior to be appropriate. In particular, we proceed by imposing a lower bound on α to ensure that a fund manager who receives $x_i = \underline{x_i}$ strictly prefers to withdraw, and a fund manager who receives $x_i = \overline{x_i}$ strictly prefers to roll over. These conditions have to hold for any level of opacity and are most stringent for $\delta = \bar{\delta}$. Using the posterior $R|\underline{x_i} \sim \mathcal{U}\left[\underline{R}, \underline{R} + \delta\right]$, a manager with signal $x_i = \underline{x_i}$ strictly prefers to withdraw, for which $R^* > \underline{R} + \bar{\delta}$ is a sufficient condition. Similarly, using the posterior $R|\overline{x_i} \sim \mathcal{U}\left[\overline{R} - \delta, \overline{R}\right]$, a manager with $x_i = \overline{x_i}$ strictly prefers to roll over, for which $R^* < \overline{R} - \bar{\delta}$ is sufficient. Using the bounds on the equilibrium face value of debt derived in Appendix B, $\frac{\mu}{2} < D^* < D^*_{max}$, we can express these conditions as a lower bound on investment risk:

$$\alpha \geqslant \underline{\alpha} \equiv 2 \max\left\{R_0 + \bar{\delta} - (1 + z\gamma)\frac{\mu}{2}, \frac{\bar{\delta}}{\kappa - 1}\right\}, \tag{26}$$

which we impose henceforth. Intuitively, for high investment risk, the prior is fairly dispersed, so failure is likely at the bottom of the distribution and unlikely at its top.

B Proof of Propositions 2 – 3 (and related results)

We solve the Salop model of imperfect competition at date 0. Consider first $N \geqslant 2$. The return of some investor k from depositing with bank j is $\rho^j - \mu d_k^j$, where d_k is distance. Since the market is covered for $N \geqslant 2$, we can focus on the two banks nearest to k, whose distance is d_k and $\frac{1}{N} - d_k$ as banks are equidistant on the unit circle. Hence, the location at which investor k is indifferent between either bank is $d_k^* = \frac{\rho^1 - \rho^2}{2\mu} + \frac{1}{2N}$. Total funding comes from both sides relative to a bank's location, so its amount is

$$h^j = 2d_k^* = \frac{\rho^j - \rho^{-j}}{\mu} + \frac{1}{N}, \tag{27}$$

which increases in the expected return to investors, $\frac{dh^j}{d\rho^j} = \frac{1}{\mu} > 0$.

The following intermediate results are useful (dropping the index j):

$$\frac{d\pi}{d\delta} = -\frac{\gamma^2 zD}{2\alpha} < 0, \qquad \frac{d\rho}{d\delta} = D\int_{R_{IL}}^{R^*} \frac{dw(R)}{d\delta}\frac{dR}{\alpha} < 0, \tag{28}$$

because more opacity leads to fewer withdrawals from banks that fail at date 2, $\frac{dw}{d\delta} < 0$. It follows that the first-order condition (FOC) of the problem in (8) with respect to opacity yields the corner solution $\delta^* = \underline{\delta}$ for all banks j:

$$\frac{d\Pi^j}{d\delta^j} = \frac{dh^j}{d\rho^j}\frac{d\rho^j}{d\delta^j}\pi^j + h^j\frac{d\pi^j}{d\delta^j} < 0. \tag{29}$$

In the remainder of this section (except for the comparative static w.r.t. $\underline{\delta}$), we evaluate all expressions at $\underline{\delta} \to 0$. Next, the FOC with respect to the deposit rate is

$$\frac{d\Pi^j}{dD^j} = \frac{dh^j}{d\rho^j}\frac{d\rho^j}{dD^j}\pi^j + h^j\frac{d\pi^j}{dD^j} = 0. \tag{30}$$

Evaluating this condition at the symmetric equilibrium, $h^j = h^* = \frac{1}{N}$, yields the condition stated in Proposition 2. Since $\frac{d\pi}{dD} = -\frac{z\gamma(1+z\gamma)D+\overline{R}-R^*}{\alpha} < 0$, the bank only increases the deposit rate if it increases the expected return to investors, $\frac{d\rho}{dD} = \frac{1}{\alpha}\left(\overline{R} - \kappa R^*\right)$. Thus, $\frac{d\rho}{dD} > 0$ in equilibrium, so $D^* < D^*_{max} \equiv \frac{\overline{R}}{(1+z\gamma)\kappa}$. Moreover, $D^* \to D^*_{max}$ and $R^* \to R^*_{max} \equiv \frac{\overline{R}}{\kappa}$ for $N \to \infty$.

The second-order condition (dropping j) is $\frac{d^2\Pi}{dD^2} = \frac{2}{\mu}\frac{d\rho}{dD}\frac{d\pi}{dD} + \frac{d^2\rho}{dD^2}\frac{\pi}{\mu} + \frac{1}{N}\frac{d^2\pi}{dD^2}$. Note that $\frac{d^2\rho}{dD^2} = -\frac{\kappa(1+z\gamma)}{\alpha} < 0$ and $\frac{d^2\pi}{dD^2} = \frac{1-z^2\gamma^2}{\alpha}$. Moreover, we have $\frac{d^2\pi}{dD^2} \leqslant 0$ if $z\gamma \geqslant 1$. Hence, $\frac{d^2\Pi}{dD^2} < 0$ (and thus a maximum of expected profits Π) is ensured by $z\gamma \geqslant 1$.

We turn to comparative statics. For part (a), we obtain $\frac{d^2\Pi}{dDdN} = -\frac{d\pi}{dD}\frac{1}{N^2} > 0$ and $\frac{dD^*}{dN} > 0$ from the implicit function theorem (IFT). Thus, $\frac{dR^*}{dN} > 0$ follows from $\frac{dR^*}{dD} > 0$ (Proposition 1). Similarly, $\frac{d^2\Pi}{dDd\mu} = -\frac{1}{\mu^2}\frac{d\rho}{dD}\pi < 0$, so we obtain $\frac{dD^*}{d\mu} < 0$ from the IFT and $\frac{dR^*}{d\mu} < 0$. For part (b), we consider the effect of exogenous changes in transparency and abstract from the limit of $\underline{\delta} \to 0$ for this comparative static only. Note that $\frac{d^2\pi}{d\delta dD} = -\frac{\gamma^2 z}{2\alpha} < 0$. Since $\frac{dR_{IL}}{dD} \leqslant 1 + \gamma z$, one can show that $\frac{d^2\rho}{d\delta dD} < 0$. Hence, $\frac{d^2\Pi}{dDd\delta} < 0$, so $\frac{dD^*}{d\underline{\delta}} < 0$ from the IFT. The result on fragility, $\frac{dR^*}{d\underline{\delta}} < 0$ again follows from Proposition 1. For part (c), we have $\frac{d\Pi_\lambda}{dD} = \frac{d\Pi}{dD} - \frac{\lambda}{\mu}\frac{d\rho}{dD}$ and $\frac{d^2\Pi_\lambda}{dD^2} = \frac{\pi-\lambda}{\mu}\frac{d\rho^2}{dD^2} + \frac{2}{\mu}\frac{d\rho}{dD}\frac{d\pi}{dD} + \frac{1}{N}\frac{d^2\pi}{dD^2} < 0$ and $\frac{d^2\Pi_\lambda}{dDd\lambda} = -\frac{1}{\mu}\frac{d\rho}{dD} < 0$. By the IFT, $\frac{dD^*}{d\lambda} < 0$ and $D^*_\lambda < D^*$. And the result on fragility, $R^*_\lambda < R^*$, again follows from Proposition 1.

We turn to the next case of a monopolist, $N = 1$. In this case, the market can be covered (i.e., all investors are served in equilibrium) or uncovered. First, we consider an uncovered market (which arises for high enough transport cost μ). When the outside option of investors is normalized to zero, the distance that makes the marginal investor indifferent between depositing with the bank and not is $d^*_k = \frac{\rho}{\mu}$. Since the bank raises funding from both sides, the funding volume is $h_M = \frac{2\rho}{\mu}$, where M indicates monopolist. The optimal opacity choice is again $\delta^* = \underline{\delta}$ and the deposit rate D^*_M is pinned down by $\frac{d\Pi}{dD} = 0$, as in the main text, but with a new value for h^*_M and $\frac{dh_M}{d\rho} = \frac{2}{\mu}$. The value function in this case is $\Pi^*(1, R_0) = \Pi(D^*_M, \underline{\delta})$.

When the monopolist instead faces a covered market (for low μ), D^*_M solves $\rho_M(D^*_M) = \frac{\mu}{2}$ and $h^*_M = 1$. The value function is still given by $\Pi^*(1, R_0) = \Pi(D^*_M, \underline{\delta})$.

C Proof of Proposition 4

We consider $N \geqslant 2$. Collecting terms, we have

$$W = \frac{1}{2\alpha}\left(\overline{R}^2 - \psi \underline{R}^2 - (1-\psi)(R^*)^2\right) - \frac{\mu}{4N}. \tag{31}$$

The total derivative w.r.t. N yields the first-order condition stated in the proposition, where

$$\frac{dR^*}{dN} = (1+z\gamma)\frac{\mu}{N^2}\frac{\frac{d\pi}{dD}}{\pi\frac{d^2\rho}{dD^2} + 2\frac{d\rho}{dD}\frac{d\pi}{dD} + \frac{\mu}{N}\frac{d^2\pi}{dD^2}}. \tag{32}$$

Let $A \equiv \frac{1}{4} - \frac{(1-\psi)R^*}{\alpha}\frac{\frac{d\pi}{dD}}{\pi\frac{d^2\rho}{dD^2}+2\frac{d\rho}{dD}\frac{d\pi}{dD}+\frac{\mu}{N}\frac{d^2\pi}{dD^2}}$ and A^∞ denote its limit for $N \to \infty$. Thus, one can use $\frac{dW}{dN}$ to show that $N^* < \infty$ if $A^\infty < 0$. Using $D^* \to D^*_{max}$ and $R^* \to R^*_{max}$, one can show that $A^\infty = \frac{1}{4} - \frac{(1-\psi)(1+z\gamma)(\kappa-1+z\gamma)}{\kappa(\kappa-1)\left(\frac{\kappa+1}{2}(1+z\gamma)-1\right)}$. Using $\kappa < 2$ and $z\gamma \geqslant 1$, one can derive an upper bound on A^∞ and show that it is always negative. Thus, N^* is interior.

D Proof of Proposition 5

To shed some light on the posterior g, consider for illustration the case of the failure of the incumbent, so $\underline{R}_1 \leqslant R_1 \leqslant R_1^*$. In this case, the entrant infers that $R_1 = \underline{R}_1$ after the worst possible signal, $x_E = \underline{R}_1 - \frac{\delta}{2}$, and that $R_1 = R_1^*$ after the best possible signal, $x_E = R_1^* + \frac{\delta}{2}$. For intermediate signals, $\underline{R}_1 + \frac{\delta}{2} \leqslant x_E \leqslant R_1^* - \frac{\delta}{2}$, the posterior distribution is uniform, $R_1|x_E \sim \mathcal{U}[x_E - \frac{\delta}{2}, x_E + \frac{\delta}{2}]$.

The bounds on the fixed cost imply entry after the best-possible or worst-possible profits in period 2 for the entrant. These profits arise when the entrant infers that the investment return is certainly $\underline{R}_1$, R_1^*, or $\overline{R}_1$. That is, after the failure and the survival of the incumbent bank, respectively:

$$\underset{\sim}{F} \equiv \Pi_2^*(1, \underline{R}_1) < \Pi_2^*(1, R_1^*) \equiv \widetilde{F}, \qquad \underline{F} \equiv \Pi_2^*(2, R_1^*) < \Pi_2^*(2, \overline{R}_1) \equiv \overline{F}, \tag{33}$$

because of strict monotonicity in R_1.

The equilibrium is characterized by a threshold strategy. The entrant invests whenever $F \leqslant V$, where the value of investment V increases in the signal x_E for two reasons. First, a higher signal x_E leads to a more favorable posterior, $R_1|x_E$, in the first-order stochastic dominance sense. Second, the entrant assigns a higher expected profit to these higher realizations of the investment return (because $\frac{d\Pi_2^*}{dR_1} > 0$). Taken together, we have $\frac{dV}{x_E} > 0$, so a unique threshold x_E^* exists for intermediate fixed costs. Note that this argument applies irrespective of the survival of the incumbent.

E Proof of Proposition 7

The first part of the proof uses a continuity argument. Suppose $\mu \to 0$. In period 1, the equilibrium is $h_1^M = 1$, $\rho_1^* \to 0$, $D_1^* \to 0$, $R_1^* = \underline{R}_1$, and $TC_T \to 0$ for $T = 1, 2$. Thus, the cost of opacity in period 1 converges to zero. Consider next the benefits of opacity, which arise in period 2. If the incumbent remains a monopolist—which can be achieved via deterrence, $\delta_1 = \delta_D$—we again have $h_2^M = 1$, $\rho_2^* \to 0$, $D_2^* \to 0$, $R_2^* = \underline{R}_2$, so the expected profits in period 2 are $\Pi_2^*(1, R_1) \to R_1$. Without deterrence, the market must be shared with the entrant, $N_2 = 2$, whenever R_1 is such that the entrant builds up capacity. In these cases, a low transport cost implies fierce competition (similar to the one-period model for $N \to \infty$), so $D_2^* = \frac{\overline{R}_2}{\kappa(1+\gamma z)}$, $R_2^* = \frac{\overline{R}_2}{\kappa}$, and $\pi_2^* = \frac{(\kappa-1)\overline{R}_2^2}{\alpha\kappa^2}\left[\frac{\kappa+1}{2} - \frac{1}{1+\gamma z}\right] > 0$. Thus, $\Pi_2^*(2, R_1) < \Pi_2^*(1, R_1)$. Hence, the incumbent strictly prefers deterrence, $\delta_1^* = \delta_D$, for $\mu \to 0$. By continuity, there exists a $\overline{\mu} > 0$ such that the benefit of opacity and deterrence exceeds its costs for any $\mu \leqslant \overline{\mu}$.

Next, as μ increases, the deposit rate in period 1, D_1^* increases. Thus, the cost of opacity increases (due to costly type I and II errors in the withdrawal choice that increase in D_1^*). Moreover, the benefit of opacity decreases because competition upon entry will be less fierce, reducing the benefit of deterrence. Hence, there exists a μ^P such that the incumbent prefers deterrence, $\delta_1 = \delta_D$, over minimum opacity, $\delta_1 = \underline{\delta}$, if and only if $\mu < \mu^P$, where P refers to the private choice of the incumbent.

F Proof of Proposition 8

In contrast to the incumbent, the regulator (i) includes the expected return to investors and transport costs in both periods in its objective function; (ii) internalizes the social benefit of intermediation when the incumbent fails; (iii) recognizes that the transfer of market share from the incumbent to the entrant is a private cost but not a social one; and (iv) accounts for the social cost of information and investment.

Taken together, welfare can be expressed as follows, where we focus on the relevant case of intermediate information costs, $\underset{\sim}{C} < C < \widetilde{C}$:

$$
\begin{aligned}
W = {} & h_1^* \pi_1^* + \rho_1^* - \frac{\mu}{4} + \mathbf{1}\Big\{\delta_1 \geqslant \delta_D\Big\} \int_{R_1^*}^{\overline{R}_1} \left[\Pi_2^*(1, R_1) + \rho_2^*(1, R_1) - \frac{\mu}{4}\right] \frac{1}{\alpha} dR_1 + \\
& + \mathbf{1}\Big\{\delta_1 < \delta_D\Big\} \left[\int_{\underline{R}_1}^{R_1^*} q \left[\Pi_2^*(1, R_1) - F + \rho_2^*(1, R_1) - \frac{\mu}{4}\right] \frac{dR_1}{\alpha} + \int_{R_1^*}^{\overline{R}_1} q \left[\Pi_2^*(2, R_1) - F\right] \frac{dR_1}{\alpha} - C\right] + \\
& + \mathbf{1}\Big\{\delta_1 < \delta_D\Big\} \int_{R_1^*}^{\overline{R}_1} (1-q) \left[\Pi_2^*(1, R_1) + \rho_2^*(1, R_1) - \frac{\mu}{4}\right] + q \left[\Pi_2^*(2, R_1) + \rho_2^*(2, R_1) - \frac{\mu}{2}\right] \frac{dR_1}{\alpha}.
\end{aligned} \tag{34}
$$

We can generalize the result from Proposition E for the regulator to derive a threshold μ^S (where S refers to the social choice of the regulator). That is, the regulator prefers deterrence, $\delta_1 = \delta_D$, over minimum opacity, $\delta_1 = \underline{\delta}$, if and only if $\mu < \mu^S$. As a result of the divergences between the incumbent and the regulator described above, these thresholds are ranked $\mu^S < \mu^P$. This result arises because the additional terms considered by the regulator benefit from transparency and entry. For example, the expected return to investors in period 1 increases in transparency and the expected transport costs in period 2 decrease in transparency because transparency supports entry. The entrant's profits are also higher when the incumbent is transparent.

We next show that the regulator chooses less opacity than the incumbent, $\delta_1^R < \delta_1^*$, in this interior range, $\mu^S < \mu < \mu^P$. First, note that, by construction of μ^S and μ^P, we have $\delta_1^* > \underline{\delta}$ and $\delta_1^R < \delta_D$. Hence, if the solutions are either $\delta_1^* = \delta_D$ or $\delta_1^R = \underline{\delta}$, or both, then the desired result follows immediately. Second, consider the case when both the private and the social choice is interior. The proof proceeds by comparing the first-order conditions for δ_1^* and δ_1^R. Comparing the first-order condition $\frac{dW}{d\delta_1} = 0$ to the first-order condition $\frac{d\Pi_I}{d\delta_1} = 0$ reveals that these conditions differ in four terms and all of which are negative due to the deterrence of opacity. As a result, $\delta_1^R < \delta_1^*$.

G Proof of Proposition 9

The net benefit of withdrawing is $(1-\phi)D$ upon bank failure ($R < R^*$) and the net benefit of not withdrawing upon no failure ($R \geqslant R^*$) is ϕD. Thus, we can use the approach outlined in Appendix A and replicate all the results for $\gamma = 1-\phi$. To ensure no early closure at date 1, we require that maximum withdrawals, $\overline{W}D$, can be covered by liquidation of investment that yields at least $\psi\underline{R}$. As a result, the upper bound on $\overline{W}$ solves $\overline{W} \equiv \frac{\psi\underline{R}}{D}$ when evaluated at the equilibrium face value of debt.

H Proof of Proposition 10

While observing the number of surviving incumbent banks n is informative about the aggregate component Θ, it is never fully revealing. The reason is that each realization of n occurs with positive probability under both conditional binomial distributions. To perfectly infer the realization of Θ, the entrant has to receive an extreme enough signal x_E.

Consider first the case in which $\Theta = 0$. Note that $x_E^{\theta,worst} = R_0 + \theta - \frac{\alpha+\delta}{2}$ is the worst possible signal the entrant could receive if Θ were equal to θ. Hence, the entrant can perfectly infer that $\Theta = 0$ and $p' = 0$ if $x_E < x_E^{\theta,worst}$. Given that $\Theta = 0$, the probability of being able to infer perfectly (and not making any costly mistakes in the investment choice) is

$$\Pr\{x_E < x_E^{\theta,worst} | \Theta = 0\} = 1 - \frac{\delta_J}{2\alpha}, \tag{35}$$

which decreases in incumbent bank opacity δ_J.

Consider next the case in which $\Theta = \theta$. Note that $x_E^{0,best} = R_0 + \frac{\alpha+\delta}{2}$ is the best possible signal that the entrant could receive if Θ were equal to 0. Hence, the entrant can perfectly infer that $\Theta = \theta$ and $p' = 1$ if $x_E > x_E^{0,best}$. Given that $\Theta = \theta$, the probability of being able to infer perfectly (and not making any costly mistakes in the investment choice) is

$$\Pr\{x_E > x_E^{0,best} | \Theta = \theta\} = 1 - \frac{\delta_J}{2\alpha}, \tag{36}$$

which again decreases in incumbent bank opacity δ_J.

Taken together, the higher incumbent bank opacity δ_J, the larger the range in which the entrant makes costly mistakes and, thus, the lower its expected profits of acquiring information at date 0, $\frac{d\Pi_E}{d\delta_J} < 0$. The uniqueness of δ_D follows immediately.