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Bank capital structure and regulation: Overcoming and embracing adverse selection☆

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ABSTRACT

We study bank regulation under optimal contracting, absent exogenous distortions. In equilibrium, banks offer a senior claim (deposits) to external investors and retain equity; the return on equity is higher than the return on deposits due to a scarcity of skilled bankers. Inefficient equilibria emerge under asymmetric information. Optimally designed regulation restores efficiency. Our main result is that disclosure requirements by themselves can be endogenously costly because they may push the economy from a separating equilibrium to a less efficient equilibrium that pools good and bad banks, but always improve welfare when combined with capital regulation.

1. Introduction

Since Basel II, bank regulators have emphasized not just capital adequacy requirements but also micro-prudential regulation aimed at enhancing bank-level transparency and fostering market discipline, the so-called third pillar. The global financial crisis further accelerated the push for transparency following the recommendation of the Squam Lake Report: the Federal Reserve discloses stress test outcomes each year, and the European Banking Authority (EBA) conducts transparency exercises at the EU-wide level on an annual basis since 2011. At the same time, regulators have substantially tightened bank capital requirements in Basel III.

In existing theories of bank capital structure, privately and socially optimal capital structures coincide, and welfare is maximized in the unregulated equilibrium (e.g., Allen et al., 2015). Then, bank regulation is only necessary in the presence of distortions such as mispriced deposit insurance and government guarantees. We present an optimal contracting model in which regulation may be relevant without resorting to institutional distortions. Under asymmetric information, the need for regulation arises from the existence of pooling equilibria in which the social cost of bad bankers is not fully internalized by the good bankers. In our setting, optimal regulation implies that unregulated (shadow) banks should not be allowed to operate since they may lead to inefficient equilibria.

Through capital adequacy requirements regulators can solve an adverse selection problem by pushing the bad banks out (see Posner, 2015), while disclosure requirements directly reduce the severity of the adverse selection problem by making banks more transparent. Surprisingly,

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even though we assume that the exogenous cost of disclosure is zero, disclosure requirements may not be used because they are endogenously costly. For some parameters, higher disclosure may shift the economy from a separating to a pooling equilibrium in which value-destroying bad banks also participate, which is welfare-reducing. This adverse selection cost associated with inefficient pooling equilibria is the endogenous cost of disclosure. However, if optimally designed capital requirements are concurrently used to drive out the bad bankers, higher disclosure is always welfare-improving. Hence, optimally designed capital requirements and disclosure requirements can jointly improve upon the unregulated market outcome, although each of them separately may not be used.

Therefore, our model implies that macro-prudential regulation, which is aimed at reducing the risk of the overall system (e.g., capital requirements), interacts with the effectiveness of micro-prudential regulation, which targets bank-specific risk and fosters market discipline (e.g., disclosure requirements). This interaction is often ignored in existing models and policy discussions (an exception being Acharya and Thakor, 2016), but we show it can be of crucial relevance. Consistent with the implication that capital and disclosure requirements can be complementary, Kovner and Van Tassel (2020) find that post-crisis regulation (featuring stricter capital requirements and increased disclosure via stress testing) has lowered systematic risk in the US banking industry and the cost of capital for banks.

Model preview. We consider a model with heterogeneously skilled investors. Given the frictions we consider, the optimal banking arrangement entails that the unskilled investors become depositors in the bank, and the skilled investors become bankers and the equity-holders (residual claimants). The return on equity is endogenously higher than the return on deposits due to the scarcity of the skill required to manage banks. Thus, we rationalize a standard assumption in the literature that bank equity is costlier than deposits (see e.g., Hellmann et al., 2000, Horvath and Wagner, 2017, Arping, 2019, and Bahaj and Malherbe, 2020, among others).

There are two types of investors: skilled and unskilled, and the investor type is publicly observable (we introduce asymmetric information later). The skilled have access to a profitable project, whereas the unskilled may either put their funds in a storage technology or invest with the skilled. The key friction in our model is that a bank manager can divert a fraction of the final cash flow from the depositors. In reality, diversion may take different forms. In the context of banking, Acharya et al. (2011) document that during the financial crisis of 2007–2009, there were large scale dividend payouts, despite widely anticipated credit losses. The payouts can be thought of as a transfer from creditors to equity holders. The diversion feature appears in many articles, both in the context of banks and non-financial firms, including Calomiris and Kahn (1991), Hart and Moore (1995) and Shleifer and Wolfenzon (2002).

If diversion is sufficiently large, bank capital structure is relevant, and the optimal arrangement entails that the unskilled investors become depositors and the skilled become equity-holders. By offering the senior (debt) contract to the unskilled investors and so priority over the pledgeable cash flows, the skilled investors attract the maximum outside funds into the bank, which maximizes bank profit. Therefore, deposit and equity markets are segmented (see also the model of Boot and Thakor (1993) where market segmentation between equity and deposits arises endogenously in an optimal security design setting). Consistent with this implication, it is empirically documented that equity and bank deposit markets are segmented (e.g., Guiso and Sodini, 2013, Guiso et al., 2002).

Although we allow for full price competition, the skilled retain the full surplus as long as their fraction is small compared to the fraction of the unskilled investors, i.e., monopoly emerges endogenously. Consider the case where all banks offer the monopoly deposit rate. If a bank tries to increase the deposit rate to attract more depositors, this will have two negative effects on its profits: first, per-unit of deposit the profit falls, and second, because of the diversion constraint, the bank will be able to accept fewer deposits. Thus, although there is potential for price competition, we end up with the monopoly equilibrium in which equity has a higher return. The higher return on equity is not related to risk but to banks' monopoly power. The monopoly power emerges because of the possibility of diversion and the relative scarcity of skill. In the complete information version of the model, there is no scope for regulatory intervention.

We introduce asymmetric information by considering the case of two types of bankers: there are both good and bad bankers who are observationally identical, i.e., a banker's type is their private information. The bad bankers own negative NPV projects, and therefore, it is socially inefficient for them to manage banks. We analyze a standard two-stage signalling game in which the informed players (the banks) move first by offering contracts. We look for pure strategy Perfect Bayesian equilibria, and particularly, restrict our attention to the "reasonable" equilibria (the ones that satisfy the Intuitive Criterion of Cho and Kreps, 1987).

In our model, separation through the standard incentive compatibility constraints is impossible since the indifference curves of the two types coincide (single-crossing does not hold). The only way to achieve separation is through participation constraints. Since the bad bankers have negative NPV projects, it is only profitable for them to manage banks if they pool with the good bankers and the leverage is sufficiently high. In contrast, since the investment by good bankers is positive NPV, their participation constraint is always satisfied for any leverage. Therefore, separation may be achieved by restricting bank leverage such that the bad banker's participation constraint is violated.

If the asymmetric information problem is severe (i.e., the fraction of bad bankers is high), the equilibrium is unique and separating. A separating equilibrium is feasible if: the diversion constraint is satisfied and the bad banker's participation constraint is violated (the bad bankers are not willing to manage banks). On the one hand, a bank increases leverage to the full extent possible such that the diversion constraint is not violated. On the other hand, the good bankers voluntarily restrict leverage to signal their type since it is unprofitable for the bad bankers to manage banks if bank leverage is too low. Therefore, the separating equilibrium is at the intersection of the two constraints.

If the asymmetric information problem is less severe, the equilibrium may be separating or pooling, depending on the beliefs of depositors. A pooling equilibrium is feasible if: the diversion constraint is satisfied and bank leverage is sufficiently high such that a bad banker is willing to manage a bank. In one of the pooling equilibria, the deposit rate is the minimum acceptable for the depositors to participate (i.e., the depositors make zero profit, in expectation), and the diversion constraint binds. In this equilibrium, bank leverage is the highest possible, given the constraints. However, there exist other pooling equilibria in which bank leverage is lower and/or the deposit rate is higher. Consider one such pooling equilibrium. Both good and bad banks have an incentive to deviate from this equilibrium by offering higher leverage and, if feasible, a lower deposit rate. Since both good and bad bankers have an incentive to deviate, the Intuitive Criterion has no bite, and hence, beliefs cannot be restricted off the equilibrium path. Therefore, upon observing such a deviation, the depositors may attach a non-zero probability that the offer comes from a bad bank, and hence, reject the offer. This implies that the equilibria with lower leverage and higher deposit rate cannot be ruled out. For the same reasons, the separating equilibrium described above may also exist in this parameter range.

Regulation. The regulator sets disclosure requirements, audits applicants and grants banking licenses, and designs capital regulation. When the asymmetric information problem is severe, the regulator sets disclosure requirements but does not intervene using other instruments. However, this is not the case when the asymmetric information problem is less severe. Suppose that without disclosure requirements parameters are such that the bad bankers with licences do not participate (i.e., the equilibrium is separating). Imposing disclosure requirements on its own may push the economy to an inefficient pooling equilibrium which implies a lower net social surplus than the efficient separating equilibrium without disclosure. Hence, disclosure requirements can be socially undesirable, even though we do not assume an exogenous (direct) cost of disclosure. The fall in the net social surplus when the economy moves from the efficient separating equilibrium to a pooling equilibrium is the endogenous cost of disclosure. However, when used in conjunction with optimally designed capital regulation, disclosure requirements are always welfare-improving. We summarize below the optimal capital regulation for different parameter regions:

The most interesting case is when the asymmetric information problem is moderate (i.e., the fraction of bad bankers is not too high or too low). For these parameters, the maximization of the net social surplus requires separation, but it is privately desirable for the good banks to pool with the bad banks. The divergence between private and social objectives arise since the good bankers do not fully internalize the social cost of pooling with the bad bankers. The regulator can achieve separation by directly restricting leverage using capital requirements. In contrast to prescription by some scholars (e.g., Admati et al., 2014), in our setting very high capital requirements can be welfare-reducing, since conditional on achieving separation, the social welfare is maximized at the highest bank leverage. This result can reverse if we consider the possible adverse impact of high leverage on banks' depositors, e.g., increased likelihood of bankruptcy which could result in bank runs (e.g., Iyer and Puri, 2012) or diminished capacity of banks to serve its customers (e.g., Greenbaum et al., 2015 and Merton and Thakor, 2019).

Optimally designed capital requirements have a non-contingent element, and a more stringent contingent element (as suggested in Parlatore and Philippon, 2021). The non-contingent element of capital requirements, on its own, may achieve the efficient separating equilibrium, but cannot rule out some inefficient pooling equilibria (which coexist). The contingent element of capital requirements effectively keeps the bad banks out and at the same time allows the good banks to increase leverage to the second best levels as the unique equilibrium. The contingent element of capital requirements is never used on the equilibrium path, but the threat it poses sustains the efficient equilibrium.

Our theory provides an explanation for the evidence presented in Posner (2015). He examines the evolution of bank capital regulation and suggests that regulators adjust capital adequacy requirements upwards in response to crisis events to weed out the weakest banks, which is the precise motive that drives regulators to use capital requirements in our model. Further, if regulators deemed higher bank capital to always be more socially desirable than lower capital, they would simply set very high capital requirements; instead, the observed behaviour of the regulators (termed 'norming' by Posner, 2015) indicates that there is a balance to be struck, which is also what our model suggests.

Finally, when the asymmetric information problem is mild (i.e., the fraction of bad bankers is low), the net social surplus is maximized in a pooling equilibrium with the highest possible leverage. However, the unregulated equilibrium may be either separating or an inefficient pooling, characterized by lower leverage compared to the efficient pooling. Despite no divergence between the objectives of bankers and the regulator, in this case, there is a coordination failure problem (due to arbitrary out-of-equilibrium beliefs) that prevents the second best equilibrium from arising. The regulator can solve the coordination failure problem by setting minimum leverage requirements.

Therefore, in our setting, the regulator may intervene not just to overcome adverse selection (as in Tirole, 2012, Philippon and Skreta, 2012; Chiu and Koeppl, 2016), but also sometimes to embrace it. Further, in contrast to these models, the regulator overcomes adverse selection not by subsidizing the banks but by inflicting a cost on them (in the form of capital requirements). Conveniently, although the unregulated equilibrium depends on depositors' beliefs, the regulator simply needs to observe the primitives of the economy to intervene and achieve the second best.

We model an extensive margin effect of disclosure requirements which is that they lead to a higher fraction of good bankers. While we do not model it here, it should be noted that disclosure may have a positive impact on the intensive margin. Possible intensive margin effects include the benefits of disclosure such as positive externalities of transparency (e.g., Bushman, 2016) and a lower cost of banking crises due to earlier detection of troubled sectors (e.g., Rosengren, 1998).

Empirical implications. The first implication of our model is that optimally designed capital requirements reduce bank scale and lending. The usual argument against capital requirements is that it may hinder credit provision (e.g., Gropp et al., 2019). This is true in our model, and yet, capital requirements lead to a higher net social surplus compared to the laissez-faire equilibrium (e.g., Thakor, 2014, Thakor, 2021). Therefore, despite the negative impact on credit provision, capital requirements can be desirable from a social perspective since they keep the value-destroying bad banks out (e.g., Posner, 2015). The second implication is that banks make strictly positive profits even though they compete in prices (e.g., Drechsler et al., 2021). Third, bank leverage increases as the threat of diversion falls. To test this prediction, we need a proxy for the threat of diversion. We conjecture that the threat of diversion is falling in the intensity of supervision by the regulator and identify variables from the database provided by Barth et al. (2013) which may be used as proxies for supervisory intensity. The fourth implication is that at low (resp. high) levels of transparency, an increase in the degree of transparency leads to a larger (resp. higher quality) banking sector, and bank leverage is unaffected (resp. higher).

Related literature. Our setting is similar to that in Morrison and White (2005), with the difference that we replace their ex-ante (effort) moral hazard friction with an ex-post moral hazard friction (diversion). We show that the diversion constraint makes capital structure relevant. Similar to us, in Morrison and White (2005) capital requirements solve an adverse selection problem, leading to a smaller banking sector but of higher average quality. In Morrison and White (2005), the skilled bank cannot commit to a level of leverage, and therefore, the regulator steps in and imposes capital requirements. In contrast, in our model, the bank can signal its type using leverage (which is observable), and still, the regulator sometimes intervenes.

We share with Allen et al. (2015) (see also, Carletti et al., 2020) the prediction that the return on equity is higher than the return on deposits when markets are segmented, despite universal risk-neutrality. In their model, the bank's privately optimal capital structure is also socially optimal, and therefore, absent exogenously assumed distortions, there is no role for regulation. In Thakor (2021) capital requirements arise endogenously in a model in which the regulator's objective differs from that of the bank's due to political benefits attached to certain types of loans. In contrast to these models, in our model, the divergence in objectives of the regulator and the bank arises due to an informational friction.

Coval and Thakor (2005) present a model in which rational agents manage banks and act as a beliefs bridge between the optimists and pessimists, as they are able to commit to screening projects efficiently. Similar to our model, certain types of agents become bankers (the rational agents in their case), while others become investors in the bank (the pessimists in their case), and the bankers hold the junior claim relative to the investors. In their model, the bank investors are pessimists and hence need riskless debt to persuade them to invest, while in our case the relative seniority arises due to the diversion constraint. In both models, more capital leads to less real sector investment. In their model, more capital is used to persuade the pessimist to invest, while in our case the good banks keep more capital to drive out the bad banks, i.e., capital solves an adverse selection problem (which is absent in Coval and Thakor, 2005).

Holmstrom and Tirole (1997) show that bank equity improves monitoring incentives and is therefore valuable (see also, Allen et al., 2011 and Mehran and Thakor, 2011). We do not consider an effort moral hazard problem that inside equity can solve. Additionally, in Holmstrom and Tirole (1997) it does not matter whether investors deposit in the bank or invest in the project independently as long as the bank performs its monitoring duties, while in our model the unskilled investors necessarily deposit in the bank, and bank capital structure is relevant.

In contrast to the moral hazard models of bank capital, in our model, equity plays a similar role as in Diamond and Rajan (2000) and Donaldson et al. (2018): equity allows the bank to attract deposits by mitigating limited pledgeability. In Diamond and Rajan (2000) the renegotiable equity capital in banks sacrifices liquidity creation to provide stability in the poor state. Bank capital is expensive from a social perspective as the equity claim prevents liquidity creation. In our setting, equity is expensive in the sense that the return on equity is higher than the return on deposits. Both in Diamond and Rajan (2000) and Donaldson et al. (2018), banks endogenously hold the efficient level of equity. Different from these models, we explicitly derive the conditions under which regulation improves welfare.

We contribute to the literature on endogenously costly disclosure (e.g., Thakor, 2015, Bouvard et al., 2015, Dang et al., 2017 and Leitner and Yilmaz, 2019). In some of this literature, opacity emerges as an equilibrium choice for the bank. For example, in Thakor (2015), the best firms choose to be opaque because the benefit of transparency to these firms is low, but the cost of disagreement engendered by disclosure is high. In Dang et al. (2017) when the average NPV of projects is positive, opacity allows the bank to create safe liquidity for (de facto) risk-averse depositors and is optimal. However, when the average NPV is negative (which they do not consider), opacity will lead to a market breakdown, and transparency will lead to the efficient outcome. In these papers, there is no scope for bank capital regulation. In our model, opacity may be desirable even if the average NPV of projects is negative in the absence of any other regulation, and there is no possibility of disagreement with investors. A novel implication of our model is disclosure and capital regulation can be complementary. Our paper also provides a perspective on how capital requirements may be used when opacity creates costs we do not model, such as reducing the quality of corporate governance by insulating management from shareholder pressure (e.g., Ferreira et al., 2021).

We also contribute to the literature on the optimality of bank deposits (see e.g., Bryant, 1980, Diamond and Dybvig, 1983, Diamond, 1984). Similar to Calomiris and Kahn (1991), deposits are optimal since the bank manager may divert funds. In contrast to Calomiris and Kahn (1991), here the depositors do not play an active monitoring role. In the presence of deposit insurance, demand deposits are no longer a disciplining device in their model, while the results are unaffected in our model as long as deposit insurance is accurately priced.

2. Complete information

2.1. Set-up

We consider a two-date economy in which all agents are risk-neutral. There are two types of agents: skilled and unskilled (similar to Morrison and White, 2005); we consider agent types to be observable, for now. Both types of agents are endowed with 1 unit of funds. At $t = 0$, there is investment in a project, and at $t = 1$ returns are realized. All agents consume at time, $t = 1$. A project yields either X (success) or 0 (failure) per-unit of investment at $t = 1$. If the project is managed by a skilled agent, it succeeds with probability p_g and fails with probability $(1 - p_g)$. If managed by an unskilled, the success probability is p_l, where $p_l < p_g$. The unskilled agents may delegate investment of their funds to the skilled or invest on their own. A proportion λ of all agents are skilled and $1 - \lambda$ are unskilled. A skilled agent's project has a positive net present value, while the NPV of the unskilled agent's project is normalized to 0:

A 1. $p_g X > p_l X = 1$

As the project is more profitable when managed by the skilled rather than the unskilled, maximization of the net social surplus (efficiency) requires that all funds are managed by the skilled agents. A bank manager may divert a fraction, $1 - \phi$, of the realized output from the external investors (similar to Calomiris and Kahn, 1991). The diverted amount can not be verified in a court of law. A manager cannot credibly commit to not divert funds from the bank even though it is beneficial for them to do so ex-ante.

A 2. $\phi < \frac{p_l}{p_g}(1 - \lambda)$

Assumption A2 puts an upper bound on ϕ; i.e., diversion should be sufficiently large, given the fraction of skilled agents in the economy. Equivalently, the fraction of skilled agents should be sufficiently small, given the degree of diversion, i.e., there is a scarcity of skill.

In the absence of diversion, all unskilled agents would like to join a bank managed by a skilled agent. This is true as the skilled banker can always offer ϵ more than what an unskilled agent can generate on his own: both the skilled and unskilled are better off. We analyze the case that each skilled agent manages a bank, while the unskilled either join banks managed by the skilled or invest on their own. However, because a banker can divert part of the realized output there is an upper bound to the number of unskilled agents who can receive the promised repayment if they join a bank.

2.2. The optimal contract

In this section, we derive the optimal contract for each type of agent. The banker maximizes his profit subject to three constraints: i. the total verifiable cash flow (after diversion) must be weakly greater than the total promised payments to the unskilled bank members and the banker (the diversion constraint), ii. the participation constraint of the unskilled investors is not violated and iii. the banker's limited liability constraint is satisfied. The contract offered to the unskilled bank members specifies the repayment, R, if the project succeeds (and possibly its seniority relative to the banker's claim). The banker's payoff is R_s. If the project fails, all bank members receive zero. Formally, the banker solves the following problem:

$$\begin{aligned} \max_{d,R} \quad & p_g(1+d)X - p_g dR - 1 \\ \text{subject to} \quad & \phi p_g(1+d)X = p_g dR + p_g R_s \\ & p_g R \geq 1 \\ & R \leq X \end{aligned} \tag{1}$$

First, note that the banker's profit is strictly increasing in the number of unskilled agents joining the bank, d. This is true because the banker retains a fraction of the incremental profitability, $p_g(X - R)$, of each unskilled investor's funds. We do not assume that the participation constraint of the unskilled is binding. The diversion constraint can be written as:

$$(p_g R - \phi p_g X)d \leq \phi p_g X - p_g R_s \tag{2}$$

Given Assumption A2 and the unskilled investor's participation constraint, the LHS increases with the number of unskilled agents joining the bank, d. Hence, in order to maximize d consistent with the diversion constraint being satisfied we set $R_s = 0$. Also, because the banker's profit increases in d, the diversion constraint will always be binding. This allows us to determine the number of unskilled agents joining the bank, which is:

$$d = \frac{\phi X}{R - \phi X} \equiv d^{DC}(R) \tag{3}$$

Given the level of diversion, $1 - \phi$, the banker can credibly promise to depositors only up to the amount of output which can not be diverted, $\phi p_g X$. This, in turn, determines the maximum amount of funds that the depositors are willing to provide to the bank. The optimal arrangement entails that the unskilled investors have priority over the verifiable fraction of the cash flow and so they receive the most senior claim which can be interpreted as debt (deposit). In fact, it is risky debt with a face value of R. This credibly ensures that the unskilled investors in the bank earn their outside option (as opposed to the all-equity bank). The banker becomes the bank equity holder (residual claimant). The following proposition summarizes these results:

Proposition 1. There are $d(R)$ unskilled investors in the bank, and the optimal contract for the unskilled is risky debt (deposit) which pays a repayment rate, R, in the case of success and 0 in the case of failure; the skilled banker holds the residual claim (equity).

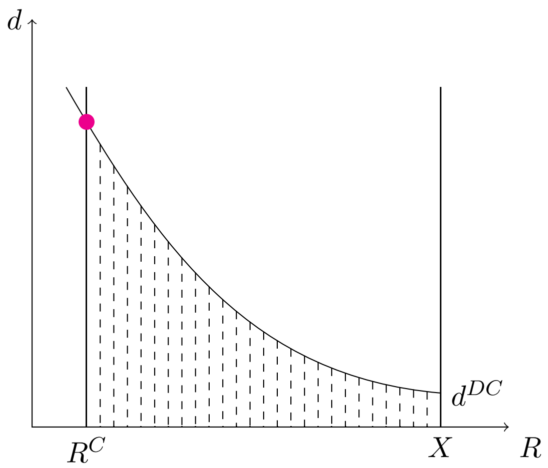

Fig. 1. Complete information.

We derive the slope of the diversion constraint in the (d, R) space by totally differentiating Eq. (3) with respect to d and R:

$$\left.\frac{dd}{dR}\right|_{DC} = -\frac{d}{R - \phi X} < 0 \tag{4}$$

The slope of the diversion constraint is negative, which indicates that the diversion constraint becomes tighter as the deposit rate offered by the bank increases.

We illustrate the various constraints in Fig. 1. R^C is derived from the depositor's participation constraint. The feasible parameter constellations for an equilibrium is the shaded area where neither of the two relevant constraints, the depositors' participation constraint and the diversion constraint, is violated. To fully characterize the complete information equilibrium, we need to determine the deposit rate, R, and substitute it into $d(R)$.

Proposition 2. Given Assumption A2, although banks compete for deposits, in equilibrium banks make monopoly profits. The equilibrium is characterized as follows:

$$R = \frac{p_l X}{p_g} \equiv R^C \tag{5}$$

$$d = \frac{\phi p_g}{p_l - \phi p_g} \equiv d^C \tag{6}$$

Proof. The proof is in the Appendix. □

According to Proposition 2, the unique equilibrium in the complete information case is represented by the pink dot in Fig. 1. The participation constraint of the depositors binds, which is equivalent to saying that the bankers behave in a monopolistic way. The intuition is that due to the diversion constraint, by increasing the deposit rate a bank cannot increase the number of depositors it attracts. In fact, it can credibly promise higher repayments to fewer depositors, which makes a deviation from the monopoly equilibrium unprofitable. As a corollary to Proposition 2, we state the following result:

Corollary 1. Bank equity earns a higher return than deposits in equilibrium, despite risk-neutrality.

The banker keeps the entire surplus from managing the funds of the unskilled depositors. The net payoff to the banker is $(1 + d)(p_g X - 1)$. The depositors earn their outside option, 1. Provided that bankers are relatively scarce, the diversion constraint becomes binding, which implies that the expected return on equity is higher than the return on deposits. In our risk-neutral setting, the higher return on equity is not related to risk. It is a premium for a scarce skill. Our result is related to Donaldson et al. (2021) who assume that banks (depositories) have a lower cost of capital relative to purely equity-financed non-banks (not modelled here) precisely due to their access to cheaper deposits. In their setting, scarcity of banks arises as a general equilibrium outcome for certain distributions of projects.

3. Asymmetric information

3.1. Set-up

In this section, we introduce a second type of banker: the bad banker. That is, there are two types of bankers denoted by $p \in \{p_g, p_b\}$, and the banker type is the banker's private information. A fraction $\beta \in (0, 1)$ of bankers are good, and a fraction $(1 - \beta)$ are bad. If a project is managed by a bad banker, it still produces the same payoffs in the success and failure states. However, the bad banker succeeds with a probability, p_b, and fails with probability $(1 - p_b)$. We assume that it is inefficient for bad bankers to manage funds:

A 3. $p_b X < 1$

Both types of bankers can divert a fraction $(1 - \phi)$ of the realized cash flows from depositors, as described in the previous section. If not managing a bank, a banker can either deposit with a bank or put his funds in a storage technology that has a net return of 0. A proportion λ of all agents are bankers (sum of good and bad types) and $1 - \lambda$ are the unskilled depositors. The following set of seven exogenous parameters fully describe the primitives of the economy: $\{p_l, p_b, p_g, X, \phi, \lambda, \beta\}$.

The parameter, β, captures the severity of the asymmetric information problem, and we interpret this variable as the degree of transparency in the banking sector. Specifically, higher transparency corresponds to a higher β. This interpretation may be micro-founded as follows. Suppose that there is heterogeneity across bad bankers in how similar they look to the good bankers. Some are more similar than others. As transparency increases, fewer bad bankers are indistinguishable from good bankers, and so, the proportion of bad bankers who are observationally equivalent to good bankers is smaller. This implies that the fraction of good bankers, β, is positively correlated with transparency: with low transparency, many bad bankers are observationally equivalent to good bankers, and with perfect transparency, the type of banker becomes public information, returning us to the complete information case. We start with the baseline case in which we take as given the degree of transparency in the banking sector. In Section 5, we endogenize β by allowing the regulator to set disclosure requirements.

A 4. $\phi > \frac{p_l - p_b}{p_g - p_b} \equiv \hat{\phi}$

A4 ensures that there are interest rates accepted by the depositors for which both the pooling and separating equilibria exist. Otherwise, for any interest rate accepted by the depositor, the bad banker always stays out, and the analysis is not interesting.

3.2. The game

We consider a standard two-stage signaling game:

Stage 1: A banker proposes a contract $C = (R, d)$ to depositors which consists of an interest rate R and a level of bank leverage, d (which is publicly observable).

Stage 2: After observing the bank's proposal, the potential depositors form their beliefs about the bank's type and decide whether they wish to deposit in the bank or invest on their own. If depositors accept, then the banker gets a level of deposit, d and invests. If depositors reject, then the banker can either invest on his own or deposit with another bank. The expected return of a type p banker who offers the contract, C, and it is accepted by the depositors, is given by:

$$\Pi_p(C) = (1+d)pX - dpR - 1 \tag{7}$$

We look for the pure strategy Perfect Bayesian Equilibria of this game that satisfy the Intuitive Criterion of Cho and Kreps (1987) (the so-called "reasonable" equilibria).[1]

3.3. Types of equilibria

Below we list all the candidate equilibria, three of which are separating, and two are pooling.

1. A candidate separating equilibrium in which both good and bad bankers accept deposits and manage banks, but offer different contracts.
2. A candidate separating equilibrium in which the bad bankers accept deposits and manage banks, while the good bankers either deposit or invest on their own.
3. A candidate separating equilibrium in which the good bankers accept deposits and manage banks, while the bad bankers either deposit or invest on their own.
4. A candidate pooling equilibrium in which both types of bankers accept deposits and manage banks.
5. A candidate pooling equilibrium in which neither type of banker accept deposits and both invest on their own (market breakdown).

Below we show that 1, 2 and 5 cannot exist.

Lemma 1. There cannot exist an equilibrium in which only the bad bankers accept deposits and manage banks.

Proof. The proof is in the Appendix. □

Lemma 2. There cannot exist an equilibrium in which both good and bad bankers accept deposits and manage banks but offer different contracts.

Proof. The proof is in the Appendix. □

The role of the participation constraint: Suppose that banks are only managed by good bankers. A good banker will manage a bank if the profit she can make is higher than her outside option, which is either depositing with another good bank or investing on her own:

$$(1+d)p_gX - dp_gR \geq \alpha p_gR + (1-\alpha)p_gX \tag{8}$$

The LHS is the profit of the good bank given leverage, d, and deposit rate, R. The RHS represents the good banker's outside option. With probability $\alpha \in [0, 1]$, the good banker deposits with another good bank, and with probability $(1-\alpha)$, she invests on her own. Since $R \leq X$ (the limited liability constraint), for any α the good banker is weakly better off from managing a bank compared to investing individually or depositing in a bank (indifferent if $R = X$, and strictly better off if $R < X$; the latter is always the case in equilibrium, as we see below). Hence, a good banker is always willing to manage a bank even if banks are only managed by other good bankers. Further, if banks are managed by bad bankers too (i.e, a pooling equilibrium obtains), the LHS is unaffected, while the RHS is smaller, which makes managing a bank even more attractive for the good banker.

The participation constraint of the bad banker is given by:

$$(1+d)p_bX - dp_bR \geq \gamma p_gR + (1-\gamma) \tag{9}$$

The LHS is the bad bank's profits given leverage, d, and deposit rate, R. Note that the deposit rate R may be set such that the participation constraint of the unskilled depositor may or may not be binding since the good bank might offer a higher deposit rate in order to break the pooling and achieve separation. The RHS represents the bad banker's outside option. With probability $\gamma \in (0, 1]$, the bad banker deposits with the good bank, and with probability $(1-\gamma)$, he puts the funds in the storage technology. $0 < \gamma < 1$ can arise if the bad bankers and the unskilled agents compete to deposit in the good bank. Since we assume that good banks are scarce, not everyone who competes to deposit in the good bank is successful in doing so. Alternatively, $\gamma = 1$ can arise if the bad bankers are the first in the queue to deposit, ahead of the unskilled depositors, and the ratio of good bankers to bad bankers is sufficiently large such that the entire population of bad bankers can deposit in the good banks, without violating the diversion constraint. We solve the model assuming $\gamma = 1$; for $0 < \gamma < 1$, all results remain qualitatively identical (see further discussion in Section 7). From Eq. (9) we derive a threshold level of deposits, $\bar{d}$, such that only the good bankers manage banks:

$$\bar{d}(R) = \frac{p_gR - p_bX}{p_b(X-R)} \tag{10}$$

The bad banker's participation constraint is violated if $d < \bar{d}$. For any $X \geq R$, $\bar{d} > 0$ (since $p_gR \geq p_lX > p_bX$). Totally differentiating Eq. (10) with respect to d and R, we derive the slope of the bad banker's participation constraint in the (d, R) space:

$$\left.\frac{dd}{dR}\right|_{PC} = \frac{dp_b + p_g}{p_b(X-R)} > 0 \tag{11}$$

[1] We show in Appendix B that using a stronger refinement such as the Universal Divinity or D1 refinements does not affect our analysis.

The slope is positive, which indicates that the higher the deposit rate, the higher is the level of deposits below which the bad banker's participation constraint is violated.

Lemma 3. There cannot exist a "reasonable" equilibrium where the market breaks down.

Proof. The proof is in the Appendix. □

From Eq. (10), there always exists $R < X$ and d strictly positive for which the bad banker's participation constraint is violated. The good bank can then profitably deviate from a breakdown equilibrium by offering any contract which violates the bad banker's participation constraint, and this contract will be accepted by the depositors.

3.4. Separating equilibria with good banks

In this section, we consider the separating equilibria in which there are only good banks. The separating equilibrium arises in this setting since the good banker increases the deposit rate such that the bad banker's participation constraint is violated.

The various conditions that need to be satisfied for a separating equilibrium to exist are as follows: First, the diversion constraint has to be satisfied, $d \le d^{DC}$ (Eq. (3)). As before, the anticipated diversion of cash flows by banks puts a limit on bank leverage, and the constraint tightens as the deposit rate increases. Second, the banker's limited liability constraint has to be satisfied, $R \le X$. Third, the unskilled agents must be willing to deposit rather than invest on their own, $R \ge R^C$. Finally, (different from the complete information case), the bad banker's participation constraint must be violated, $d \le \bar{d}$ (Eq. (9)).

To determine the deposit rate in the separating equilibrium, we consider the good bank's problem. The good bank's profit in a separating equilibrium is:

$$\Pi_G = \bar{d}p_g(X - R) + (p_gX - 1) = \frac{(p_gR - p_bX)}{p_b}p_g + (p_gX - 1) \tag{12}$$

Note that Π_G is increasing in R. The intuition is that, starting from a binding participation constraint for a bad banker, an increase in the deposit rate would lead to a violation of this participation constraint even at higher leverage. Thus, the leverage $\bar{d}$ goes up. The rents lost due to paying a higher deposit rate are smaller than the higher profits due to the increased leverage. Therefore, the good banker would wish to increase the deposit rate to achieve separation, as long as the diversion constraint is not violated: whether or not she succeeds in doing so depends on depositor beliefs, as we see below. As before, when the diversion constraint binds, it is no longer possible to increase the deposit rate to increase the leverage (see Proposition 2). This gives us a candidate separating equilibrium in which both the bad banker's participation constraint and the diversion constraint are binding. At the intersection of the two constraints:

$$\bar{d}(R) = d^{DC}(R) \tag{13}$$

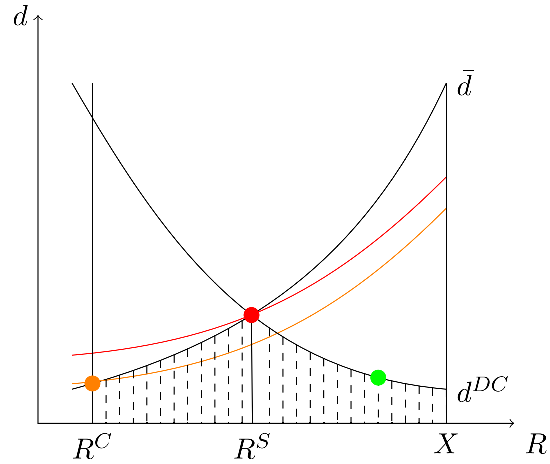

Fig. 2. Separating equilibria.

Solving, the candidate separating equilibrium is characterized as follows:

$$R = \frac{\phi X(p_g - p_b) + p_bX}{p_g} \equiv R^S \tag{14}$$

$$d = \frac{\phi p_g}{(1 - \phi)p_b} \equiv d^S \tag{15}$$

Given Assumption A4, $R^S > R^C$.

We illustrate the various constraints in Fig. 2. The feasible parameter constellations for a separating equilibrium is the shaded area where none of the relevant constraints is violated (to the right of $R = R^C$, under both the bad banker's participation constraint and the diversion constraint, and to the left of $R = X$). The red dot denotes the intersection of the bad banker's participation constraint and the diversion constraint, the orange dot is at the intersection of participation constraints of the bad banker and the depositors, and the green dot is an arbitrary point on the diversion constraint to the right of R^S. We draw the indifference curves for bankers through the orange and red dots, with the colour of each indifference curve matching the colour of the dot it goes through. Note that the slope of an indifference curve, Eq. (7), is smaller than the slope of the bad banker's participation constraint, Eq. (9), which makes the indifference curve relatively flatter in the (d, R) space:

$$\left.\frac{dd}{dR}\right|_{PC} = \frac{dp_b + p_g}{p_b(X - R)} = \frac{d + \frac{p_g}{p_b}}{(X - R)} > \frac{d}{(X - R)} = \left.\frac{dd}{dR}\right|_{IC} \tag{16}$$

Hence, to the left (right) of the red dot, the red indifference curve lies above (below) the bad banker's participation constraint. This implies that the red indifference curve lies above the orange indifference curve.

We characterize the separating equilibrium in the following proposition:

Proposition 3. There exists a unique "reasonable" separating equilibrium for all values of β. It lies at the intersection of the bad banker's participation constraint and the diversion constraint, and the equilibrium is characterized by (R^S, d^S) as given in Eqs. (14) and (15).

Proof. We provide a graphical proof and refer to Fig. 2. The feasible separating equilibria are in the shaded region.

Consider the case of $R > R^S$. In this region, the bad banker's participation constraint lies above the diversion constraint. Suppose that the equilibrium lies anywhere to the right of R^S on the diversion constraint (say, the green dot in Fig. 2). Starting from the green dot, there are contracts on the diversion constraint with a lower R and higher d, which imply a higher profit for the good bankers and which still violate the bad banker's participation constraint. According to the Intuitive Criterion, observing such a deviation, a depositor must attach probability 1 that the offer comes from a good banker since any such offer makes the good banker strictly better off and makes the bad banker strictly worse off. Hence, the green dot is not a "reasonable" equilibrium. By the same argument, we can eliminate all other separating equilibria which lie in between the green and red dots on the diversion constraint, and in the shaded area directly below this segment.

Next, we consider the case of $R < R^S$. In this region, the diversion constraint lies above the bad banker's participation constraint. Suppose that the equilibrium lies at the intersection of the bad banker's participation constraint and the unskilled depositors' participation constraint (say, the orange dot in Fig. 2). To see why the orange dot is not a stable equilibrium, we consider the banker's indifference curves going through the orange and red dots. The red indifference curve lies above the orange indifference curve. So, the good banker can profitably deviate from the orange dot to anywhere in the shaded region in between the red and the orange indifference curves. Observing the deviation, the depositor must hold the belief that the deviation comes from the good banker with probability 1 since the bad banker's participation constraint is violated in this region. Hence, the depositor accepts the offer and the orange dot is not a "reasonable" equilibrium. By the same argument, we can eliminate all other separating equilibria which lie in between the orange and red dots on the bad banker's participation constraint, and in the shaded area below this segment.

The analysis so far shows that no separating equilibrium except the allocation represented by the red dot can exist. The next step is to show that this is indeed an equilibrium for all values of β. Suppose that β is sufficiently high such that there are pooling allocations which make both types of bankers better off, compared to the allocation at the red dot. This is the area above the red indifference curve and below the diversion constraint for $R^C \le R \le R^S$. Starting from the red dot, moving to any point in the area between the red indifference curve and the diversion constraint makes both types strictly better off, compared to the separating equilibrium. Therefore, the Intuitive Criterion does not have a bite, and we can always find a strictly positive set of beliefs for which the red dot is an equilibrium. Therefore, the separating equilibrium at the red dot is the unique reasonable separating equilibrium. □

3.5. Pooling equilibria

Next, we consider pooling equilibria. In a pooling equilibrium, there are both good and bad banks. The average quality of the banking sector is lower than the case when all bankers are good, $\hat{p} = \beta p_g + (1-\beta)p_b$. First, we define the pooling deposit rate, R^P, such that the depositor's participation constraint binds:

$$\hat{p}R^P = 1 \tag{17}$$

Clearly, R^P is decreasing in the fraction of good bankers, β. Note that the deposit rate in the pooling equilibrium can be $R > R^P$. Additionally, two other constraints are relevant. First, the diversion constraint has to be satisfied, $d \le d^{DC}$ (Eq. (3)). Second, the bad banker's participation constraint must be satisfied, $d \ge \bar{d}$ (Eq. (9)).

Define β^* as the value of β at the intersection of the diversion constraint and the bad banker's participation constraint:

$$\beta = \frac{p_l p_g - p_b(\phi(p_g - p_b) + p_b)}{(\phi(p_g - p_b) + p_b)(p_g - p_b)} \equiv \beta^* \tag{18}$$

First, we check that $\beta^* > 0$ exists. This condition is always satisfied since $p_g > p_l > p_b$. For a pooling equilibrium to exist we need $\beta^* < 1$, which is equivalent to $\phi > \hat{\phi}$, which we have assumed to be the case in Assumption A4.

We illustrate the various constraints in Fig. 3. At $\beta = \beta^*$, $R^P = R^S$ (using Eqs. (17) and (18)). When $\beta < \beta^*$ the fraction of bad bankers is so large that $R^P > R^S$, while for $\beta > \beta^*$ the fraction of bad bankers is so small that $R^P < R^S$. The feasible parameter constellations for a pooling equilibrium lie to the right of R^P, above the bad banker's participation constraint and under the diversion constraint. In Panel a, we present the case of $\beta < \beta^*$. As can be seen from Fig. 3a, there are no feasible pooling equilibria since the diversion constraint lies below the bad banker's participation constraint. In Panel b, we present the case of $\beta > \beta^*$. The shaded area shows the feasible pooling equilibria.

Lemma 4. The set of parameters for which a pooling equilibrium may exist is non-empty.

Proof. The proof is in the Appendix. □

We characterize the pooling equilibria in the following proposition:

Proposition 4. When $\beta > \beta^*$, there exists a continuum of pooling equilibria, where both types of bankers invest and pay depositors an interest rate, $R \in \left[\frac{p_l}{\hat{p}}X, R^S\right)$.

Proof. We provide a graphical proof and refer to Fig. 3b. The shaded area depicting the feasible pooling equilibria lies entirely to the left of R^S.

Suppose that the deposit rate is such that the unskilled depositor's pooling participation constraint binds, i.e., $R = R^P$. A candidate equilibrium lies at the intersection of the diversion constraint and the unskilled depositor's participation constraint when he faces both good and bad bankers (this is the blue dot on the figure). This equilibrium is clearly feasible since no constraint is violated. This is an equilibrium since there are no profitable deviations for either type: both the good and bad bankers are worse off moving anywhere in the shaded region since any such deviation entails lower leverage and/or a higher deposit rate, both of which make a bank strictly worse off.

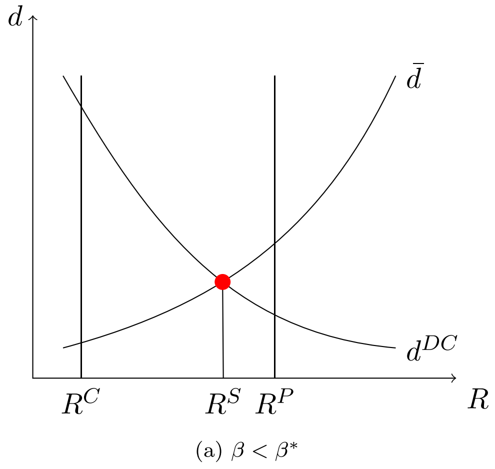

Fig. 3. Pooling equilibria.

Next, consider any point on the diversion constraint in between the blue and the red dots. We show that these feasible equilibria are also "reasonable", i.e., they survive the Intuitive criterion and may not be eliminated. Consider any point on the diversion constraint in between the blue and the red dots to be a candidate pooling equilibrium. Moving up the diversion constraint towards the blue dot entails higher leverage and a lower deposit rate, which make both the good and the bad bankers strictly better off. Because both types are better off, the Intuitive Criterion does not have a bite, and there is a strictly positive set of beliefs for which the equilibrium sustains.

Next, we consider the rest of the feasible pooling equilibria in the shaded region below the diversion constraint and see which ones may be ruled out.

Consider the red indifference curve going through the intersection of the bad banker's participation constraint and the diversion constraint (the red dot). Pick any point in the shaded region below the red indifference curve. Since the red indifference curve lies above, the good bankers profitably deviate to the red dot and separate from the bad bankers. Observing the deviation, the depositor must hold the belief that the deviation comes from a good banker with probability 1 since the bad banker's participation constraint is (just) violated at the red dot. Hence, any point in the shaded region below the red indifference curve is not a "reasonable" equilibrium.

Consider the intersection of the red indifference curve with the depositor's participation constraint, $R = R^P$ (vertically below the blue dot). We show that this point also represents a "reasonable" equilibrium. Starting from this point, both bankers profitably deviate by moving vertically up the depositor's participation constraint towards the blue dot. However, since both the good and bad bankers are better off, the Intuitive criterion does not bite. Hence, this point may not be eliminated. By the same argument, no point in the shaded region above the red indifference curve may be ruled out as "reasonable". Therefore, there are pooling equilibria in which the diversion constraint does not bind, and for any deposit rate, R, the leverage may be $d \leq \bar{d}(R)$. Thus, the set of "reasonable" pooling equilibria lie anywhere in the shaded region above the red indifference curve on Fig. 3b. □

3.6. Equilibrium characterization

Collecting all the results so far, we characterize the unregulated equilibria under asymmetric information in the following proposition:

Proposition 5. Our two-stage signaling game has the following Perfect Bayesian Equilibria, satisfying the Intuitive Criterion:

i. For all values of β, there exists a separating equilibrium in which only good bankers invest and the deposit rate is R^S.

ii. If $\beta > \beta^*$, there exist multiple pooling equilibria, where both types of bankers invest and pay depositors an interest rate, $R \in [\frac{p_l}{\hat{p}}X, R^S)$. The diversion constraint may or may not bind.

4. Welfare analysis

Suppose that there exists a benevolent regulator whose objective is to maximize the net social surplus. Can the regulator intervene to improve upon the unregulated market outcome? How does the regulator intervene? Consider the case that the unregulated equilibrium is pooling, (R^P, d^P), where d^P is such that the diversion constraint binds (the blue dot in Fig. 3b). With the binding diversion constraint, bank leverage becomes:

$$d = \frac{\phi X}{R^P - \phi X} \equiv d^P \tag{19}$$

In this equilibrium, the good banker may find it privately optimal to subsidize the bad banker in order to increase the amount of deposits he can accept and reduce the interest paid to depositors, thereby increasing the bank profit. However, there is a social cost, in that some banks are being managed by value-destroying bad bankers. The regulator faces a trade-off between a larger but lower quality banking sector and a smaller but higher quality banking sector. To see whether the regulator intervenes, we check the regulator's incentives when the good banker is privately indifferent between separation and pooling. The net social surplus in the separating equilibrium is higher than that in the best feasible pooling equilibrium if:

$$\beta(1+d^S)(p_g-p_l)X > (1+d^P)(\hat{p}-p_l)X \tag{20}$$

The LHS is the net social surplus in a separating equilibrium, in which bank leverage equals $d=d^S$ and only the good bankers manage banks. Note that compared to the good banker's private incentive constraint, the regulator does not take into account that the deposit rate, R^S, is higher than R^C. The reason for this is that from the regulator's perspective, a higher deposit rate is simply a transfer between the bank and the depositors, which does not affect the net social surplus. The RHS is the net social surplus in a pooling equilibrium, in which both good and bad bankers manage banks. We re-write Eq. (20) as follows:

$$\beta(1+d^S)(p_g-p_l)X > \beta(1+d^P)(p_g-p_l)X + \underbrace{(1-\beta)(1+d^P)(p_b-p_l)X}_{-ve} \tag{21}$$

At the point that the good banker is indifferent between separating and pooling, $\beta=\beta^*$, we have $d^S=d^P$ which equalizes the LHS with the first term of the RHS. Further, it should be noted that the second term in the RHS is negative (since $p_b<p_l$), and hence, for $\beta=\beta^*$, the LHS is always greater than the RHS. This implies that when the good banker's incentive constraint just binds, the planner strictly prefers separation.

For $\beta\leq\beta^*$, there is no divergence between the private and social objectives: the unregulated equilibrium is separating and it is efficient (see Fig. 3a and Proposition 6, below). In contrast, for $\beta>\beta^*$, there may be a divergence between the private and social objectives. To see why this divergence may arise, we refer to Fig. 3b. Suppose that the equilibrium is at the red dot, which is the separating equilibrium. Then, going up the diversion constraint towards the blue dot, the good banker is *always* better off since such a deviation entails higher leverage and a lower deposit rate, both contributing to a higher bank profit. However, the good banker does not internalize that by pooling with the bad banker there is a cost to the society since bad bankers destroy value, $p_b<p_l$. The regulator only prefers the deviation from the separating to a pooling equilibrium if the benefit (more funds channeled to good bankers) is greater than the cost (some funds are channeled to the bad bankers). Since the good banker does not fully internalize the social cost of pooling with the bad banker, for some parameters, she prefers the pooling equilibrium even when the regulator prefers the separating equilibrium. Suppose that the regulator is indifferent between the separating and pooling equilibria at $\beta=\beta^R$.

Lemma 5. *β^R lies in the range, $(\beta^*,1)$.*

Proof. The proof is in the Appendix. □

Lemma 5 shows that there always exist some parameters for which the socially efficient outcome is the pooling. Propositions 6 and 7 summarize when and how the regulator intervenes.

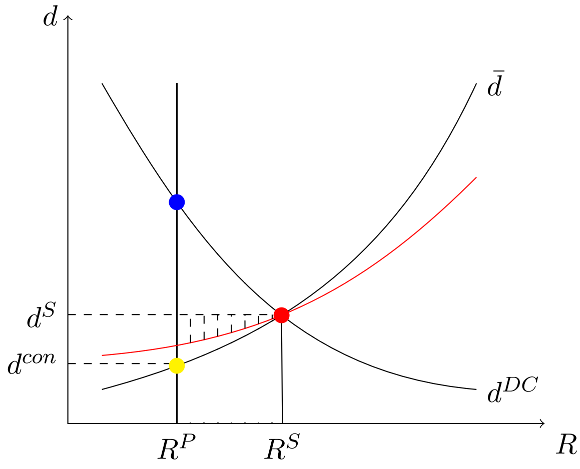

Fig. 4. Optimal capital requirements.

Proposition 6. *If $\beta<\beta^*$, then the separating equilibrium is unique and efficient.*

Proof. The proof is in the Appendix. □

Proposition 7. *If $\beta>\beta^*$, then*

i) *for $\beta<\beta^R$ the regulator prefers the separating equilibrium with (R^S,d^S), and can achieve it using optimally designed capital requirements as follows:*
   a. *$d\leq d^S$ is always applied.*
   b. *$d<d^{con}$ is applied if any equilibrium other than the efficient separating equilibrium is observed. d^{con} is strictly smaller than d^S and the expression for d^{con} is:*

$$d^{con}=\frac{p_g p_l-p_b\hat{p}}{p_b(\hat{p}-p_l)} \tag{22}$$

ii) *for $\beta>\beta^R$ the regulator prefers the pooling equilibrium with (R^P,d^P) and can achieve it by imposing a leverage requirement on the banks.*

Proof. We provide a graphical proof and refer to Fig. 4.

First, consider the case that $\beta^*<\beta<\beta^R$. For these parameters, the regulator prefers the separating equilibrium at the red dot. However, many pooling equilibria survive the Intuitive Criterion and cannot be ruled out. The regulator's objective is to achieve separation at the red dot and rule out the pooling equilibria. Suppose that the equilibrium is at the blue dot. It is a pooling equilibrium, and the regulator can restrict leverage in order to achieve separation. If the regulator imposes a minimum capital requirement, $d\leq d^S$, it effectively rules out the blue dot as an equilibrium but may lead to another pooling equilibrium, (d^S,R^P) (on the depositor's participation constraint, vertically below the blue dot). Since $R^P<R^S$, both good and bad bankers strictly prefer the (d^S,R^P) equilibrium to the (d^S,R^S) equilibrium. Indeed, any point in the shaded region in between the red indifference curve and $d=d^S$ can be supported as a "reasonable" pooling equilibrium, and so, this region is not eliminated by the minimum

capital requirements, $d \le d^S$. The red dot is an equilibrium, but not the unique one. Indeed, in order to ensure separation only using capital requirements, the regulator needs to impose a stricter requirement, and impose d to be below the point where the bad banker's participation constraint intersects $R = R^P$ (the yellow dot in Fig. 4). The highest minimum capital requirement which achieves separation as an unique equilibrium is d^{con} (defined in the statement of the proposition). Note that this equilibrium is inefficient compared to the separating at the red dot since conditional on achieving separation the objective should be to set the leverage as high as feasible.

In order to achieve the red dot allocation as the unique equilibrium, the regulator sets the following capital requirements: lax capital requirements, $d \le d^S$, is always applied (we refer to this as the non-contingent capital requirement), and more stringent capital requirements, $d < d^{con}$, if any equilibrium other than the one at the red dot is observed (this is the contingent capital requirement). Further, the regulator makes the contingent part irreversible and anticipating this the bad bankers stay out since d^{con} is on their participation constraint. Also, for the same reason, the good bankers will never offer anything other than the separating contract at the red dot (since it is strictly preferred by them to the yellow dot). Therefore, the optimally designed capital requirements eliminate the shaded area in between the red indifference curve and $d = d^S$.

Next, consider the case that $\beta > \beta^R$. For these parameters, the regulator prefers the pooling with the maximum feasible leverage, (R^P, d^P) (the blue dot). However, many inefficient pooling equilibria and the separating equilibrium at the red dot survive the Intuitive Criterion and cannot be ruled out (the whole shaded region in Fig. 3b, above the red indifference curve). From the regulator's perspective, a lower R is welfare-neutral as it represents transfer between agents, but $d < d^P$ is inefficient. Therefore, from the regulator's perspective, the blue dot is strictly preferred to any other "reasonable" equilibrium. The reason is that at the blue dot the maximum possible amount of funds are channeled to the banks (which are mostly managed by good bankers, since β is high). Thus, the regulator intervenes to rule out the inefficient pooling equilibria and the separating equilibrium. There should be a minimum leverage requirement, $d \ge d^P$. The resulting equilibrium is represented by the blue dot on Fig. 4. □

We can interpret the optimal capital requirements as risk-sensitive. If the equilibrium is at the red dot, the regulator believes that only good banks participate; this is the safe equilibrium and only the non-contingent element applies. Observing an equilibrium different from the red dot, the regulator infers that this is a pooling equilibrium in which bad banks participate, i.e., this is the risky equilibrium. In this case, the contingent element kicks in. Note that on the equilibrium path the contingent element is never used. Thus, our risk-sensitive capital requirement is different from that proposed recently by Ahnert et al. (2021). In their model, capital resolves a moral hazard problem and optimal sensitivity of capital regulation is non-monotonic in the accuracy of risk assessment.

5. The regulator's game

5.1. Regulatory instruments

In this section, we endogenize the degree of transparency in the banking sector, β. On the micro-prudential side, the regulator audits applicants, determines disclosure requirements, and grants banking licenses, and on the macro-prudential side, the regulator sets leverage/capital requirements. Our choice of regulatory instruments reflects reality: in the US, the Office of the Comptroller of the Currency (OCC) issue federal charters, whereas individual state authorities issue state charters. The chartering agency ensures that the new bank meets minimum standards of capital and management expertise.

At $t = 0$ agents apply for banking licenses. The regulator audits the applicants and generates a noisy signal; she grants a license to an applicant if the signal indicates that the applicant is a good banker. The regulator may or may not impose disclosure requirements, which has an impact on the precision of the signal generated. Specifically, the fraction of good bankers in the pool of licensed bankers is given by $\beta \in \{\rho, \rho + \kappa\}$, where $\beta = \rho$ without disclosure and $\beta = \rho + \kappa$ with disclosure. Disclosure requirements improve the average quality of the bankers who receive licenses, i.e., $\kappa > 0$, but still, some bad bankers remain in the pool, i.e., $\rho + \kappa < 1$.

Another interpretation is that there is an intensive margin effect of disclosure. Suppose that bankers can exert unobservable effort to increase the probability of being the good type, effort is costly, and the cost of effort is heterogeneous across bankers. Disclosure makes it more likely that the good type will be identified as such, and hence, it provides a stronger incentive for the bankers to exert effort and the average quality of bankers increases. Empirically, increased disclosure leads to better compliance by banks (e.g., Gopalan, 2021) and resolution of agency conflicts (e.g., Klein et al., 2021), which result in an increase in the average quality of the banking sector. The regulator determines whether or not to set disclosure requirements by weighing up the costs and benefits by fully anticipating the equilibrium. We do not assume an exogenous (direct) cost of disclosure.

5.2. Disclosure requirements can be endogenously costly

In this section, we consider disclosure requirements as the sole regulatory instrument. We consider the following three cases:

Case 1: $\rho + \kappa \le \beta^*$**.** For these parameters, the separating equilibrium at the red dot is the unique equilibrium with or without disclosure, which is also the efficient outcome (see Proposition 6). The only difference between the disclosure and no-disclosure regimes is that with disclosure, the fraction of good bankers is higher. Hence, the regulator imposes disclosure requirements to increase the amount of funds channeled to investment through good bankers which increases the net social surplus.

Case 2: $\beta^* < \rho + \kappa \leq \beta^R$**.** For these parameters, given β, the efficient outcome is the separating equilibrium at the red dot. However, disclosure requirements may lead to adverse selection. More specifically, disclosure requirements (which increase β) may lead to multiple "reasonable" pooling equilibria which imply a lower net social surplus than the separating equilibrium without disclosure since value-destroying bad bankers also participate (see part (i) of Proposition 7). The fall in the net social surplus is the adverse selection cost of higher disclosure, i.e., this adverse selection cost is the endogenous cost of disclosure (for an illustration see Lemma 6 and the discussion afterwards).

Note that for these parameters, the separating equilibrium at the red dot cannot be ruled out either (since both good and bad bankers wish to deviate from the separating equilibrium, the Intuitive criterion does not have a bite). If the separating equilibrium obtains, then disclosure is strictly preferred to no-disclosure, since the fraction of good banks is higher (similar to case 1 above). However, ex-ante the regulator cannot predict whether the separating or pooling equilibrium will arise. Therefore, there is a coordination failure problem. As we see in Section 5.3, this coordination failure problem is resolved when the regulator has access to other instruments such as capital requirements.

Case 3: $\rho + \kappa > \beta^R$**.** For these parameters, with or without disclosure the efficient outcome is the pooling equilibrium on the diversion constraint with the highest possible leverage (the blue dot on Fig. 4). Starting from an efficient pooling equilibrium without disclosure, the imposition of disclosure requirements may lead to inefficient pooling equilibria or the separating equilibrium at the red dot, which may entail lower net social surplus than the efficient pooling equilibria without disclosure. Thus, in the absence of any other regulatory instruments, there is a similar coordination failure as above which may be resolved if leverage requirements can be used (see Section 5.3).

Lemma 6. For $\rho + \kappa > \beta^*$, in the absence of any other regulatory instruments, disclosure requirements could lead to an equilibrium with a lower net social surplus (the endogenous cost of disclosure).

We illustrate the endogenous cost of disclosure with an example. Consider the case that $\rho = \beta^* < \rho + \kappa < \beta^R$, which implies that the equilibrium is separating without disclosure and there is a multiplicity of equilibria when there is disclosure. If there is disclosure, suppose that the best possible "reasonable" pooling equilibrium obtains, which is represented by the blue dot (see Fig. 4). Comparing the net social surplus in the two equilibria, for κ sufficiently small the net social surplus is higher in the separating:

$$\rho(1+d^S)(p_g - p_l)X > (\rho+\kappa)(1+d^P)(p_g - p_l)X + \underbrace{(1-\rho-\kappa)(1+d^P)(p_b - p_l)X}_{-ve} \tag{23}$$

The LHS represents the net social surplus in the separating equilibrium when there is no disclosure, while the RHS represents the net social surplus in the best possible pooling equilibrium with disclosure. The advantage of disclosure is that there are more good bankers in the pooling, $\rho + \kappa > \rho$, while the disadvantage is that value-destroying bad bankers also participate. As $\kappa \to 0$, the first term in the RHS becomes arbitrarily close to the LHS because at this point ρ is arbitrarily close to $\rho + \kappa$ and d^S is arbitrarily close to d^P. Further, since the second term in the RHS is strictly negative due to $p_b < p_l$ (for any admissible κ), the above inequality holds. So, as $\kappa \to 0$, the advantage of disclosure is outweighed by the disadvantage. Therefore, the net social surplus in the no-disclosure separating equilibrium is higher than the net social surplus even in the best possible pooling equilibrium for κ sufficiently small. Clearly, this holds true for any other pooling equilibrium.

5.3. Disclosure requirements and capital regulation

In this section, we show that the regulator can use disclosure requirements with or without capital or leverage requirements to always implement the efficient (second best) allocation. Which combination of instruments the regulator uses depends on the case at hand. For some parameter values, the regulator will use disclosure requirements on their own, and for other parameter values, the regulator pairs disclosure requirements with capital or leverage requirements. There are three cases that correspond to the cases discussed above in Section 5.2:

Disclosure requirements only. Consider the case that $\rho + \kappa \leq \beta^*$. For these parameters, the efficient outcome is the separating equilibrium at the red dot, which is the unique equilibrium with or without disclosure requirements (see Proposition 6). The only difference between the disclosure and no-disclosure regimes is that with disclosure the fraction of good bankers is higher, compared to the no-disclosure regime. Hence, the regulator imposes disclosure requirements to increase the fraction of good bankers and the net social surplus.

Disclosure and capital requirements. The most interesting case arises when the prior is $\rho < \beta^* < \rho + \kappa \leq \beta^R$. The unregulated equilibrium is the separating at the red dot with a fraction of good bankers, ρ. The imposition of disclosure requirements could be followed by two outcomes: i. an efficient separating equilibrium with $\rho + \kappa$ good bankers, which is preferred by the regulator to the separating without disclosure, and ii. multiple inefficient pooling equilibria, which entail lower net social surplus compared to the separating without disclosure (the endogenous cost of disclosure). The regulator cannot predict which out of the two outcomes will prevail. Hence, in the absence of any other regulatory tools, disclosure requirements could lead to an equilibrium with a lower net social surplus (Lemma 6). However, if disclosure requirements are combined with capital requirements, then the coordination failure problem is completely resolved, and the regulator can always implement the efficient separating equilibrium at the red dot. The separating equilibrium at the red dot can be achieved using the appropriately designed capital requirements, with non-contingent and contingent elements (the formal analysis is provided in part (i) of Proposition 7).

Further, disclosure is always better than no-disclosure since disclosure increases the fraction of good bankers from ρ to $\rho+\kappa$, but does not affect leverage (which equals d^S with or without disclosure, as long as the optimal capital requirements are also used). The above analysis shows that the endogenous cost of disclosure provides an additional rationale for the use of capital requirements. As a result, the combination of disclosure and capital requirements overcomes the potential adverse selection problem and always implements the efficient outcome which improves on the unregulated equilibrium.

Disclosure and leverage requirements. If $\rho+\kappa>\beta^R$, with or without disclosure, the efficient outcome is the pooling equilibrium at the blue dot. As discussed in Proposition 5, the separating equilibrium and several inefficient pooling equilibria may not be ruled out for these parameters. Starting from an efficient pooling equilibrium without disclosure, as described in Case 3 of Section 5.2, in the absence of any other regulatory tools, inefficient equilibria may not be ruled out. The use of leverage requirements resolves the coordination failure problem as it achieves the efficient pooling equilibrium at the blue dot as the unique equilibrium. Additionally, disclosure makes the blue dot equilibrium even more desirable from the net social surplus perspective since β is higher with disclosure compared to no disclosure, $\rho+\kappa>\rho$. Thus, the regulator simultaneously uses disclosure and leverage requirements to embrace the efficient pooling equilibrium.

The following proposition describes the optimal regulatory intervention for various parameters:

Proposition 8. Optimally designed regulatory intervention achieves the second best:

i) *For $\rho+\kappa\le\beta^*$, the regulator imposes disclosure requirements only. The regulated equilibrium is the separating equilibrium at the red dot, (R^S, d^S), with $\beta=\rho+\kappa$.*
ii) *For $\beta^*<\rho+\kappa\le\beta^R$, the regulator imposes disclosure requirements and sets capital requirements. The regulated equilibrium is the separating equilibrium at the red dot, (R^S, d^S), with $\beta=\rho+\kappa$.*
iii) *For $\rho+\kappa>\beta^R$, the regulator imposes disclosure requirements and sets leverage requirements. The regulated equilibrium is the pooling equilibrium at the blue dot, (R^P, d^P), with $\beta=\rho+\kappa$.*

To summarize, higher disclosure has two opposite effects: the positive effect is that the fraction of good bankers is higher which leads to a higher net social surplus and the negative effect is that it may lead to an equilibrium with a lower net social surplus than the equilibrium without disclosure. The use of other regulatory instruments (capital or leverage requirements) eliminates the negative effect and allows the regulator to implement the efficient equilibrium with disclosure. As a result, the combination of disclosure requirements and leverage/capital requirements always improves on the unregulated equilibrium. These results echo the implication in Thakor (2015) (see footnote 2 in their paper) that disclosure and capital requirements can be complementary regulatory instruments in achieving higher stability: in Thakor (2015) the interaction arises through a reduced cost of capital due to disclosure, while here the capital requirements are used as a separating device when disclosure disrupts the separating equilibrium.

6. Empirical implications

1. *Optimal capital requirements lead to higher net social surplus but reduce bank scale (lending).*
   Suppose that $\beta^*<\beta\le\beta^R$ and a pooling equilibrium obtains with leverage, $d>d^S$. The regulator imposes minimum capital requirements to achieve separation and improve welfare. The regulation-induced separating equilibrium (the red dot) reduces the scale of the good banks. The prediction is consistent with empirical evidence that higher capital requirements lead to lower lending by affected banks (e.g., Fraisse et al., 2019, Gropp et al., 2019 and DeJonghe et al., 2020). As quoted in Admati et al. (2014), in a 2009 interview, then CEO of Deutsche Bank, Josef Ackermann, said:
   "More equity might increase stability of banks. At the same time however, it would restrict their ability to provide loans to the rest of the economy. This reduces growth and has negative effects for all."
   In our model, capital requirements may reduce lending, as Ackermann suggested, but it also improves net social surplus by keeping the bad banks out (consistent with the evidence in Posner, 2015). So, despite Ackermann's reservations, capital requirements are an improvement on laissez-faire (e.g., Thakor, 2014 and Thakor, 2018).
2. *Banks make strictly positive profits even though they compete in prices.*
   A key prediction of our model is that although we allow for price competition, banks make strictly positive profits in equilibrium. More specifically, banks retain all the surplus in the complete information case and some pooling equilibria of the asymmetric information case (with $R=R^P$), while they retain a part of the surplus in the other pooling equilibria and the separating equilibrium of the asymmetric information case. The prediction is consistent with the evidence presented by Drechsler et al. (2021) who find that US banks are characterized by substantial market power in the retail deposit market. Drechsler et al. (2021) suggest that banks derive the market power from having a deposit franchise. Ours is a complementary explanation: the threat of diversion puts an endogenous upper bound on banks' ability to accept deposits (a capacity constraint), which in turn gives them market power in the deposit market.
3. *Bank leverage increases as the threat of diversion falls (higher ϕ).*
   For $\beta\le\beta^R$, the unique regulated equilibrium is the separating at the red dot with leverage, d^S, while for $\beta>\beta^R$, the unique regulated equilibrium is the pooling at the blue dot with leverage, d^P. In either case, as the threat of diversion falls, a lower level of equity is needed to convince depositors to accept deposit

contracts since both d^S and d^P are increasing in ϕ (from Eqs. (15) and (19), respectively).

To the best of our knowledge, this prediction has not been tested. The challenge in testing this prediction lies in identifying a good proxy for the threat of diversion. One candidate is the intensity of supervision by the regulator. Arguably, as the regulator supervises more closely and enforces more strictly, the amount that can be diverted will be smaller. There are enforcement actions, such as restricting dividend payments or share repurchases, that will reduce diversion. Barth et al. (2013) conduct surveys to create a database of bank regulation and supervision in 180 countries for 13 years. The database includes variables such as the "Overall Restrictions on Banking Activities" and "Official Supervisory Action" (which includes "Official Supervisory Power") which may be used as a proxy for the threat of diversion to test the prediction in the cross-section of countries. When banking activities are more restricted or supervisors have more power and less forbearance discretion, the threat of diversion by bankers is likely to be smaller.

The threat of diversion is likely to be negatively related to the quality of governance and supervision. Ideally, we need to find exogenous variations in the independent variable. Potentially suitable settings are instances of corporate inversions (e.g., Cortes et al., 2021) and unexpected changes in supervisory intensity (e.g., Kandrac and Schlusche, 2021, Gopalan et al., 2021, Passalacqua et al., 2020, Bonfim et al., 2021).

4. *At low levels of transparency (β), an increase in the degree of transparency leads to a larger banking sector and bank leverage is unaffected. At high levels of transparency, an increase in the degree of transparency leads to a higher quality banking sector and more levered banks.*

An increase in the degree of transparency, β, leads to a higher fraction of good bankers obtaining banking licenses.

At low levels of transparency, $\beta \leq \beta^R$, higher transparency leads to an increase in the number of active banks since the separating equilibrium at the red dot obtains uniquely for these parameters, either by itself or due to the imposition of capital requirements, and only the good bankers manage banks. However, bank leverage is not affected since the leverage in the red dot equilibrium does not depend on the fraction of good bankers (Eq. (15)).

Leverage is affected when the banking sector is very transparent, $\beta > \beta^R$. In this case, the regulator imposes leverage requirements along with disclosure requirements (part (iii) of Proposition 8) and the pooling with the maximum leverage obtains as the unique equilibrium. An increase in the quality of auditing leads to a higher fraction of good bankers and the average quality of the banking sector is higher. This, in turn, implies that the minimum acceptable deposit rate in the pooling equilibrium, R^P, is lower, so the pooling equilibrium at the blue dot is characterized by higher leverage after disclosure. To the best of our knowledge, this prediction has not been tested.

To test this prediction, we need to find a proxy for β. To measure changes in β, variables such as "Entry into Banking Requirements" and "Financial Statement Transparency" from the Barth et al. (2013) database can be used. The "Entry into Banking Requirements" variable reflects the stringency of requirements to obtain banking licenses and the "Financial Statement Transparency" variable reflects banks' disclosure requirements and the quality of disclosure. Hence, a higher value of these variables should lead to a higher β.

7. Extensions

Bad banker's outside option, γ. We have assumed that $\gamma = 1$ in Eq. (9): a bad banker is always able to deposit in a good bank if he chooses to do so. However, competition with other depositors (both other bad bankers and the unskilled depositors) implies that the parameter, γ, may take a value less than 1. Specifically, γ is given as the ratio of bad bankers to the sum of bad bankers and unskilled depositors. In this case, the bad banker deposits with a positive probability, $0 < \gamma < 1$. All results from the baseline are qualitatively identical. The reason is that the banker's indifference curve is still flatter than the bad banker's participation constraint in the (d, R) space, as is the case in the baseline. All arguments provided in the proofs go through, unchanged.

The three-type case. Our results are qualitatively unchanged when there are more than two types of bankers (see Appendix C for the full analysis). Bankers may be good, intermediate, or bad. We show that the equilibrium is either full pooling in which case all three types become bankers or partial pooling in which adjacent types pool and separate from the third type (i.e., either the good and intermediate type bankers pool to manage banks, while the bad type stays out, or only the good bankers manage banks, while the intermediate type and bad bankers stay out). The reason is that whenever the participation constraint of the bad banker is satisfied, then so is that of the intermediate type banker (but not the other way around). The equilibria that survive the Intuitive Criterion are similar to the benchmark case. The analysis generalizes to any number of banker types, but it gets complicated since there are more cases to consider.

8. Conclusion

We consider a model which involves two informational frictions: ex-post moral hazard (output diversion) and ex-ante asymmetric information (the banker's type is her private information). The model delivers several interesting results: (i) the return on equity is endogenously higher than the return on deposits, (ii) in the presence of asymmetric information, there is scope for regulation despite no exogenously assumed distortions, (iii) disclosure requirements are endogenously costly since disclosure can lead to adverse selection, and (iv) the combination of disclosure and capital requirements always improve welfare, which provides a novel rationale for capital requirements.

In the presence of asymmetric information, the unique equilibrium is separating if banks are very opaque. If banks are sufficiently transparent, there are multiple equilibria, either separating or pooling. From a policy perspective, a divergence between the incentives of the good banker and the regulator arises when banks are moderately transparent, despite optimally designed contracts and no externally imposed distortions: the equilibrium outcome may be a pooling equilibrium, while the regulator prefers separation. The divergence in objectives of the regulator and the bank arises due to an informational friction that is fully internalized by the regulator but only partially internalized by the banker. The regulator can overcome the adverse selection problem using optimally designed capital requirements. When banks are very transparent, both the good banker and the regulator prefer the pooling with the maximum leverage. However, some inefficient equilibria cannot be ruled out due to off-equilibrium beliefs of depositors, which makes regulation relevant. In this case, the regulator embraces adverse selection by setting a minimum leverage requirement. This intervention rules out the separating and the inefficient pooling equilibria and allows the banks to achieve the pooling with the maximum leverage.

We endogenize the degree of transparency in the banking sector by allowing the regulator to impose disclosure requirements. Disclosure requirements can be endogenously costly since disclosure may shift the economy from a separating to a pooling equilibrium, which implies a lower net social surplus compared to the equilibrium without disclosure. However, when paired with optimally designed capital regulation, higher disclosure is always welfare-improving. Thus, the endogenous cost of disclosure provides a novel rationale for the use of bank capital requirements. Consistent with recent trends in bank regulation, our model generates the implication that disclosure and capital requirements can be used jointly to improve upon the unregulated equilibrium.

Appendix A. Omitted proofs

Proposition 2: *Given Assumption A2, although banks compete for deposits, in equilibrium banks make monopoly profits. The equilibrium is characterized by Eqs. (5) and (6).*

Proof. First, we rule out an equilibrium in which $R < \frac{p_l X}{p_g} = R^C$. If $R < R^C$, then the depositors are better off investing on their own which implies that their participation constraint is violated. Hence, this cannot be an equilibrium. Assumption A2 implies that even if $R = R^C$, the supply of deposits, $1 - \lambda$, exceeds the amount of deposits, λd^C, which the banker can accept without violating the diversion constraint. Consider an equilibrium in which $R > R^C$, i.e., the depositors' participation constraints are slack. Then, a banker can deviate by reducing R by ϵ. There are two effects: first, the diversion constraint becomes more lax, which implies that the bank can credibly promise repayments to more depositors and so, increase its leverage, and second, the per-unit rent extracted from deposits increases. Both effects increase the banker's profitability. Therefore, $R > R^C$ cannot be an equilibrium either. Next, we check that the point at which the depositors' participation constraint binds is an equilibrium. An increase in R has two negative effects on the banker's profits: first, the higher repayment can be credibly promised to fewer depositors, and second, the profit per-unit of deposit falls. This clearly implies that a banker who offers a higher deposit rate would make a lower profit. Therefore, the unique equilibrium is characterized by $R = R^C$. Substituting $R = R^C$ into $d(R)$, we derive the equilibrium bank leverage. The unique equilibrium is represented at the pink dot on Fig. 1. □

Lemma 1: *There cannot exist an equilibrium in which only the bad bankers accept deposits and manage banks.*

Proof. In a separating equilibrium in which only the bad banker accepts deposits, the participation constraint of the depositor is violated given the limited liability constraint, $R \leq X$:

$$p_b R < 1 \tag{A.1}$$

Therefore, there cannot exist an equilibrium in which only the bad banker accepts deposits. □

Lemma 2: *There cannot exist an equilibrium in which both good and bad bankers accept deposits and manage banks but offer different contracts.*

Proof. From Eq. (7), the slope of a banker's indifference curve in the (d, R) space is given as follows:

$$\left.\frac{dd}{dR}\right|_{IC} = \frac{d}{X - R} > 0 \tag{A.2}$$

As p disappears from the slope, the indifference curves for the good and bad bankers coincide, i.e., the single-crossing property does not obtain. This implies that, contrary to the standard settings, separation in our model does not arise through the incentive compatibility constraints, as we illustrate below.

Suppose that the bad banker offers a contract, $C_b = (R_b, d_b)$ and the good banker offers a contract, $C_g = (R_g, d_g)$. Profit maximization ensures that the diversion constraint binds, which means that one element of the contract is pinned down by the other. Without loss of generality, we consider that the separating equilibrium is characterized by $d_b = d_g = d$ and $R_b(d) \neq R_g(d)$. The bad banker truthfully reveals his type if his incentive compatibility constraint is satisfied:

$$\begin{aligned}&(1+d)p_b X - d p_b R_b \geq (1+d)p_b X - d p_b R_g\\ &\Rightarrow R_g \geq R_b\end{aligned} \tag{A.3}$$

Similarly, the good banker reveals his type if:

$$\begin{aligned}&(1+d)p_g X - d p_g R_g \geq (1+d)p_g X - d p_g R_b\\ &\Rightarrow R_g \leq R_b\end{aligned} \tag{A.4}$$

The two constraints are simultaneously satisfied only if $R_b = R_g$. This contradicts the starting assumption, $R_b \neq R_g$. Therefore, it is not possible to achieve separation using the incentive compatibility constraints. □

Lemma 3: *There cannot exist a "reasonable" equilibrium where the market breaks down.*

Proof. Suppose that the market breaks down in equilibrium (similar to Akerlof, 1970). From Eq. (10), there always exists $R < X$ and d strictly positive for which the bad banker's participation constraint is violated. The good bank can then profitably deviate from the breakdown equilibrium by offering any contract which violates the bad banker's participation constraint: the good bank proposes (R, d) such that Eq. (9) is violated. If this contract is accepted by the depositors, the bad bank is strictly worse off compared to the market breakdown equilibrium, while the good bank is strictly better off. Then, according to the Intuitive Criterion, the depositors would assign probability 1 to the event that the offer comes from a good banker. The depositor is (weakly) better off if the contract is offered by the good banker (strictly, if $R > R^C$, as we will show below to be the case). Hence, the depositors accept the contract and deposit their funds with the bank offering the contract. Thus, the market breakdown equilibrium does not survive the Intuitive Criterion. □

Lemma 4: *The set of parameters for which a pooling equilibrium may exist is non-empty.*

Proof. Assumption A2, which states that diversion is sufficiently large, puts an upper bound on ϕ, i.e., $\phi < \frac{p_l}{p_g}(1-\lambda)$. Assumption A4 puts a lower bound, $\phi > \hat{\phi}$. To show that a pooling equilibrium exists, we need to make sure that there exists $\hat{\phi}$ which satisfies $0 < \hat{\phi} < \frac{p_l}{p_g}(1-\lambda)$. $\hat{\phi} > 0$ since $p_b < \{p_g, p_l\}$, and we need to check that $\hat{\phi} < \frac{p_l}{p_g}(1-\lambda)$ exists. This condition simplifies as follows:

$$\lambda < \frac{p_b(p_g - p_l)}{p_l(p_g - p_b)} \tag{A.5}$$

Since p_b and p_l are both positive, there always exists feasible values of λ for which the condition is satisfied. Therefore, the set of parameters for which the pooling equilibrium may exist for any value of β is non-empty. □

Lemma 5: *β^R lies in the range, $(\beta^*, 1)$.*

Proof. β^R comes from solving the regulator's IC (Eq. (21)):

$$\beta^R = \frac{(1+d^P)(p_l - p_b)}{(p_g - p_l)(d^P - d^S) + (1+d^P)(p_l - p_b)} \tag{A.6}$$

$\beta^R > \beta^*$ is immediate from the discussion in the text (and Eq. (21)). From Eq. (A.6), $\beta^R < 1$ if:

$$(1+d^P)(p_l - p_b) < (p_g - p_l)(d^P - d^S) + (1+d^P)(p_l - p_b)$$
$$\Rightarrow (p_g - p_l)(d^P - d^S) > 0 \tag{A.7}$$

$p_g > p_l$, and for $\beta > \beta^*$, $d^P > d^S$. Therefore, the above condition is always satisfied, and $\beta^R < 1$. □

Proposition 6: *If $\beta < \beta^*$, then the separating equilibrium is unique and efficient.*

Proof. If $\beta < \beta^*$, R^P lies to the right of R^S (Fig. 3a). No pooling equilibria are feasible and the feasible separating equilibria lie below both the diversion constraint and the bad banker's participation constraint. Given that the objective of the regulator is to maximize the net social surplus, the regulator aims to maximize bank leverage, without regard to the deposit rate. The highest leverage in this area is at the red dot, which is also the market equilibrium. □

Appendix B. Stronger refinements

In standard settings, the single-crossing condition is satisfied and separation arises through the incentive compatibility constraints. Instead, in our setting, separation can only arise through the participation constraints because the single-crossing condition fails. Given that the two banker types' indifference curves coincide, conditional on the participation constraints of both types being satisfied, any deviation which makes one type better (resp. worse) off, also makes the other type better (resp. worse) off. Therefore, whether we use the Intuitive Criterion or a stronger refinement such as the Universal Divinity or D1 refinements does not affect our analysis, which we illustrate below.

In the application of the Intuitive Criterion, it cannot be ruled out that a deviation from an equilibrium comes from a particular type as long as the type deviates with a non-zero probability. The Intuitive Criterion does not discriminate between types based on the likelihood of deviation. In contrast, in the stronger refinements, the deviation is assumed to come with probability one from the type which is more likely to deviate. Starting from any equilibrium, any deviation which makes one type strictly better off also makes any other type strictly better off (given the coincidence of the indifference curves). Hence, one type is not more likely than the other to deviate. Therefore, stronger refinements are equally ineffective as the Intuitive Criterion in restricting beliefs off the equilibrium path.

Appendix C. The three-type case

In the baseline model, we present results for the two-type case: bankers are either good or bad. In this extension, we consider the three-type case, where bankers may be good, intermediate, or bad, to show that the baseline results generalize to the case in which there are more than two types of bankers. An intermediate type banker has success probability, p_m, such that $p_g > p_m > p_b$. The fraction of good bankers is $\beta \in (0, 1)$, the fraction of intermediate type bankers is $\iota \in (0, 1)$, and the fraction of bad bankers is $(1 - \beta - \iota)$. For the sake of generality, we allow the intermediate type's project to be positive or negative NPV.

Below we list all the candidate equilibria.

1. A candidate full separating equilibrium in which all banker types accept deposits and manage banks, but offer different contracts.
2. A candidate partial pooling equilibrium in which the good bankers accept deposits and manage banks, while the bad and intermediate bankers either deposit or invest on their own.
3. A candidate partial pooling equilibrium in which the bad and intermediate bankers accept deposits and manage banks, while the good bankers either deposit or invest on their own.
4. A candidate partial pooling equilibrium in which the good and intermediate bankers accept deposits and manage banks, while the bad bankers either deposit or invest on their own.

5. A candidate partial pooling equilibrium in which the good and bad bankers accept deposits and manage banks, while the intermediate bankers either deposit or invest on their own.
6. A candidate full pooling equilibrium in which all banker types accept deposits and manage banks.
7. A candidate full separating equilibrium in which none of the banker types accepts deposits and they invest on their own (market breakdown).

Below, we show that 1, 3, 5 and 7 cannot exist.

As before, the different types' indifference curves coincide in the (d, R) space since types differ only with respect to their success probabilities and the success probabilities do not enter the slope of the indifference curves of bankers (see Eq. (A.2)), i.e., the single crossing condition fails. Therefore, the standard incentive compatibility constraints cannot be satisfied and the only way that the good banker can separate from one or both of the other banker types is through the participation constraints.

Lemma 7. There cannot exist a full separating equilibrium in which all three banker types manage banks but offer different contracts.

Proof. The proof relies on the observation that the different banker types' indifference curves coincide, and follows the same logic as in the proof of Lemma 2 where we prove this result for the two-type case. □

Lemma 8. If the participation constraint of an intermediate banker is violated, then so is the one of the bad banker. But, the intermediate type's participation constraint may be satisfied even if the bad type's is violated.

Proof. The participation constraint of the type $k \in \{m, b\}$ is given by:

$$d \geq \frac{\pi(k)R - p_k X}{p_k(X - R)} \equiv \bar{d}_k(R) \tag{C.1}$$

π reflects the average success probability of banks in equilibrium. Given π, comparing the participation constraints of the intermediate and bad types, $\bar{d}_m < \bar{d}_b$ for any $R < X$ since $p_m > p_b$. This implies that if the participation constraint of the intermediate banker is violated, then so is the participation constraint of the bad banker, but not the other way around. Therefore, the intermediate banker's outside option is depositing in a good bank, i.e., $\pi(m) = p_g$, while the bad banker's outside option is depositing in a bank managed by either a good or an intermediate banker, i.e., $\pi(b) = \frac{\beta}{\beta+\iota} p_g + \frac{\iota}{\beta+\iota} p_m \equiv \hat{p}_m$. □

Lemma 8 implies that option 5 is eliminated since the good banker cannot pool with the bad banker and separate from the intermediate type at the same time. Option 3 is eliminated since the good banker is always strictly better off managing banks than staying out (Eq. (8)). Further, note that there cannot exist a breakdown equilibrium in which none of the types manages banks (the logic is the same as in Lemma 3 where we prove the result for the two-type case); thus, option 7 is eliminated. Any of Options 1, 2 and 6 are feasible. Which of the three equilibria arises depends on the exogenous parameters and beliefs of depositors.

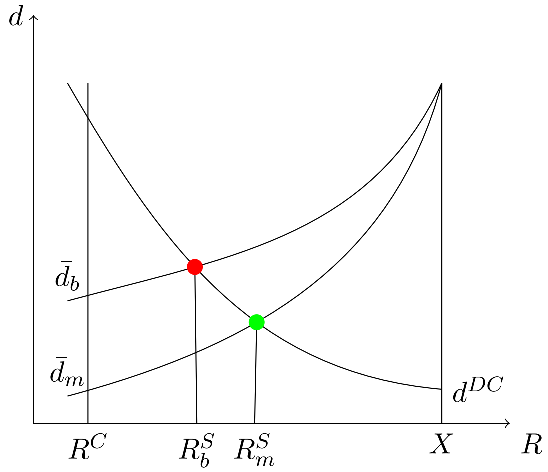

Fig. C.5. Three-type case.

Similar to the two-type case, there are candidate partial pooling equilibria in which a good bank separates from type k bankers by offering contracts at the intersection of the diversion constraint and the type k banker's participation constraint:

$$\bar{d}_k(R) = d^{DC}(R) \tag{C.2}$$

Since $\bar{d}_m < \bar{d}_b$ (Lemma 8), the point at which the diversion constraint intersects with the intermediate banker's participation constraint is below the point at which the diversion constraint intersects with the bad banker's participation constraint. Denote the intersections as (R_k^S, d_k^S) for $k \in \{m, b\}$. (R_b^S, d_b^S) is represented at the red dot in Fig. C.5, while (R_m^S, d_m^S) is the green dot.

If instead, the good banker pools with one or both other types, the deposit rate must satisfy the unskilled depositors' participation constraint, given the average quality of banks:

$$\hat{R}_k \geq \frac{1}{\hat{p}_k} \quad \text{for } k \in \{m, b\} \tag{C.3}$$

where $k = m$ if the good bankers only pool with the intermediate type bankers, $\hat{p}_m = \frac{\beta}{\beta+\iota} p_g + \frac{\iota}{\beta+\iota} p_m$ and $k = b$ if the good bankers pool with both intermediate and bad bankers, $\hat{p}_b = \beta p_g + \iota p_m + (1 - \beta - \iota) p_b$. Clearly, $\hat{R}_b > \hat{R}_m$ since $p_m > p_b$.

We illustrate the various constraints in Fig. C.5. We consider three cases.

Case 1. β and/or p_m are small such that $\hat{R}_m > R_m^S$. A partial pooling in which the intermediate banker also manages banks (alongside the good bank) cannot be an equilibrium. Such a pooling equilibrium will lie at the intersection of $\hat{R}_m$ and the diversion constraint. However, this point cannot be an equilibrium since the intermediate banker's participation constraint is violated. By the same argument, the full pooling in which all three banker types manage banks is also eliminated. The unique equilibrium is the full separating one in which only the good bankers manage banks and the equilibrium is given at the green dot on Fig. 1. The good type restricts leverage severely and offers a high deposit rate to separate from both the intermediate type and bad bankers. There are other feasible separating equilibria, which lie along the intermediate banker's participation constraint, but these do not survive the Intuitive Criterion. The argument is identical as provided in the two-type case (see the proof of Proposition 3).

Case 2. β is in the intermediate range such that $\hat{R}_m < R_m^S$ and $\hat{R}_b > R_b^S$. There may exist partial pooling equilibria in which both the good and intermediate type bankers manage banks, but not the bad bankers. First, we need to determine the pooling equilibrium between the good and intermediate type bankers with the highest possible leverage. If $\hat{R}_m$ lies in between R_b^S and R_m^S, then the pooling equilibrium with the highest possible leverage is at the intersection of the diversion constraint and $\hat{R}_m$. If $\hat{R}_m$ lies to the left of R_b^S (e.g., since p_m is large), the pooling equilibrium with the highest possible leverage is at the red dot, (R_b^S, d_b^S); in effect, the good and intermediate type bankers restrict leverage to separate from the bad type.

Depending on the profitability of the intermediate type bankers, p_m, some of the inefficient pooling equilibria and the separating equilibrium may be ruled out. Consider the case that p_m is high such that $\frac{1}{p_m}$ lies in between $\hat{R}_m$ and R_m^S. Suppose that the equilibrium is at the green dot, i.e., only the good bankers manage banks. A deviation from the green dot equilibrium along the diversion constraint by offering a lower deposit rate ($R_m^S > R > \frac{1}{p_m}$) may come from both a good or intermediate banker (but not the bad banker, since the bad banker's participation constraint is violated in this region). For this deposit rate, the depositor will be better off compared to the case when she invests on her own, even if the offer comes from the intermediate type. Therefore, such an offer will be accepted by the depositor. Both the good and intermediate type bankers will deviate from the green dot, thereby eliminating it as an equilibrium. By the same argument, all pooling equilibria with deposit rate in between $\frac{1}{p_m}$ and R_m^S will be eliminated. There will remain multiplicity of equilibria with the deposit rate in between $\frac{1}{p_m}$ and $\hat{R}_m$ (since for these deposit rates, the depositor is worse off than investing on her own if the offer comes from the intermediate type). Now, consider the case that the intermediate type banker's project is not very profitable such that $\frac{1}{p_m} > R_m^S$. None of the feasible equilibria to the left of the green dot can be eliminated, since a deviation from any of these equilibria, if it comes from the intermediate type, will make the depositors worse off, and hence will be rejected.

Case 3. β is high such that $\hat{R}_b < R_b^S$. The equilibrium in which only the good banker manages banks may still exist and so do the equilibria in which both the good and intermediate type bankers manage banks, but the bad bankers stay out (some of these equilibria may be eliminated if p_m is sufficiently high, as in Case 2). Additionally, there are equilibria in which all bankers participate. The full pooling equilibrium with the highest possible leverage is at the intersection of the diversion constraint and $\hat{R}_b$. The multiplicity of equilibria arise for the same reasons as the two-type case: while the full pooling with the maximum leverage is feasible, all banker types can strictly increase their profits by deviating from any of the other equilibria to this one, which implies that the Intuitive Criterion does not have a bite, and hence, these equilibria survive.

Importantly, extending to the three-type case does not affect the analysis qualitatively. For many parameters, the set of equilibria that survive the Intuitive Criterion are very similar to the benchmark case and policy implications are unchanged. The analysis generalizes to any number of bank types, but it gets complicated since more cases need to be considered. In standard settings (when the single crossing condition is satisfied), often the Intuitive Criterion fails to eliminate equilibria in the two-type case, which are eliminated in the three-type case. In our model, this is not the case since in contrast to standard settings, separation arises through participation constraints. Given that different bank types' indifference curves coincide, conditional on the participation constraints of all types being satisfied, any deviation which makes one type better (resp. worse) off, also makes the other types better (resp. worse) off. Therefore, the Intuitive Criterion does not have a bite, and it cannot restrict beliefs.

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