IMF *Staff Papers*
Vol. 45, No. 1 (March 1998)

Public Disclosure and Bank Failures

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We study how public disclosure of banks' risk exposure affects banks' risk taking incentives and assess the impact of the presence of informed depositors on the soundness of the banking system. We find that, when banks have complete control over the volatility of their loan portfolio, public disclosure reduces the probability of banking crises. However, when banks do not control their risk esposure, the presence of informed depositors may increase the probability of bank failures. [JEL D28, G14, G21, G28]

THIS PAPER examines the impact of public disclosure of information about banks' risk exposure on the probability of bank failures. Although recent literature has addressed the problem of information exchange among banks,[1] to our knowledge no attempt has yet been made to rigorously analyze the consequences of public disclosure on bank soundness. This paper is intended as a first step to fill such a gap.

The idea that, in the absence of an explicit or implicit deposit insurance scheme, public disclosure of information about banks' balance sheets may induce depositors to monitor banks' performances, and thus reduce risk-taking incentives in credit markets, has been receiving renewed attention lately.[2] As a leading example, the Reserve Bank of New Zealand recently stopped conducting on-site examinations of banks while, at the same time, it introduced the requirement of quarterly disclosure statements with

*The authors are both Economists in the Monetary and Exchange Affairs Department. They would like to thank Paul Hilbers for drawing their attention to the issue, and Tomás Baliño, Pietro Garibaldi, Alain Ize, Alfredo Leone, Tonny Lybek, Stefano Vannini, and an anonymous referee, as well as participants at the European and Latin American meetings of the Econometric Society and at IMF seminars, for helpful comments and suggestions.

[1]See, for example, Pagano and Jappelli (1993) and Padilla and Pagano (1997).

[2]A notorious example of this view can be found in the new "free banking" literature that advocates full disclosure, elimination of bank regulations and deposit insurance schemes, and reliance on creditors' monitoring of banks. See, for example, Dowd (1996).

detailed information about asset quality, provisioning, banks' market risk and exposures, et cetera. Although New Zealand's approach is often regarded by central bankers, and specialists in general, as too radical,[3] it is undeniable that there is a consensus among supervisory authorities about the importance of enhancing the dissemination of financial information.[4]

Intuitively, one would expect that informed investors would exert a tighter control on commercial banks, penalizing risk-taking behavior by demanding returns on deposits commensurate with the banks' risk exposures. The impact of information disclosure would then depend on the existence of an uninsured fraction of deposits, and therefore would be sizable when the deposit insurance is limited to small sums. However, this disciplining effect is limited to the fraction of portfolio risk that the bank can assess and manage. Even for large diversified banks, the risk component beyond their control is substantial, particularly in volatile economies or when sophisticated financial instruments are involved. In such circumstances, public disclosure may induce massive runs from one bank to the other, as idiosyncratic factors alter relative risk levels, thus inducing negative feedback as the cost of new funding increases for banks in distress. Likewise, information transparency may render the banking system more sensitive to systemic shocks, with important economic consequences—for example, an increase in the cyclical variability of interest rates and credit supply.

Taking all the above into account, should bank information be disclosed to the public and, if so, to what extent, how, and to whom? To start answering these questions, we develop a model in which a monopolistic bank receives funds from depositors and invests them in risky entrepreneurial projects. Within this framework, we examine two polar cases: in the first one, the riskiness of the bank's portfolio is chosen by the bank; in the second one, risk is chosen by nature. In both scenarios, we discuss the case in which the bank's risk exposure is common knowledge (disclosure), and the case in which it is the bank's private information (nondisclosure). Finally, we compute and compare the probability of bank failure under the two regimes.

Our main finding is the following. When the riskiness of the bank's loan portfolio is chosen by the bank, disclosure of information reduces risk-

[3] Moreover, many argue that since five of the seven largest New Zealand banks are foreign owned, the country is free-riding on banking supervision. For a discussion of the New Zealand case, see Smith (1995).

[4] The current wisdom is well summarized by the Chairman of the Basle Committee of Banking Supervisors, who recently stated that: "In the past, bank supervisors did not place a great deal of emphasis on the issue of transparency and disclosure. This attitude has changed. We do not share the extreme view that a fully informed market can provide discipline to the point of making supervision unnecessary, but we do think that market-imposed discipline is desirable and requires adequate disclosure." See BIS (1996).

taking incentives and thus the probability of bank failures. However, when risk is chosen by nature, disclosing the bank's portfolio information increases the probability of bank failure in cases in which the risk level of the domestic banking system fluctuates within a wide range. This is because, under disclosure, deposit rates react to changes in risk levels. In particular, for wide fluctuations, the negative feedback on the probability of bank failures arising from higher deposit rates in high-risk states of nature dominates the positive feedback from lower rates in low-risk states. In such circumstances, it is optimal for the bank to distribute the cost of risk evenly across periods, but such an arrangement is time inconsistent under disclosure.

Our work is related to that of Matutes and Vives (1995), who study the link between competition for deposits and risk taking in the banking sector, considering both the case in which banks' portfolio decisions are known by depositors (the case of disclosure, in our terminology) and the case in which they are not (nondisclosure). However, since they do not consider situations in which risk is exogenous, they disregard the possible trade-off of information disclosure. Moreover, since they abstract from failure costs borne by banks, they conclude that when the banks' risk choice is observable, any asset risk choice is compatible with equilibrium, while when the risk of the banks' portfolio is not observable, banks have incentives to undertake maximum risk. In our framework, since the bank maximizes its charter value (i.e., the discounted sum of current and future profits), there is a loss associated with failure that works as a disincentive for the bank to engage in high risk. Accordingly, we find that, under nondisclosure, only a bank with a low charter value would find it optimal to engage in high-risk activities. Moreover, low risk is always optimal in the case of disclosure. This is in line with the empirical evidence, as in Keeley (1990) and particularly in Demsetz, Saidenberg, and Strahan (1996), who find a significantly negative correlation between charter values and assets risk for a sample of U.S. banks during 1986–94.[5]

I. The Model

We consider an economy where n (large) identical depositors, each of them endowed with $1/n$ units of cash, decide whether to invest in a foreign risk-free asset or to deposit their cash holdings in a domestic bank. Domestic deposits are uninsured. Depositors are risk neutral, and supply funds to

[5] Suarez (1994) presents a model in which a monopolistic bank chooses between low and high risk, depending on the relative magnitude of its charter value. However, that paper assumes full deposit insurance and therefore it does not discuss the consequences of public disclosure.

the bank if the expected gross return to their deposits is larger than (or equal to) the gross returns R^* offered by the foreign risk-free asset. Without loss of generality, we make the normalization $R^* = 1$. Furthermore, we define $\phi^e(r,.)$ as the depositors' (common) assessment of the expected returns of a unit of cash deposited in the bank, given their information on the bank's risk profile, with r denoting the (gross) deposit rate. Accordingly, the aggregate deposit supply schedule S is given by

$$S = 1, \quad \text{if} \quad \phi^e(r,.) \geq 1;$$
$$S = 0, \quad \text{if} \quad \phi^e(r,.) < 1. \tag{1}$$

The bank is risk neutral. It invests deposits in risky entrepreneurial projects and maximizes the sum of discounted profits (its charter value, from now on). We consider both the case in which the risk profile of investments is chosen by the bank and the case in which it is determined exogenously by nature. In both scenarios, we discuss the situation in which the volatility of the investments is known by depositors (disclosure) and the case in which it is not (nondisclosure). The timing of the game we study is the following: (1) the bank (nature) chooses the risk of the loan portfolio; (2) the bank sets the deposit rate; (3) depositors decide whether to deposit in the bank, on the basis of the deposit rate and the available information set; (4) the bank invests the funds it receives; and (5) finally, at the end of the period, loans are reimbursed to the bank and payments to depositors are made. If the bank cannot cover deposits in full at the end of the period, it is audited and liquidated, and the available funds are distributed proportionately among depositors.[6]

II. The Bank Chooses Risk

Let us suppose that the bank can choose its loan portfolio among a continuum of portfolios, R_j, offering the same expected returns, $\bar{R} > 1$, but having different variance. More precisely, we assume that R_j is uniformly distributed over the interval $[\bar{R} - \gamma_j/2; \bar{R} + \gamma_j/2]$, and that γ_j belongs to the interval $[0, 2R]$.[7] Accordingly, by choosing its loan portfolio R_j, the bank chooses its level of asset risk, but not the expected return. The bank offers a standard debt contract that pays a sum r per unit of deposit at maturity,

[6] We assume that the bank does not adjust its risk position after deposits are made. It should be clear that if this were not the case, depositors would behave as in the nondisclosure scenario.

[7] The upper bound of γ_j is such that it insures nonnegative (gross) returns on investments.

subject to the availability of funds.[8] Since deposits are not insured, if the receipts from loan repayments, which are equal to the realization of R_j times the deposit supply, are not enough to cover deposits, each unit of deposit is paid $R_j < r$. Deposits pay zero (alternatively, they cannot be withdrawn) before maturity. Furthermore, we assume that the distribution of portfolio returns is common knowledge.

Disclosure

Assume that, when deciding whether to deposit in the bank or to invest in the risk-free asset, depositors know the risk level γ chosen by the bank.[9] If this is the case, depositors' (common) assessment of the expected returns $\phi^e(r,.)$ equals the actual expected return $\phi(r, \gamma)$, that is,

$$\phi^e(r,.) = \phi(r,\gamma) = r \int_{\max(r,\bar{R}-\gamma/2)}^{\bar{R}+\gamma/2} f(R)dR + \max\left\{0, \int_{\bar{R}-\gamma/2}^{r} Rf(R)dR\right\}. \tag{2}$$

The first term in equation (2) denotes the depositors' expected returns when the bank pays deposits in full times the probability that the bank does not go bankrupt, while the second term denotes the expected returns in the case of bankruptcy, times the probability of bankruptcy. Since R is uniformly distributed over the interval $[\bar{R} - \gamma/2; \bar{R} + \gamma/2]$, equation (2) can be rewritten as

$$\phi(r,\gamma) = \frac{r}{\gamma}\int_{\max(r,\bar{R}-\gamma/2)}^{\bar{R}+\gamma/2} dR + \frac{1}{\gamma}\max\left\{0, \int_{\bar{R}-\gamma/2}^{r} Rd(R)\right\}. \tag{3}$$

Let us now consider the bank's problem. The bank maximizes its charter value, which is the discounted sum of its expected stream of profits. The solution of the bank's maximization problem can be expressed as

$$V_t = \max_{(r,\gamma)_t^\infty}\left\{\pi_t(.) + \delta p_t(.)\pi(.)_{t+1} + \delta^2 p_t p_{t+1}\pi(.)_{t+2} + \ldots\right\}$$

$$\text{s.t. } \pi_t(.) \geq 0, \text{ for all } t, \tag{4}$$

[8] Note that, because of limited liability, payments to depositors are limited to the bank's equity capital (assumed to be equal to zero without loss of generality), plus whatever funds can be recouped from the bank's investments. Hence, for a given deposit rate, expected current profits are increasing in risk, as higher risk (modeled as a mean preserving spread of the distribution of project returns) raises profits in good times ($R_j > r$), without affecting the outcome in bad times.

[9] From now on, we drop the subindex j for notational simplicity.

where V_t is the bank's charter value at time t, $\pi_t(.)$ denotes the bank's expected profits, given by

$$\pi_t(r_t,\gamma_t) = S\int_{\max(r_t\bar{R}-\gamma_t/2)}^{\bar{R}+\gamma_t/2}(R-r_t)f(R)dR = \frac{S}{\gamma_t}\int_{\max(r_t\bar{R}-\gamma_t/2)}^{\bar{R}+\gamma_t/2}(R-r_t)dR, \quad (5)$$

where $p_t(.)$ is the probability of not going bankrupt in period t, that is,

$$p_t(.) \equiv p(r_t,\gamma_t) = \frac{1}{\gamma_t}\int_{\max(r_t,\bar{R}-\gamma_t/2)}^{\bar{R}+\gamma_t/2} dR, \quad (6)$$

and $\delta \cdot \in [0, 1]$ is a discount factor, representing the rate at which the bank's owner discounts future profits.

Note that, from equations (4)–(6), the bank's choice does not depend on past history. Therefore, the problem is stationary and can be characterized in the following recursive form:

$$V = \max_{\gamma,r}\ \{\pi(r,\gamma) + p(r,\gamma)\delta V_{+1}\} = V_{+1}, \quad \text{s.t. } \pi(r,\gamma) \geq 0, \text{for all } t, \quad (7)$$

where V and V_{+1} denote the bank's value at the beginning of the current and the following period, respectively. Solving equation (7), we obtain the optimal pair (r^*, γ^*), and replacing it back into (7), we have the following expression for the bank's charter value:

$$V = \frac{\pi(r^*,\gamma^*)}{1-\delta p(r^*,\gamma^*)}. \quad (8)$$

In turn, using equations (5) and (6),

$$V = \max\left\{0, \frac{\left[\bar{R}+\gamma^*/2-\max\{r^*,\bar{R}-\gamma^*/2\}\right]^2}{2\left\{\gamma^*-\delta\left[\left(\bar{R}+\gamma^*/2\right)-\max\left\{r^*,\bar{R}-\gamma^*/2\right\}\right]\right\}}\right\}. \quad (9)$$

Depositors accept any rate r such that their expected return is greater than that of the risk-free alternative, that is, r has to satisfy $\phi(r, \gamma^*) \geq 1$. The following lemma shows that, to maximize its charter value, the bank always quotes the lowest deposit rate for which there is a positive supply of funds.[10]

[10] Our results carry on in the case in which deposit supply rises as the interest rate increases. But, since the introduction of an elastic deposit supply schedule would substantially complicate the algebra without providing additional insights, we decided to stick to our simpler framework.

Lemma 1. *The optimal deposit rate $r^*(\gamma)$ satisfies $\phi(\gamma, r^*) = 1$.*

Proof:

First, note that $sgn\left|\frac{\partial\pi(.)}{\partial r}\right| = sgn\left|\frac{\partial p(.)}{\partial r}\right| \leq 0$, so that from equation (7), for deposit rates consistent with a positive supply of funds, it is optimal for the bank to offer the minimal interest that satisfies $\phi(r,\gamma) = 1$. In what follows, we will denote this rate $\hat{r}(\gamma)$.

Two cases should be considered:

(1) If $\gamma \in [0, 2(\overline{R} - r)]$, the bank's investment is risk free, so that $\hat{r}(\gamma) = 1$, $\phi[\hat{r}(\gamma), \gamma] = 1$;
(2) If $\gamma \in]2(\overline{R} - r), 2R]$, the bank's portfolio is risky and, from equation (3) and after some algebra, it follows that $\phi[\hat{r}(\gamma), \gamma] = 1$ implies

$$1 < \hat{r}(\gamma) = \overline{R} + \frac{\gamma}{2} - \sqrt{2\gamma(\overline{R} - 1)} < \overline{R} + \frac{\gamma}{2}.$$

Since in both cases the bank gets nonnegative profits, $\hat{r}(\gamma)$ is optimal, that is, $\hat{r}(\gamma) = r^*(\gamma)$.

Summarizing, the equilibrium deposit rate $r^*(\gamma)$ is given by[11]

$$\begin{aligned} r^*(\gamma) &= 1, && \text{iff} \quad \gamma \in [0, 2(\overline{R} - 1)]; \\ r^*(\gamma) &= R + \tfrac{\gamma}{2} - \sqrt{2\gamma(\overline{R} - 1)}, && \text{iff} \quad \gamma \in [2(\overline{R} - 1), 2R]. \end{aligned} \tag{10}$$

Lemma 2. *Current bank profits do not depend on the bank's risk profile:* $\frac{\partial(\pi(\hat{r}(\gamma), \gamma))}{\partial\gamma} = 0$.

Proof:

Substituting the equilibrium interest rate in equation (5), it is easy to check that

$$\pi[r^*(\gamma), \gamma] = \overline{R} - 1, \forall\gamma \in [0, 2R]. \tag{11}$$

Lemma 1 is reminiscent of Matutes and Vives' (1995) result that profits are independent of the asset risk position of a bank, so that the bank is indifferent between any candidate risk choice $\gamma \in [0, 2R]$. However, in our setting, the bank maximizes not its current profits but its charter value, and the indeterminacy is eliminated, as the following proposition demonstrates.

[11] The reader can verify that $\hat{r}(\gamma)$ is continuous in γ.

Proposition 1. *If the riskiness of the bank's loan portfolio is chosen by the bank and is observable to depositors, the bank always chooses a risk-free portfolio.*

Proof:

From equation (7) and Lemma 1, it is immediate to see that the charter value of the bank is maximized at $p = 1$, which in turn implies that the bank chooses $\gamma \in [0, 2(\overline{R} - 1)]$.[12]

According to Proposition 1, when depositors observe the bank's loan portfolio choice, they force the bank to behave safely by demanding a deposit rate that perfectly compensates for any risk the bank incurs, thus extracting all the potential benefits that the bank could make by increasing its risk exposure. Since the probability of being liquidated because of bankruptcy increases with risk, the bank is better off choosing the safest alternative.

Nondisclosure

In the above subsection, we have shown that if information about the riskiness of the bank's portfolio is disclosed to the public, the bank always chooses a risk-free portfolio. We now consider the other polar case, in which depositors are not informed about the attendant portfolio risk. To compare this situation with the previous one, we still suppose that all other information is common knowledge, that is, depositors know the distribution of portfolios and the characteristics of the bank, namely, the discount factor δ. In such a setup, depositors, being able to infer the bank's risk choice, form "rational" priors about the riskiness of the bank's portfolio, and supply funds in accordance. Formally:

Proposition 2. *If the riskiness of the bank's loan portfolio is chosen by the bank and it is nonobservable to depositors, the bank chooses a risk-free portfolio if* $\delta \geq 1 / 2\overline{R} - 1$, *and chooses the riskiest portfolio* ($\gamma = \overline{\gamma} = 2\overline{R}$) *otherwise. Depositors' expected returns are the same in both cases.*

Proof:

In Appendix.

[12] The bank is indifferent between any γ within the interval, since for all these choices the deposit is safe, $\hat{r} = 1$, and $V = (\overline{R} - 1)/(1 - \delta)$.

Comparison

According to Proposition 2, if the riskiness of the portfolio is not disclosed to depositors, the bank chooses a risk-free portfolio only when the discount factor is sufficiently large [$\delta \geq 1/(2\bar{R} - 1)$]. This result may be interpreted in two ways. On the one hand, the discount rate δ may be understood as a measure of the banker's conservatism. Accordingly, for given values of r and $\bar{R}$, a conservative banker that assigns a high weight to future profits will tend to prefer safer investment. In this sense, δ is a measure of the subjective cost assigned by the owner to the failure of its bank, cost that determines the trade-off between current and future profits.

On the other hand, Proposition 2 may be read as a condition on $\bar{R}$. Thus, for a given δ, sufficiently high investment returns [$\bar{R} \geq (2 + \delta/2\delta)$] are associated with safer investments. This comes from the fact that, as $\bar{R}$ increases, the gains in terms of current profits arising from an increase in risk ($\partial\pi/\partial\gamma$) decrease, while the costs in terms of expected future profits due to a higher probability of failure increase.[13] Hence, the incentive to deviate from any candidate equilibrium investing in riskier projects decreases with the investment's expected returns.

Note that, while depositors are as well off in both cases, the bank is worse off under nondisclosure when $\delta < [1/(2\bar{R} - 1)]$. The bank cannot choose the risk-free portfolio and pay the corresponding interest rate because it cannot credibly commit itself to do that. This is why, if $\delta < [1/(2\bar{R} - 1)]$, the bank's charter value is lower, and the probability of banking failure higher, under nondisclosure than under disclosure. Formally:

Proposition 3. *If the bank chooses its portfolio risk, for* $\delta < [1/(2\bar{R} - 1)]$, *a disclosure policy reduces the risk of bank failure; for* $\delta \geq [1/(2\bar{R} - 1)]$, *the probability is the same under both policies.*

Within our framework, the ex ante depositors' surplus only depends on the returns offered by the risk-free asset. Moreover, since all investment projects have the same expected returns, the only component of total welfare that is affected by public disclosure is the bank's value, which decreases as the probability of bankruptcy increases. Hence, we have that

Corollary 1. *If the bank chooses its portfolio risk, and* $\delta < [1/(2\bar{R} - 1)]$, *a disclosure policy is welfare optimal.*

[13]The reader can easily check that, for $r > \bar{R} - \gamma/2$, $\partial\pi/\partial\gamma > 0$, $\partial^2\pi/\partial\gamma\partial\bar{R} < 0$, $\partial p/\partial\gamma < 0$, and $\partial^2 p/\partial\gamma\partial\bar{R} < 0$.

III. Nature Chooses Risk

In the previous section, we assumed that the bank had full command over the risk level of its investment portfolio. However, the bank's ability to choose its risk position is likely to be hindered by the existence of factors beyond its control that affect the evolution of the risk level of its assets. In this section, we study how the previous results change when the bank has limited scope for risk management, by focusing on the extreme case in which the bank's risk profile evolves according to exogenous factors. In particular, we assume that, before deposits are made, nature chooses the risk level γ, which remains constant over the deposit period. The following lemma characterizes the bank's optimal strategy.

Lemma 3. *If the riskiness of the bank's loans portfolio is chosen by nature, the bank maximizes its charter value by setting* $r = \min\{\arg\min [\phi^e(r) = 1], \bar{R} + \gamma/2\}$.

Proof:

In Appendix.

For expositional simplicity, from now on, we assume that nature chooses γ from two values, $\underline{\gamma}$ and $\bar{\gamma}$, $\underline{\gamma} < \bar{\gamma}$, which we will denote the "safe" and the "risky" state, respectively. Moreover, we assume that $\bar{\gamma} > 2(\bar{R} - 1)$[14] and $\Pr(\gamma = \underline{\gamma}) = 1/2$.

Disclosure

If information about the riskiness of the bank's portfolio is disclosed, the analysis is similar to that under disclosure in Section I, with the exception that the type of equilibrium is determined by the current state of nature. The equilibrium deposit rates, $r(\underline{\gamma})$ and $r(\bar{\gamma})$, respectively, can be computed from equation (10).

Note that, in this case, there is clearly no way in which depositors can use the information on risk to discipline the risk management behavior of the bank: the market adjusts to risk changes through the deposit rate to leave depositors indifferent between the domestic and the foreign assets.

[14] Note that for smaller values of $\bar{\gamma}$, the deposit does not involve any risk and the problem becomes trivial.

Nondisclosure

Since the bank's current profits are decreasing in the deposit rate, if there is no risk information disclosure, any deposit rate offered by the bank in the "safe" state can be matched by the bank in the "risky" state. Therefore, there is no separating equilibrium in which the bank is active (i.e., captures a positive supply of funds) in both states of nature, and the deposit rate is high in the "risky" state and low in the "safe" state.[15] Thus, two possible candidate equilibria for this game exist: a pooling equilibrium, in which the bank offers the same rate irrespective of the current state of nature, and a "lemon" equilibrium, in which the bank posts a (high) rate in the "risky" state of nature and does not operate in the "safe" state. Note that this problem is equivalent to one with two types of banks. The risky type always mimics the safe type, and therefore no separation is possible. The safe type, however, follows the risky type as long as the deposit rate does not exceed the maximum return that it can obtain from its investment, $\bar{R} + \underline{\gamma}/2$. If that is not the case, it stays out of the market, thereby revealing the active bank's type.

Accordingly, a pooling equilibrium exists only if there is a deposit rate $r < \bar{R} + \underline{\gamma}/2$ such that

$$\phi^e(\tilde{r}) = 1/2\,[\phi(\underline{\gamma}, r) + \phi(\bar{\gamma}, r)] \geq 1, \tag{12}$$

in which case the pooling equilibrium deposit rate is the solution to

$$1/2\,[\phi(\underline{\gamma}, r) + \phi(\bar{\gamma}, r)] = 1. \tag{13}$$

The following proposition shows that there is a unique equilibrium for all possible combinations of parameter values, and describes its characteristics.

Proposition 4. *(i) If* $\underline{\gamma} \in [0, 2\sqrt{4(\bar{R}-1)\bar{\gamma} + 2\bar{\gamma}^2} - 3\bar{\gamma}]$, *the unique equilibrium is such that, for any state of nature, the bank offers the deposit rate*

$$\tilde{r} = \bar{R} + 3\bar{\gamma}/2 - \sqrt{4(\bar{R}-1)\bar{\gamma} + 2\bar{\gamma}^2}, \tag{14}$$

and depositors deposit only in the domestic bank.

(ii) If $\gamma \in [2\sqrt{4(\bar{R}-1)\bar{\gamma} + 2\bar{\gamma}^2} - 3\bar{\gamma}, 2\bar{R}]$, *and* $\gamma > \bar{\gamma} - 4\sqrt{\bar{\gamma}(\bar{R}-1)}$, *the unique equilibrium is such that, for any state of nature, the bank offers the deposit rate*

[15] The proof is straightforward and hence it is omitted here.

$$\tilde{r} = \overline{R} + \underline{\gamma}\overline{\gamma} - \sqrt{\underline{\gamma}\overline{\gamma}\left[-\left(\frac{\overline{\gamma}-\underline{\gamma}}{2}\right)^2 + 4(\overline{R}-1)(\underline{\gamma}+\overline{\gamma})\right]} \quad (\underline{\gamma}+\overline{\gamma}), \tag{15}$$

and depositors deposit only in the domestic bank.

(iii) If $\underline{\gamma} \in [2\sqrt{4(\overline{R}-1)\overline{\gamma}+2\overline{\gamma}^2} - 3\overline{\gamma}, 2\overline{R}]$, *and* $\underline{\gamma} < \overline{\gamma} - 4\sqrt{\overline{\gamma}(\overline{R}-1)}$, *the unique equilibrium is such that (a) in the "risky" state, the bank offers the deposit rate*

$$\tilde{r} = \overline{R} + \frac{\overline{\gamma}}{2} - \sqrt{2\overline{\gamma}(\overline{R}-1)}, \tag{16}$$

and depositors deposit only in the domestic bank, and (b) in the "safe" state, the bank does not operate in the domestic market and depositors invest in foreign risk-free assets.

Proof:

(i) Note that if

$$0 \le \underline{\gamma} \le (2\overline{R} - \tilde{r}), \tag{17}$$

depositors bear no risk in the "safe" state, and equation (13) simplifies to

$$\phi^e(\tilde{r}) = \frac{1}{2}[\tilde{r} + \phi(\overline{\gamma}, \tilde{r})] = 1, \tag{18}$$

which implicitly defines $\hat{r}$ in equation (14). It is easy to check, using equation (14), that equation (17) holds if, and only if,

$$0 \le \underline{\gamma} \le 2\sqrt{4(\overline{R}-1)\overline{\gamma}+2\overline{\gamma}^2} - 3\overline{\gamma}. \tag{19}$$

Finally, since

$$\tilde{r} < \overline{R} - \underline{\gamma}/2 < \overline{R} + \underline{\gamma}/2,$$

the bank has positive profits in both states of nature, and no "lemon" equilibrium exists.

(ii) If

$$\underline{\gamma} \in]2(\overline{R} - \tilde{r}), 2\overline{R}], \tag{20}$$

from equation (13) the equilibrium deposit rate is given by equation (15).[16] It is easy to check, using equation (15), that the condition (20) is equivalent to

$$2\sqrt{4(\overline{R}-1)\overline{\gamma}+2\overline{\gamma}^2}-3\overline{\gamma}<\underline{\gamma}<2\overline{R}.$$

For the existence of a pooling equilibrium in which the bank offers the deposit rate $\hat{r}$, we need

$$\tilde{r}<\overline{R}+\frac{\gamma}{2},$$

which, using equation (15), simplifies to

$$\underline{\gamma}>\overline{\gamma}-4\sqrt{\overline{\gamma}(R-1)}. \qquad (21)$$

(iii) If equation (21) is not satisfied, there is no deposit rate such that the bank makes positive profits in both states of nature. Therefore, the bank operates only when $\gamma=\overline{\gamma}$, thus revealing the state to depositors and offering depositors $r(\overline{\gamma})$, as defined by equation (16).

Note that, for all $\underline{\gamma}>0$, conditions (19) and (21) collapse to

$$\overline{R}>\overline{R}^c\equiv 1+1/16\overline{\gamma}, \qquad (22)$$

in which case, we are either in case (i) or case (ii) of the previous proposition. As result, we can state the following:

If $\overline{R}>\overline{R}^c$, there are no "lemon" equilibria.

Comparison

As we did in Section II, in this section we compare the probability of bank failure under the disclosure and nondisclosure policies. We show that, contrary to the result in the previous section, in this case there are situations in which disclosure raises the ex ante probability of bank failures. The intuition for this is simple. Suppose risk is distributed in such a way that, at the pooling rate demanded by uninformed depositors, the probability of failure is zero in "safe" states. If we now move to a disclosure policy, the equilibrium deposit rate will be lower than the pooling rate in "safe" states (therefore leaving the probability of failure unaffected) and higher in "risky" states (therefore increasing the probability of failure in "risky" states). The ex ante probability of failure will clearly be higher under the new policy.

[16]It is easy to check that equation (20) ensures that $\tilde{r}$ in equation (15) is a real number.

Thus, lack of information, leading to a pooling deposit rate that is strictly between those in the disclosure scenario, partially eliminates the negative feedback from interest rates to asset risk in "risky" states of nature, and it does so without affecting bank soundness in "safe" states.

In general, disclosure may increase or decrease the chances of bankruptcy, depending on the range within which the risk level fluctuates. More precisely, we have:

Proposition 5. *For any* $\bar{\gamma} \in [2(\bar{R}-1), 2\bar{R}]$, *there is a value of* $\underline{\gamma}$, $\underline{\gamma}^c \in [2(\bar{R}-\tilde{r}), 2(\bar{R}-1)]$ *such that for* $\underline{\gamma} < \underline{\gamma}^c$, *the probability that the bank fails is higher in the case of full information disclosure, and for* $\underline{\gamma} > \underline{\gamma}^c$, *the opposite is true, where*

$$\underline{\gamma}^c = -a + \sqrt{a^2 + [16(\bar{R}-1)\bar{\gamma} - \bar{\gamma}^2]}, \tag{23}$$

and

$$a = 4\left[\frac{\bar{\gamma}}{4} + \sqrt{2\bar{\gamma}(\bar{R}-1)} - (\bar{R}-1)\right].$$

Proof:

See Appendix.

By the same argument used for Corollary 1, it follows that:

Corollary 2. *Public disclosure is welfare optimal if, and only if,* $\underline{\gamma} > \underline{\gamma}^c$.

Figure 1 illustrates the different cases as a function of $\underline{\gamma}$ and $\bar{R}$, for $\bar{\gamma} = 2\bar{R}$.[17] In region 0, the difference between domestic returns to investment and the risk-free rate is too small for the bank to make profits in "safe" states, while paying the premium demanded by uninformed depositors to compensate for the possibility of a "risky" state. Therefore, under nondisclosure, only "lemon" equilibria exist: the bank operates in risky states, and depositors assign a high-risk level to any operating bank. In these circumstances, disclosure is obviously optimal, as it allows the bank to operate in both the states of nature.[18]

The case discussed at the beginning of the section belongs to region 1, where the bank makes profits in both states of nature, and $\underline{\gamma}$ is small enough to make deposits at a rate $\tilde{r}$ riskless in the "safe" state. Public disclosure only raises the probability of failure in the "risky" state, thus increasing the ex ante probability of failure and lowering welfare.

[17] The results are qualitatively the same for any choice of $\bar{\gamma}$.

[18] Note that, again, depositors are indifferent between any policy, since their expected return is always equal to the risk-free rate. The bank, however, by not playing, loses whatever profits it could extract during good times.

Figure 1. *Equilibrium Configurations in the Nondisclosure Case and γ^c*

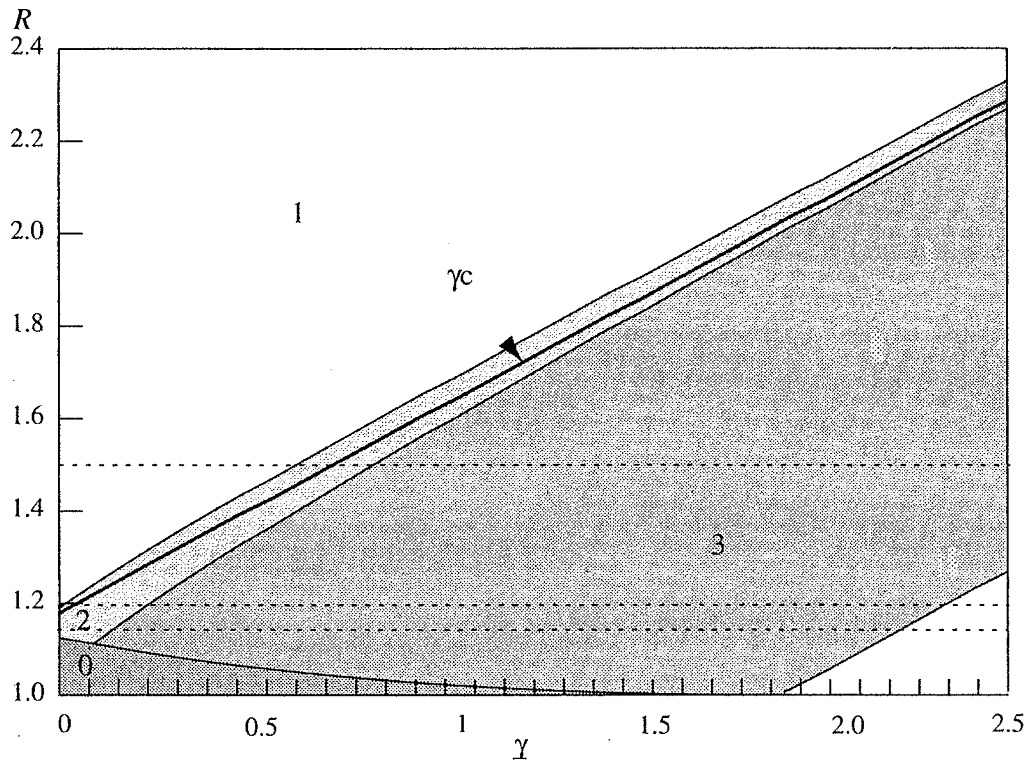
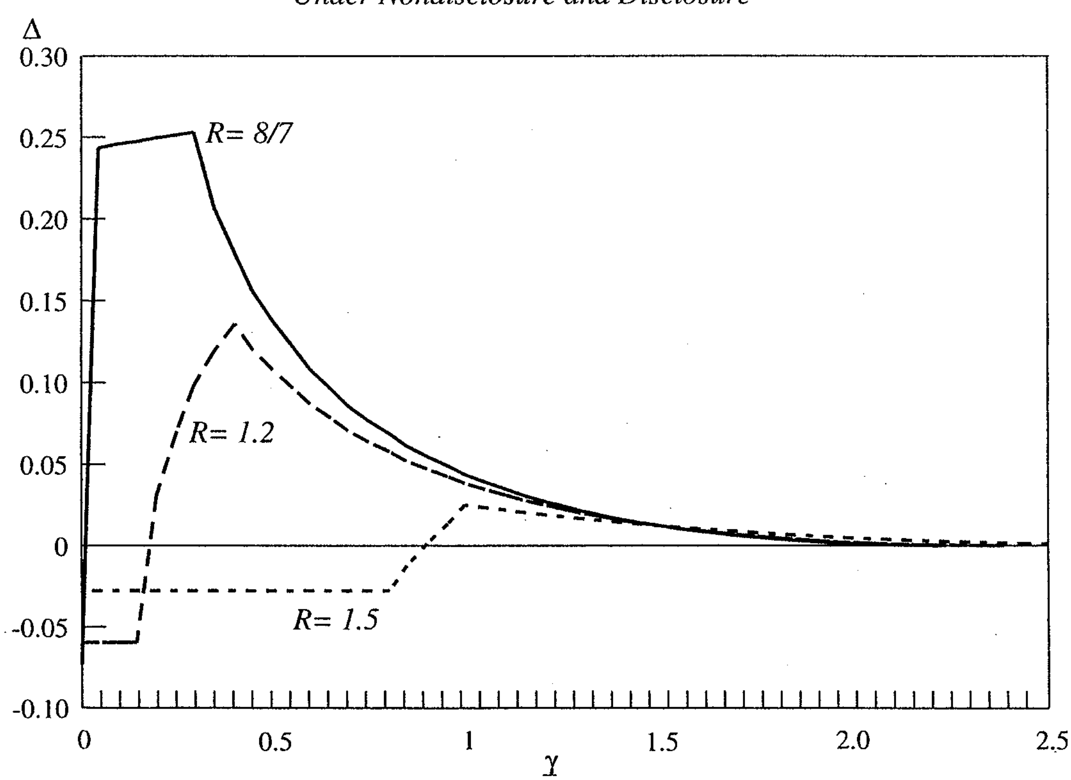


Figure 2. *The Difference Between the Probability of Banking Failure Under Nondisclosure and Disclosure*



Region 2 comprises the intermediate cases. In the "safe" state, deposits are riskless at $r = 1$, but risky at $\tilde{r} > 1$. The critical point $\underline{\gamma}^c$ belongs to this region. For $\underline{\gamma} < \underline{\gamma}^c$, that is, for wide fluctuations in the attendant risk level, nondisclosure reduces the probability of bank failures. The opposite is always the case when $\underline{\gamma} > \underline{\gamma}^c$, as is in region 3, where deposits are risky in both states of nature.

Figure 2 shows the profile of Δ, the difference between the probability of failure under nondisclosure and disclosure, as a function of $\underline{\gamma}$, for $\overline{R} = \overline{R}^c (= 8/7)$, 1.2, and 1.5, and $\overline{\gamma} = 2\overline{R}$. At $\overline{R} = \overline{R}^c$, region 1 collapses to a point, and Δ rises sharply from zero, at $\underline{\gamma} = 0$, to about 25 percent within region 2. At $\overline{R} = 1.2$ and 1.5, Δ is constant and negative within region 1 and increases within region 2, crossing the horizontal axis at $\underline{\gamma}^c$. In all three cases, Δ declines in region 3 to approach zero asymptotically at $\underline{\gamma} = \overline{\gamma}$.

IV. Discussion and Conclusions

In this paper we studied the impact on the probability of bank failures of disclosing bank information to the public. Our main findings are the following.

First, for disclosure to play a disciplining role in the bank's risk-taking decisions, the bank has to be able to choose its portfolio risk.[19] If that is the case, we showed that the penalty imposed by informed depositors by demanding a deposit rate commensurate to the associated risk may induce the bank to adopt a low-risk strategy, depending on the cost implied by the loss of its charter value in case of liquidation. Alternatively, if risk is largely exogenous, there are cases in which disclosure can indeed increase the probability of bank failures. Those cases correspond broadly to volatile environments with high expected returns to domestic investment, where risk in the banking sector tends to fluctuate within a wide range of values.

The main intuition behind the last result is that, when risk is exogenous, disclosure no longer affects risk-taking behavior but still induces negative feedback on the probability of bank failure by allowing deposit rates to adjust. Thus, the bank is "taxed" during hard times and "rewarded" during good times. While the bank may prefer a more even distribution of the burden, for example, by subsidizing depositors in good times to ensure lower funding cost in bad times, there is no way depositors can commit to not charging the bank a higher rate once risk goes up. In those cases, non-

[19]This rather obvious point is rarely mentioned in the controversy surrounding the "free banking" view.

disclosure, by eliminating the state-dependent tax, improves the bank's chances of survival.

One should be careful in drawing policy conclusions from the highly stylized framework used in the paper. Whereas informed depositors can influence the bank's risk-taking decisions, public disclosure may have a perverse effect if risk shifts are exogenous. Reality seems to be between these two polar scenarios. In principle, one could conclude that, in those cases, government "insurance" against the occurrence of negative exogenous shocks (e.g., through the provision of emergency credit) would allow the system to benefit from information disclosure while avoiding its pitfalls, but the distinction between what is exogenous and what is the result of banks' excessive risk taking is likely to be problematic. In addition, our assumption that risk is perfectly measurable (i.e., that *true* risk may be completely revealed to the public) is rather heroic. In practice, risk measurement is subject to a substantial error margin, which makes risk management a highly qualitative task, and information disclosure potentially misleading.

The model presented in the paper provides some testable implications. In Section II, we noted that informed depositors can influence the bank's risk level when its charter value is high enough. Therefore, a negative correlation between charter value and risk should be expected. Implicit in the analysis of Section III is the idea that, when risk has a significant exogenous component, public information increases the volatility of deposit rates over time. Finally, when risk information is public (i.e., when it is supplied to the public in such a way that it can be digested and used by unsophisticated depositors), deposit rates should reflect differences in risk levels across banks. Moreover, for a given distribution of risk ratings, the more information that is provided, the higher the dispersion of deposit rates. Therefore, the analysis of deposit rates vis-à-vis bank credit ratings would provide a first check on how well the market uses the information provided and on whether risk information has any effect on depositors' behavior.[20]

The model is open to several extensions. First, the assumption of a monopolistic bank can be relaxed. This would allow comparison between systemic and idiosyncratic risk, and would provide interesting insights on how different disclosure policies may affect competitive behavior. Second, the introduction of deposit demand elasticity (e.g., through risk-averse depositors or horizontal product differentiation) would introduce deposit supply volatility as an additional dimension over which to analyze the ben-

[20] In a more general setting that incorporates deposit supply elasticity, both deposit rates and supply should be more volatile in the presence of informed depositors.

efits and pitfalls of information disclosure. Finally, the analysis of the case in which only a noisy signal of the risk level is observed may shed light on how the possibility of unwarranted bank distress as a result of misperceptions affects the conclusions drawn here.

APPENDIX

Proof of Proposition 2

1. Assume a candidate equilibrium deposit rate r. Taking derivatives with respect to γ, of the maximand in equation (7), and using equations (5) and (6), the first- and second-order conditions for the existence of a solution $\gamma \in [\underline{\gamma}, \overline{\gamma}]$ are

$$\frac{1}{2\gamma^2}\left[(\gamma/2)^2 - a\right] = 0 \tag{A1}$$

and

$$\frac{a}{\gamma^3} < 0, \tag{A2}$$

respectively, where

$$a \equiv \left(\overline{R} - r\right)^2 + 2\delta V_{+1}\left(\overline{R} - r\right). \tag{A3}$$

Two cases arise. If $a > 0$, equation (A2) is always positive, and only corner solutions are possible in equilibrium, that is, $\gamma \in \{\underline{\gamma}, \overline{\gamma}\}$. If $a < 0$, then equation (A1) is always positive and the only possible solution is $\gamma = \overline{\gamma}$. It follows that, for any given deposit rate r, no $\gamma \in]\underline{\gamma}, \overline{\gamma}[$ can be an equilibrium.

2. Define r^s as the deposit rate that satisfies

$$V(r, \overline{\gamma}) = V\left(r, \gamma^F\right), \tag{A4}$$

where $\gamma^F = 2(R - r)$ is the higher γ such that the bank's portfolio is risk free.

Using equation (9), it is easy to check from equation (A4) that

$$r^s = \frac{2\delta\overline{R}}{1+\delta} \leq \overline{R}, \tag{A5}$$

which, in turn, implies that

$$r < r^s \Leftrightarrow V(r, \gamma^F) > V(r, \overline{\gamma}). \tag{A6}$$

3. Then, for $r < r^s \leq \overline{R}$, from equation (A3) we know that $a > 0$. Moreover, from equation (A6) we know that in this case, the bank chooses the minimum risk portfolio. If $r > r^s$, a may be positive or negative. However, in both cases the bank chooses the maximum variance portfolio.

(4) Thus, since depositors know δ, they are able to infer the bank's portfolio choice from the posted deposit rate, and the aggregate deposit supply is then given by

$$\begin{aligned} S &= 1, \quad \text{if} \quad r \in \left[1, r^s\right]; \\ S &= 0, \quad \text{if} \quad r \in \left]r^s, r(\bar{\gamma})\right[; \\ S &= 1, \quad \text{if} \quad r \geq r(\bar{\gamma}); \end{aligned} \tag{A7}$$

with $r(\bar{\gamma}) = 2\left[\bar{R} - \sqrt{\bar{R}(\bar{R}-1)}\right]$, from equation (10).

(5) Finally, note that interest rates within $]1, r^s]$ are never offered by the bank, because it can always lower the cost of funds without losing deposits, by offering a lower deposit rate. Moreover, for rates within $]r^s, r(\bar{\gamma})[$, the supply of funds (and therefore, profits) are zero. Hence, only 1 and $r(\bar{\gamma})$ can be equilibrium rates. The interval $[1, rs]$ is not empty if, and only if, $\delta \geq 1/(2R-1)$ This, together with the fact that $V(1, \gamma^r) > V(r(\bar{\gamma}), \bar{\gamma})$, as from Proposition 1, completes the proof.

Proof of Lemma 3

The bank's value function is

$$\begin{aligned} V(\gamma) &= \max_r\{\pi(\gamma, r) + \delta p(\gamma, r) V^e\}, \\ &\quad \text{s.t. } \pi(.) \geq 0, \text{ for all } t, \end{aligned} \tag{A8}$$

where, taking expectations of both sides of equation (A8) over γ,

$$\begin{aligned} V^e &= \int_\gamma V(\gamma) dH(\gamma) \\ &= \int_\gamma \pi(\gamma) dH(\gamma) + \delta V^e \int_\gamma p(\gamma) dH(\gamma), \end{aligned}$$

from which

$$V^e = \frac{\int_\gamma \pi(\gamma) dH(\gamma)}{1 - \delta \int_\gamma p(\gamma) dH(\gamma)} > 0.$$

Therefore, V^e is independent of the choice of deposit rate in the current period. The fact that $\text{sgn}\left|\frac{\partial \pi(.)}{\partial r}\right| = \text{sgn}\left|\frac{\partial p(.)}{\partial r}\right|$, and $r > \bar{R} + \gamma/2 \Rightarrow \pi(\gamma, r) < 0$ completes the proof.

Proof of Proposition 5

We fix $\bar{\gamma}$ at any arbitrary value within $[2(\bar{R}^d - 1), 2\bar{R}^n{}^-]$ and compute the probabilities of bank failure with and without disclosure, pd and $p_n d$, respectively, for different values of $\underline{\gamma}$.

Case 1: $\underline{\gamma} \in \left[0, 2\sqrt{4(\bar{R}-1)\bar{\gamma} + 2\bar{\gamma}^2} + 3\bar{\gamma}\right]$.

As from Proposition 4, this interval corresponds to values of γ between 0 and $2(\bar{R} - \tilde{r})$, in the "safe" state the deposits are safe both with and without disclosure. Therefore, the ex ante probabilities of failure in each state are

$$p_d = \frac{1}{2}[p_d(\underline{\gamma}) + p_d(\bar{\gamma})] = \frac{-\bar{R} + \bar{\gamma}/2 + r(\gamma)}{2\bar{\gamma}}, \tag{A9}$$

$$p_{nd} = \frac{1}{2}[p_{nd}(\underline{\gamma}) + p_{nd}(\bar{\gamma})] = \frac{-\bar{R} + \bar{\gamma}/2 + \tilde{r}}{2\bar{\gamma}}. \tag{A10}$$

Thus,

$$\Delta \equiv p_{nd} - p_d = \frac{\tilde{r} + r(\bar{\gamma})}{2\bar{\gamma}}. \tag{A11}$$

Taking derivatives of equation (3) with respect to *r*,

$$\frac{\phi(\gamma, r)}{\partial r} = \frac{1}{\bar{\gamma}}(\bar{R} + \bar{\gamma}/2 - r) > 0, \tag{A12}$$

for $r < \bar{R} + \bar{\gamma}/2$. Therefore, equations (10) and (A12) imply

$$\phi(\bar{\gamma}, 1) < 1. \tag{A13}$$

Combining equations (A13), (A12), and (18), $\phi^e(\tilde{r}) = 1 \Rightarrow \tilde{r} > 1$. This, combined with (18), in turn implies that $\phi(\bar{\gamma}, \tilde{r}) < \phi[\bar{\gamma}, r(\bar{\gamma})] = 1$, and $r(\bar{\gamma}) > \tilde{r}$. Hence, $\Delta < \phi$, and the probability of failure is larger under disclosure.

Case 2: $\bar{\gamma} \in [2(\bar{R} - 1), 2\bar{R}]$.

In this case, deposits bear some risk in all states of nature, with or without disclosure and

$$\Delta = \frac{1}{2\underline{\gamma}\bar{\gamma}}\left[\left(\underline{\gamma} + \bar{\gamma}\right)\tilde{r} - \left(r\left(\underline{\gamma}\right)\bar{\gamma} + r\left(\bar{\gamma}\right)\bar{\gamma}\right)\right]. \tag{A14}$$

Using equations (10) and (15),

$$r\left(\underline{\gamma}\right)\bar{\gamma} + r\left(\bar{\gamma}\right)\bar{\gamma} = \bar{R}\left(\bar{\gamma} + \underline{\gamma}\right) + \underline{\gamma}\bar{\gamma} - \left(\bar{\gamma}\sqrt{\underline{\gamma}} + \underline{\gamma}\sqrt{\bar{\gamma}}\right)\sqrt{2\left(\bar{R} - 1\right)} \tag{A15}$$

and

$$\left(\underline{\gamma} + \bar{\gamma}\right)\tilde{r} = \bar{R}\left(\underline{\gamma} + \bar{\gamma}\right) + \underline{\gamma}\bar{\gamma} - \sqrt{\underline{\gamma}\bar{\gamma}\left[-\left(\frac{\bar{\gamma} - \underline{\gamma}}{2}\right)^2 + 4\left(\bar{R} - 1\right)\left(\underline{\gamma} + \bar{\gamma}\right)\right]}. \tag{A16}$$

Substituting equations (A15) and (A16) into (A14), and after some algebra

$$\Delta \geq 0 \Leftrightarrow \sqrt{2(\bar{R}-1)} \leq \frac{\left(\sqrt{\bar{\gamma}}+\sqrt{\underline{\gamma}}\right)}{2}, \tag{A17}$$

which is always true, since $\bar{\gamma} \geq \underline{\gamma} \geq 2(\bar{R}-1)$.

Case 3: $\underline{\gamma} \in \left[2\sqrt{4(\bar{R}-1)\bar{\gamma}+2\bar{\gamma}^2}-3\bar{\gamma},\, 2(\bar{R}-1)\right]$.

This case includes intermediate values of γ within the interval $[2(\bar{R}-\tilde{r}), 2(\bar{R}-1)]$. Deposits are risky except in the "safe" state and with disclosure (without disclosure, as the equilibrium deposit rate is higher, there is a positive probability of bank failure). The difference between probabilities of failure with and without disclosure is

$$\Delta = \frac{\bar{\gamma}\left(-\bar{R}+\underline{\gamma}/2\right)+\left(\bar{\gamma}+\underline{\gamma}\right)\tilde{r}-r(\bar{\gamma})\underline{\gamma}}{2\underline{\gamma}\bar{\gamma}}. \tag{A18}$$

From Case 1, we know that, at $\gamma = 2(\bar{R}-\tilde{r})$ $\Delta < 0$, whereas from condition (A17) we know that at $\gamma = 2(\bar{R}-1)$, $\Delta > 0$. Therefore, since Δ is continuous in $\underline{\gamma}$, it has to be equal to zero for at least one value of $\underline{\gamma}$ within the interval $[2(\bar{R}-\tilde{r}), 2(\bar{R}-1)]$. Define this value as γ^c. Substituting equations (10) and (A15) into (A18), $\Delta = 0$ implies

$$\underline{\gamma}\bar{\gamma}+\sqrt{2\bar{\gamma}(\bar{R}-1)\underline{\gamma}} = \sqrt{\underline{\gamma}\bar{\gamma}\left[-\left(\frac{\bar{\gamma}-\underline{\gamma}}{2}\right)^2+4(\bar{R}-1)(\underline{\gamma}+\bar{\gamma})\right]}, \tag{A19}$$

or, raising to the square and rearranging,

$$\underline{\gamma}^2+8\gamma\left[\frac{\bar{\gamma}}{4}+\sqrt{2\bar{\gamma}(\bar{R}-1)}-(\bar{R}-1)\right]+\bar{\gamma}^2-16(\bar{R}-1)\bar{\gamma}=0. \tag{A20}$$

Solving for γ, we have that the only nonnegative solution to equation (A20) is

$$\gamma^c = -a+\sqrt{a^2+\left[16(\bar{R}-1)\bar{\gamma}-\bar{\gamma}^2\right]}, \tag{A21}$$

where

$$a = 4\left[\frac{\bar{\gamma}}{4}+\sqrt{2\bar{\gamma}(\bar{R}-1)}-(\bar{R}-1)\right].$$

It is easy to check that $\gamma > \gamma^c \Rightarrow\ > 0$.

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