Optimal Bank Transparency*

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Abstract

We study a competitive banking sector where a bank’s illiquid assets are funded by short-term debt that must be refinanced. We show that welfare is a non-monotonic function of the level of transparency, and therefore that maximal transparency is not socially optimal. Moreover, if bank failures have negative externalities, then the socially optimal level of transparency is further reduced. Asset risk taking increases with the level of transparency above and around the socially optimal level. The sign of the impact of transparency on refinancing risk is negative given the asset’s risk, but is ambiguous accounting for the indirect effect via risk taking.

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1 Introduction

Since Louis D. Brandeis famously claimed that “...sunlight is the best of disinfectants” (*Harper’s Weekly*, December 20, 1913), enhanced transparency is recurrently offered as a remedy for the problems of banking. Indeed, Basel III, the new international banking regulatory framework developed in response to the recent global financial crisis, has as a key aim to strengthen banks’ transparency and assure disclosure. However, the discussions on whether the results of banks’ stress tests should be publicized, and on how stringent these tests should be, suggests that the case for increasing transparency is not clear-cut – see Landier and Thesmar (2011) for a discussion of the costs and benefits of increasing disclosure of financial information. In this paper we provide an analysis of the impact of changes of the level of transparency on welfare, and banks’ risk taking and refinancing risk.

Consider a competitive bank whose illiquid asset portfolio is funded by short-term debt supplied by risk-neutral creditors. The bank selects the level of asset risk. Creditors decide whether or not to roll over their credit upon receiving a noisy signal of the probability that the asset will pay its return. We identify the level of transparency with the precision of creditors signals of the probability that the bank’s asset pays its return. The bank’s asset portfolio can be totally or partially liquidated before maturity, although incurring a cost. We show that under some natural parameter restrictions, given the bank’s asset risk choice the creditor’s game has a unique equilibrium, and that this equilibrium is identified by a simple equation. Solving this equation we obtain closed form expressions for the equilibrium levels of credit rollover and welfare.

Our analysis shows that welfare is a non-monotonic function of the level of transparency: when the banking system is (not) very transparent, i.e., when creditors’ signals are (not) very precise, increasing the level of transparency decreases (increases) total welfare. Thus, maximal transparency is *not* socially optimal. Moreover, since in our competitive setting the interests of a bank and its creditors are perfectly aligned, regulating the level of transparency is unnecessary unless the failure of a bank involves social costs beyond those imposed on the bank’s creditors. We show that if bank failures have negative social externalities, then the optimal level of transparency is below the optimal level when externalities are absent; that is, the existence of neg-
ative social externalities of bank failures calls for making banks more opaque rather than more transparent.

Our comparative static analysis shows that a bank’s asset risk taking increases with the level of transparency above and around its socially optimal level. Nonetheless, the impact of changes in transparency on risk taking for levels of transparency sufficiently lower than the socially optimal is ambiguous. As for the sign of the effect of changes in transparency on refinancing risk, i.e., on the probability that a bank refinances its short-term debt, it is negative for a given level of asset risk, but is ambiguous when we account for its indirect effect via risk taking.

A key element explaining our results is the existence of a negative externality that arises when creditors withdraw their credit: the liquidation costs that must be assumed to pay back a creditor who withdraws has a negative impact on the expected payoff of the creditors who roll over that is larger the larger is the fraction of creditors who withdraw.

Increasing transparency decreases the equilibrium fraction of creditors’ who mistakenly roll over as well as the fraction of creditors who mistakenly withdraw. When the realized probability that the asset pays its return is sufficiently low that it is optimal to withdraw, the fraction of creditors who actually withdraw is large. For such realizations, increasing transparency, which reduces the fraction of creditors who mistakenly roll over, has a large negative impact on the payoff to rolling over. When the realized probability that the asset pays its return is sufficiently high that it is optimal to roll over, then the fraction of creditors who withdraw is small. For these realizations, increasing transparency, which reduces further the fraction of creditors who mistakenly withdraw, has a small positive impact on the payoff to rolling over. These asymmetries imply that the net effect of an increase of transparency is a decrease of the payoff to rolling over.

Thus, given the level of risk increasing transparency leads creditors to optimally raise their threshold to roll over, and consequently impedes banks’ refinancing. Banks may compensate this effect by increasing risk taking, thus offering higher returns to those creditors who roll over. The negative effects of increasing transparency on welfare are counter-balanced by its positive effect in discouraging (fostering) inefficient (efficient) liquidation. This counter-balancing effect is dominant when the level of
transparency is low.

Our model shares some features with the classical bank-run model of Diamond and Dybvig (1983) and is hence related to the work in this tradition. Chari and Jagannathan (1988), Calomiris and Kahn (1991), Chen (1999) and Chen and Hasan (2006), for example, study the role of creditors’ information at an interim stage in generating information and panic-based bank runs, and observe its disciplining effect on banks behavior. In this literature, as in our model, creditors observe an interim signal on the asset’s return before they decide whether or not to roll over their credit, and withdrawals cause negative payoff externalities. We, too, find that enhanced transparency may decrease creditors’ willingness to roll over, but in our setting a bank may counter this effect by increasing risk taking. Another paper closely related to ours is Chen and Hasan (2008) who, akin to our results, show that increasing the precision of creditors’ signal of the asset’s return fosters efficient liquidation, and increases the likelihood of a bank run when the prospects of the asset paying its return are poor. (However, these authors focus on the Pareto dominant equilibrium, and neither study banks’ risk choice, nor identify the socially optimal level of transparency.)

There is also a related literature on ex-ante bank transparency initiated by Matutes and Vives (1996) and Cordella and Yeyati (1998). This literature studies the impact of information on creditors’ lending decisions and, ultimately, on banks’ risk choice. Blum (2002) shows that enhanced transparency may increase banks’ risk taking if banks can adjust their asset portfolio after obtaining funding. While we model asset risk taking in a similar fashion as in these papers, we study the impact of interim transparency. We find that enhanced transparency may increase risk taking even if a bank can commit to its asset portfolio choice.

Our paper also has a connection to the literature studying transparency regulation and financial market liquidity - see, e.g., Dang, Gorton, and Holmström (2009) and Pagano and Volpin (2010). While we do not model liquidity provision explicitly, we show that enhanced transparency has an adverse direct effect on banks’ ability to roll over short-term funding.

Since transparency hinges on incomplete information, and since banks are inherently vulnerable to self-fulfilling runs, models of bank transparency easily generate multiple equilibria, and often render comparative statics and welfare analyses incon-
clusive. While the literature on bank runs has been influential in pointing out the importance of creditors confidence and its dependence on creditors’ expectations, it does not allow an assessment of how confidence relates to the level of creditors’ information. Our result on uniqueness of equilibrium builds on the theory of global games, and is closely related to Morris and Shin (1998). Our simple characterization of the unique equilibrium allows us to explicitly compute the volume of credit roll over, facilitating comparative statics and welfare analyses exercises. In this respect, our paper relates to other papers that use global game methodology to study the problems of banking and lending such as Rochet and Vives (2004), Goldstein and Pauzner (2005) and, more closely, to Morris and Shin (2006) who study the roll over decisions of government debt. While most of the papers in this literature deal with a binary action game, in our setting, similarly to Morris and Shin (2006), we have to deal with an agent (the bank) whose decisions (risk choice) affect the support of creditors’ signals.

In the global game literature, the impact of the level of information on equilibrium has been extensively studied. In a pioneering work, Morris and Shin (2002) study the value of public information in a setting reminiscent of a beauty contest, in which the payoff of an agent depends on how well the agent is able to guess the state and on the level of conformity. They conclude that the social value of public information is negative whenever its precision is low relative to the precision of agents’ private information. In their model, the detrimental effect of public information arises from the coordination motive that drives agents’ actions, which leads agents to overreact to public information. The significance and interpretation of Morris and Shin (2002)’s results has been debated by, among others, Angeletos and Pavan (2004), Hellwig (2005), and Svensson (2006). In particular, Angeletos and Pavan (2004) study a model where conformity plays no role and coordination is socially beneficial, and conclude that public information always has a beneficial effect. In contrast, we find that welfare does not monotonically increases with transparency, even though in our setting, like in Angeletos and Pavan (2004), conformity does not play a role.

We depart from these papers in that we study the impact of transparency by examining directly the effect on equilibrium of changes in the precision of agents’ private signals. This allows for a simple and precise analysis of the effects of transparency
on welfare, risk taking and refinancing risk. Under our distributional assumptions, increasing the precision of creditors’ signals amounts to decreasing the size of the support of their posterior beliefs of the probability of success. Introducing instead an additional independent public signal distributed as the creditors’ private signals (perhaps differing on the level of precision), has an analogous effect on creditors’ posterior beliefs. However, the presence of a public signal makes the analysis more complex without providing additional insights beyond those familiar in the literature.

Alternative levels of transparency may result from specific regulation on how much information banks must disclose to their creditors about their asset portfolios. Such disclosures need not be public, but privately communicated to creditors. Also we may interpret that bank transparency is also affected by public disclosures, e.g., by the disclosure policy on banks’ stress tests.

The paper is organized as follows. In Section 2 we layout the basic setting. In section 3 we describe the creditors’ game. In section 4 we prove that creditors’ game has a unique equilibrium, which we show is the solution to a simple equation. In Section 5 we study the impact of transparency given the asset risk. Section 6 studies the banks’ risk choice. In Section 7 we extend our welfare analysis. The Appendix presents some calculations used to derive our results.

2 The Model

We consider a competitive bank whose illiquid asset portfolio is funded by short-term credit that needs to be refinanced. The bank’s asset pays at maturity a return of $1 + R$ with probability $p$ and zero with probability $1 - p$, where $p$, the probability of success, is drawn from a uniform distribution $P$ on $[1 - \mu, 1]$. The parameter $\mu \in (0, 1)$ is a proxy for the asset’s riskiness: the larger $\mu$ the more likely it is that the asset pays no return. (Naturally, the asset’s return $R$ will generally depend on the level of risk $\mu$. In this section we take $\mu$, and therefore $R$, as given, but we endogenize the bank’s choice of risk $\mu$ in Section 6.) Thus, the return of the asset is $(1 + R)P$, which is distributed uniformly on $[(1 - \mu)(1 + R), 1 + R]$. The mean return is

$$Q := E((1 + R)P) = (1 + R)E(P),$$
where
\[ E(P) = 1 - \frac{\mu}{2} \]
is the mean probability of success. The bank’s asset portfolio is divisible and can be liquidated before maturity: one unit of the asset liquidated before maturity yields \( \lambda \) monetary units. We assume that
\[ Q > 1 > \lambda > 0, \tag{1} \]
which implies that liquidating the asset before maturity is both costly and ex-ante inefficient.

The bank has a continuum of creditors, whose measure is normalized to one, each of whom has one unit of uninsured credit. Creditors maximize expected returns (i.e., they are risk neutral). Hence, in contrast to many bank run models, in our setting risk-sharing is not an issue. A fraction \( h > 0 \) of creditors are active and may withdraw their credit before the asset matures. The remaining fraction of creditors, \( 1 - h \), maintain their unit of credit until the asset matures, and therefore play a passive role. Henceforth we refer to the active creditors simply as creditors when no confusion may arise. The assumption that only a fraction of creditors are active captures the fact that some of the bank’s loans (e.g., long-term retail deposits) are stickier than others (e.g., wholesale funding from the overnight interbank market). We assume that
\[ h < \lambda, \tag{2} \]
which implies that the bank is always liquid, i.e., the bank does not fail even if all active creditors withdraw their credit. (The bank only fails when the realized return of the asset is zero.) Although the bank is always liquid, condition (1) implies that ex-ante it is in a creditor’s (and society’s) interest to roll over. These simplifying assumptions allow for an analysis focused on the impact of transparency on risk taking, refinancing risk, and welfare.

Each creditor observes a noisy signal of the realized probability of success \( p \),
\[ S_i = p + T_i, \]
where the noise terms \( T_i \) are conditionally independently and uniformly distributed on \([ -\varepsilon, \varepsilon ]\), for some \( \varepsilon > 0 \). Then all creditors simultaneously decide whether to withdraw
or to roll over their credit. Note that although creditors information about the state differs, no creditor has superior information.

The timing of the game that active creditors face is as follows: (1) The bank select the level of risk $\mu$; (2) nature draws the success probability $p$; (3) each creditor observes a noisy signal of $p$, and then decides whether to withdraw or to roll over her credit; (4) the returns are realized and the creditors are compensated accordingly.

## 3 The Creditors Game

In the creditors game, a strategy for a creditor is a mapping from the set of signals $[1 - \mu - \varepsilon, 1 + \varepsilon]$ into the set of actions \{roll over, withdraw\}. The payoff to a creditor depends on her action, the state $p$, and the fraction of all creditors who withdraw, which we denote by $x \in [0, h]$. We normalize the nominal value of the banks’ short-term debt to unity. Our assumption that $h < \lambda$ implies that the payoff to a creditor who withdraws is 1, whatever may be the state and the fraction of creditors who withdraw. (Note that a creditor who withdraws gets more than the liquidation value of her asset.) Also, in line with Diamond and Dybvig (1983), we assume that competition for renewal of short-term credit leads banks to promise to pay the creditors who roll over the entire asset’s return. Thus, the payoff to a creditor who rolls over depends on $p$ and $x$, and is given by

$$u(p, x) = \frac{1 - x/\lambda}{1 - x} (1 + R)p.$$  (3)

Since $\lambda < 1$, then $\partial u(p, x)/\partial x < 0$. Hence withdrawing becomes more attractive relative to rolling over the more creditors withdraw. (This strategic complementarity is key to obtaining uniqueness of equilibrium.) Also $\lambda < 1$ implies that $\partial^2 u(p, x)/\partial x^2 < 0$, and therefore that the negative externality of withdrawals on the creditors who roll over is increasing in the fraction of creditors who withdraw. Obviously, the payoff to rolling over increases with the probability of success, i.e., $\partial u(p, x)/\partial p > 0$. These properties play an important role in establishing our results.

A Lebesgue measurable profile of creditors’ strategies may be described by a strategy distribution $\tau$ that for each signal $s \in [1 - \mu - \varepsilon, 1 + \varepsilon]$ provides the fraction of active creditors that withdraw their credit upon receiving the signal $s$, $\tau(s) \in [0, 1]$. 
Given a strategy distribution $\tau$ the fraction of all creditors who withdraw if the state is $p$ is

$$x(p, \tau) = hE(\tau(\cdot)|p),$$

and the expected payoff to a creditor who rolls over when her signal is $s$ is

$$U(s, \tau) = E(u(\cdot, x(\cdot, \tau))|s),$$

where $P|s$ is the probability of success conditional on signal $s$, which is distributed uniformly on $[1 - \mu, 1] \cap [s - \varepsilon, s + \varepsilon] = [\max\{1 - \mu, s - \varepsilon\}, \min\{1, s + \varepsilon\}]$. Since the upper and lower bounds of this interval are both increasing in $s$, then $P|s'$ first order stochastically dominates $P|s$ whenever $s' > s$. And since $u(p, x)$ is continuous, then $U(s, \tau)$ is continuous. Moreover, if $\tau, \hat{\tau}$ satisfy $\hat{\tau}(s) \geq \tau(s)$ for all $s$, then

$$x(p, \hat{\tau}) = hE(\hat{\tau}(\cdot)|p) \geq hE(\tau(\cdot)|p) = x(p, \tau)$$

for all $p \in [1 - \mu, 1]$, and therefore, since $u$ is decreasing in $x$, we have

$$U(s, \hat{\tau}) \leq U(s, \tau).$$

A strategy distribution $\tau$ is an equilibrium of the creditors’ game if for all $s \in [1 - \mu - \varepsilon, 1 + \varepsilon], U(s, \tau) < 1$ implies $\tau(s) = 1$, and $U(s, \tau) > 1$ implies $\tau(s) = 0$; i.e., the strategy profile defining the strategy distribution $\tau$ is such that (almost) all active creditors follow an optimal strategy.

Under complete information, i.e., when creditors observe the probability of success with no error ($\varepsilon = 0$), since $u$ is continuous, increasing in $p$ and decreasing in $x$, if $u(1, h) > 1$ then for $p \in (\bar{p}, 1)$, where $u(\bar{p}, h) = 1$, we have

$$u(p, x) > u(\bar{p}, h) = 1,$$

i.e., rolling over is a strictly dominant strategy. Likewise, if $u(1 - \mu, 0) < 1$, then for $p \in (1 - \mu, \underline{p})$, where $u(\underline{p}, 0) = 1$, we have

$$u(p, x) < u(\underline{p}, 0) = 1,$$

i.e., withdrawing is strictly dominant strategy. However, for intermediate values of $p \in (\bar{p}, \underline{p})$, i.e., values such that $u(p, h) < 1 < u(p, 0)$, a creditor’s optimal action
depends on the fraction of creditors who roll over. Therefore depending on which action creditors coordinate on different equilibria arise – e.g., there is an equilibrium in which all creditors coordinate on withdrawing whenever \( p \leq \bar{p} \), and roll over otherwise; and there is another equilibrium in which all creditors coordinate on rolling over whenever \( p \geq p \), and withdraw otherwise. (It is easy to see that this game of complete information has a continuum of equilibria.) This multiplicity of equilibria is common in models of banking.

Under incomplete information (i.e., when \( \varepsilon > 0 \)), the existence of dominance or contagious regions as those described above, in which a creditor’s optimal behavior does not depend on the actions of the other creditors, implies uniqueness of equilibrium. We derive some natural parameter restrictions that guarantee the existence of these dominance regions.

The existence of an upper dominance region requires that there be an interval of sufficiently high signals of the probability of success that a creditor’s optimal action is to roll over her credit even if all the other active creditors withdraw (i.e., \( x = h \)). Specifically, if the inequality

\[
\frac{(\lambda - h)}{\lambda(1 - h)} (1 + R) (1 - \varepsilon) > 1
\]

holds, then the expected payoff to a creditor who rolls over when her signal is \( s > 1 - \varepsilon \) is

\[
E(u(\cdot, x)|s) \geq E(u(\cdot, h)|s)
\]

\[
= \frac{\lambda - h}{\lambda(1 - h)} (1 + R) E(P|s)
\]

\[
\geq \frac{\lambda - h}{\lambda(1 - h)} (1 + R) (1 - \varepsilon)
\]

\[
> 1;
\]

i.e., the expected payoff to rolling over is greater than the expected payoff to withdrawing regardless of what the other active creditors do. Hence a creditor getting a signal \( s > 1 - \varepsilon \) rolls over. Since \( Q > 1 \) implies that \( 1 + R > 1 \), the inequality (5) holds when \( \varepsilon \) is small and \( \lambda h \) is sufficiently close to \( h \). The difference \( \lambda h - h \) is the maximum (negative) externality of withdrawals on the payoff of the creditors who roll over, which is smaller the closer is \( \lambda \) to one and the closer is \( h \) to zero.
The existence of a lower dominance region requires that there be an interval of sufficiently low signals of the probability of success that a creditor’s optimal action is to withdraw even if everyone else rolls over (i.e., $x = 0$). Specifically, if the inequality

$$(1 + R)(1 - \mu + \varepsilon) < 1$$  \hfill (7)$$

holds, then the expected payoff to a creditor who rolls over when her signal is $s < 1 - \mu + \varepsilon$ is

$$E(u(\cdot, x)|s) \leq E(u(\cdot, 0)|s)$$

$$= (1 + R) E(P|s)$$

$$\leq (1 + R)(1 - \mu + \varepsilon)$$

$$< 1;$$

i.e., the expected payoff to withdrawing is greater than the expected payoff to rolling over regardless of what the other active creditors do. Hence a creditor getting a signal $s < 1 - \mu + \varepsilon$ withdraws. In essence, (7) implies that the return distribution must have a sufficiently wide support to allow for net-present values below 1 even though the ex-ante expected return of the asset is above 1.

The inequality

$$0 < \varepsilon < \bar{\varepsilon} := \min \left\{ \frac{1}{1 + R} - (1 - \mu), 1 - \frac{\lambda (1 - h)}{(1 + R)(\lambda - h)} \right\}$$  \hfill (9)$$

warrants the existence of the upper and the lower dominance regions, i.e., that conditions (5) and (7) hold. Note that the existence of the upper dominance region requires the inequality (2) to hold. (Goldstein and Pauzner (2005) guarantee the existence of this region by assuming that premature liquidations do not reduce asset returns.) It is easy to see that the inequalities $u(1 - \mu, 0) < 1 < u(1, h)$ are implied by conditions (5) and (7), and therefore that the creditors’ game has multiple equilibria when $\varepsilon = 0$.

Henceforth we assume that (9), as well as (1) and (2), hold. We show that under these conditions the creditors’ game has a unique equilibrium.

## 4 Equilibrium of the Creditors Game

A simple class of strategies is that of switching strategies, whereby a creditor withdraws if her signal is below a threshold $t \in [1 - \mu - \varepsilon, 1 + \varepsilon]$, and rolls over otherwise.
When all creditors follow the same switching strategy identified by a threshold $t$, then we denote by $\tau_t$ the resulting strategy distribution, which is given by $\tau_t(s) = 1$ if $s < t$, and $\tau_t(s) = 0$ otherwise. Also we write $V(s, t) := U(s, \tau_t).$ Since $\tau_t(s) \geq \tau_{\hat{t}}(s)$ whenever $\hat{t} \geq t$, then $V(s, t)$ is decreasing in $t$. Moreover, since $\tau_t$ is decreasing in $s$, $P|s'$ first order stochastically dominates $P|s$ whenever $s' > s$, and $u$ is increasing in $p$ and decreasing in $x$, then $V(s, t)$ is increasing in $s$. We establish below that $V(t, t)$ (i.e., the restriction of $V$ to the diagonal) is strictly increasing on the interval $[1 - \mu + \varepsilon, 1 - \varepsilon]$. Note that the inequalities (1) and (7) jointly imply that

$$(1 + R) (1 - \mu + \varepsilon) < 1 < Q = (1 + R)(1 - \mu/2),$$

i.e.,

$$2\varepsilon < \mu.$$ 

Hence $1 - \mu + \varepsilon < 1 - \varepsilon$, so that the interval $[1 - \mu + \varepsilon, 1 - \varepsilon]$ is non-empty.

For $t \geq 1 - \varepsilon$ the inequality (6) implies

$$V(t, t) = E(u(\cdot, x(\cdot, \tau_t))|t) > 1.$$ 

Likewise, for $t \leq 1 - \mu + \varepsilon$ the inequality (8) implies

$$V(t, t) = E(u(\cdot, x(\cdot, \tau_t))|t) < 1.$$ 

Hence there is a unique $t^* \in (1 - \mu + \varepsilon, 1 - \varepsilon)$ such that $V(t^*, t^*) = 1$. Moreover, the strategy distribution $\tau_{t^*}$ is an equilibrium: Since $V$ is increasing in $s$, if

$$V(s, t^*) = U(s, \tau_{t^*}) < 1 = V(t^*, t^*),$$

then $s < t^*$, and therefore $\tau_{t^*}(s) = 1$; and if

$$V(s, t^*) = U(s, \tau_{t^*}) > 1 = V(t^*, t^*),$$

then $s > t^*$ and $\tau_{t^*}(s) = 0$. We establish that in fact $\tau_{t^*}$ is the unique equilibrium of the creditors’ game.

**Proposition 1.** The creditors’ game has a unique equilibrium. In equilibrium all creditors follow the same switching strategy. This strategy is identified by the threshold $t^* \in (1 - \mu + \varepsilon, 1 - \varepsilon)$, which uniquely solves the equation $V(t, t) = 1.$
**Proof.** The proof follows the lines of Morris and Shin (1998)’s Lemma 3. Assume that $\tau$ is an equilibrium strategy distribution, and define

$$\underline{s} := \inf \{s \mid \tau(s) < 1\},$$

and

$$\bar{s} := \sup \{s \mid \tau(s) > 0\}.$$  

Then

$$\bar{s} \geq \sup \{s \mid 0 < \tau(s) < 1\} \geq \inf \{s \mid 0 < \tau(s) < 1\} \geq \underline{s}.$$  

Since $\tau$ is an equilibrium and $U$ is continuous, then

$$U(\underline{s}, \tau) \geq 1 \geq U(\bar{s}, \tau).$$

Consider the strategy distribution $\tau_{\underline{s}}$. We have $\tau(s) \geq \tau_{\underline{s}}(s)$ for all $s$, and therefore

$$V(\underline{s}, \underline{s}) = U(\underline{s}, \tau_{\underline{s}}) \geq U(\underline{s}, \tau) \geq 1 = V(t^*, t^*).$$

Since $V(t, t)$ is increasing, then $t^* \leq \underline{s}$.

Likewise, consider the strategy distribution $\tau_{\bar{s}}$. We have $\tau_{\bar{s}}(s) \geq \tau(s)$ for all $s$, and therefore

$$V(\bar{s}, \bar{s}) = U(\bar{s}, \tau_{\bar{s}}) \leq U(\bar{s}, \tau) \leq 1 = V(t^*, t^*).$$

Since $V(t, t)$ is increasing, then $\bar{s} \leq t^*$.

Thus, $\bar{s} = \underline{s} = t^*$, and therefore $\tau(s) = \tau_{t^*}(s)$ for all $s$. □

We calculate the function $V(s, t)$ on $[1 - \mu + \varepsilon, 1 - \varepsilon]^2$. When all active creditors follow the threshold strategy $t \in [1 - \mu + \varepsilon, 1 - \varepsilon]$, then the expected fraction of active creditors who withdraw $E(\tau_t(s) \mid p)$ is zero if $p \in [t + \varepsilon, 1]$, it is one if $p \in [1 - \mu, t - \varepsilon]$, and it is

$$\frac{1}{2\varepsilon} \int_{p-\varepsilon}^{t} ds = \frac{1}{2\varepsilon} (t - p + \varepsilon),$$

for intermediate values $p \in (t - \varepsilon, t + \varepsilon)$. Hence, using equation (4) we can calculate the expected fraction of all creditors who withdraw as

$$x(p, \tau_t) = \begin{cases} 
0 & \text{if } p \in [t + \varepsilon, 1], \\
\frac{h}{2\varepsilon}(t - p + \varepsilon) & \text{if } p \in (t - \varepsilon, t + \varepsilon), \\
\frac{h}{\varepsilon} & \text{if } p \in [1 - \mu, t - \varepsilon].
\end{cases} \quad (10)$$
If a creditor signal is \( s \in [1 - \mu + \varepsilon, 1 - \varepsilon] \), then \( P|s \) is distributed uniformly on \([s - \varepsilon, s + \varepsilon]\), and her expected payoff if she rolls over is

\[
V(s, t) = \frac{1}{2\varepsilon} \int_{s-\varepsilon}^{s+\varepsilon} u(p, x(p, \tau_t)) dp,
\]

which can be rewritten using (3) as

\[
V(s, t) = \frac{1 + R}{\lambda h} \left( \frac{1}{2\varepsilon} \int_{s-\varepsilon}^{s+\varepsilon} p dp - (1 - \lambda) \int_{s-\varepsilon}^{s+\varepsilon} \frac{p dp}{2\varepsilon (1 - x(p, \tau_t))} \right).
\]

Evaluating the integrals in this expression, and setting a creditor’s signal equal to the threshold \( t \), we obtain the function \( V(t, t) \). This is a tedious task that we relegate to the Appendix. There we show that for \( t \in (1 - \mu + \varepsilon, 1 - \varepsilon) \) we have

\[
V(t, t) = \frac{1 + R}{\lambda h} (\beta t + \alpha \varepsilon),
\]

where

\[
\alpha := -\frac{(1 - \lambda)}{h} [2h + (2 - h) \ln (1 - h)],
\]

and

\[
\beta := h + (1 - \lambda) \ln (1 - h).
\]

In the Appendix we also show that \( \alpha > 0 \) and \( h > \beta > 0 \). Hence,

\[
\frac{dV(t, t)}{dt} = \frac{1 + R}{\lambda h} \beta > 0,
\]

i.e., \( V(t, t) \) is strictly increasing in \( t \).

The equilibrium threshold \( t^* \) solves \( V(t, t) = 1 \); i.e.,

\[
t^* = \frac{1}{\beta} \left( \frac{\lambda h}{1 + R} - \alpha \varepsilon \right).
\]

The ex-ante expected fraction of creditors who withdraw is

\[
E(x(\cdot, \tau_t)) = \frac{1}{\mu} \int_{1-\mu}^{1} x(p, \tau_t) dp
\]

\[
= \frac{1}{\mu} \left( \int_{1-\mu}^{t-\varepsilon} x(p, \tau_t) dp + \int_{t-\varepsilon}^{t+\varepsilon} x(p, \tau_t) dp + \int_{t+\varepsilon}^{1} x(p, \tau_t) dp \right).
\]

Since \( t^* \in (1 - \mu + \varepsilon, 1 - \varepsilon) \), using equations (10) we calculate the equilibrium ex-ante expected fraction of creditors who withdraw,

\[
x^* = E(x(\cdot, \tau_{t^*})) = \frac{h}{\mu} (t^* - (1 - \mu)).
\]

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Note that $x^* \in (h\varepsilon/\mu, h(\mu - \varepsilon)/\mu)$. We may be interpret $(t^*(1-\mu))/\mu = 1 - (1-t^*)/\mu$ as the ex ante limiting probability of a bank run as $\varepsilon \rightarrow 0$. (See Goldstein and Pauzner (2005).) With this interpretation, $x^*$ is the fraction of active creditors times the probability that an agent runs on the bank.

Proposition 2 below states these results.

**Proposition 2.** The equilibrium threshold is $t^* = (\lambda h/(1 + R) - \alpha \varepsilon)/\beta$ and the ex-ante expected fraction of creditors who withdraw is $x^* = h(t^*(1-\mu))/\mu$, where

$\alpha = -(1 - \lambda)[2h + (2 - h) \ln (1 - h)]/h > 0$ and $\beta = h + (1 - \lambda) \ln (1 - h) > 0$.

### 5 The Effects of Transparency Given Asset Risk

In this section we study the effect of transparency on refinancing risk, i.e., on the ex-ante expected fraction of creditors who withdraw $x^*$, and on welfare. In this first pass we continue treating the level of asset risk $\mu$ as exogenous, focusing on the effect of transparency on banks’ liabilities.

Changes in the level of transparency may be associated with the release of public information regarding the bank’s asset portfolio. The literature has studied the impact on equilibrium outcomes of the introduction of a noisy public signal. Notably, in a beauty contest setup in which the payoff of an agent depends on how well the agent is able to guess the state and on the level of conformity of her guess and the guesses of the other agents, Morris and Shin (2002) show that if the precision of the public signal relative to that of the agents’ private signals is below (above) a threshold, then public information has a negative (positive) effect on welfare. Angeletos and Pavan (2004) show, however, that if conformity plays no role and coordination is socially beneficial, then it is the overall precision of agents information that influences the agents’ actions and determines the equilibrium outcome, and therefore that public information always has a beneficial effect.

We identify the level of transparency with the precision of creditors’ private signals of the probability of success, i.e., with the value of $\varepsilon$. Smaller values of $\varepsilon$ correspond to greater levels of transparency, and vice versa. What we have in mind is that alternative levels of transparency may result from regulating how much information
a bank must disclose to their creditors about its asset portfolio. Such disclosures are privately communicated to the creditors.

Our approach allows for a simple and precise analysis of the impact of changes in transparency via comparative static exercises, avoiding the complication of adding a noisy public signal. Nevertheless, given our distributional assumptions the introduction of a public signal whose distribution is also uniform and conditionally independent of the creditors private signal, e.g., the disclosure of the results of banks’ stress tests, would have an impact on equilibrium akin to that of a discrete increase on the precision of creditors’ signals, and therefore provide no additional insights beyond those familiar in the literature.

Specifically, in our setting, a creditor’s posterior beliefs about the probability of success upon receiving a signal \( s \) is a uniform distribution on the interval \([1 - \mu, 1] \cap [s - \varepsilon, s + \varepsilon] \). Thus, when the precision of creditors’ signals increases (i.e., \( \varepsilon \) decreases) the support of a creditor’s posterior around her signal shrinks. The effect of observing an additional conditionally independent uniform public signal \( t \) (perhaps with a precision \( \eta \) different from that of creditors’ private signals) is also to shrink the support on the creditors’ posterior beliefs, which in this case would be a uniform distribution on the interval \([1 - \mu, 1] \cap [s - \varepsilon, s + \varepsilon] \cap [t - \eta, t + \eta] \). Of course, dealing a public signal requires establishing conditions on the levels of precision that are compatible with uniqueness of equilibrium.

For simplicity, we assume that the level of transparency can be increased at no cost – see Landier and Thesmar (2011) for a description of the costs of transparency, and Hyytinen and Takalo (2002) for an analysis of their implications for bank stability.

In order to evaluate the impact of \( \varepsilon \) on refinancing risk (i.e., on \( x^* \)), it is first instructive to study the impact of \( \varepsilon \) on the fraction of creditors who withdraw for a given \( p \). Taking derivatives in equation (10) reveals that the sign of \( \partial x(p, \tau_t)/\partial \varepsilon \) is the same as that of \( (p - t) \); that is, the fraction of creditors who withdraw increases with the level of transparency (i.e., as \( \varepsilon \) becomes smaller) when the probability of success is high relative to the threshold for withdrawal (i.e., \( p > t \)), and vice versa. This is intuitive: as \( \varepsilon \) decreases, choosing the optimal action becomes more likely; that is, a creditor is more likely to roll over (withdraw) when the true value of \( p \) is above (below) the threshold \( t \). In this sense, increasing transparency has procyclical effects,
facilitating refinancing when the prospects of getting the asset returns are good, but impeding refinancing when they are bad.

The effect of transparency on refinancing risk through the cycle is given by the derivative \( \partial x^* / \partial \varepsilon \). Equation (14) shows that \( x^* \) depends on \( \varepsilon \) only indirectly through \( t^* \). Taking derivatives in (13) we get

\[
\frac{\partial t^*}{\partial \varepsilon} = -\frac{\alpha}{\beta} < 0.
\]

Hence the equilibrium threshold \( t^* \) increases with the level of transparency; i.e., the more precise are the creditors’ signals (i.e., the smaller is \( \varepsilon \)), the larger is the creditors’ equilibrium threshold. Taking derivatives in (14) we get

\[
\frac{\partial x^*}{\partial \varepsilon} = \frac{h}{\mu} \frac{\partial t^*}{\partial \varepsilon} < 0.
\]

Hence the ex-ante expected fraction of creditors who withdraw increases with the level of transparency; i.e., the more precise are the creditors’ signals, the larger is refinancing risk \( x^* \). We state this result in Proposition 3 below.

**Proposition 3.** Given the level of asset risk \( \mu \), increasing the level of transparency (i.e., decreasing \( \varepsilon \)) increases refinancing risk (i.e., increases \( x^* \)).

Proposition 3 is a direct implication of the fact that \( V(t, t) \) is increasing in \( \varepsilon \) – see equation (12). The intuition of this property is as follows: increasing transparency (i.e., decreasing \( \varepsilon \)) reduces the probability that a creditor mistakenly rolls over as well as the probability that a creditor mistakenly withdraws. Thus, increasing transparency decreases the fraction of creditors who withdraw \( x(p, \tau^t) \) when the prospects of the asset paying its return are good (because the probability that a creditor mistakenly withdraws becomes smaller), but increases the fraction of creditors who withdraw when the prospects of the asset paying its return are bad (because the probability that a creditor mistakenly rolls over becomes smaller). Hence its effects on the payoff to rolling over are procyclical, i.e., \( u(p, x) \) increases when \( p \) is large and decreases when \( p \) is small. Since the fraction of creditors who withdraw \( x(p, \tau^t) \) is larger when the prospect are bad than when they are good, and since the negative externality of withdrawals is larger the larger is \( x \) (recall that \( \partial u(p, x) / \partial x^2 < 0 \)), then the negative effect on \( u \) is more pronounced than the positive effect. Thus, over the cycle an
increase in transparency causes a decrease of the payoff to rolling over, and hence lead creditors to optimally raise their threshold to roll over.

The equilibrium fraction of creditors who roll over, $1 - x^*$, may also be interpreted as a measure of creditors’ confidence on banks. By Proposition 3, increasing transparency has a negative effect on creditors’ confidence. The comparative statics of creditors’ confidence with respect to other exogenous parameters, such as $\lambda$ and $h$, are complex. However, it is straightforward to show that $\partial^2 x^*/\partial \varepsilon \partial \lambda > 0$; i.e., the larger the liquidation value of the asset, the smaller is the negative impact of transparency on creditors’ confidence. This again hinges on the (absolute) value of the derivative $\partial^2 u(p, x)/\partial x^2$, which is proportional to $(1 - \lambda)$.

Let us now study the impact of transparency on welfare given the asset’s risk. Since competitive banks promise the full asset returns to creditors, an index of social welfare is simply the sum of creditors’ ex ante expected payoffs, and is therefore given by

$$W(\varepsilon, \mu) = E \left[ x(P, \tau_{t^*}) + \left(1 - \frac{x(P, \tau_{t^*})}{\lambda}\right) (1 + R)P \right]$$

$$= x^* + (1 + R) \left( E(P) - \frac{E(x(P, \tau_{t^*})P)}{\lambda} \right).$$

Here $x(p, \tau_{t^*})$ is the total payoff to the creditors who withdraw and get their monetary unit, and $(1 - x(p, \tau_{t^*})/\lambda) (1 + R) p$ is the returns of the non-liquidated assets, which is also the total payoff to the creditors who roll over.

For $t \in [1 - \mu + \varepsilon, 1 - \varepsilon]$, using (10) we have

$$E \left[ x(P, \tau_{t})P \right] = \frac{1}{\mu} \int_{1-\mu}^1 x(p, \tau_{t})pd\mu$$

$$= \frac{h}{\mu} \int_{1-\mu}^{t-\varepsilon} pdp + \frac{h}{2\mu \varepsilon} \int_{t-\varepsilon}^{t+\varepsilon} (t - p + \varepsilon) pdp$$

$$= \frac{h}{6\mu} \left( 3t^2 + \varepsilon^2 - 3(1 - \mu)^2 \right).$$

Thus, using (14) and $E(P) = 1 - \mu/2$ we may write (15) as

$$W(\varepsilon, \mu) = \frac{h}{\mu} (t^* - (1 - \mu)) + (1 + R) \left( 1 - \frac{\mu}{2} - \frac{h}{6\lambda \mu} \left( 3t^*^2 + \varepsilon^2 - 3(1 - \mu)^2 \right) \right).$$

Since $t^*$ is linear in $\varepsilon$, then $W$ is a quadratic function of the level of transparency $\varepsilon$. 

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We have
\[
\frac{\partial W}{\partial \varepsilon} = \frac{h}{\mu} \left( 1 - \frac{(1+R)p^*}{\lambda} \right) \frac{\partial t^*}{\partial \varepsilon} - \frac{(1+R)h\varepsilon}{3\lambda \mu}
\]
\[
= -\frac{h}{\mu} \left( 1 - \frac{h}{\beta} + \frac{(1+R)}{\lambda \beta} \alpha \varepsilon \right) \frac{\alpha}{\beta} - \frac{(1+R)h\varepsilon}{3\lambda \mu}
\]
\[
= \frac{h}{\mu} (a - b\varepsilon),
\]
where
\[
a = \frac{(h - \beta) \alpha}{\beta^2},
\]
and
\[
b = \frac{(1+R)}{\lambda} \left( \frac{\alpha^2}{\beta^2} + \frac{1}{3} \right) > 0.
\]
Also we have
\[
\frac{\partial^2 W}{\partial \varepsilon^2} = -\frac{hb}{\mu} < 0.
\]

Since \(0 < \beta < h\) and \(\alpha > 0\), then \(a > 0\). Hence \(\partial W/\partial \varepsilon > 0\), when \(\varepsilon\) is smaller than \(a/b\). In particular, \(\partial W/\partial \varepsilon > 0\) near \(\varepsilon = 0\). And \(\partial W/\partial \varepsilon < 0\) for \(\varepsilon\) larger than \(a/b\). That is, when creditors’ signals are very noisy, social welfare increases with the level of transparency. When creditors’ signals are sufficiently precise, however, social welfare decreases with the level of transparency. Hence maximal transparency is not socially optimal.

We summarize these findings in Proposition 4 below.

**Proposition 4.** Given the level of asset risk \(\mu\), social welfare increases with the level of transparency when the level of transparency is low (i.e., when \(\varepsilon > a/b\)), but decreases when it is high (i.e., when \(\varepsilon < a/b\)). Thus, maximal transparency is not socially optimal.

Even though increasing transparency impedes refinancing by Proposition 3, its impact on welfare is counter-balanced by reducing creditors’ mistakes, which are costly for individual creditors and, when they lead to inefficient liquidation, involve negative externalities. In addition, increasing transparency fosters efficient liquidation when the realized value of \(p\) is low, i.e., when \(p \leq \lambda/(1+R)\), and discourages liquidation when it is inefficient. These counter-balancing effects favor an intermediate level of transparency \(\varepsilon^* = a/b\).
Recall that in order to guarantee uniqueness of equilibrium we have assumed that $0 < \varepsilon < \bar{\varepsilon}$ — see condition (9). If $\varepsilon > \bar{\varepsilon}$, multiple equilibria may arise, and the banking system may become vulnerable to self-fulfilling crises. Thus, maximum transparency is not socially optimal, but a low level of transparency may also be undesirable because self-fulfilling crises may arise. In the literature, this rationale has suggested regulation to warrant a sufficiently high level of transparency to prevent these self-fulfilling crises from arising — see, e.g., Rochet and Vives (2004). In our setting, it can be shown that $\varepsilon^* < \bar{\varepsilon}$, and thus that $\varepsilon^*$ optimal, if, e.g., $\lambda$ is sufficiently close to one. If $a/b > \bar{\varepsilon}$, however, this argument may favor a more transparent banking system than that implied by $\varepsilon = a/b$.

6 Asset Risk Taking

In order to endogenize asset risk, we assume that banks choose the level of risk $\mu$, which becomes common knowledge, from an interval $I$ of values with a non-empty interior. Also we assume that condition (9) that guarantees existence and uniqueness of equilibrium holds for the values of $\mu$ in $I$, so that the creditors equilibrium payoffs are well defined on $I$.

Let us write the asset’s return conditional on success, as well as the mean asset return, explicitly as a function of $\mu$; i.e.,

$$Q(\mu) = (1 + R(\mu)) E(P(\mu)).$$

The expected probability of success

$$E(P(\mu)) = 1 - \mu/2$$

decreases with $\mu$. We assume that the mean asset return increases with the level of risk, i.e.,

$$Q'(\mu) \geq 0.$$ 

Hence

$$R'(\mu) \geq \frac{1 + R(\mu)}{2 - \mu} > 0,$$

i.e., the return conditional on success is strictly increasing with the level of risk. If $Q$ is a mean-preserving spread, i.e., $Q'(\mu) = 0$, then $R'(\mu) = (1 + R(\mu)) / (2 - \mu) > 0$. 

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(This is a case often studied in the literature – e.g., Matutes and Vives (1996), Cordella and Yeyati (1998).)

Competition forces banks to choose the level of asset risk $\mu$ that maximizes the ex-ante expected payoff of a creditor, which coincides with the sum of the creditors ex-ante expected payoffs $W(\varepsilon, \mu)$ – see equation (15). Thus, in a perfect Bayesian equilibrium $\mu^*$ solves the problem

$$\max_{\mu \in I} W(\varepsilon, \mu).$$

We proceed under the assumption that the solution to this problem is interior, i.e., we assume that the banks’ asset risk choice $\mu^* \in I$ solves the equation

$$\frac{\partial W}{\partial \mu} = 0,$$

and that $W$ satisfies the second order sufficient condition for welfare maximization

$$\frac{\partial^2 W}{\partial \mu^2} \leq 0.$$  \hspace{1cm} (17)

(If $\mu^*$ were a corner solution, then transparency would have no impact on the banks’ asset risk choice.)

Let us consider the impact of transparency on the level of risk $\mu^*$. Since in an interior equilibrium the level of asset risk $\mu^*$ solves $\partial W/\partial \mu = 0$, we have

$$\frac{\partial W^2}{\partial \mu^2} d\mu + \frac{\partial W^2}{\partial \mu \partial \varepsilon} d\varepsilon = 0,$$

and therefore

$$\frac{d\mu^*}{d\varepsilon} = \frac{\partial W^2}{\partial \mu \partial \varepsilon} \left( - \frac{\partial W^2}{\partial \mu^2} \right)^{-1}.$$  \hspace{1cm} .

Moreover, since $\partial^2 W/\partial \mu^2 < 0$, then

$$\text{sign} \left( \frac{d\mu^*}{d\varepsilon} \right) = \text{sign} \left( \frac{\partial W^2}{\partial \mu \partial \varepsilon} \right).$$

By Young’s theorem, we have

$$\frac{\partial W^2}{\partial \mu \partial \varepsilon} = \frac{\partial W^2}{\partial \varepsilon \partial \mu}.$$  \hspace{1cm} .

Differentiating (16) with respect to $\mu$ we get

$$\frac{\partial W^2}{\partial \varepsilon \partial \mu} = -\frac{h}{\mu^2} (a - b\varepsilon) - \frac{h\varepsilon}{\mu} \frac{\partial b}{\partial \mu}$$

$$= -\frac{h}{\mu^2} (a - b\varepsilon) - \frac{h\varepsilon R'}{\mu \lambda} \left( \frac{\alpha^2}{\beta^2} + \frac{1}{3} \right).$$ \hspace{1cm} (18)
Since \( R' > 0 \), then the second term on the RHS of (18) is negative. As for the first term, it is negative for \( \varepsilon < a/b \), and it is positive for \( \varepsilon > a/b \). Thus, if \( \varepsilon \leq a/b \), then \( \partial W^2/\partial \varepsilon \partial \mu < 0 \), whereas if \( \varepsilon > a/b \), then the sign \( \partial W^2/\partial \varepsilon \partial \mu \) is ambiguous.

Therefore if the level of transparency decreases towards the socially optimal level, i.e., if \( \varepsilon \) approaches \( a/b \) from below, then risk taking increases; i.e., \( d\mu^*/d\varepsilon < 0 \) on \((0, a/b]\). In particular, if \( \varepsilon \) is around its optimal value of \( a/b \), then risk taking increases with the level of transparency. However, if \( \varepsilon \) is well above its optimal value, then the impact of increasing transparency towards the socially optimal level on risk taking is ambiguous. We state these results in Proposition 5 below.

**Proposition 5.** Banks’ asset risk taking increases with the level of transparency above and around the socially optimal level. For levels of transparency sufficiently low, however, the impact of transparency on risk taking is ambiguous.

Recall that more risk taking (i.e., a greater value of \( \mu \)) is associated with a larger probability of a bank failure in our model. Thus, Proposition 5 implies that for high levels of transparency, and for levels of transparency around the socially optimal, increasing the level of transparency increases the probability of a bank failure, i.e., \( d\mu^*/d\varepsilon < 0 \). More generally, even if \( \varepsilon > a/b \), then \( d\mu^*/d\varepsilon < 0 \) may hold since the second term on the RHS of (18) is negative. In fact, we can show that if the elasticity of asset returns with respect to the level of risk is above one, then \( d\mu^*/d\varepsilon < 0 \). An increase in transparency makes creditors less willing to roll over for a given asset risk (Proposition 3), leading the bank to try to compensate this effect by taking more risk. From (13) we observe that

\[
\frac{\partial t^*}{\partial \mu} = -\frac{\lambda h R'}{\beta (1 + R)^2} < 0,
\]

i.e., the creditors’ threshold to rolling over decreases with the asset’s risk. The effect arises because the expected asset returns at maturity increases with the level of risk (i.e., \( Q' \geq 0 \)), which implies that the expected payoff to rolling over increases with the level of risk – see (3).

The impact of changes in the level of transparency on the level of refinancing risk \( x^* \) is now twofold: there is a **direct effect** on a bank’s refinancing risk given its asset risk choice, and an **indirect effect** through its influence on the bank’s asset risk choice;
i.e.,

\[
\frac{dx^*}{d\varepsilon} = \frac{\partial x^*}{\partial \varepsilon} + \frac{\partial x^*}{\partial \mu} \frac{d\mu^*}{d\varepsilon}.
\]

By Proposition 3, the direct effect \(\partial x^*/\partial \varepsilon\) is negative. As for the sign of the indirect effect, in view of Proposition 5, let us assume that \(d\mu^*/d\varepsilon \leq 0\). Differentiating (14) with respect to \(\mu\) yields

\[
\frac{\partial x^*}{\partial \mu} = \frac{h}{\mu^2} (1 - t^* (1 + \eta)),
\]

where

\[
\eta := -\frac{\partial t^*}{\partial \mu} \frac{\mu^*}{t^*}
\]

is the elasticity of the equilibrium threshold with respect to the asset risk. Note from (19) that \(\eta\) is positive. Since \(t^* \in (1 - \mu + \varepsilon, 1 - \varepsilon)\) by Proposition 1, then \(1 - t^* > 0\). However, the sign \(1 - t^* (1 + \eta)\) is ambiguous and, by implication, the sign of the indirect effect \(\partial x^*/\partial \mu\) is ambiguous too. If \(\eta\) is small, then \(\partial x^*/\partial \mu > 0\), and the sign of both the indirect effect and total effect are negative. We state these results in Proposition 6.

**Proposition 6.** *If the elasticity of the equilibrium threshold with respect to asset risk is sufficiently small, then increasing the level of transparency around and above its socially optimal level increases refinancing risk. Otherwise, the effect of changes in the level of transparency on refinancing risk is ambiguous.*

Transparency has potentially ambiguous effects on refinancing risk because the impact of asset risk taking on withdrawals \(\partial x^*/\partial \mu\) is ambiguous due to two opposing forces. On the one hand, the probability that creditors get low signals of \(p\) and withdraw increases with risk taking. This effect of asset risk taking increases refinancing risk. On the other hand, (19) suggests that the bank can lower the creditors’ threshold by taking more risk. This effect of asset risk taking decreases refinancing risk.

### 7 Welfare Analysis

Let us reconsider the impact of changes in the level of transparency on welfare accounting for the change it induces on the level of asset risk. Given the level of
transparency $\varepsilon$ social welfare is therefore given by

$$W^*(\varepsilon) = W(\varepsilon, \mu^*(\varepsilon)),$$

where $\mu^*(\varepsilon)$ is the bank’s risk choice given $\varepsilon$. Thus,

$$\frac{dW^*}{d\varepsilon} = \frac{\partial W}{\partial \varepsilon} + \frac{\partial W}{\partial \mu} \frac{\partial \mu^*}{\partial \varepsilon}.$$

Since $\mu = \mu^*$ maximizes $W(\varepsilon, \mu)$ given $\varepsilon$, the Envelope Theorem implies that

$$\frac{dW^*}{d\varepsilon} = \frac{\partial W}{\partial \varepsilon}.$$

Thus, the marginal impact of changes of the level of transparency on welfare are the same as in the version of the model where $\mu$ is exogenous. Therefore the results established in Proposition 4 above apply with no change. In particular, maximal transparency is not socially optimal.

Since in our setting there is no conflict of interests between the bank and its creditors, one may argue that competitive pressure may force the bank to choose the socially optimal level of transparency as well as the socially optimal level of asset risk, which suggests that there is no need for regulating the level of transparency. Nonetheless, a bank’s decisions may have welfare implications beyond their direct effects on its creditors. In particular, the failure of a bank may have social costs beyond the costs it imposes on its creditors. For example, depriving some agents of banking services may lead to a misallocation of savings and investments, or may constrain the credit available to borrowers in the real sector. Moreover, banks’ investments may generate social returns in addition to private returns. Also, bank failures may be contagious and lead to a credit crunch. The existence of these externalities may lead to a misalignment of the objectives of banks and those of society.

Consider a social welfare function $\tilde{W}^*$ that accounts for these externalities,

$$\tilde{W}^*(\varepsilon) = W^*(\varepsilon) - F\left(1 - E(P(\mu^*)))\right).$$

In this expression, the term $F\left(1 - E(P(\mu^*)))$, with $F > 0$, captures the external social cost of a bank’s failure, as in, e.g., Freixas, Lóránt and Morrison (2007).

Since $dW^*/d\varepsilon = \partial W/\partial \varepsilon$, as shown above, we have

$$\frac{d\tilde{W}^*(\varepsilon)}{d\varepsilon} = \frac{\partial W}{\partial \varepsilon} - \frac{F}{2} \frac{d\mu^*}{d\varepsilon}. \quad (20)$$

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Since $W^*$ increases and $\mu^*$ decreases with $\varepsilon$ on $(0,a/b)$ by Propositions 4 and 5, then the RHS of (20) is strictly increasing at least on $(0,a/b)$. Furthermore, around $\varepsilon = a/b$ the first term on the RHS is zero but the second term is positive. Hence, when the social cost of bank failures are taken into account, social welfare $\hat{W}^*$ increases with $\varepsilon$ beyond $a/b$. That is, when we account for the social cost of bank failures, the socially optimal level of transparency is smaller than when only the private interests of creditors are taken into account. This result is stated in Proposition 7.

\textbf{Proposition 7.} If bank failures have negative social externalities, in addition to their direct effect on creditors payoffs, then the socially optimal level of transparency is below the level that is optimal when such externalities are absent.

The policy implications of Proposition 7 are strong: to the extent that bank failures call for transparency regulation, this regulation should result in a more opaque rather than a more transparent banking system.

8 A Numerical Example

Despite its apparent complexity, our model is parsimonious in that the primitives are just the liquidation cost, $\lambda$, the fraction of active creditors, $\lambda$, and the return function, $R(\mu)$. It is not obvious which range of values for $\lambda$ we should postulate since in practice the liquidation value of an asset may depend upon the realized state (it may be low if it is the result of a fire sale in a recession, but large if the asset is traded in a booming market) and on its specific nature (e.g., loans to high-tech startups may have a low liquidation value, whereas prime mortgage loans may have a high one). As for the fraction of active creditors $h$, we may identify it with the share of short-term debt relative to the banks’ total external debt or total liabilities, which also varies wildly. We therefore postulate values for these parameters that we deem as reasonable, but certainly there are other interesting values to try.

In our numerical example we set up $\lambda = 2h = 3/4$, and postulate a linear return function, $R(\mu) = \mu$. Note that $h < \lambda$, and

\[
Q(\mu) = (1 + R(\mu)) \left(1 - \frac{\mu}{2}\right) = 1 + \frac{1}{2} \mu (1 - \mu) > 1,
\]

25
so that

\[ Q(\mu) > 1 > \lambda > h > 0, \]

holds as required.

Using the values of \( \lambda \) and \( h \), we calculate \( \alpha \) and \( \beta \). Then we use these values and the function \( R \) to calculate the equilibrium threshold \( t^* \), the values \( a \) and \( b \), and the optimal level of transparency \( \varepsilon^* = a/b \). Substituting these values in (15) we obtain the welfare function \( W(\varepsilon^*, \mu) \). Ignoring condition (9), and assuming that a broad set of assets are available, we calculate the optimal level of transparency, \( \varepsilon^* = a/b \), and the level of risk that maximizes \( W(\varepsilon^*, \mu) \), to obtain \( \mu^* \approx 0.64738 \). We then use the value of \( \mu^* \) to calculate \( \varepsilon^* \approx 0.022112 \). When the level of asset risk is \( \mu^* \) the bound \( \bar{\varepsilon} \) given by condition (9) is \( \bar{\varepsilon} \approx 0.24122 > \varepsilon^* \). If the feasible levels of asset risk is small interval around \( \mu^* \), then equilibrium would be unique for a broad range of values of \( \varepsilon \) around \( \varepsilon^* \).

9 Conclusion

Our main conclusion is that maximal bank transparency is not socially optimal. Moreover, in a competitive banking sector transparency may need to be regulated only when there are social costs or social externalities associated to bank failures; when this is the case regulation is required to reduce the level of transparency below the level that is socially optimal in the absence of these externalities. In addition, asset risk taking increases with the level of transparency above and around the socially optimal level. (The relation between risk taking and transparency is ambiguous for levels of transparency sufficiently below the socially optimal.) As for the sign of the impact of transparency on refinancing risk, it is negative given the asset’s risk, but it is ambiguous if we account for its indirect effect via risk taking.

That the socially optimal level of transparency is interior results from optimally trading off the opposing effects induced by changes of the level of transparency: for high levels of transparency, further increasing transparency increases efficient liquidation but also increases risk taking and may increase refinancing risk. These effects have been considered in the literature to argue in favor and against increasing bank transparency, rendering an inconclusive debate – see Landier and Thesmar (2011).
Our model allow us to put these effects in perspective, and lead us to the conclusion that calls for maximal transparency are not justified, and that assessing the socially optimal level of transparency requires a quantitative exercise.

In our model, the negative externality imposed by the creditors who withdraw their short-term debt on the creditors who roll over plays a key role. Studying the effect of transparency on the agency problem facing bank “insiders” (e.g. its management and controlling shareholders) and outside creditors (e.g. short-term creditors and small investors) seems an interesting topic of future research – see Vauhkonen (2010). Another important issue outside the scope of the present paper is the analysis of the effects of transparency on contagion – see Chen and Hasan (2006) and Giannetti (2007).

10 Appendix

In this appendix we calculate the function $V(s, t)$ for $s, t \in (1 - \mu + \varepsilon, 1 - \varepsilon)$. As established in (11) in the main text

$$V(s, t) = \frac{1 + R}{\lambda} \left( \frac{1}{2\varepsilon} \int_{s-\varepsilon}^{s+\varepsilon} pdp - (1 - \lambda) \int_{s-\varepsilon}^{s+\varepsilon} \frac{pdp}{2\varepsilon (1 - x(p, \tau))} \right).$$

We have

$$\frac{1}{2\varepsilon} \int_{s-\varepsilon}^{s+\varepsilon} pdp = s.$$

For $p$ and $t$ satisfying $p - \varepsilon < t < p + \varepsilon$ we have

$$2\varepsilon \left(1 - x(p, \tau_t)\right) = 2\varepsilon \left(1 - \frac{h(t - p + \varepsilon)}{2\varepsilon}\right) = c + hp,$$

where

$$c := 2\varepsilon - h(t + \varepsilon).$$

Also we have

$$\int \frac{pdp}{2\varepsilon (1 - x(p, \tau_t))} = \frac{p}{h} - \frac{c}{h^2} \ln (c + hp) + \text{constant}.$$
Assume that \( s > t \). For \( p \in (t + \varepsilon, s + \varepsilon) \) equation (4) yields \( x(p, \tau_t) = 0 \). Also, since \( p - \varepsilon < t < p + \varepsilon \) for \( p \in (s - \varepsilon, t + \varepsilon) \), we may write

\[
\frac{1}{2\varepsilon} \int_{s-\varepsilon}^{s+\varepsilon} p \frac{dp}{1 - x(p, \tau_t)} = \int_{s-\varepsilon}^{t+\varepsilon} p \frac{dp}{2\varepsilon (1 - x(p, \tau_t))} + \frac{1}{2\varepsilon} \int_{t+\varepsilon}^{s+\varepsilon} p \frac{dp}{1 - x(p, \tau_t)}
\]

\[
= -\frac{1}{h^2} \left[ c \ln (c + hp) - hp \right]_{s-\varepsilon}^{t+\varepsilon} + \frac{1}{2\varepsilon} \int_{t+\varepsilon}^{s+\varepsilon} p \frac{dp}{1 - x(p, \tau_t)}
\]

\[
= -\frac{1}{h^2} \left( c \ln \frac{c + h (t + \varepsilon)}{c + h (s - \varepsilon)} - h (t + \varepsilon) + h (s - \varepsilon) \right) + \frac{1}{4\varepsilon} (s - t) (s + t + 2\varepsilon).
\]

Hence

\[
V(s, t) = \frac{1 + R}{\lambda} \left( s - \frac{(1 - \lambda) (s - t) (s + t + 2\varepsilon)}{4\varepsilon} \right) + \frac{(1 + R) (1 - \lambda)}{\lambda h^2} \left( c \ln \frac{c + h (t + \varepsilon)}{c + h (s - \varepsilon)} - h (t + \varepsilon) + h (s - \varepsilon) \right).
\]

Assume that \( s < t \). For \( p \in (s - \varepsilon, t - \varepsilon) \) equation (4) yields \( x(p, \tau_t) = h \). Also, since \( p - \varepsilon < t < p + \varepsilon \) for \( p \in (t - \varepsilon, s + \varepsilon) \), then we may write

\[
\frac{1}{2\varepsilon} \int_{s-\varepsilon}^{t+\varepsilon} p \frac{dp}{1 - x(p, \tau_t)} = \frac{1}{2\varepsilon} \int_{s-\varepsilon}^{t-\varepsilon} p \frac{dp}{1 - h} + \frac{1}{2\varepsilon} \int_{t-\varepsilon}^{s+\varepsilon} p \frac{dp}{2\varepsilon (1 - x(p, \tau_t))}
\]

\[
= -\frac{(s - t) (s + t - 2\varepsilon)}{4\varepsilon (1 - h)} - \frac{1}{h^2} \left[ c \ln (c + hp) - hp \right]_{t-\varepsilon}^{s+\varepsilon}
\]

\[
= -\frac{(s - t) (s + t - 2\varepsilon)}{4\varepsilon (1 - h)} - \frac{1}{h^2} \left( c \ln \frac{c + h (s + \varepsilon)}{c + h (t - \varepsilon)} - h (s + \varepsilon) + h (t - \varepsilon) \right).
\]

Hence

\[
V(s, t) = \frac{1 + R}{\lambda} \left( s + \frac{(1 - \lambda) (s - t) (s + t + 2\varepsilon)}{4\varepsilon (1 - h)} \right) + \frac{(1 + R) (1 - \lambda)}{\lambda h^2} \left( c \ln \frac{c + h (s + \varepsilon)}{c + h (t - \varepsilon)} - h (s + \varepsilon) + h (t - \varepsilon) \right).
\]

When the signal of the creditor coincides with the threshold, i.e., \( s = t \), then \( c + h (s + \varepsilon) = 2\varepsilon \) and \( c + h (s - \varepsilon) = 2\varepsilon (1 - h) \), and the expected payoff becomes

\[
V(t, t) = \frac{1 + R}{\lambda h} \left\{ [h + (1 - \lambda) \ln (1 - h)] t - \varepsilon (1 - \lambda) \left[ 2 + \frac{2 - h}{h} \ln (1 - h) \right] \right\}.
\]
Define
\[ \alpha := -[2h + (2 - h) \ln(1 - h)](1 - \lambda)/h \]
and
\[ \beta := h + (1 - \lambda) \ln(1 - h). \]
We can then rewrite \( V(t, t) \) as
\[ V(t, t) = \frac{1 + R}{\lambda h} (\beta t + \alpha \varepsilon), \]
which is equation (12) in Section 4.

We show that \( 0 < \beta < h \). Since \( 1 > \lambda > h > 0 \), then \( (1 - \lambda) \ln(1 - h) < 0 \) and therefore \( \beta < h \). And since
\[ \frac{\partial \beta}{\partial h} = \frac{\lambda - h}{1 - h} > 0, \]
and \( \beta = 0 \) for \( h = 0 \), then \( \beta > 0 \).

We show that \( \alpha > 0 \). Since \( 1 > \lambda > h > 0 \), then \( (1 - \lambda)/h > 0 \). Moreover, for \( h > 0 \) we have
\[ \frac{\partial}{\partial h} (2h + (2 - h) \ln(1 - h)) = -\frac{h + (1 - h) \ln(1 - h)}{1 - h} < 0. \]
(Showing that the numerator is positive is analogous to proving that \( \beta > 0 \).) Hence
\[ 2h + (2 - h) \ln(1 - h) < 0, \]
and therefore
\[ \alpha = -(2h + (2 - h) \ln(1 - h)) \frac{1 - \lambda}{h} > 0. \]
References


