Reporting Discretion, Market Discipline, and Panic Runs

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Abstract

This paper investigates the economic consequences of a financial institution’s reporting discretion in the context of bank runs. A fundamental-based run imposes market discipline on insolvent institutions, but a panic-based run shuts down institutions that could have survived with better coordination among investors. We augment a bank-run model with the financial institution’s discretion over reporting to investors. We show that reporting discretion reduces panic runs, but excessive reporting discretion weakens the market discipline. Moreover, one institution’s opportunistic use of reporting discretion exerts a negative externality on others.

JEL classification:

Key Words: Disclosure, Discretion, Market Discipline, Bank Runs, Banking Regulation
1 Introduction

The recent financial crisis has focused a spotlight on the importance of financial institutions’ information environment. Financial institutions provide a great deal of information to outsiders, but the process that governs such provision, which consists of a complex web of regulations and accounting rules, involves substantial scope for discretion. Empirical evidence has accumulated that financial institutions indeed use such reporting discretion to manage earnings and/or capital levels, especially in bad times. For example, banks structure the commercial paper conduits in such a way to inflate capital (Acharya, Schnabl, and Suarez (2013)), manipulate Basel risk-weights under the internal ratings-based (IRB) approaches of Basel II (Mariathasan and Merrouche (2014)), and overstate earnings, assets, and capital with aggressive use of accounting rules over various areas, including loan loss provision (e.g., Bushman and Williams (2012)), impairment (e.g., Vyas (2011)), valuation for level 2 and 3 assets (e.g., Kolev (2009) and Song, Thomas, and Yi (2010)), securitization (e.g., Dechow, Myers, and Shakespeare (2010)), deferred tax assets (e.g., Skinner (2008)), or a combination of these areas (e.g., Huizinga and Laeven (2012)). Such evidence is also compiled and reviewed in Laux and Leuz (2010), Beatty and Liao (2013) and Bushman (forthcoming, 2014). Laux and Leuz (2010) conclude that “banks used accounting discretion to overstate the value of their assets substantially” during the 2008 financial crisis.

What are the economic consequences of financial institutions’ reporting discretion? How does it affect the institution’s stakeholders and other financial institutions? Do stakeholders see through the opportunistic use of reporting discretion and fully undo the bias? What determines the optimal level of reporting discretion to be built into accounting rules and regulations for financial institutions?

In this paper we analyze these questions by extending the classic bank run model of Diamond and Dybvig (1983) to incorporate financial institutions’ reporting discretion. While financial institutions differ from non-financial firms in a number of aspects, we will focus on one: a maturity mismatch between their assets and liabilities that gives rise to the possibility of runs. A financial institution finances its long-term assets (e.g., loans, derivatives, or other
illiquid assets) with short term instruments (e.g., demand deposits, commercial papers, repos, or redeemable equity shares). This characterization seems descriptive of commercial banks, investment banks, as well as investment funds. For simplicity we call all these institutions banks and their investors creditors.

It is well-known that the maturity mismatch exposes a bank to the possibility of massive withdrawals, or runs, due to the “strategic complementarity” among creditors’ withdrawal decisions. A creditor’s benefit to withdraw earlier increases with the number of other creditors who are withdrawing. [Diamond and Dybvig (1983)] show that there are a continuum of equilibria if the bank’s fundamental is certain and common knowledge among creditors. In the “best” equilibrium, creditors choose not to run, believing that others are not running. As a result, all creditors enjoy the higher returns on the long-term assets. However, in the “worst” equilibrium, all creditors rush to withdraw because they fear that other creditors are going to do the same and that the bank will fail. As a result, the bank is forced to liquidate its long-term assets at their liquidation value and indeed fails, self-fulfilling the creditors’ initial fear. Creditors’ pessimism about other creditors’ actions underlies the panic-based runs.

The multiple equilibria make it difficult to conduct comparative statics and draw empirical predictions. [Goldstein and Pauzner (2005) and Morris and Shin (2000)] demonstrate that the bank-run model in [Diamond and Dybvig (1983)] has a unique equilibrium, using the techniques from the global games literature (e.g., [Carlsson and van Damme (1993), Morris and Shin (1998)]). In the unique equilibrium, a creditor runs if and only if her signal falls below a threshold. Their analysis reveals that bank runs can be either fundamental-based or panic-based. The former liquidates insolvent banks efficiently, but the latter shuts down some solvent but illiquid banks. In other words, while bank runs impose market disciplines, they can also be excessive.

Against this benchmark we introduce into a bank-run model a manager of the bank. The manager prefers less withdrawal and has discretion to misreport to creditors. The degree of reporting discretion is modeled as the inverse of the manager’s cost to misreport. The presence of reporting discretion exacerbates the multiplicity of equilibria, as creditors now have to make inference about the manager’s reporting behavior above and beyond forecasting other
creditors’ actions. We use the global games methodology to obtain the unique equilibrium of the model and conduct comparative statics to examine the effects of reporting discretion on the incidence and efficiency of bank runs.

We show that in equilibrium the presence of reporting discretion alters the incidence of runs. In other words, the manager succeeds in influencing creditors’ decisions through misreporting. In particular, we show three results. First, reporting discretion reduces panic-based runs. Reporting discretion inflates creditors’ beliefs about the fundamentals of banks that suffer panic-based runs in the benchmark. Such inflation induces creditors to be more optimistic about others’ actions, which in turn offsets the pessimism underlying the panic-based runs. Second, as the discretion increases further, the run probability is reduced further to the point that even the insolvent banks can survive with inflated reports. Therefore excessive reporting discretion impedes fundamental-based runs and weakens the market discipline on banks. Third, one bank’s opportunistic reporting imposes a negative externality on other banks. As reporting discretion increases, the set of banks who inflate reports in equilibrium contains not only banks that are vulnerable to panic-based runs but also banks that could have survived in the benchmark. The access to reporting discretion forces even solvent and liquid banks to inflate their reports in equilibrium.

That the manager’s misreporting influences creditors’ decisions in equilibrium occurs naturally in the model. We show that creditors play a threshold strategy in equilibrium. As a response, the manager’s misreporting incentive is not monotonic in the bank’s fundamentals. For a bank whose fundamental is just below the run threshold, a small shift of creditors’ beliefs can switch the run equilibrium to a no-run equilibrium and such a switch yields a jump in the manager’s payoff. Thus, the manager’s incentive to influence the creditors’ beliefs is strong. In contrast, for a bank with extremely good or extremely bad fundamentals, its creditors’ withdrawal decisions are less sensitive to the change of their beliefs and thus the manager’s incentive to influence their beliefs is also weak.

This non-monotonicity of misreporting incentive impedes creditors’ ability to undo the reporting bias. Since the manager’s bias is not monotonic in the fundamental, creditors cannot distinguish between the signals of a weaker bank with a larger bias and those of
a stronger bank with a smaller bias. Therefore, reporting discretion results in a partial pooling of banks with different fundamentals. Moreover, the bank mix in this pool is such that creditors do not run on the pool. In equilibrium, the worst fraction of banks report truthfully and fail, the best fraction of banks report truthfully and survive, while the banks in between misreport to be pooled together and survive.

This paper intends to contribute to our understanding of the economic consequences of reporting discretion for financial institutions in the bank run setting characterized by the strategic complementarity among creditors that may cause panic-based runs. It belongs to the bank run literature initiated by Diamond and Dybvig (1983). Goldstein and Pauzner (2005) and Morris and Shin (2000) have applied the global games methodology to obtain a unique equilibrium in the bank run setting without reporting discretion. We introduce reporting discretion, an important institutional feature in a banking setting.

The role of disclosure and transparency in a bank run setting has received much attention, as surveyed in Goldstein and Sapra (2013). A common theme in this literature is that disclosure is a two-edged sword. While disclosure improves market disciplines on banks in an intuitive manner, it also interacts with the coordination friction to generate undesirable consequences. It may induce agents to put excessive weights on the public information (Morris and Shin (2002)), distorts private incentive for information acquisition (He and Manela (forthcoming, 2014)), and contaminates market participants’ learning from prices (Bond, Goldstein, and Prescott (2010)). This literature has mainly focused on commitment to disclosure so far. After the disclosure policy is chosen, the bank cannot temper with the realization of the signal to be disclosed. Our paper complements this literature by studying banks’ ex post reporting decisions. In our model, the bank does not have commitment over disclosure at all and decides what to disclose after observing the signal.

A recent paper by Bouvard, Chaigneau, and De Motta (2013) studies the optimal transparency policy by a regulator in a setting in which runs arise from coordination failure. Without disclosure of bank-specific fundamentals, creditors base their decisions on their priors about the state of the economy. They run on all banks in the bad time (when the prior is low) and don’t run in the good time. With disclosure of bank-specific information, creditors
can better discriminate among banks. They run on weak banks and don’t run on strong banks. The optimal transparency policy trades off the benefit of saving strong banks in the bad time and the cost of exposing some vulnerable banks to panic-based runs in the good time. They also show that the lack of commitment by the regulator precludes the implementation of the ex ante optimal transparency policy.

Our paper is also related to the literature on costly misreporting in a communication game for non-financial firms. A benchmark of this literature is a "signal-jamming" equilibrium as characterized in Stein (1989). A sender distorts the message at a cost with an attempt to influence the receiver’s beliefs, but the receiver fully sees through the misreporting in equilibrium. Against this benchmark the literature has developed various models in which pooling can arise. For example, partial pooling equilibria are obtained through a bounded type space in Kartik (2009) and through a criterion favoring the sender’s welfare in Guttman, Kadan, and Kandel (2006). Our paper extends this literature to a bank-run setting in which a partial pooling equilibrium arises endogenously.

More broadly, there are also regime change models in which the regime can take a costly action to influence agents’ beliefs, such as Angeletos, Hellwig, and Pavan (2006) and Edmond (2013). A regime change model differs from a bank-run model in an important aspect. Agents benefit from the collapse of a regime regardless of the fundamentals while creditors’ preferences for runs are contingent on the fundamentals. This difference affects not only the models’ solutions but also their implications.

The rest of the paper are organized as follows. Section 2 describes the model, Section 3 presents the benchmark without reporting discretion and the multiple equilibria with reporting discretion, Section 4 solves for the unique equilibrium with reporting discretion, Section 5 examines the effects of reporting discretion on the incidence and efficiency of bank runs, Section 6 discusses the empirical and policy implications of our results, and Section 7 concludes. The appendix contains all the proofs.
2 The model

Our model adds a bank’s reporting discretion into the bank-run setting in Morris and Shin (2000) (hereafter MS). To the extent that the key feature of the MS model is a bank’s exogenous mismatch of its assets and liabilities that creates strategic complementarity among creditors’ withdrawal decisions, the model is better understood as a description of financial institutions with a generic asset-liability mismatch. For example, an investment fund that finances its illiquid asset holdings with short term debts or redeemable equity shares also fits the description of our model. For convenience, we will still use the labels “bank” and “creditors” in the model.

Consider a risk neutral economy with no discounting, one consumption good, three dates, \( t = 0, 1, 2 \), and a continuum \([0, 1]\) of creditors. At date 0, each creditor is endowed with one unit of the good and invests it in a bank. Each creditor’s utility over consumption at \( t = 1 \) and \( t = 2 \); \( c_1 \) and \( c_2 \); is \( \ln(c_1 + c_2) \):

The bank is characterized by the mismatch of its assets and liabilities. On its liability side, the bank issues a demandable contract that permits creditors to withdraw their investment at either \( t = 1 \) or \( t = 2 \). If a creditor withdraws at \( t = 1 \), she receives her one unit consumption good back. If she leaves it with the bank until \( t = 2 \), she receives the random output of the bank’s asset to be described below.

On its asset side, the bank has an exclusive access to a long-term illiquid investment technology that converts one unit of the consumption good at \( t = 0 \) to \( R \) units at \( t = 2 \). The technology, however, is illiquid. If proportion \( l \) of the consumption good invested in the technology are withdrawn at \( t = 1 \), then the remaining investment generates \( R e^{-\delta l} \) per unit. In other words, for one unit investment at \( t = 0 \) and early withdrawal \( l \) at \( t = 1 \), the technology yields \( l \times 1 \) at \( t = 1 \) and \((1 - l) \times R e^{-\delta l} \) at \( t = 2 \). \( \delta \geq 0 \) captures the costs of premature liquidation. Defining \( r = \ln R \), we can rewrite the remaining investment’s gross rate of return with early withdrawal \( l \) as \( e^{r-\delta l} \). \( r \) has an improper prior over the real line and is referred to as the bank’s fundamental.

At \( t = 1 \), each creditor \( i \in [0, 1] \) receives a perfect signal \( x_i \) about the fundamental \( r \),
i.e., $x_i = r$, and compares the utility of withdrawing versus waiting. If she withdraws, she guarantees her utility of 0 ($= \ln 1$), which is independent of others’ choices. If she waits, her utility is $r - \delta l$ ($= \ln e^{r-\delta l}$) when a proportion $l$ of creditors withdraw. Thus, her utility differential between late withdrawal at $t = 2$ (i.e., wait) and early withdrawal at $t = 1$ (i.e., withdraw) is

$$v(r, l) = r - \delta l.$$  (1)

$v(r, l)$ has two properties. First, it increases with $r$, i.e., $\frac{\partial v(r, l)}{\partial r} > 0$. A creditor’s payoff to wait increases in the bank’s fundamental. Second, $v(r, l)$ decreases with $l$, i.e., $\frac{\partial v(r, l)}{\partial l} = -\delta < 0$. A creditor’s payoff to wait also increases as the number of creditors who wait increases. This is the strategic complementarity among creditors’ withdrawal decisions. The intensity of the complementarity is captured by $\delta$.

Denote creditor $i$’s withdrawal decision as $n_i(x_i) \in \{0, 1\}$, with $n_i(x_i) = 1$ indicating withdrawal. Thus, a creditor chooses $n_i(x_i) = 1$ if and only if $v < 0$. As a tie breaker, we assume that a creditor indifferent between early and late withdrawal chooses to stay. Moreover, the aggregate withdrawal for a bank with fundamental $r$ is $l(r) = E[n_i(x_i)|r]$.

This completes the description of the bank-run setting in MS. It captures the idea that a bank’s maturity mismatch induces strategic complementarity among creditors’ decisions in a very stylized manner. We adopt this tractable setting so as to accommodate the new element of the bank’s reporting discretion. Goldstein and Pauzner (2005) have demonstrated that a bank’s maturity mismatch can still be efficient even though it causes panic bank runs and that the uniqueness of the bank-run equilibrium is still preserved in a richer model that captures faithfully the “one-sided complementarity” of a prototypical commercial bank.

We also note that, empirically, both the maturity mismatch and its consequences for possible runs seem descriptive of some financial institutions.

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1 Assuming otherwise will not change any of the results as such creditors are of measure zero.

2 Following Diamond and Dybvig (1983), a bank’s maturity mismatch has often been micro-founded through impatient creditors who demand insurance against idiosyncratic liquidity shocks, as in Goldstein and Pauzner (2005). Given that the maturity mismatch is treated as given in our model, we have also removed the impatient creditors in MS and implicitly assumed that all creditors are patient. Adding impatient creditors to our model does not affect the main results qualitatively.

3 For example, Goldstein and Pauzner (2005) have discussed the importance of runs for commercial banks; Chen, Goldstein, and Jiang (2010) provide evidence of “runs” in mutual funds; Gorton and Metrick (2012) present evidence of “runs” in repo markets during the 2008 financial crisis.
On top of the MS model, we introduce the bank’s manager who can influence creditors’ signals and whose interest is not fully aligned with creditors. Specifically, instead of observing the fundamental perfectly (i.e., \( x_i = r \)), creditors now receive a report \( M(r) \) from the bank, i.e., \( x_i = M(r) \). The manager observes the fundamental \( r \) perfectly and can add a bias \( m(r) \) to report \( M(r) \):

\[
M(r) = r + m(r).
\]  

(2)

The bias \( m \) costs the manager privately \( C(k, m) \equiv kc(m) \) where \( c'(0) = 0, c'(m) > 0 \) for \( m > 0, c''(m) > 0 \) and \( c(0) = 0 \). \( k > 0 \) measures the cost of misreporting or the (inverse of the) amount of reporting discretion permitted in reporting regulations and rules.

MS is thus a special case of our model with \( k = \infty \).

Finally, the manager’s interest is not fully aligned with creditors. While creditors benefit from state-contingent withdrawals, the manager always prefers less withdrawal. To capture this conflict of interest, we assume that the manager’s payoff with misreporting \( m \) is

\[
w(m, r) = 1 - l - kc(m).
\]  

(3)

For any given \( r \), the manager benefits from a smaller fraction of withdrawal, \( l \). One interpretation is that the manager’s compensation, power, job security, reputation, and human capital are all tied to the bank’s size and decrease as the incidence of withdrawal increases. For example, fees charged by most investment funds increase in the size of assets under management. For another example, that managers enjoy more private benefit from controlling a larger firm has received empirical support (e.g. Dyck and Zingales (2004)). Thus, we implicitly assume that while financial institutions may fine tune the contract with the manager to mitigate this conflict of interest, they will not be able to eliminate it due to contracting frictions.

A more general payoff for the manager can be \( w(m, r) = g(r, l) - C(k, m) \), to which our specification is a special case of \( g(r, l) = 1 - l \). We don’t consider the manager’s utility derived

\[\text{Some of the properties of } C(k, m), \text{ such as } c'(0) = 0 \text{ and the strictness of convexity, are not necessary for our main results, but they simplify the exposition.}\]
directly from fundamental $r$. This alternative can be accommodated without much loss. Our main results are qualitatively the same if $\frac{\partial g(r,l)}{\partial r} > 0$, $\frac{\partial g(r,l)}{\partial l} < 0$ and $\frac{\partial^2 g(r,l)}{\partial l \partial r} = 0$. Moreover, we don’t consider a direct interaction between $l$ and $r$, i.e., $\frac{\partial^2 g(r,l)}{\partial l \partial r} \neq 0$. As it will be clear later, $l$ and $r$ do interact indirectly in our model because the manager’s misreporting incentive to influence withdrawal $l$ depends on the bank’s fundamental $r$.

The timeline of the model is summarized as follows:

- At $t = 0$, the bank offers a short-term contract, receives 1 unit of consumption good, and invests it in an illiquid project.

- At $t = 1$, the manager observes $r$ privately and chooses a bias $m(r)$. Each creditor observes a signal $x_i = r + m(r)$ and decides whether to withdraw.

- At $t = 2$, the remaining investment, if any, pays out. Creditors consume.

A perfect Bayesian equilibrium (PBE) of our model consists of the manager’s reporting strategy $m(r)$ and each creditor’s withdrawal strategy $n_i(x_i)$ and beliefs about the fundamental $r$ such that 1) both the manager and creditors maximize their respective objective functions, given their beliefs and the strategies of others; 2) each creditor uses the Bayes rule, if possible, to update their belief about $r$.

3 The multiple equilibria

In this section, we first examine the model in the absence of reporting discretion. We review how the multiple equilibria arise and how the global games methodology can be used to obtain a unique equilibrium. We then characterize the multiple equilibria in the presence of reporting discretion and leave its refinement to the next section.

We set a benchmark with neither coordination failure nor reporting discretion. Suppose there is only one creditor who learns $r$ perfectly. She chooses $l$ to maximize the expected utility $E[l*\ln 1+(1-l)*\ln e^{(r-\delta l)}] = (1-l)(r-\delta l)$. Thus, $l^{FB}(r) = 1$ if and only if $r < r^{FB}$.

We suspect that our main results can be preserved if the direct interaction between $l$ and $r$ is included in the manager’s payoff in the form of $\frac{\partial^2 g(r,l)}{\partial l \partial r} \leq 0$, that is, a stronger bank benefits more from a reduction of withdrawal.
A single creditor withdraws from the bank if and only if the bank’s continuation value is lower than its liquidation value. We refer to banks with $r < 0$ as insolvent, and runs on them as fundamental-based runs. Such runs exert market discipline on banks.

Since Diamond and Dybvig (1983) it has been well understood that the combination of the common knowledge about the fundamental and the strategic complementarity among creditors’ withdrawal decisions can lead to multiple equilibria. There are three regions in our model in the absence of reporting discretion.

1. When banks are insolvent, i.e., $r < 0$, it is a dominant strategy for a creditor to withdraw because $v(r, l) < 0$ for any $l \in [0, 1]$.

2. When banks are solvent and liquid, i.e., $r \geq \delta$, it is a dominant strategy for a creditor to wait because $v(r, l) \geq 0$ for any $l \in [0, 1]$.

3. When banks are solvent but illiquid, i.e., $r \in [0, \delta)$, there are a continuum of equilibria characterized by a threshold $r^{DD} \in [0, \delta)$. The “best” equilibrium is characterized by the lowest possible run threshold $r^{DD} = 0$. In this equilibrium, a “confident” creditor expects all others to wait, i.e., $l = 0$, and thus finds it optimal to wait as well because $v(r, 0) = r \geq 0$. In contrast, the “worst” equilibrium is characterized by the highest possible run threshold $r^{DD}$ approaching $\delta$ from below. In this equilibrium, a “panic” creditor expects all others to withdraw, i.e., $l = 1$, and thus finds it optimal to withdraw as well because $v(r, 1) = r - \delta < 0$. In both equilibria, creditors’ initial beliefs about others’ actions are self-fulfilling.

All the runs on the “solvent but illiquid” banks are driven solely by creditors’ pessimistic beliefs about others’ decisions. Take the worst equilibrium as an example. All creditors agree that a bank with $r \in [0, \delta)$ can be saved from runs because of its solvent fundamentals. Yet they are completely uncertain about what other creditors will do. Such strategic uncertainty justifies the pessimistic beliefs that all others are withdrawing and make the worst equilibrium self-fulfilling. Following the literature, we refer to runs on solvent but illiquid banks (with $r \in [0, \delta)$) as panic-based runs. $\delta$ measures the incidence of panic-based runs and the degree of coordination frictions.
This multiplicity of equilibria is not conducive to comparative statics. The occurrence of each equilibrium is completely dictated by creditors’ arbitrary beliefs (about others’ actions) that are not anchored in the model’s parameters. MS uses the global game methodology to obtain a unique equilibrium of this bank-run model. The main technique is to inject an arbitrarily small amount of independent noise into creditors’ beliefs about the fundamental. Instead of assuming common knowledge about $r$, each agent is assumed to receive a private signal

$$x_i = r + \varepsilon_i,$$  \hspace{1cm} (4)

where $\varepsilon_i$ is a normal random variable with mean 0 and variance $\sigma^2$ and independent across creditors. One interpretation, adopted by Morris and Shin (1998), is that even though all creditors receive a common report $r$, their interpretations of the report may differ slightly. $\sigma^2$ can be arbitrarily small. As $\sigma^2$ approaches 0, MS show that the model has a unique equilibrium.

**Lemma 1 (The MS Benchmark)** *In the absence of reporting discretion, there is a unique equilibrium. The equilibrium takes a threshold form. As $\sigma^2$ approaches 0, a creditor withdraws if and only if her signal is below threshold $r^{MS} = \frac{\delta}{2}$, and the incidence of runs is $l^{MS}(r) = 1$ for $r < r^{MS}$ and $l^{MS}(r) = 0$ for $r \geq r^{MS}$.*

Lemma 1 shows that there are both fundamental-based and panic-based runs in the unique bank-run equilibrium. Weaker banks are more likely to experience runs than stronger banks in the solvent but illiquid region $r \in [0, \delta)$. The run threshold turns out to be an average of those in the best and worst equilibria (due to the assumption that $r$ has an improper prior). The size of the incidence of panic-based runs is $\frac{\delta}{2}$, half of that of the worst equilibrium.

We briefly explain the intuition behind Lemma 1 and develop more notations of the model with the noisy signals to facilitate the discussions later. We define the counterpart of $v$ in equation (1), a creditor’s expected utility differential between late and early withdrawal, as

$$\Delta(x_i, l,.) \equiv E_{r,\varepsilon_i}[v(r, l)|x_i] = x_i - \delta E_{r,\varepsilon_i}[l|x_i].$$  \hspace{1cm} (5)
Similarly, a creditor withdraws, i.e., \( n_i(x_i) = 1 \), if and only if \( \Delta(x_i, l) < 0 \). Equation (5) suggests that a creditor’s signal \( x_i \) affects her withdrawal decision through two channels. First, it informs her of the fundamental, i.e., \( E_{r,x_i}[r|x_i] = x_i \) (because \( r \) has an improper prior). She finds it more attractive to stay if her signal indicates a higher profitability of the investment. Second, the private signal also helps her to infer other creditors’ signals and decisions, i.e., \( E_{r,x_i}[l|x_i] \). It can be shown that \( E_{r,x_i}[l|x_i] \) is increasing in \( x_i \) (in a threshold equilibrium). The intuition is that a higher \( x_i \) increases creditor \( i \)'s belief about the fundamental \( r \), which makes her more optimistic about signals other creditors receive and their willingness to wait.

Combining these two channels, a higher private signal improves the creditor’s beliefs about both the fundamental and other creditors’ decisions. This monotonicity implies that the creditor’s decision rule is monotonic in her signal. The threshold then is tied down by the indifference condition \( \Delta(x^{MS}, l(., x^{MS})) = 0 \), which is Lemma 1.

We now introduce reporting discretion to the bank run model and assume that creditors observe the bank’s report \( M(r) = r + m(r) \). Not only do creditors forecast other creditors’ withdrawal decisions, they also make inference about the manager’s reporting strategy. When the bank’s report \( M(r) \) is common knowledge among creditors, the multiple equilibria of the bank-run model carry over to this new setting.

**Lemma 2** When \( M(r) \) is common knowledge among creditors, the model has multiple equilibria in the following form. Creditors withdraw if and only if their signals are below a constant \( X, X \in [X, X] = \left[ \frac{1}{2}c^{-1}(\frac{1}{k}), \delta + c^{-1}(\frac{1}{k}) \right] \). The manager misreports by an amount \( m^+(r) = X - r \) for \( r \in [X - c^{-1}(\frac{1}{k}), X] \) and 0 otherwise.

We illustrate Lemma 2 with two equilibria, one that generates the smallest incidence of runs and the other the largest. The least run-prone equilibrium is characterized by creditors’ lowest possible run threshold \( X = \frac{1}{2}c^{-1}(\frac{1}{k}) \). In this equilibrium, the set of banks that suffer runs is \( r \in (-\infty, -\frac{1}{2}c^{-1}(\frac{1}{k})) \) and the set of banks that engage in misreporting is \( r \in [-\frac{1}{2}c^{-1}(\frac{1}{k}), \frac{1}{2}c^{-1}(\frac{1}{k})] \). Not only do all solvent but illiquid banks avoid panic-based runs, but also some insolvent banks with \( r \in [-\frac{1}{2}c^{-1}(\frac{1}{k}), 0) \) escape fundamental-based runs. Moreover, the cost of misreporting is not borne by the same set of banks. In particular, when
\( \delta < \frac{1}{2} c^{-1}(\frac{1}{e}) \), the solvent banks with \( r \in [\delta, \frac{1}{2} c^{-1}(\frac{1}{e})] \) engage in misreporting to avoid runs even though they wouldn’t worry about runs even in the worst equilibrium in the absence of reporting discretion. Therefore, compared with the best equilibrium in the absence of reporting discretion, reporting discretion weakens market discipline on some insolvent banks and imposes a negative externality on solvent banks.

The most run-prone equilibrium is characterized by creditors’ highest possible run threshold \( \bar{X} = \delta + c^{-1}(\frac{1}{e}) \). In this equilibrium, the set of banks that suffer runs is \( r \in (-\infty, \delta) \) and the set of banks that engage in misreporting is \( r \in [\delta, \delta + c^{-1}(\frac{1}{e})] \). All solvent but illiquid banks, banks with \( r \in [0, \delta) \), suffer panic-based runs, while the solvent banks with \( r \in [\delta, \bar{X}] \) engage in costly misreporting to survive. Therefore, compared with the worst equilibrium in the absence of reporting discretion, reporting discretion imposes negative externality on solvent banks without changing the incidence of runs.

Such pair comparison, however, is not very informative. Since the economic consequences of reporting discretion differ in these equilibria, it is important to determine which equilibrium is likely to arise, to which we turn now.

### 4 The unique equilibrium with reporting discretion

In this section, we use the global games technique to refine the multiple equilibria in Lemma 2. Like in MS, we introduce some small, independent noise to creditors’ signals:

\[
x_i = M(r) + \varepsilon_i = r + m(r) + \varepsilon_i,
\]

where \( \varepsilon_i \) is a normal random variable with mean 0 and variance \( \sigma^2 \) and independent across creditors. \( \varepsilon_i \) captures a creditor’s idiosyncratic interpretation of the bank’s report \( M(r) \). \( \sigma^2 \) can be arbitrarily small and we will focus on the equilibrium as \( \sigma^2 \) approaches 0.

Reporting discretion introduces an interaction between creditors’ and the manager’s decisions. The manager has to anticipate the creditors’ use of the report when choosing the reporting strategy, while the creditors have to infer the manager’s reporting strategy when making the withdrawal decisions on the basis of the report. Such interaction is typically
tackled by examining each party’s best response to others’ strategies. However, the direct application of this approach to our model is difficult because there are few restrictions on the possible forms of both the creditors’ withdrawal strategies and the manager’s reporting strategy. Thus, our proof strategy is first to derive some equilibrium restrictions on the strategies of both the manager and the creditors, and then to proceed with the usual approach of examining best responses. Specially, we will show that the manager’s equilibrium strategy satisfies a monotonicity property (Lemma 3), regardless of creditors’ strategies. With this monotonicity, we then prove that creditors use a common threshold strategy in equilibrium (Lemma 4). With these endogenous restrictions, we characterize the manager’s and the creditors’ respective best responses to others’ strategies and prove the existence of a unique equilibrium.

**Lemma 3** The manager’s equilibrium report \( M^*(r) = r + m^*(r) \) is increasing in \( r \), regardless of the creditors’ withdrawal strategies.

Lemma 3 mirrors a “single-crossing” property: a stronger bank’s report is higher than a weaker bank’s for any possible strategy profile of creditors. Note that Lemma 3 applies to the manager’s report \( M^*(r) \), not the bias \( m^*(r) \) the manager adds to the report. In fact we will show later that the equilibrium bias is not monotonic in the fundamental \( r \). We leave the proof to the appendix and discuss its intuition here.

Suppose, for any given profile of creditors’ strategies that determines the aggregate withdrawal \( l(M(r)) \), a bank \( r_L \) finds it optimal to choose report \( M(r_L) = r_L + m^*(r_L) \) with \( m^*(r_L) > 0 \). Now consider the decision of a stronger bank with \( r_H > r_L \). We argue that it will choose a larger mean \( M(r_H) > M(r_L) \). On one hand, since \( r_H > r_L \), bank \( r_H \) needs to add a smaller bias to report \( M(r_L) \) than bank \( r_L \). Since the misreporting cost \( c(m) \) is strictly convex, the marginal cost of an additional bias \( \eta \) at the point of \( M(r_L) \) is strictly smaller for bank \( r_H \) than for \( r_L \). On the other hand, even though we don’t know the form of the creditors’ strategy profile, we do know that the marginal effect of an additional bias \( \eta \) beyond \( M(r_L) \) on creditors’ withdrawal decisions is the same for both banks, because the manager’s
marginal payoff from the aggregate withdrawal, \( i.e., \frac{\partial w}{\partial r} \), is independent of \( r \). Therefore, if report \( M(r_L) \) equates bank \( r_L \)'s marginal benefit and cost, bank \( r_H \) must find it profitable to issue a higher report than \( M(r_L) \). Hence, in equilibrium \( M(r_H) > M(r_L) \) for any \( r_L < r_H \) (for any positive \( \sigma^2 \)).

A useful corollary of Lemma 3 is stated below and will be used repeatedly later.

**Corollary 1** A creditor’s conditional expectation of the fundamental, \( E[r|x_i] \), is increasing in \( x_i \).

Corollary 1 states that despite potential misreporting a creditor’s signal \( x_i \) still has a monotone likelihood property with respect to the fundamental \( r \). A higher \( x_i \) leads creditor \( i \) to have a more optimistic belief about the fundamental \( r \), which in turn leads to a more optimistic belief about others’ signals and decisions.

Lemma 3 and Corollary 1 help prove the next result.

**Lemma 4** Creditors play a symmetric threshold strategy in equilibrium.

In the absence of reporting discretion, a result similar to Lemma 4 can be proved by the iterated elimination of dominated strategies. This approach, however, is less convenient in the presence of reporting discretion. The dominated strategies that can be eliminated are not tight enough to converge because creditors know nothing more about the manager’s strategy above and beyond Lemma 3. Instead, we use a proof strategy, borrowed from Goldstein and Pauzner (2005), that relies only on the existence of upper and lower dominance regions and the monotonicity of \( M(r) \) in Lemma 3.

The first step is to show the existence of an upper and lower dominance regions in our model. There exist two signals \( \underline{x} \) and \( \overline{x} \) such that it is a dominant strategy for creditors to withdraw for \( x_i < \underline{x} \) and to stay for \( x_i > \overline{x} \). To see this, note that the manager misreports in order to reduce withdrawal. Since the maximal withdrawal reduction is 1, the manager is willing to add a bias \( m \) only if \( 1 \geq kc(m) \). Therefore, a creditor’s most pessimistic belief is that the manager has chosen the maximal bias \( c^{-1}(\frac{1}{k}) \) and all other creditors withdraw. Under

\[ \text{It can be proved that Lemma 3 still holds if } \frac{\partial w}{\partial r} \text{ is increasing in } r, \text{ that is, if a stronger bank benefits more from the reduction of withdrawal. This supports our conjecture in Footnote 5.} \]
this most pessimistic belief, creditor $i$’s expected payoff differential is $\Delta(x_i, l) = E[r|x_i] - \delta = x_i - c^{-1}(\frac{1}{k}) - \delta$. If $x_i \geq \bar{x} \equiv c^{-1}(\frac{1}{k}) + \delta$, then $\Delta(x_i, l) \geq 0$ and it is a strictly dominant strategy for creditor $i$ to wait. Hence, $[\bar{x}, \infty)$ is the upper dominance region.

Similarly, a creditor’s most optimistic belief is that the manager does not manipulate and that all other creditors stay. Under this most optimistic belief, creditor $i$’s expected payoff differential is $\Delta(x_i, l) = E[r|x_i] = x_i$. If $x_i < \bar{x} \equiv 0$, then $\Delta(x_i, l) < 0$ and it is a strictly dominant strategy for creditor $i$ to withdraw. Hence, $(-\infty, \bar{x}]$ is the lower dominance region.

The second step of the proof of Lemma 4 is intuitive, but technically involved. We outline the intuition here and leave the details to the appendix. The proof exploits Corollary 1 to show that a creditor becomes more optimistic about both the fundamental and other creditors’ beliefs about the fundamental when she receives a higher signal $x_i$. Recall that a creditor receiving $x_i$ calculates her expected utility differential as $\Delta(x_i, l(\cdot)) = E[r|x_i] - \delta E[l|x_i]$ and withdraws if and only if $\Delta(x_i, l(\cdot)) < 0$. Like in the MS benchmark without reporting discretion, the creditor uses her private signal $x_i$ to forecast both the fundamental $r$ and other creditors’ decisions summarized by $l$. Unlike the benchmark, she now takes into account the effect of the manager’s potential misreporting on her inferences. The discussion following Corollary 1 suggests that both components of $\Delta(x_i, l(\cdot))$ are monotone in $x_i$ for any strategy profile of other creditors. From there it is a short step to prove Lemma 4.

Lemma 4 simplifies the interaction between the manager and the creditors’ decisions. It indicates that it is without loss of generality to focus only on the manager’s best response $m^{BR}(r; \hat{x})$ to creditors’ common threshold strategy $\hat{x}$, which we turn to next.

Lemma 5 Suppose all creditors use the common threshold $\hat{x}$. The manager’s best response $m^{BR}(r; \hat{x})$ is unique (almost everywhere).

We characterize the manager’s reporting decision in the text and leave the technical details of the proof of uniqueness to the appendix. From the manager’s perspective, the expected withdrawal is equal to the probability that a creditor’s signal $x_i$ is smaller than $\hat{x}$ (by the law of large numbers). Moreover, $x_i$ is normally distributed with mean $r + m(r; \hat{x})$ and variance $\sigma^2$. Thus, the manager with fundamental $r$ and bias $m(r; \hat{x})$ expects an aggregate withdrawal
of

\[ l(m(r; \hat{x}), \hat{x}) = \Pr(x_i < \hat{x}) = \Phi\left(\frac{1}{\sigma}(\hat{x} - r - m(r))\right). \]  

(6)

A bias \( m \) shifts the distribution of creditors’ signals towards the right and thus reduces withdrawals. Substituting equation (6) into the manager’s payoff \( w(m, r) \), we can write the manager’s reporting decision as

\[
\max_{m(r; \hat{x})} \quad w(m(r; \hat{x}), r) \equiv 1 - \Phi\left(\frac{1}{\sigma}(\hat{x} - r - m(r; \hat{x})) - kc(m(r; \hat{x}))\right) \\
\text{s.t. } m(r; \hat{x}) \geq 0
\]

Because of \( c'(0) = 0 \), we have \( m^{BR}(r; \hat{x}) > 0 \) for any \( \sigma > 0 \). Thus the constraint \( m = 0 \) does not bind. A necessary condition for the manager’s best response is the first-order condition

\[
\frac{1}{\sigma} \phi\left(\frac{1}{\sigma}(\hat{x} - r - m^{BR}(r; \hat{x})) - kc(m^{BR}(r; \hat{x}))\right) = 0. \tag{7}
\]

Note that since the objective function \( w(m, r) \) is not globally concave in \( m \), equation (7) could have multiple solutions that satisfy the second order conditions. In this case, we need to compare the value of the objective function \( w(m, r) \) evaluated at these solutions. We leave the proof of uniqueness to the appendix.

Finally, rational expectations require that the manager and creditors’ strategies are consistent with each other. Imposing this condition and denoting \( m^*(r) \equiv m^{BR}(r; x^*) \) give us an equation that characterizes the creditor’s optimal threshold \( x^* : \)

\[
\Delta(x^*, l(m^*(r), x^*)) = 0. \tag{8}
\]

We further prove that there is a unique solution to equation (8). Therefore, we have completely characterized the equilibrium.

**Proposition 1** There is a unique equilibrium. In the equilibrium, the manager adds a bias \( m^*(r) \) and each creditor withdraws if and only if her signal is below threshold \( x^* \). \( m^*(r; x^*) \) and \( x^* \) are jointed determined by equation (7) (evaluated at \( m^{BR}(r; x^*) = m^*(r) \) and \( \hat{x} = x^* \) )
and equation (8).

When the fundamental is common knowledge, the bank run model has multiple equilibria. MS show that the equilibrium is unique when an arbitrarily small amount of noise is added to agents’ private beliefs. Proposition 1 shows that the uniqueness of the equilibrium is extended to the case when the manager has reporting discretion.

Recall that Lemma 2 characterizes the multiple equilibria when the bank’s report is common knowledge among creditors, i.e., $\sigma = 0$. To benchmark the unique equilibrium in Proposition 1 against the multiple equilibria in Lemma 2, we characterize the unique equilibrium as $\sigma^2 \rightarrow 0$. It is obtained by taking the proper limits of $m^*(r)$ from equation 7 and $x^*$ from equation (8).

**Proposition 2** As $\sigma^2 \rightarrow 0$, the unique equilibrium $(m^*(r), x^*)$ is as follows:

$$m^*(r) = \begin{cases} x^* - r & \text{if } r \in [r_1, r_2] \\ 0 & \text{if } r \notin [r_1, r_2] \end{cases}$$

$$r_1 = r^{MS} - \frac{1}{2}c^{-1}\left(\frac{1}{k}\right), \quad r_2 = x^* = r^{MS} + \frac{1}{2}c^{-1}\left(\frac{1}{k}\right).$$

The incidence of runs is $l^*(r) = 1$ if $r < r_1$ and $l^*(r) = 0$ if $r \geq r_1$.

Recall that $r^{MS} = \frac{\delta}{2}$ is the run threshold in the MS benchmark. In the absence of reporting discretion, the unique equilibrium in MS is the average of the best and worst equilibria from Diamond and Dybvig (1983), i.e., $r^{MS} = \frac{\delta + \delta}{2}$, with half of the solvent but illiquid banks suffering panic-based runs. Recall that, in the presence of reporting discretion, the least and most run-prone equilibria in Lemma 2 are characterized by a run threshold pair $\{X, \bar{X}\}$ with an average of $\frac{\delta}{2} + \frac{3}{4}c^{-1}(\frac{1}{k})$ and a misreporting threshold pair $\{X - c^{-1}(\frac{1}{k}), \bar{X} - c^{-1}(\frac{1}{k})\}$ with an average of $\frac{\delta}{2} - \frac{1}{4}c^{-1}(\frac{1}{k})$. The unique equilibrium in Proposition 2 differs from either extreme equilibrium and from the average of the two. In particular, compared with the average, creditors adopt a lower withdrawal threshold (i.e., $x^* < \frac{\delta}{2} + \frac{3}{4}c^{-1}(\frac{1}{k})$) and the manager uses a lower misreporting threshold (i.e., $r_1 < \frac{\delta}{2} - \frac{1}{4}c^{-1}(\frac{1}{k})$).

The proof of Proposition 2 provides intuition about the determination of the equilibrium.
As \( \sigma^2 \to 0 \), each creditor’s signal \( x_i \) approaches \( M^*(r) \equiv r + m^*(r) \). We start with the manager’s reporting strategy \( m^*(r) \). The proof in the appendix shows that if \( r \geq x^* \), the solution to the FOC of equation (7) converges to 0. Intuitively, a bank with \( r \geq x^* \) does not misreport because the costly misreporting cannot further reduce withdrawal that is already 0. Hence,

\[
r_2 = x^*.
\]

Similarly, the proof in the appendix shows that if \( r < x^* \), the solution to the FOC of equation (7) converges to either 0 or \( x^* - r \). Intuitively, for a bank with \( r < x^* \), the marginal benefit of misreporting is 0 until the report \( M(r) \) reaches \( x^* \). Thus, the bank either reports truthfully \( m^* = 0 \) to avoid misreporting cost or misreports by an amount of \( m^*(r) = x^* - r \) to avoid runs. Since the total misreporting cost is decreasing in \( r \), there exists a \( r_1 \) such that the manager at \( r_1 \) is indifferent between two choices (while the manager below \( r_1 \) strictly prefers \( m^* = 0 \)). This indifference condition, \( i.e., w(x^* - r_1, r_1) = w(0, r_1) \), gives us an equation that determines \( r_1 \):

\[
1 - kc(x^* - r_1) = 0
\]

Given the manager’s reporting strategy \( m^*(r) \) characterized by \( r_1 \) and \( r_2 \), creditors understand that the pool of banks generating signal \( x^* \) consists of all banks in the region of \( r \in [r_1, r_2) \). Thus, a creditor with signal \( x^* \) expects that \( E[r|x^*] = \int_{r_1}^{r_2} r \frac{1}{r_2 - r_1} dr = \frac{r_1 + r_2}{2} \). Moreover, she expects that exactly half of other creditors have signals lower than hers, resulting in \( E[l|x^*] = \Pr[x_j < x^*] = \frac{1}{2} \). Therefore, equation (8) can be written as

\[
\Delta(x^*, l(m^*, x^*)) = \frac{r_1 + r_2}{2} - \frac{\delta}{2} = 0.
\]

\( r_2, r_1, \) and \( x^* \) are jointly determined by equation (9), (10), and (11).
5 Comparative statics and the economic consequences of reporting discretion

We conduct comparative statics of the unique equilibrium to analyze the effects of reporting discretion on the incidence and efficiency of bank runs. We focus on two questions. First, does reporting discretion reduce the incidence of bank runs in equilibrium? If so, what types of runs are reduced? Second, who bear the cost of misreporting?

To answer these questions, we review two types of bank runs discussed earlier. A bank run is fundamental-based if \( r < 0 \) and panic-based if \( r \geq 0 \). From creditors’ perspectives, fundamental-based runs discipline insolvent banks, but panic-based runs are inefficient as creditors could have collectively achieved higher utilities with better coordination. In addition, recall that \( k \) is a cost parameter of the manager’s misreporting. A higher \( k \) makes it more costly for the manager to misreport. Thus, we interpret \( k \) as the inverse of the degree of the manager’s reporting discretion.

**Proposition 3** Reporting discretion reduces the equilibrium incidence of runs, i.e., \( \frac{\partial r_1(k)}{\partial k} > 0 \) and \( \lim_{k \to \infty} r_1(k) = r^{MS} \). Moreover,

1. if \( k \geq \frac{1}{c(\delta)} \), reporting discretion reduces panic-based runs but does not affect fundamental-based runs. That is, \( r_1 \geq 0 \) if \( k \geq \frac{1}{c(\delta)} \).

2. If \( k < \frac{1}{c(\delta)} \), reporting discretion eliminates panic-based runs and reduces fundamental-based runs. That is, \( r_1 \leq x^{FB} = 0 \) if \( k < \frac{1}{c(\delta)} \).

3. The cut-off \( \frac{1}{c(\delta)} \) is decreasing in \( \delta \).

Proposition 3 asserts that the manager’s attempt to influence creditors’ withdrawal decisions through costly misreporting indeed succeeds in equilibrium, even as the noises of creditors’ signals approach 0. The set of banks that suffer runs is \((-\infty, r_1)\) and the size of the set shrinks as reporting discretion increases (or as \( k \) decreases). Compared with Lemma 3 banks with \( r \in [r_1, r^{MS}] \), who suffered runs in the absence of reporting discretion \( (k \to \infty) \), now survive with costly misreporting.
That misreporting influences creditors’ equilibrium withdrawal decisions is interesting and we explain its intuition. The direct reason is that the reporting equilibrium is a partial pooling. Banks with \( r \in [r_1, r_2] \) all send the same report \( M^*(r) = r_2 \). Creditors receiving \( x^* = r_2 \) assign an average belief of \( E[r|x^*] = \frac{r_1 + r_2}{2} = r^{MS} \) and coordinate on waiting. From an individual bank’s perspective, misreporting inflates creditors’ beliefs about the fundamentals of banks with \( r \in [r_1, r^{MS}] \) and deflates those of banks with \( r \in [r^{MS}, r_2] \).

This partial pooling reporting equilibrium is sustained because creditors play a threshold strategy in equilibrium. The binary nature of a threshold equilibrium means that the consequences of the inflation and deflation of creditors’ beliefs are asymmetric. While the inflation of creditors beliefs benefits banks with \( r \in [r_1, r^{MS}] \), the deflation of creditors beliefs don’t hurt banks with \( r \in [r^{MS}, r_2] \). As long as creditors’ beliefs don’t fall below \( r^{MS} \), banks with \( r \in [r^{MS}, r_2] \) have little incentive to incur an extra cost to separate themselves from the pool. In other words, the marginal benefit of misreporting for banks is not monotone. It varies in the bank’s fundamental, or more precisely, in the distance between the bank’s fundamental and creditors’ withdrawal threshold. The marginal benefit of misreporting spikes when the bank’s report \( M(r) \) approaches threshold \( x^* \) from below, and decreases as \( M(r) \) drifts away from \( x^* \) in either direction.

Parts 1 and 2 of Proposition 3 further specify the types of bank runs reduced by reporting discretion. Because \( \lim_{k \to \infty} r_1(k) = r^{MS} \) and \( \frac{\partial r_1(k)}{\partial k} < 0 \), the set of banks who misreport to avoid runs, i.e., \( [r_1, r^{MS}] \), expands to the left first to banks who suffer panic-based runs \( (r \in [0, r^{MS}] \) and then to banks who experience fundamental-based runs \( (r \in [r_1, 0]) \). Therefore, some reporting discretion mitigates panic-based runs, but excessive reporting discretion reduces fundamental-based runs and weakens market disciplines on insolvent banks.

It is useful to highlight the intuition why reporting discretion reduces panic-based runs. Recall that panic-based runs are caused by creditors’ pessimistic beliefs about others’ decisions. Reporting discretion enables banks with \( r < r^{MS} \) to inflate creditors’ beliefs about the fundamental up to \( r^{MS} \). Since creditors use their beliefs about the fundamental to forecast other creditors’ signals and decisions, the inflation of creditors’ beliefs about the fundamental leads to the inflation of their beliefs about others’ decisions as well. Thus, misreporting by
banks with \( r < r^{MS} \) induces creditors to be more optimistic in both their first-order and higher-order beliefs about the bank’s fundamental. Such optimism offsets the pessimism resulting from the coordination frictions and reduces panic-based runs. Reporting discretion serves as an effective tool to coordinate creditors’ beliefs. As reporting discretion increases, the cost to induce such optimism drops to the point that the induced optimism exceeds the pessimism from the coordination frictions (when \( r_1 < 0 \)). At this point, reporting discretion eliminates panic-based runs and reduces fundamental-based runs.

An interesting implication is that there exists an intermediate degree of discretion (i.e., \( k^* = \frac{1}{c(\delta)} \)) such that reporting discretion eliminates panic-based runs without reducing fundamental-based runs. Part 3 of Proposition 3 shows that the optimal amount of reporting discretion increases in \( \delta \). When the coordination friction is more important (a larger \( \delta \)), the optimal discretion is larger (a lower \( k^* \)). To the extent that coordination frictions are more severe for financial institutions and banks than non-financial firms, our result is consistent with the common wisdom that the special business model of financial institutions warrants more reporting discretion.

Now we examine the second question about who bears the cost of misreporting. It is obvious that banks with \( r \in [r_1, r^{MS}] \) bear the cost of misreporting in return for the benefit of avoiding runs they would have experienced in the absence of reporting discretion. However, the set of banks who misreport in equilibrium is larger. Banks that would not suffer runs in MS or even in \( \text{Diamond and Dybvig (1983)} \) may also engage in costly misreporting to survive. For these banks, reporting discretion creates a negative externality.

**Proposition 4** Reporting discretion has negative externality for banks with \( r \in [r^{MS}, r_2], r_2 > r^{MS} \) for any finite \( k \), and \( r_2 > \delta \) if \( k < \frac{1}{c(\delta)} \).

Proposition 4 shows that misreporting by banks with \( r \in [r_1, r^{MS}] \) to avoid runs generates negative externality on banks with \( r \in [r^{MS}, r_2] \). Note that none of the banks with \( r \in [r^{MS}, r_2] \) suffer panic-based runs in the absence of reporting discretion in MS. Moreover, banks with \( r \in [\delta, r_2] \), which is non-empty when \( k < \frac{1}{c(\delta)} \), never suffer any runs even in the worst equilibrium in the absence of reporting discretion. Nevertheless, they all misreport in
equilibrium by \( m^*(r) = r_2 - r > 0 \) to avoid runs in the presence of reporting discretion. Intuitively, the equilibrium misreporting by weak banks with \( r \in [r_1, r^{MS}] \) induces rational creditors to discount the reports that can be made by those weak banks. Since creditors don’t directly observe the bank’s fundamentals, they end up discounting the reports of all banks. The stronger banks with \( r \in [r^{MS}, r_2) \) are “forced” to engage in costly misreporting to overcome the discounting. Given the equilibrium in Proposition 2, the manager with \( r \in [r^{MS}, r_2) \) who misreport by less than \( r_2 - r \) suffers runs (i.e., \( l = 1 \)) and can avoid this by engaging in a bias of \( r_2 - r \). Since \( kc(r_2 - r) < kc(r_2 - r_1) = 1 \), the manager finds it optimal to misreport. However, even though the stronger banks have incentive to keep up with the report by the weaker banks, they don’t have the incentive to misreport more to separate themselves, due to the asymmetric consequences of creditors’ beliefs in a threshold equilibrium we discussed earlier.

In sum, the economic consequences of reporting discretion are mixed. It reduces the incidence of panic bank runs, but at the same time it can also weaken the market disciplines on insolvent banks and force strong banks to engage in costly misreporting.

6 Empirical and policy implications

Given the partial equilibrium nature of our model, we don’t consider its welfare implications. However, we hope that, by identifying the specific components of the cost and benefit associated with reporting discretion, our model can be of some help to empirical studies and policy discussions. The model has three testable empirical predictions. First, reporting discretion enables banks to hide unfavorable information at some cost. Second, reporting discretion reduces the incidence of bank runs, including both panic-based runs and/or fundamental-based runs. Third, banks’ preference for reporting discretion differ. Weaker banks support reporting discretion while stronger banks oppose it.

These predictions have implications for policy making. For example, in the midst of the recent financial crisis, FASB issued new guidance to allow banks more discretion in implementing mark-to-market accounting rules, which could be viewed as a reduction in the
misreporting cost $k$. The popular press has alleged that the additional reporting discretion enables managers to "fudge the truth" (e.g., Barr (2009), Bigman and Desmond (2009), Scannell (2009)). Such allegation is consistent with both our first empirical prediction and the motivating empirical evidence discussed in the Introduction. Based on this allegation, one might jump to the conclusion that such policy is not desirable. However, the second and third predictions above offer a different evaluation. To the extent that panic-based runs are prominent in the banking industry and banks are especially prone to such runs in the crisis period, that is, $\delta$ was higher, the economic consequences of FASB’s policy change might be more nuanced and complicated than the popular press alleged.

7 Conclusion

We study the economic consequences of financial institutions’ reporting discretion in a bank-run setting. In the absence of reporting discretion creditors’ pessimism arising from the coordination frictions induces panic-based runs that bring down solvent but illiquid banks, as in Goldstein and Pauzner (2005) and Morris and Shin (2000). We show that reporting discretion enables weak banks to inflate creditors’ beliefs effectively in equilibrium. Such belief inflation mitigates panic-based runs but can also reduce fundamental-based runs. Moreover, misreporting by weak banks exerts a negative externality on stronger ones. Overall, our results suggest that the economic consequences of reporting discretion for financial institutions are indeed different from non-financial firms to the extent that financial institutions are more prone to panic-based runs.

8 Appendix

Proof of Lemma 1

Proof. We just solve for the unique symmetric switching strategy equilibrium as the proof for the unique symmetric switching strategy equilibrium being the only equilibrium is already contained in Morris and Shin (2000). Consider a candidate threshold $\hat{x}$ such that creditor $i$ runs if and only if $x_i < \hat{x}$. Creditor $i$’s utility differential between running and not running
when other creditors use the same switching strategy is given by

\[ \Delta(x_i, l(\hat{x})) = E[r|x_i] - \delta E[l(\hat{x})|x_i] \]  \tag{12} \]

Since \( x_j = r + \varepsilon_j \) and \( r \) has an improper prior, \( r|x_i \) is normal with \( E[r|x_i] = x_i \) and \( \text{Var}[r|x_i] = \sigma^2 \). Moreover, creditor \( i \) uses her signal to forecast other creditors’ withdrawal decisions. By the law of large numbers, the mass of creditors who run, i.e., \( l \), is the probability that creditor \( j \) has a signal \( x_j < \hat{x} \). Recall that \( x_j = r + \varepsilon_j \). Thus, \( x_j|x_i \) is normal with \( E[x_j|x_i] = E[r|x_i] = x_i \) and \( \text{Var}[x_j|x_i] = \text{Var}[r|x_i] + \text{Var}[\varepsilon_j] = \sigma^2 + \sigma^2 = 2\sigma^2 \).

We now have

\[ E[l(\hat{x})|x_i] = \text{Pr}(x_j < \hat{x}|x_i) = \Phi\left(\frac{\hat{x} - E[x_j|x_i]}{\sqrt{\text{Var}[x_j|x_i]}}\right) = \Phi\left(\frac{1}{2\sigma^2}(\hat{x} - x_i)\right). \]

Insert \( E[r|x_i] \) and \( E[l(\hat{x})|x_i] \) into equation (12), we have

\[ \Delta(x_i, l(\hat{x})) = x_i - \delta \Phi\left(\frac{1}{2\sigma^2}(\hat{x} - x_i)\right) \]

\( \Delta(x_i, l(\hat{x})) \) is strictly increasing in \( x_i \) as the derivative with respect to \( x_i \) is \( 1 + \sqrt{1/2\sigma^2} \delta \Phi\left(\frac{1}{2\sigma^2}(\hat{x} - x_i)\right) > 0 \). When \( x_i \to -\infty \), \( \Delta(x_i, l(\hat{x})) \to x_i - \delta < 0 \). When \( x_i \to +\infty \), \( \Delta(x_i, l(\hat{x})) \to x_i > 0 \). Thus, for any given \( \hat{x} \), there is one unique \( x^{MS}_i(\hat{x}) \) such that \( \Delta(x^{MS}_i(\hat{x}), l(\hat{x})) = 0 \). Finally, for \( \hat{x} \) to be an equilibrium, rational expectations require that \( x^{MS}_{i}(\hat{x}) = \hat{x} \equiv x^{MS} \), where \( x^{MS} \) is determined by

\[ \Delta(x^{MS}, l(\hat{x}, x^{MS})) = x^{MS} - \frac{\delta}{2} = 0 \]

Thus the fixed point \( x^{MS} = \frac{\delta}{2} \) is unique. In addition, based on the discussion above, \( \Delta(x_i, l(x^{MS})) > 0 \) if and only if \( x_i > x^{MS} \), consistent with the threshold strategy. The total withdrawal for bank \( r \) is then \( l^{MS}(r) = \text{Pr}(x_i < x^{MS}) = \Phi\left(\frac{1}{\sigma}(x^{MS} - r)\right) = \Phi\left(\frac{1}{\sigma}\left(\frac{\delta}{2} - r\right)\right) \). As \( \sigma \) approaches 0, \( x_i \to r \). Denote \( r^{MS} = x^{MS} = \frac{\delta}{2} \), we then have \( l^{MS}(r) = 1 \) if \( r \leq r^{MS} \) and 0 if \( r > r^{MS} \). QED

Proof of Lemma 2

**Proof.** We first prove that given creditors’ strategy, manager’s optimal manipulation strategy
is specified by the Lemma. Given creditors’ strategy, manager will choose \( m^*(r) \) to maximize 
\[ 1 - E[l|r] - c(m). \]
When \( r > X \), \( E[l|r] = 0 \) and \( m^*(r) = 0 \). When \( r \leq X \), if the manager chooses to manipulate, it is sufficient to manipulate only up to \( X - r \), i.e., to report \( X \). The manager’s payoff from manipulation is therefore \( 1 - kc(X - r) \) and the manager’s payoff from not manipulation is \( 0 \). Thus, the manager will choose to manipulate if and only if 
\[ 1 - kc(X - r) \geq 0, \text{ or } c^{-1}(\frac{1}{k}) \geq X - r, \]
which is equivalent to \( r \geq X - c^{-1}(\frac{1}{k}) \). This results in manager choosing to manipulate \( m^*(r) = X - r \) when \( X - c^{-1}(\frac{1}{k}) \leq r \leq X \) and \( 0 \) when \( r < X - c^{-1}(\frac{1}{k}) \), which is manager’s optimal strategy specified in the Lemma.

Next, given manager’s manipulation strategy and other creditors’ strategy, each creditor’s expected payoff of staying when observing \( M(r) > X \) is \( M(r) > X \geq \frac{1}{2}c^{-1}(\frac{1}{k}) > 0 \) as \( X \geq \frac{1}{2}c^{-1}(\frac{1}{k}) \). This implies that staying is optimal when creditor observes \( M(r) > X \).

Each creditor’s expected payoff of staying when observing \( M(r) = X \) is 
\[ E[r|M(r) = X] = \frac{X - c^{-1}(\frac{1}{k}) + X}{2} = X - \frac{1}{2}c^{-1}(\frac{1}{k}) \geq 0 \]
as \( X \geq \frac{1}{2}c^{-1}(\frac{1}{k}) \) and staying is still optimal. Note that manager’s manipulation strategy implies that there is no report \( M(r) \) between \( X - c^{-1}(\frac{1}{k}) \) and \( X \). This means any report \( M(r) \) below \( X \) must be below \( X - c^{-1}(\frac{1}{k}) \). Each creditor’s expected payoff of staying when observing \( M(r) < X \) is then \( M(r) - \delta < X - c^{-1}(\frac{1}{k}) - \delta < 0 \) and therefore withdrawing is optimal. Thus, given manager’s manipulation strategy, withdrawing when \( M(r) < X \) and stay when \( M(r) \geq X \) is optimal. Lemma 2 is then proved. QED

Proof of Lemma 2

Proof. We prove it by contradiction. Suppose that the lemma is not true. Then there must exist two banks with fundamental \( r_H > r_L \) but \( M_H \equiv M^*(r_H) < M^*(r_L) \equiv M_L \). Since \( M_L \) is the optimal report by bank \( r_L \), we have \( w(r_L, M_L - r_L) \geq w(r_L, M_H - r_L) \), which is equivalent to 
\[ \frac{1}{k}(l(M_H) - l(M_L)) \geq c(M_L - r_L) - c(M_H - r_L) > 0. \]

Similarly, since \( M_H \) is the optimal report by bank \( r_H \), we have \( w(r_H, M_H - r_H) \geq w(r_H, M_L - r_H) \), which is equivalent to 
\[ \frac{1}{k}(l(M_H) - l(M_L)) \leq c(M_L - r_H) - c(M_H - r_H). \]
Combining the two we get
\[ c(M_L - r_L) - c(M_H - r_L) \leq c(M_L - r_H) - c(M_H - r_H) \] (13)

Note that since \( c(m) \) is strictly convex, \( c(m + a) - c(m) \) is strictly increasing in \( m \) for any constant \( a > 0 \). Since \( M_L - M_H > 0 \), equation (13) implies that \( (M_H - r_L) - (M_H - r_H) = r_H - r_L < 0 \), i.e., \( r_H < r_L \), which leads to contradiction. QED ■

Proof of Corollary 4

Proof. To show that \( E[r|x] \) is increasing with respect to \( x \), consider the likelihood ratio of the conditional distribution of \( x_i \) on \( r_1 \) and \( r_2 \) with \( r_1 > r_2 \), \( \frac{f(x|r_1)}{f(x|r_2)} = \frac{\frac{1}{\sqrt{2\pi}\sigma}e^{-\frac{(x-M(r_1))^2}{2\sigma^2}}}{\frac{1}{\sqrt{2\pi}\sigma}e^{-\frac{(x-M(r_2))^2}{2\sigma^2}}} = e^{x(M(r_1)-M(r_2)) + \frac{M^2(r_2)-M^2(r_1)}{2}} \). By Lemma 3, we know that \( r_1 > r_2 \) implies \( M(r_1) \geq M(r_2) \). Therefore, \( \frac{f(x|r_1)}{f(x|r_2)} \) increases with respect to \( x \). This implies that the conditional distribution of \( r \) on \( x \), \( g(r|x) \), satisfies Monotone Likelihood Ratio Property (MLRP). MLRP implies first order stochastic dominance, which in turn implies that \( E[r|x] \) is increasing with respect to \( x \). QED ■

Proof of Lemma 3

Proof. The lemma is proved in two steps. In the first step, we show that any equilibrium must be a switching strategy equilibrium by contradiction and in the second step we prove that any switching strategy equilibrium must be symmetric, i.e., each creditor uses the same threshold by contradiction.

We start by establishing the existence of dominance regions, i.e., there exists two signals \( \underline{x} \) and \( \overline{x} \) such that withdrawal is strictly optimal for any \( x_i < \underline{x} \) and stay is strictly optimal for any \( x_i > \overline{x} \). To see this, note that manager’s benefit from manipulation is to reduce the proportion of creditors withdrawing. Since \( l \in [0, 1] \), the maximal benefit manager can obtain from manipulating is 1. This implies that the maximum amount a manager will manipulate is \( c^{-1}(\frac{1}{k}) \). Thus, the most pessimistic scenario for any creditor is that manager manipulates the maximum amount and all other creditors choose to withdraw. This would result in \( \Delta(x_i, l) = E[r|x_i, m] - \delta = x_i - c^{-1}(\frac{1}{k}) - \delta \). Thus, set \( \overline{x} = c^{-1}(\frac{1}{k}) + \delta \). For all \( x_i > \overline{x} \), \( \Delta(x_i, l) > 0 \) under even the most pessimistic scenario and thus it is always positive. Stay
is therefore strictly dominant for all $x_i > \bar{x}$. Similarly, the most optimistic scenario for any creditor is that there is no manipulation and that all other creditors choose to stay. In this scenario $\Delta(x_i, l) = E[r|x_i, m] = x_i$. Thus, set $\bar{x} = 0$. For all $x_i < \bar{x}$, $\Delta(x_i, l) < 0$ under even the most optimistic scenario and thus it is always negative. Withdrawal is therefore strictly dominant for all $x_i < \bar{x}$.

We now complete the first step, i.e., any equilibrium must be a switching strategy equilibrium. For any equilibrium, let $\tilde{l}(.)$ be the equilibrium distribution of the proportion of agents who withdraw as a function of fundamental $r$ as well as manager’s equilibrium manipulation strategy $m(r)$. Denote $x_B = \sup\{x_i : \Delta(x_i, \tilde{l}(.)) \leq 0\}$. Intuitively, $x_B$ represents the highest signal that the creditors prefer to withdraw. Because of the existence of upper dominance region $x_B < \bar{x}$. If the equilibrium is not a switching strategy equilibrium, there are signals below $x_B$ such that the creditors will want to stay. Denote $x_A$ to be the largest of them, i.e., $x_A = \inf\{x_i < x_B : \Delta(x_i, \tilde{l}(.)) \geq 0\}$. From Lemma 3 $M(r)$ is monotone in $r$. Therefore $M(r)$ must be almost everywhere continuous, resulting in $\Delta(x_i, \tilde{l}(.))$ continuous in $x_i$. We thus have $\Delta(x_B, \tilde{l}(.)) = \Delta(x_A, \tilde{l}(.)) = 0$. Also note that for any non-switching strategy equilibrium we must have $x_A < x_B$. Figure 1 illustrates an (impossible) non-switching strategy equilibrium. All creditors will stay when $x_i > x_B$ and run between $x_A$ and $x_B$ and may or may not run below $x_A$. Because of the existence of the lower dominance region we know that creditors must run when $x_i < \bar{x}$.

![Figure 1: Illustration of a (impossible) non-threshold equilibrium](image)

We now prove that such a non-switching strategy equilibrium does not exist. Note that from Corollary 1 $E[r|x_A] \leq E[r|x_B]$ as $x_A < x_B$. Now consider $E[\tilde{l}|x_A]$ and $E[\tilde{l}|x_B]$. Since conditional on one’s own signal $x_i$, other creditor’s signal $x_j$ is normally distributed with $x_i$. 

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and precision of $\sqrt{\frac{1}{2\sigma^2}}$, we have

$$E[\tilde{l}|x_i] = \Pr(x_j < x_i) + \Pr(x_i < x_j < x_A, n_j(x_j) = 1|x_i) + \Pr(x_A < x_j < x_B|x_i)$$

$$= \Phi[\sqrt{\frac{1}{2\sigma^2}(x - x_i)}] + \int_x^A \phi(\sqrt{\frac{1}{2\sigma^2}(x - x_i)})n_j(x_j)dx_j + \Phi[\sqrt{\frac{1}{2\sigma^2}(x_B - x_i)}] - \Phi[\sqrt{\frac{1}{2\sigma^2}(x_A - x_i)}]$$

for $i = A, B$.

Taking the difference between $E[\tilde{l}|x_A]$ and $E[\tilde{l}|x_B]$, we have

$$E[\tilde{l}|x_A] - E[\tilde{l}|x_B]$$

$$= \Phi[\sqrt{\frac{1}{2\sigma^2}(x_A - x_A)}] - \Phi[\sqrt{\frac{1}{2\sigma^2}(x_A - x_B)}] + \int_x^A [\phi(\sqrt{\frac{1}{2\sigma^2}(x - x_A)}) - \phi(\sqrt{\frac{1}{2\sigma^2}(x - x_B)})]n_j(x_j)dx_j$$

$$+ \Phi[\sqrt{\frac{1}{2\sigma^2}(x_B - x_A)}] - \Phi[\sqrt{\frac{1}{2\sigma^2}(x_A - x_B)}]$$

Note that when $x < x_A$, $\phi(\sqrt{\frac{1}{2\sigma^2}(x - x_A)}) > \phi(\sqrt{\frac{1}{2\sigma^2}(x - x_B)})$, implying that

$$\int_x^A [\phi(\sqrt{\frac{1}{2\sigma^2}(x - x_A)}) - \phi(\sqrt{\frac{1}{2\sigma^2}(x - x_B)})]n_j(x_j)dx_j \geq 0.$$ Thus,

$$E[\tilde{l}|x_A] - E[\tilde{l}|x_B] \geq \Phi[\sqrt{\frac{1}{2\sigma^2}(x_A - x_A)}] - \Phi[\sqrt{\frac{1}{2\sigma^2}(x_A - x_B)}] + \Phi[\sqrt{\frac{1}{2\sigma^2}(x_B - x_A)}] - \Phi[\sqrt{\frac{1}{2\sigma^2}(x_A - x_B)}]$$

$$= \Phi[\sqrt{\frac{1}{2\sigma^2}(x_A - x_A)}] - \Phi[\sqrt{\frac{1}{2\sigma^2}(x_A - x_B)}] + 2\Phi[\sqrt{\frac{1}{2\sigma^2}(x_B - x_A)}] - 1$$

$$> 2\Phi[\sqrt{\frac{1}{2\sigma^2}(x_B - x_A)}] - 1 > 0$$

where the first inequality follows from the fact that $\Phi[\sqrt{\frac{1}{2\sigma^2}(x - x)}]$ is strictly decreasing in $x$. Thus, we have $E[r - \delta\tilde{l}|x_B] > E[r - \delta\tilde{l}|x_A]$, which is a contradiction.

We complete the proof by finishing the second step, i.e., showing that any switching strategy equilibrium has to be symmetric. Suppose not, then denote $S$ as the set of all switching thresholds adopted by at least one of the creditors in equilibrium. Denote $x_C = \inf S$ and $x_D = \sup S$. Intuitively, $x_C$ is the smallest switching threshold adopted by creditors and $x_D$ is the largest threshold. Since creditors must be indifferent at the threshold, we have $\Delta(x_C, \tilde{l}(.)) = \Delta(x_D, \tilde{l}(.)) = 0$. By definition of $x_C$ and $x_D$, every creditor withdraws when
Figure 2: Illustration of an (impossible) asymmetric switching strategy equilibrium

$x < x_C$ and every creditor stays when $x > x_D$. When $x_C \leq x \leq x_D$ some creditors may withdraw and some creditors may stay, as illustrated in figure 2 below.

We now show that $(x_C, l(.) = 0$ cannot hold. Again from corollary 1 $E[r|x_C] \leq E[r|x_D]$ as $x_C < x_D$. Now consider $E[l|x_C]$ and $E[l|x_D]$.

We have

$$E[l|x_i] = \Pr(x_j < x_C|x_i) + \Pr(x_C \leq x_j \leq x_D, n(x_j) = 1|x_i)$$

$$= \Phi[\sqrt{\frac{1}{2\sigma^2}}(x_C - x_i)] + \int_{x_C}^{x_D} \phi(\sqrt{\frac{1}{2\sigma^2}}(x - x_i))n_j(x_j)dx_j$$

for $i = C, D$.

Taking the difference between $E[l|x_C]$ and $E[l|x_D]$, we have

$$E[l|x_C] - E[l|x_D]$$

$$= \Phi[\sqrt{\frac{1}{2\sigma^2}}(x_C - x_C)] - \Phi[\sqrt{\frac{1}{2\sigma^2}}(x_C - x_D)] + \int_{x_C}^{x_D} [\phi(\sqrt{\frac{1}{2\sigma^2}}(x - x_C)) - \phi(\sqrt{\frac{1}{2\sigma^2}}(x - x_D))]n_j(x_j)dx_j$$

$$= \frac{1}{2} - \Phi[\sqrt{\frac{1}{2\sigma^2}}(x_C - x_D)] + \int_{x_C}^{x_D} [\phi(\sqrt{\frac{1}{2\sigma^2}}(x - x_C)) - \phi(\sqrt{\frac{1}{2\sigma^2}}(x - x_D))]n_j(x_j)dx_j$$

Note that when $x$ is between $x_C$ and $x_D$, $\phi(\sqrt{\frac{1}{2\sigma^2}}(x - x_C)) > \phi(\sqrt{\frac{1}{2\sigma^2}}(x - x_D))$ if and
only if \( x < \frac{x_C + x_D}{2} \). We can then write

\[
\int_{x_C}^{x_D} \left[ \phi\left( \sqrt{\frac{1}{2\sigma^2}} (x - x_C) \right) - \phi\left( \sqrt{\frac{1}{2\sigma^2}} (x - x_D) \right) \right] n_j(x_j) dx_j
\]

\[
= \int_{\frac{x_C + x_D}{2}}^{x_D} \left[ \phi\left( \sqrt{\frac{1}{2\sigma^2}} (x - x_C) \right) - \phi\left( \sqrt{\frac{1}{2\sigma^2}} (x - x_D) \right) \right] n_j(x_j) dx_j
\]

\[
+ \int_{\frac{x_C + x_D}{2}}^{x_D} \left[ \phi\left( \sqrt{\frac{1}{2\sigma^2}} (x - x_C) \right) - \phi\left( \sqrt{\frac{1}{2\sigma^2}} (x - x_D) \right) \right] n_j(x_j) dx_j \quad (14)
\]

The first term of the right hand side of equation (14) is non-negative whereas the second term is non-positive. Thus, \( \int_{x_C}^{x_D} \left[ \phi\left( \sqrt{\frac{1}{2\sigma^2}} (x - x_C) \right) - \phi\left( \sqrt{\frac{1}{2\sigma^2}} (x - x_D) \right) \right] n_j(x_j) dx_j \) will be minimized when \( n_j(x_j) = 0 \) in the first term and \( n_j(x_j) = 1 \) in the second term. This implies that

\[
\int_{x_C}^{x_D} \left[ \phi\left( \sqrt{\frac{1}{2\sigma^2}} (x - x_C) \right) - \phi\left( \sqrt{\frac{1}{2\sigma^2}} (x - x_D) \right) \right] n(x) dx
\]

\[
\geq \int_{\frac{x_C + x_D}{2}}^{x_D} \left[ \phi\left( \sqrt{\frac{1}{2\sigma^2}} (x - x_C) \right) - \phi\left( \sqrt{\frac{1}{2\sigma^2}} (x - x_D) \right) \right] dx
\]

\[
= \Phi\left[ \sqrt{\frac{1}{2\sigma^2}} (x_D - x_C) \right] - \Phi\left[ \sqrt{\frac{1}{2\sigma^2}} \left( x_D - \frac{x_C}{2} \right) \right] - \frac{1}{2} + \Phi\left[ \sqrt{\frac{1}{2\sigma^2}} \left( x_C - x_D \right) \right]
\]

\[
= \frac{1}{2} + \Phi\left[ \sqrt{\frac{1}{2\sigma^2}} (x_D - x_C) \right] - 2\Phi\left[ \sqrt{\frac{1}{2\sigma^2}} \left( x_D - \frac{x_C}{2} \right) \right]
\]

where we used \( \Phi(-x) = 1 - \Phi(x) \) in arriving at the last equality. Thus,

\[
E[\tilde{l} | x_C] - E[\tilde{l} | x_D] \geq \frac{1}{2} - \Phi\left[ \sqrt{\frac{1}{2\sigma^2}} (x_C - x_D) \right] + \frac{1}{2} + \Phi\left[ \sqrt{\frac{1}{2\sigma^2}} (x_D - x_C) \right] - 2\Phi\left[ \sqrt{\frac{1}{2\sigma^2}} \left( x_D - \frac{x_C}{2} \right) \right]
\]

\[
= 2\Phi\left[ \sqrt{\frac{1}{2\sigma^2}} (x_D - x_C) \right] - 2\Phi\left[ \sqrt{\frac{1}{2\sigma^2}} \left( x_D - \frac{x_C}{2} \right) \right] > 0
\]

where the last inequality follows from \( x_D > x_C \). Note we again used \( \Phi(-x) = 1 - \Phi(x) \) in the derivation.

We thus have \( \Delta(x_C, \tilde{l}(\cdot)) < \Delta(x_D, \tilde{l}(\cdot)) \), resulting in contradiction. The lemma is thus proved. QED
Proof of Lemma 5

Proof. We only prove the (almost everywhere) uniqueness of $m^{BR}(r; \hat{x})$ as the characterization of $m^{BR}(r; \hat{x})$ is already contained in the text.

Since $c'(0) = 0$, the first order condition must be satisfied, i.e.,

$$
\phi\left(\frac{1}{\sigma}(\hat{x} - (r + m))\right) = \sigma kc'(m).
$$

(15)

We now divide the discussion into cases.

Case 1: When $r \geq \hat{x}$, $r + m \geq \hat{x}$. Second order condition is $kc''(m)\sigma + \frac{1}{\sigma} \phi'(\frac{1}{\sigma}(\hat{x} - (r + m))) > 0$ as $\phi'(\frac{1}{\sigma}(\hat{x} - (r + m))) \geq 0$ when $\hat{x} - (r + m) \leq 0$. Thus, first order condition is both necessary and sufficient for optimality and we have a unique solution $m^{BR}(r; \hat{x})$ that satisfies equation (15) and is the optimal manipulation strategy as the objective function is concave when $r \geq \hat{x}$.

Case 2: When $r < \hat{x}$, the objective function is not necessarily concave and there may be multiple solutions to equation (15) that also satisfy second order conditions. The optimal $m^{BR}$ is then achieved by comparing $w(m, r)$ evaluated at those solutions that satisfy both first order and second order conditions, which need not be unique. However, we are able to show that $m^{BR}(r; \hat{x})$ is unique for almost every $r$.

To see this, suppose that $m^{BR}(r; \hat{x})$ is not unique for almost every $r$. This means that there must exist a closed set $T$ of non-zero measure such that $m^{BR}(r; \hat{x})$ is not unique on $T$. This implies that $\forall r \in T$, there are at least two optimal $m^{BR}(r; \hat{x})$. Denote those optimal solutions as $m^{BR}_1(r; \hat{x})$ and $m^{BR}_2(r; \hat{x})$ respectively, we have $m^{BR}_2(r; \hat{x}) - m^{BR}_1(r; \hat{x}) \geq \kappa(r; \hat{x}) \geq \tau = \min_{r \in T} \kappa(r; \hat{x}) > 0$ for some $\kappa$ and $\tau$. If this is not satisfied, then $m^{BR}_2(r; \hat{x}) = m^{BR}_1(r; \hat{x})$ for some $r \in T$, contradicting the non-uniqueness assumption.

From Lemma 3, we know that $M(r) = r + m^{BR}(r; \hat{x})$ is a non-decreasing function of $r$. Because $c'(m) > 0$ except at $m = 0$, $M(r)$ must be almost everywhere strictly increasing on $T$. The reason is if not, we will have a closed subset of non-zero measure $S \subset T$ such that $M(r)$ is a constant $\forall r \in S$, which implies that $m^{BR}(r; \hat{x}) \neq 0$ for all but (possibly) one $r \in S$. Since $c'(m) > 0$ almost everywhere on $S$, there exists $r_\eta \neq r_\theta \in S$ and $m^{BR}(r_\eta; \hat{x}) \neq 0$, $m^{BR}(r_\theta; \hat{x}) \neq 0$ such that $M(r_\eta) = M(r_\theta)$ and that $c'(m^{BR}(r_\eta; \hat{x})) \neq c'(m^{BR}(r_\theta; \hat{x}))$ as
\[ m^{BR}(r_\eta; \hat{x}) \neq m^{BR}(r_\theta; \hat{x}). \] But this is impossible as both \( m^{BR}(r_\eta; \hat{x}) \) and \( m^{BR}(r_\theta; \hat{x}) \) have to satisfy the first order condition, which results in the same left hand side as \( M(r_\eta) = M(r_\theta) \) but different right hand side as \( m^{BR}(r_\eta; \hat{x}) \neq m^{BR}(r_\theta; \hat{x}) \). Denote the largest closed set where \( M(r_\eta) \) is strictly increasing in \( T \) as \( V \) and \( r = \min_{r \in T} r \). Note that we can find points in \( V \) that are arbitrarily close to each other as \( V \) is closed. We have, for \( r_\alpha = \min_{r \in V} r \) which is well-defined as \( V \) is closed, \( M(r_\alpha) \geq r + m_2^{BR}(r_\alpha; \hat{x}) \geq r + \tau + m_1^{BR}(r_\alpha; \hat{x}) > r + \frac{\tau}{2} + m_1^{BR}(r_\alpha; \hat{x}). \) Now for some \( r_\beta \in V \) that is infinitesimally greater than \( r_\alpha \), \( M(r_\beta) > r_\alpha + m_2^{BR}(r_\alpha; \hat{x}) \geq r_\alpha + m_1^{BR}(r_\alpha; \hat{x}) + \tau > r + \frac{\tau}{2} + m_1^{BR}(r_\alpha; \hat{x}) + \tau > M(r_\beta) + \frac{3}{2}\tau. \) Since there are infinitely many points on \( V \) where \( c'(m) > 0 \) and \( M(r) \) strictly increasing in \( r \), we can establish a similar inequality as above infinitely many times, resulting in \( M(r_\beta) \to +\infty \) where \( r \in V \). This, however, cannot be true as this implies that \( m_1^{BR}(r; \hat{x}) \to +\infty \) and \( c'(m_1^{BR}(r; \hat{x})) \to +\infty. \)

Thus, \( m^{BR}(r; \hat{x}) \) is unique for almost every \( r \) and the lemma is proved. QED

Proof of Proposition \[ \text{Proof. We need to prove that there is a unique solution, denoted as } x^*, \text{ to equation (8), i.e., } \Delta(x^*, l(m^*(r), x^*)) = 0, \text{ or, equivalently, } E[r - \delta l[x^*] = 0. \text{ We analyze } E[l|x^*] \text{ and } E[l|x^*] \text{ separately.}

First,

\[
E[l|x^*] = E[Pr(x_j < x^*|x^*)] = E[Pr(r + m^*(r) + \varepsilon_j < x^*|x^*)] \\
= E[Pr(x^* - \varepsilon_j < x^*|x^*)] = E[Pr(\varepsilon_j < \varepsilon_j|x^*)] \\
= E[Pr(\varepsilon_j < \varepsilon_j)] = \int_{-\infty}^{+\infty} \int_{-\infty}^{+\infty} \frac{1}{2\pi\sigma^2} e^{-\frac{\varepsilon_i^2}{2\sigma^2}} d\varepsilon_j \sqrt{\frac{1}{2\pi\sigma^2}} e^{-\frac{\varepsilon_j^2}{2\sigma^2}} d\varepsilon_i \\
= \int_{-\infty}^{+\infty} \Phi(\frac{\varepsilon_i}{\sigma}) \phi(\frac{\varepsilon_i}{\sigma}) d\varepsilon_i = \int_{-\infty}^{+\infty} \Phi(t) \phi(t) dt
\]

The last step uses the properties that \( \varepsilon_i \) and \( \varepsilon_j \) are i.i.d. with mean zero. Denote this
integral as $I$ and using integration by parts, we have

$$I = \Phi(t)\Phi(t)\bigg|_{-\infty}^{+\infty} - \int_{-\infty}^{+\infty} \phi(t)\Phi(t)dt = 1 - I.$$ 

Therefore, $E[l|x^*] = I = \frac{1}{2}$.

Second, we show that $E[r|x^*]$ is strictly increasing with respect to $x^*$. Note that

$$E[r|x^*] = E[x^* - m^*(r)|x^*] = x^* - E[m^*(r)|x^*].$$

Moreover, $m^*(r)$ has to satisfy the first order condition, which results in $\phi(\frac{1}{\sigma}(x^* - (r + m^*(r)))) = \sigma ke'(m^*(r))$. Taking derivative with respect to $x^*$ and rearranging terms, we have

$$\frac{\partial m^*(r)}{\partial x^*} = \frac{\frac{1}{\sigma}\phi'(\frac{1}{\sigma}(x^* - (r + m^*(r))))}{\frac{1}{\sigma}\phi'(\frac{1}{\sigma}(x^* - (r + m^*(r)))) + \sigma ke''(m^*(r))} < 1.$$ 

This is because the denominator is positive from the second order condition and $\sigma ke''(m^*(r)) > 0$. Thus, if the numerator is non-positive, $\frac{\partial m^*(r)}{\partial x^*} \leq 0 < 1$; if the numerator is positive, $\frac{\partial m^*(r)}{\partial x^*} < 1$.

Now we are ready to show that $E[r|x^*]$ is strictly increasing with respect to $x^*$. Consider arbitrary $x^*_2 > x^*_1$ and write $m(x^*, r) \equiv m^*(r)$ as $m^*(r)$ is a function of $x^*$. Since $\frac{\partial m^*(r)}{\partial x^*} < 1$ \forall $r$ and $x^*$, by mean value theorem, there exists some $\zeta \in [x^*_1, x^*_2]$ such that

$$m(x^*_2, r) - m(x^*_1, r) = \frac{\partial m(x^*, r)}{\partial x^*}|_{x^*=\zeta}(x^*_2 - x^*_1) < (x^*_2 - x^*_1).$$

Since this inequality holds for every $r$, we have

$$E[m^*(r)|x^*_2] - E[m^*(r)|x^*_1] < x^*_2 - x^*_1. \quad (16)$$

Otherwise there must exists a non-zero measure of set $S$ s.t. $m(x^*_2, r) - m(x^*_1, r) \geq x^*_2 - x^*_1 \forall r \in S$. Equation (16) implies that $x^*_2 - E[m^*(r)|x^*_2] > x^*_1 - E[m^*(r)|x^*_1]$, or $E[r|x^*_2] > E[r|x^*_1]$. Since $x^*_1$ and $x^*_2$ are arbitrary, we have proved that $E[r|x^*, m(x^*, r)]$ is strictly increasing with

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respect to \( x^* \).

Combing the two steps above, we have proved that \( E[r - \delta l|x^*] \) is strictly increasing in \( x^* \). When \( x^* > \overline{x} \), we are in the upper dominance region and \( E[r - \delta l|x^*] > 0 \). Similarly, when \( x^* < \overline{x} \), we are in the lower dominance region and \( E[r - \delta l|x^*] < 0 \). Thus, there is a unique solution of the equation \( E[r - \delta l|x^*] = 0 \) and the proposition is thus proved. QED

Proof of Proposition 2:

Proof. The proposition is proved by taking the proper limits of \( m^*(r) \) from equation (7) and \( x^* \) from equation (8). The key of the proof is the following claim: as \( \sigma \to 0 \), \( m^* \) converges to either 0 or \( x^* - r \). We prove it first.

For ease of notation in this proof we suppress the dependence of \( m^* \) on \( r \). Recall that any \( m^* \) with \( \sigma > 0 \) is interior and has to satisfy the first and second order conditions, which we reproduce here:

\[
\frac{1}{\sigma} \phi\left(\frac{1}{\sigma}(x^* - (r + m^*))\right) - kc'(m^*) = 0 \quad \text{(FOC)}
\]
\[
-\frac{1}{\sigma^2} \phi\left(\frac{1}{\sigma}(x^* - (r + m^*))\right) - kc''(m^*) < 0 \quad \text{(SOC)}
\]

We denote \( m^* \) as \( m^*(\sigma) \) for the rest of the proof. Since \( m^*(\sigma) \leq e^{-1}\left(\frac{1}{\sigma^2}\right) < +\infty \) for any \( \sigma > 0 \), we know that \( m^*(\sigma) \) is continuous and bounded. This implies that \( m^*(\sigma) \) must converge to some number as \( \sigma \to 0 \). We prove the above claim by dividing into cases depending on whether \( r \) is smaller or larger than \( x^* \).

Case 1: \( r > x^* \). As \( \sigma \to 0 \), \( kc'(m) = \frac{1}{\sigma} \phi\left(\frac{1}{\sigma}(x^* - (r + m))\right) \to 0 \). Therefore, \( m^*(\sigma) \to 0 \).

Case 2: \( r \leq x^* \). We prove the claim by contradiction. The intuition is as follows.

As \( \sigma \to 0 \), \( m^*(\sigma) \) must converge to some number. If the limit is neither 0 nor \( x^* - r \), it must be sufficiently away from 0 or \( x^* - r \). But this implies \( x^* - (r + m^*(\sigma)) \neq 0 \) and \( \frac{1}{\sigma} \phi\left(\frac{1}{\sigma}(x^* - (r + m^*(\sigma)))\right) \to 0 \). The first order condition (FOC) then results in \( kc'(m^*(\sigma)) \to 0 \) and \( m^*(\sigma) \to 0 \), which contradicts the claim that \( m^*(\sigma) \) is sufficiently away from 0.

We now formally prove the claim. Suppose the claim is not true and \( m^*(\sigma) \) converges to neither 0 nor \( x^* - r \) as \( \sigma \to 0 \). Then \( m^*(\sigma) \) must converge to some other finite number \( s \) that is neither 0 nor \( x^* - r \) as \( \sigma \to 0 \). This would imply that \( \forall \varepsilon > 0, \exists \tau(\varepsilon) \) s.t. \( |m^*(\sigma) - s| < \varepsilon \).
for all $\sigma < \tau(\varepsilon)$. Take $2\varepsilon < |s - 0|$, we have $|m^*(\sigma) - 0| = m^*(\sigma) > s - \varepsilon > \varepsilon$ for all $\sigma < \tau(\varepsilon)$. Similarly, we can prove that $|m^*(\sigma) - (x^* - r)| > \varepsilon$ for all $\sigma < \tau(\varepsilon)$ and some small finite number $\varepsilon$. This results in $(x^* - (r + m))^2 > \varepsilon^2$. Since $\frac{1}{\sigma} \phi\left(\frac{1}{\sigma}(x^* - (r + m))\right)$ is decreasing in $(x^* - (r + m))^2$, we have $\frac{1}{\sigma} \phi\left(\frac{1}{\sigma}(x^* - (r + m))\right) < \frac{1}{\sigma} \phi\left(\frac{\varepsilon}{\sigma}\right) \to 0$ when $\sigma \to 0$ (for any finite $\varepsilon$). Thus, the first order condition implies that $kc'(m^*) = \frac{1}{\sigma} \phi\left(\frac{1}{\sigma}(x^* - (r + m))\right) \to 0$ when $\sigma \to 0$. This implies that $m^*(\sigma) < \varepsilon$ for all $\sigma < \chi(\varepsilon)$ for some $\chi(\varepsilon)$, which is in contradiction with $|m^*(\sigma) - 0| > \varepsilon$ for $\sigma < \min(\chi(\varepsilon), \tau(\varepsilon))$. The claim is thus proved.

After establishing the claim that as $\sigma \to 0$, $m^*(\sigma)$ converges to 0 if $r > x^*$ and to either 0 or $x^* - r$ if $r \leq x^*$, we pin down $x^*$ and $m^*$. If $r > x^*$, then $m^*(\sigma)$ converges to 0 and the manager’s payoff is

$$\lim_{\sigma \to 0, m^*(\sigma) \to 0} w(m^*(\sigma); r) = \lim_{\sigma \to 0, m^*(\sigma) \to 0} 1 - \Phi\left(\frac{1}{\sigma}(x^* - (r + m^*(\sigma)))\right) - kc(m^*(\sigma)) = 1.$$ 

However, if $r < x^*$, $m^*(\sigma)$ converges to either 0 or $x^* - r$. The manager compares the payoff under two choices to pick one. If $m^*(\sigma) \to 0$, the manager’s payoff is

$$\lim_{\sigma \to 0, m^*(\sigma) \to 0} w(m^*(\sigma); r) = \lim_{\sigma \to 0, m^*(\sigma) \to 0} 1 - \Phi\left(\frac{1}{\sigma}(x^* - (r + m^*(\sigma)))\right) - kc(m^*(\sigma)) = 0.$$ 

If $m^*(\sigma)$ converges to $x^* - r$, we now show that the manager’s payoff is

$$\lim_{m^*(\sigma) \to x^* - r} w(m^*(\sigma); r) = \lim_{m^*(\sigma) \to x^* - r} 1 - \Phi\left(\frac{1}{\sigma}(x^* - (r + m^*(\sigma)))\right) - kc(m^*(\sigma)) = 1 - kc(x^* - r).$$

(17)

To prove this, from the first order condition, we have $\lim_{\sigma \to 0, m^*(\sigma) \to 0} \frac{1}{\sigma} \phi\left(\frac{1}{\sigma}(x^* - (r + m^*(\sigma)))\right) = kc'(x^* - r)$. Since $c'(x^* - r)$ is finite, it must be that $\phi\left(\frac{1}{\sigma}(x^* - (r + m^*(\sigma)))\right) \to 0$, which implies that $\frac{1}{\sigma}(x^* - (r + m^*(\sigma))) \to +\infty$ or $-\infty$. Next we prove that $\frac{1}{\sigma}(x^* - (r + m^*(\sigma))) \to -\infty$ by contradiction. Suppose the opposite is true, that is, $\frac{1}{\sigma}(x^* - (r + m^*(\sigma))) \to +\infty$. We use
the property $\phi'(X) = -X\phi(X)$ to rewrite the second order condition as

$$SOC = -\frac{1}{\sigma^2} \phi'(\frac{1}{\sigma}(x^* - (r + m^*))) - k\phi''(m^*)$$

$$= \frac{x^* - (r + m^*)}{\sigma^3} \phi'(\frac{1}{\sigma}(x^* - (r + m^*))) - k\phi''(m^*)$$

$$= \frac{1}{\sigma} x^* - (r + m^*) \frac{1}{\sigma} \phi'(\frac{1}{\sigma}(x^* - (r + m^*))) - k\phi''(m^*)$$

If $\frac{1}{\sigma}(x^* - (r + m^*(\sigma))) \rightarrow +\infty$, then $\lim_{\sigma \rightarrow 0} SOC > 0$, which is a contradiction. Therefore, $\frac{1}{\sigma}(x^* - (r + m^*(\sigma))) \rightarrow -\infty$, which generates the manager’s payoff in equation 17.

When $r = x^*$, $m^*(\sigma)$ would always converge to one limit 0. Since $\frac{1}{\sigma}(x^* - (r + m^*(\sigma))) \rightarrow +\infty$ or $-\infty$ and $m^*(\sigma) > 0$ when $\sigma \neq 0$. Thus, $x^* - (r + m^*(\sigma)) < 0$ when $\sigma \neq 0$. This results in $\frac{1}{\sigma}(x^* - (r + m^*(\sigma))) \rightarrow -\infty$ and the manager’s payoff is still equation 17 when $r = x^*$.

Since $1 - kc(x^* - r)$ is increasing in $r$ and equals 0 at $r_1 = x^* - c^{-1}(\frac{1}{k})$, the manager chooses $m^* = x^* - r$ if $r \in [r_1, x^*]$ and $m^* = 0$ if $r < r_1$.

Collecting the results and defining $r_2 = x^*$, we have shown that for given $x^*$ the manager’s optimal strategy is $m^* = r_2 - r$ if $r \in [r_1, r_2]$ and $m^* = 0$ if $r < r_1$ or $r > r_2$.

The final step is to pin down $x^*$ by using the creditors’ indifference condition (equation 8). Note first that $E[l|x^*] = \Pr(x_j < x^*|x^*) = \frac{1}{2}$ for any $\sigma$. Note also that given the manager’s strategy above, the distribution of $r$ conditional on $x^*$ is uniform over $[r_1, r_2]$. Thus, we have

$$\Delta(x^*) = \lim_{\sigma \rightarrow 0} E[r - \delta l|x^*] = \lim_{\sigma \rightarrow 0} E[r|x^*] - \delta \lim_{\sigma \rightarrow 0} E[l|x^*] = \frac{r_1 + x^*}{2} - \frac{\delta}{2} = 0$$

Solving this equation, we obtain $x^* = r_2 = \frac{\delta}{2} + c^{-1}(\frac{1}{k})$. This completes the characterization of the equilibrium as $\sigma \rightarrow 0$. The incidence of runs can be calculated as follows: $l^*(r) = \Phi(\frac{1}{\sigma}(x^* - r - m^*)) \rightarrow 0$ if $r \geq r_1$ and $l^*(r) = \Phi(\frac{1}{\sigma}(x^* - r - m^*)) \rightarrow 1$ if $r < r_1$. This completes the proof. QED  

Proof of Proposition 3 and 4

Proof. These two propositions are proved with simple comparative statics of the equilibrium in Proposition 2.

First, since $r_1(k) = \frac{\delta}{2} - \frac{c^{-1}(\frac{1}{k})}{2}$, $\frac{\partial r_1(k)}{\partial k} = \frac{1}{2c^{1}(\frac{1}{k})} \frac{1}{k^2} > 0$. As $k \rightarrow +\infty$, $\frac{1}{k} \rightarrow 0$ and $c^{-1}(\frac{1}{k}) \rightarrow 0$. 

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$c^{-1}(0) = 0$. Thus $\lim_{k \to +\infty} r_1(k) = \frac{\delta}{2} = r^{MS}$.

If $k \geq \frac{1}{c(\delta)}$, then $\frac{1}{k} \leq c(\delta)$ and $\frac{c^{-1}(\frac{1}{k})}{2} \leq \frac{c^{-1}(\delta)}{2} = \frac{\delta}{2}$ as $c^{-1}$ is strictly increasing. Thus, $r_1(k) = \frac{\delta}{2} - \frac{c^{-1}(\frac{1}{k})}{2} \geq \frac{\delta}{2} - \frac{\delta}{2} = 0$. The case when $k < \frac{1}{c(\delta)}$ can be proved analogously and is thus omitted. That $\frac{1}{c(\delta)}$ is decreasing in $\delta$ comes directly from $c(\delta)$ being an increasing function.

Second, since $r_2 = \frac{\delta}{2} + \frac{1}{2k}, r_2 > \frac{\delta}{2} = r^{MS}$ for any $k$. $r_2 > \delta$ if and only if $\frac{\delta}{2} + \frac{1}{2k} > \delta$, or $k < \frac{1}{\delta}$. QED ■

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