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An Economic Inquiry into Information Disclosure by Banking Institutions

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Dedicated to my parents

Contents

CHAPTER 1

Information Disclosure by Banking Institutions: A Primer

1.1. Introduction

Banking institutions play a central role in modern economies. As stated by Merton (1993), "A well developed smoothly functioning financial system facilitates the efficient life-cycle allocation of household consumption and the efficient allocation of physical capital to its most productive use in the business sector." Indeed, before the recent development of market-based financial systems, banks were almost the sole provider of many financial intermediary services. Banks offer payment services, monitor borrowers, provide liquidity, and transform assets in terms of credit risk, liquidity and maturity (Freixas and Rochet, 2008). Numerous events, especially the ones during the recent crisis, have also highlighted that issues of information disclosure and information structure have profound implications for banks. For instance, both banks and bank regulators are concerned with the effect of fair value accounting in triggering excessive write-downs of banks' assets and causing downward spirals of assets prices (Plantin, Sapra, and Shin, 2008). Furthermore, many critics even argue that a loss of information was a major contributor to the recent banking panics (Gorton, 2008). In addition, there have been long and ongoing debates on which types of information (accounting information versus price information) the prudential regulation of banks should be based upon. Given the great importance of informational issues, it is thus crucial to study the information disclosure by banks. Departing from previous researches in banking that also contain informational issues, this dissertation intends to place the disclosure and the structure of information, especially accounting information, in the central stage of examining various banking problems.

There is a vast empirical accounting literature that focuses specifically on banks. Beatty and Liao (2013) summarize this literature into three streams: the use of accounting information in the bank equity and debt pricing, the relation between financial reporting, earnings management and capital regulation, and the effect of different accounting regimes on banks' real decisions. This vast empirical literature addresses many banking issues that are interesting and important from both an academic and a practical perspective. For instance, how does the equity market assess banks' disclosures of securitization activities (Landsman, Peasnell, and Shakespeare, 2008)? What is the implication of various accounting discretion permitted to banks in disciplining banks' risk-taking under the current regulatory regimes (Bushman and Williams, 2012)? Does fair value accounting lead banks to adjust their leverage procyclically (Amel-Zadeh, Barth and Landsman, 2014)? These studies have enhanced our understanding of the role of information disclosure in the banking industry as well as provide key policy implications.

Compared to the flourishing empirical literature, somewhat surprisingly, the analytical literature in the field of bank accounting is relatively sparse.[1] However, the analytical approach seems of critical importance to the study of bank accounting, especially when one takes account of the forward-looking nature of many banking issues. Dewatripont, Freixas, and Tirole (2010) argue that regulation should be designed to avoid the next crisis rather than "to fight the previous crisis." Beatty and Liao (2013), in their review of the extant bank accounting literature, also call for future research to "provide insights into the likely effects of counter-factual regulatory and accounting regimes." In this light, the analytical approach seems a plausible remedy because of its comparative advantage in delivering counter-factual implications. Analytical models can be built around various features of banking and accounting. Such models can cast light on questions that the empirical approach alone has difficulties explaining due to a lack of observations: Why is the current prudential regulation of banks exclusively contingent on accounting information which measures banks' fundamentals? Would a greater reliance on price information, which is not directly driven by fundamentals but rather aggregates the information owned by market participants, better discipline banks? What is special about the role of accounting in regulating banks? Is accounting, just like many other information channels, merely a messenger whose job is to simply provide as much information as possible? Do the essential processes

[1] See Allen and Carletti (2008), Plantin, Sapra, and Shin (2008) and Lu, Sapra, and Subramanian (2011) for a few exceptions.

of accounting, such as recognition, measurement, and aggregation, have any key implications for bank regulation?

A complete answer to this list of questions requires an entire stream of literature that combines both the analytical and the empirical approach, which is beyond the scope of a single paper or dissertation. This dissertation intends to take the first step by presenting analytical models that focus on very specific issues of information disclosure and banking. I examine two particular characteristics that are specific to banks: vulnerability to runs by short-term investors (chapter 2) and the prudential bank regulation (chapter 3). I find that these banking features give rise to distinctive roles of information disclosure that seem to be under-explored in the previous literature. My dissertation intends to address the following questions:

(1) How does the emergence of the market-based financial system, i.e., shadow banking, affect the disclosure incentive of the traditional commercial banking system?

(2) Why are shadow banks opaque and fragile?

(3) How does the quality of accounting information influence banks' risk-taking decisions, given that the bank capital is measured based on accounting information?

The detailed analysis is left to the second and third chapter of this dissertation. In this primer, I will focus on developing a simple analytical framework to highlight the main economic trade-offs.

1.2. Analytical Framework

Using a stylized existing model of banking, I argue that there exist endogenous demands for information within an analytical framework, which invites a rigorous study of the role of information disclosure by banks. Consider the following variation of Diamond and Dybvig (1983) that has three dates and a bank which is endowed with an investment project (a loan). For simplicity, I assume that the project requires \$2 of initial investments at date 0. The bank finances the project by issuing deposits to two depositors, each of whom contributes \$1. At date 1, depositors are allowed to withdraw their deposits at the face value. The project yields a stochastic payoff $\tilde{R}$ at date 2. The project is illiquid and if interrupted at date 1, the salvage value is \$1. At date 1, an intermediate signal $\tilde{x}$, which is informative about the future outcome of the project, is realized. The time line of the model is shown below.

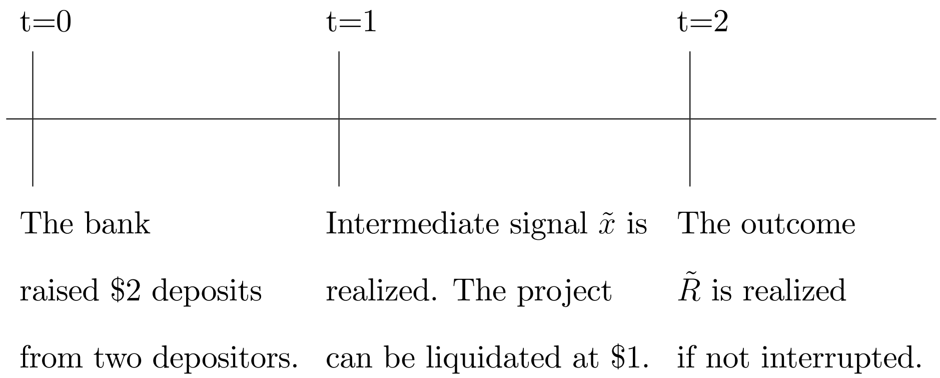


Figure 1.1: Time line.

In the spirit of Diamond and Dybvig (1983), this model captures a key banking feature: the bank accepts liquid deposits and originates illiquid loans. That is, the bank creates liquidity by transforming the liquid deposits that are desirable by depositors into the illiquid loan that is preferred by borrowers. Importantly, the model captures the role of information disclosure by introducing information on the final outcome that arrives in the intermediate date. This intermediate signal allows the depositors (and the regulator to be introduced later) to take actions upon the realization of the signal. I leave the details of the information structure and the project payoff unspecified until later analysis. This model, albeit highly stylized and simplified, seems to offer a tractable framework to study the roles of information disclosure in various banking contexts. I utilize this framework to investigate the role of information disclosure in bank runs as well as in the prudential regulation.

1.2.1. The Role of Information in Bank Runs

I first illustrate the role of information in bank runs. The key insight in Diamond and Dybvig (1983) shows that the liquidity creation by banks comes at an expense: the liquidity mismatch between loans and deposits also exposes the banks to the risk of runs. Bank runs are self-fulfilling prophecies: a depositor will withdraw only when she anticipates others will withdraw. This is because the liquidation value of the loans is insufficient to satisfy all the claims by the depositors. Prior to the offering of the deposit insurance and the liquidity provision by the public sector, bank runs were a common phenomenon. The recent runs on the shadow banking system further remind us how fragile banking institutions are when the public liquidity support is missing (Pozsar et al., 2010).

To highlight the importance of information in bank runs, let us first consider a situation that in the analytical framework, the distribution of the project payoff $\tilde{R}$ is degenerate, $\tilde{R}$ is \$4 for sure. This payoff is also perfectly observable by the depositors. For simplicity, I assume that when both depositors choose not to withdraw, the project is continued and the final payoff is split evenly. When only one withdraws, the project is liquidated and the liquidation value \$1 goes to the depositor who withdraws, leaving nothing to the other. When both withdraw, they split the liquidation value $1. The payoff for the depositors is shown in the table below:

	Withdraw	Stay
Withdraw	0.5,0.5	1,0
Stay	0,1	2,2

This simple game basically reproduces the insights in Diamond and Dybvig (1983). In this game, either of two Nash equilibria may prevail: one with both depositors to stay and the other with both to withdraw. The (Stay, Stay) equilibrium achieves the first-best in the production efficiency. The other (Withdraw, Withdraw) equilibrium (a bank run) has the two depositors to withdraw, causing the interruption of the production. This multiple-equilibrium result undoubtedly captures the fragility of banking institutions: the production efficiency critically hinges on the effective coordination among the depositors. However, in the original work of Diamond and Dybvig (1983), which of these two equilibria occurs is either indeterminate or depends on extraneous variables ("sunspots"). This indeterminacy, despite its intuitive appeal and intellectually interesting, can be unsatisfactory and debilitating from a practical and policy stand point. For instance, Morris and Shin (2001) argue that such indeterminacy not only "runs counter to our theoretical scruples against indeterminacy" and generates "the obvious difficulties of any comparative-statics analysis," but "more importantly, it runs counter to our intuition that bad fundamentals are somehow 'more likely' to trigger a financial crisis..." The last point is particularly striking. Indeed, from a historical point of view, banking panics seem to occur more frequently around economic downturns (Allen and Gale, 1998).

A recent development in the global games literature (Carlsson and van Damme, 1993; Morris and Shin, 1998, 2001) provides a key insight that challenges the indeterminacy in multiple-equilibrium models. Key to the global games approach in the model of bank runs is to reconsider the stark information environment condition (i.e., \$4 known to all). Under the approach, even when the depositors observe the final payoff with just a very small amount of idiosyncratic uncertainty, the indeterminacy will disappear and we will be able to pin down a unique equilibrium. So the innovation is an information idea. More convincingly, using the global games approach also generates a correlation between the equilibrium outcomes and the fundamentals that is consistent with our economic intuitions and empirical observations. This theory predicts that the equilibrium of bank runs occurs when the final project payoff is bad.

The basic story is to bring an information idea to the banking economy subject to runs which is at the heart of the global games approach. In a bank run model with the perfectly observable final payoff, the multiplicity of equilibria can be seen as a consequence of the indeterminacy of a depositor's beliefs about the other's. The depositor can justifiably make any decision depending on what beliefs she chooses to hold. However, when there are some uncertainties about the project's final payoff, the depositors are no longer free to form any beliefs in their deliberations. This is because the information available to each depositor determines her beliefs about the final payoff and hence her decisions. Furthermore, knowing that the other is rational and also acts based on the fundamental information, a rational depositor is compelled to form the beliefs about the other's decision that are tied closely to the information. In other words, the fundamental information dictates what beliefs to hold, leaving no room for the indeterminacy of the beliefs or the multiplicity of equilibria.

To elaborate on the role of information in bank runs, I slightly revise the setup of the analytical framework discussed above. For expositional purpose, I assume that the final payoff $\tilde{R}$ is normally distributed with a mean $\bar{R}$ and a variance $\frac{1}{\alpha}$. Let us denote the two depositors Peter and Mary for the analysis below. The payoff for the two depositors hence becomes:

	Mary withdraws	Mary stays
Peter withdraws	0.5,0.5	1,0
Peter stays	0,1	$\frac{\tilde{R}}{2}, \frac{\tilde{R}}{2}$

At date 1, each depositor receives a private signal $\tilde{x}_j$ about the final payoff:

$$\tilde{x}_j = \tilde{R} + \varepsilon_j,\ j \in \{M, P\} \tag{1.1}$$

where the noise ε_j is also normally distributed with a mean 0 and a variance $\frac{1}{\beta}$. As shown in Morris and Shin (2001), without loss of generality, only one kind of strategy, a switching strategy, needs to be considered, where a depositor chooses to withdraw if and only if she observes a private signal $\tilde{x}_j$ below some threshold,

k:

$$s(\tilde{x}_j) = \begin{cases} \text{Withdraw} & \text{if } \tilde{x}_j \leqslant k, \\ \text{Stay} & \text{if } \tilde{x}_j > k. \end{cases} \tag{1.2}$$

To solve for the equilibrium threshold, with loss of generality, consider a case where Peter observes a signal $\tilde{x}_P$ equal to the threshold, k. Let us first compute his expected payoff when he chooses to stay, which is equal to:

$$\Pr(\text{Mary withdraws}|\tilde{x}_P = k) \times 0 + \Pr(\text{Mary stays}|\tilde{x}_P = k) \times E[\frac{\tilde{R}}{2}|\tilde{x}_P = k], \tag{1.3}$$

where $\Pr(\text{Mary withdraws}|\tilde{x}_P = k)$ and $\Pr(\text{Mary stays}|\tilde{x}_P = k)$ denotes Peter's belief of the probabilities that Mary withdraws and that Mary stays, respectively. $E[\frac{\tilde{R}}{2}|\tilde{x}_P = k]$ denotes Peter's belief about the final payoff. Notice that the information, $\tilde{x}_P$, serves two purposes: it not only signals information about the fundamentals, $\tilde{R}$, but more importantly, signals information about Mary's beliefs and action. Specifically, Peter's belief about the final payoff,

$$E[\frac{\tilde{R}}{2}|\tilde{x}_P = k] = \frac{1}{2}\,\frac{\alpha\,\bar{R} + \beta\,k}{\alpha + \beta}. \tag{1.4}$$

In addition, from Peter's point of view, since Mary also adopts the switching strategy, the probability that she withdraws is equal to the probability that she observes a signal $\tilde{x}_M$ below the threshold k:

$$\Pr(\text{Mary withdraws}|\tilde{x}_P = k) = \Pr(\tilde{x}_M \leqslant k|\tilde{x}_P = k), \tag{1.5}$$

Given Peter's own signal, he thinks that Mary's signal is normally distributed with a mean $\frac{\alpha\,\bar{R}+\beta\,k}{\alpha+\beta}$ and a variance $\frac{1}{\beta}+\frac{1}{\alpha+\beta}$. Therefore,

$$\begin{aligned}\Pr(\tilde{x}_M \leqslant k|\tilde{x}_P = k) &= \Pr\left(\frac{\tilde{x}_M - \frac{\alpha\,\bar{R}+\beta\,\tilde{x}_P}{\alpha+\beta}}{\sqrt{\frac{1}{\beta}+\frac{1}{\alpha+\beta}}} \leqslant \frac{k - \frac{\alpha\,\bar{R}+\beta\,\tilde{x}_P}{\alpha+\beta}}{\sqrt{\frac{1}{\beta}+\frac{1}{\alpha+\beta}}}|\tilde{x}_P = k\right) \\ &= \Phi\left(\sqrt{\frac{\alpha^2\,\beta}{(\alpha+\beta)\,(\alpha+2\,\beta)}}\,\left(k-\bar{R}\right)\right),\end{aligned} \tag{1.6}$$

and

$$\Pr(\text{Mary stays}|\tilde{x}_P = k) = 1 - \Pr(\text{Mary withdraws}|\tilde{x}_P = k). \tag{1.7}$$

Similarly, Peter's expected payoff if he withdraws is equal to:

$$\Pr(\text{Mary withdraws}|\tilde{x}_P = k) \times 0.5 + \Pr(\text{Mary stays}|\tilde{x}_P = k) \times 1. \tag{1.8}$$

In equilibrium, since Peter observes a signal equal to the threshold, he is indifferent between staying and withdrawing:

$$
\begin{aligned}
(1.9) \qquad & \Pr(\text{Mary withdraws}|\tilde{x}_P = k) \times 0.5 \\
& + \Pr(\text{Mary stays}|\tilde{x}_P = k) \times 1 \\
= \; & \Pr(\text{Mary withdraws}|\tilde{x}_P = k) \times 0 \\
& + \Pr(\text{Mary stays}|\tilde{x}_P = k) \times E[\frac{\tilde{R}}{2}|\tilde{x}_P = k],
\end{aligned}
$$

which can be reduced into

$$
(1.10) \qquad \Phi\left(\sqrt{\frac{\alpha^2\,\beta}{(\alpha+\beta)\,(\alpha+2\,\beta)}}\;\left(k-\bar{R}\right)\right) = \frac{\frac{\alpha\,\bar{R}+\beta\,k}{\alpha+\beta}-2}{\frac{\alpha\,\bar{R}+\beta\,k}{\alpha+\beta}-1}.
$$

This equation gives a unique solution of the threshold k. In the limit as the private information precision β tends to infinity, the threshold k tends to 3. That is, when each depositor observes the final payoff with only a very small noise, the equilibrium in the model of bank runs is unique: the bank run equilibrium occurs only when the realization of the final payoff is lower than 3; otherwise, the first-best equilibrium prevails. This example illustrates well that, in a bank-run situation, the fundamental information plays a key role in determining the equilibrium outcomes.

1.2.2. The Role of Information in the Prudential Regulation

Next, I illustrate the role of information in the prudential regulation of banks. The prudential regulation is often justified by the desire to protect ordinary bank depositors. Dewatripont and Tirole (1994) summarize this reasoning in the "representation hypothesis," which argues that bank depositors are "small and dispersed and thus need to be represented" by a regulator. Depositors' collective action problem in monitoring banks results from externalities such as free riding, lack of expertise, or the deposit insurance, which is provided in order to reduce the occurrences of bank runs. One prominent example of the prudential regulation is the capital requirement that determines the minimum amount of capital required to be held by banks for a certain amount of risky assets. Interestingly, the current capital requirement in most countries uses only accounting information disclosed by banks to measure their capital, suggesting the vital importance of accounting information in regulating banks.

I adapt the analytical framework discussed earlier to illustrate the role of information in the prudential regulation. To abstract from the issues of bank runs, I assume that the two depositors are fully insured by a regulator, the Federal Deposit Insurance Corporation (FDIC), which always repays the depositors at the face value of the deposits. For simplicity, I also assume that the final outcome $\tilde{R}$ is binary, $\tilde{R} \in \{4, 0\}$. At date 1, all parties observe a signal $\tilde{x}$ equal to the probability that the project succeeds and yields a payoff of 4. After the realization of the signal, the project can be liquidated at \$1. The time line of this revised model is as follows.

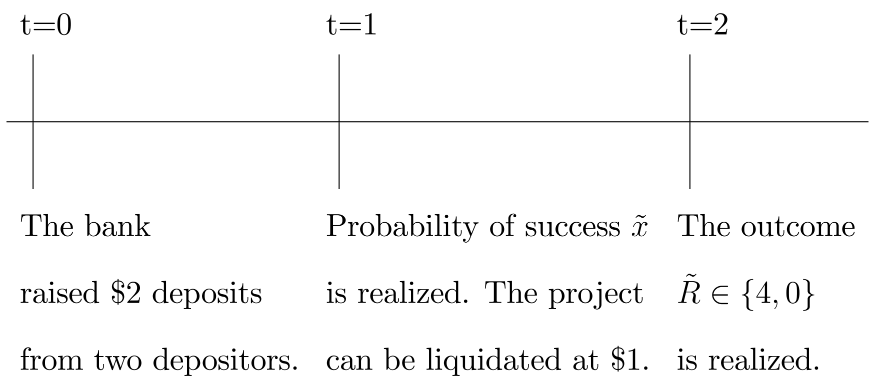


Figure 1.2: Time line.

It is easy to verify that the (ex post) optimal rule is to liquidate the project if and only if $\tilde{x} \leqslant 0.25$ because the \$2 of the initial investments sunk. To make a case for the prudential regulation, following the incomplete contracting approach by Dewatripont and Tirole (1994), I further assume that the liquidation decision at date 1 cannot be precisely specified ex ante. In this environment with incomplete contracts, the key challenge is that, the control right must be allocated such that the controlling party at date 1 has the private incentive to exert the liquidation decision in a socially optimal way. Let us first examine the incentive of the bank and the FDIC in liquidating the project. On one hand, the bank always prefers to continue the project, since the payoff from the liquidation is 0 (the liquidation value \$1 is lower than the face value of the deposits \$2) while the payoff from the continuation is always nonnegative (because of the limited liability). This observation provides a rationale for regulatory interventions: if the bank always has the control, it will liquidate the project less frequently than what is under the first-best (liquidate if $\tilde{x} \leqslant 0.25$). Therefore, it is sometimes necessary for a regulator to step in and liquidate a bad project (bank).

On the other, the FDIC's liquidation decision depends on the realization of the signal $\tilde{x}$. If the FDIC chooses to liquidate, its expected payoff is -\$1 (the liquidation value \$1 minuses the payments to the two depositors \$2). If the FDIC chooses to continue, its expected payoff is:

$$\underbrace{2 \times \tilde{x}}_{\text{Project succeeds}} + \underbrace{0 \times (1 - \tilde{x})}_{\text{Project fails}} - 2, \tag{1.11}$$

which gives $2\tilde{x} - 2$. Comparing the FDIC's payoffs in the two cases shows that the FDIC prefers to liquidate if $\tilde{x} \leqslant 0.5$ and to continue otherwise. This result suggests a pitfall in the intervention by the FDIC: if the FDIC is always granted the control of the liquidation decision, it will liquidate the bank more often than what implements the first-best (liquidate if $\tilde{x} \leqslant 0.25$). This is because the FDIC, as the representative of the depositors (debtholders), cannot fully internalize all the project gains in the case of success.

The model so far demonstrates that the unconditional control right to either the bank or the FDIC doesn't induce the socially optimal decision. It can be shown that the following allocating rule, $r(\tilde{x})$, that is contingent on the intermediate signal $\tilde{x}$ achieves the first-best:

$$r(\tilde{x}) = \begin{cases} \text{The FDIC has the control} & \text{if } \tilde{x} \leqslant 0.25, \\ \text{The bank has the control} & \text{if } \tilde{x} > 0.25. \end{cases} \tag{1.12}$$

It is straightforward to verify that $r(\tilde{x})$ achieves the first-best. When $\tilde{x} > 0.25$, the bank has the control and will choose to continue; when $\tilde{x} \leqslant 0.25$, the FDIC has the control and will choose to liquidate. That is, the project is liquidated if and only if $\tilde{x} \leqslant 0.25$, which exactly implements the first-best.

One interpretation of this allocating rule is the capital requirement policy. When a bank reports a profit (usually a signal that indicates strong future performance), the profit contributes to the bank's equity. As a result, the bank meets the capital requirement and is allowed to continue. However, when the bank reports a severe loss (usually indicating weak future performance), the loss impairs the bank's equity, triggering a violation of the capital requirement. Failure to meet the capital requirement grants regulators, such as the FDIC, rights to perform intervention, such as a reorganization, layoff or even liquidation.

1.3. Conclusion

This primer is designed to convey the importance and the relevance of studying the information disclosure by banking institutions. An application of the global games approach reveals that information plays a central role in determining the equilibrium outcomes in bank runs. Information sways the beliefs of short-term investors, which in turn shifts coordination outcomes. Information disclosed by banks is also a key source of information for the effective prudential regulation. Bad signals, such as poor performances shown in financial reports, trigger regulatory intervention, which helps to mitigate inefficiencies in banks' operations.

Although the two roles of information disclosure discussed in this primer are closely related to the features of banking institutions, it is important to point out that these roles can be linked back to the existing roles of information disclosure that have been investigated in the accounting and economics literature. The study of information in bank runs shares a similar spirit with the study of accounting disclosure and real effects (Kanodia, 2007). The key insight of the real effect approach is that accounting measures and disclosures have strong effects on firms' real decisions. The study of information in bank runs extends this insight to a banking setting where coordination among investors is of vital importance. Through coordinating investors' beliefs, information disclosure has a real effect in altering investors' investment decisions, which in turn determines the equilibrium outcomes in bank runs.

The role of information in the prudential regulation of banks also shares similarities with the stewardship role of accounting information that has been extensively studied in the agency and contracting theory (Lambert, 2001). In particular, the capital requirement for banks may resemble a debt covenant for a non-banking firm because both arrangements utilize accounting measures, and their violation can trigger a loss of control rights for shareholders (taken by the regulators in the former and the lenders in the latter). These similarities further encourage us to draw upon the insights from the debt covenant literature in order to better understand the capital requirement for banks. However, it is crucial to be aware of the distinctions between the two. A debt covenant is a private contract between a borrowing firm and a lender. The terms of this contract are agreed taking into consideration only the welfare of the parties involved and, therefore, depend on their idiosyncratic characteristics. In contrast, a capital requirement is a set of regulatory rules that are designed to maximize total social welfare and impose on all regulated banks indistinctively.

The potential research opportunities in the field of information disclosure and banking institutions are abundant. The prospective of such studies also seems promising and capable of generating key policy implications. It is thus encouraging that accounting literature has recently begun to step into this traditionally under-explored territory (Allen and Carletti, 2008; Plantin, Sapra, and Shin, 2008; Lu, Sapra, and Subramanian, 2011). This dissertation intends to expand this stream of research. Chapter 2 studies the interplay between public disclosure and liquidity risk stemming from runs by short-term investors, and shows that this interplay can contribute to the emergence of the shadow banking system. In this chapter, when the shadow and the traditional banks compete with each other, banks exploit the effect of public disclosure on liquidity risk to their advantage by employing public disclosure as an (additional) competition device. I find that competition with an opaque and fragile shadow bank can benefit the traditional bank, especially when the traditional bank is vulnerable to liquidity risk. The opacity and fragility of the shadow bank help to coordinate (higher-order) beliefs and actions of individual investors, which improve the management of the liquidity risk faced by the traditional bank. In the parallel banking equilibrium, the traditional bank induces the shadow bank to be both opaque and fragile by lowering its own disclosure precision.

Chapter 3 examines the use of accounting information in the prudential regulations and how the quality of accounting information affects banks' risk-taking decision in a competitive environment. In this chapter, accounting information is used to monitor whether banks meet the regulatory capital requirement. I find that sometimes an improvement in the quality of accounting information actually induces the banks to take more risk. The provision of high-quality accounting information reduces the probability that well-capitalized banks will be mistakenly forced to liquidate assets to meet capital requirement. Because of this improvement in the discriminating efficiency of the capital requirement policy, banks respond by competing more aggressively in the deposit market and the resulting increase in deposit costs motivates banks to take more risk. Concisely, the improvement of accounting information quality exacerbates the competition among banks, inducing banks to pursue more risky projects in order to maintain the profit margin.

The remainder of the dissertation is organized as follows. Chapter 2 examines the interaction between information and bank runs in the emergence of the shadow banking system. Chapter 3 studies the implication of accounting information quality in disciplining banks' risk-taking incentives. Chapter 4 concludes.

CHAPTER 2

Public Disclosure, Liquidity Risk, and the Parallel Banking System

ABSTRACT: This paper presents a model of shadow banking in which the shadow and the traditional banking systems share a symbiotic relationship. The analysis shows that competition with an opaque and fragile shadow bank can benefit the traditional bank, especially when the traditional bank faces liquidity risk stemming from collective actions by investors, such as runs. The opacity and fragility of the shadow bank help to coordinate (higher-order) beliefs and actions of individual investors, which improve the management of liquidity risk faced by the traditional bank. In the parallel banking equilibrium, the traditional bank induces the shadow bank to be both opaque and fragile by lowering its own disclosure precision.

2.1. Introduction

The last three decades have witnessed a profound transformation in the U.S. banking sector. Since the mid-1980s, a shadow banking system has emerged and developed rapidly in parallel to the traditional banking system. Shadow banking is referred to as "the business of borrowing and lending money outside the traditional banking system" (Cox, 2010). As of March, 2008, this shadow system had grown to a gross size of $20 trillion, which is significantly above the total liabilities of the traditional banking system (Pozsar et al., 2010). The shadow banking system is often criticized for its opacity (i.e., less public information disclosed) and fragility (i.e., vulnerable to runs and liquidity risk). The interplay between the public disclosure and the liquidity risk exposure arguably played a critical role in triggering the near collapse of the system itself and in bringing about the financial crisis of 2007-08 (Allen and Carletti, 2008; Plantin, Sapra, and Shin, 2008). The emergence of the shadow banking system has also greatly impacted the traditional banking system. In particular, growing competition from shadow banks substantially eroded traditional banks' profit margin (FCIC, 2011). By designing products that closely resemble bank accounts, shadow banks have attracted a substantial amount of consumers and businesses away from traditional banks.[1] Interestingly, in spite of this competitive pressure, the traditional banking system has chosen to coexist with the shadow banking system, leading to the parallel structure of the banking industry (Pozsar et al., 2010). Common intuition suggests the incumbent banks would enjoy entry barriers to limit competition (Dell'Ariccia et al., 1999). In

[1]For instance, shadow banks competed with traditional banks by launching money market mutual funds. These mutual funds, sometimes called "cash management accounts," resemble several salient features of bank accounts: fund sponsors implicitly promise a $1 stable net asset value; fund shares are withdrawable on demand; and fund holders are allowed to write checks (FCIC, 2011). As a result, investors consider these funds almost equivalent to deposits in banks, both in terms of security and liquidity.

this light, the sudden and almost unfettered growth of the shadow banking system seems puzzling.

In this paper, I argue that there exist strong incentives for the traditional banking system to encourage and facilitate the entry of the shadow banking system. I present a model in which accommodating the competing shadow banking system can be beneficial to the traditional banking system because of the induced choices made by the shadow banking system. These choices allow the traditional banking system to better manage its liquidity risk stemming from runs by individual investors.[2] This idea coincides with conjectures by some regulators and academicians. For instance, Plantin (2012) argues that there is a "symbiotic relationship" between traditional and shadow banking. I examine this symbiotic relation by addressing the root cause of liquidity risk, which is driven by collective actions of individual investors who fund these banks. While a bank's payoff depends critically on the beliefs and actions of individual investors, the bank can sway these beliefs and actions through its public disclosure decision in order to manage its exposure to liquidity risk. Public disclosure is extremely effective in coordinating individual beliefs because it is a source of information commonly available to all investors (Morris and Shin, 2002; Gao, 2008; Gigler, Kanodia and Venugopalan,

[2]A bank faces liquidity risk because of its role in conducting liquidity transformation and the associated liquidity mismatch (Diamond and Dybvig, 1983; Plantin, Sapra, and Shin, 2008). Banks often fund long-term illiquid assets via issuing liquid short-term claims, which are withdrawable at investors' requests. Therefore, when investors withdraw from a bank (decrease their investments), the bank would be forced to sell its illiquid assets at a loss to meet the withdrawal request, leading to a lower return on the remaining investment.

2013). Through coordinating individual beliefs, public disclosure has a real effect, in the spirit of Kanodia (2007), in altering individual investment decisions, which in turn determines the liquidity risk borne by the bank. In this regard, accommodating a competing bank and inducing this bank to make certain choices can be complementary to this real effect of public disclosure. In equilibrium, the shadow banking system is induced to disclose less precise public information (i.e., being opaque) and become more vulnerable to runs (i.e., being fragile), consistent with the observed empirical patterns. The traditional banking system prefers and induces these features by lowering its own disclosure precision.

Specifically, I examine an entry-deterrence model in which a shadow bank decides whether to enter a banking market occupied by an incumbent traditional bank. Each bank is endowed with an investment project and raises funds by competing for a common group of investors in a Bertrand competition. A salient feature of my setting is that both the banks and investors are subject to not only fundamental risk, which depends on the quality of projects, but also liquidity risk, which depends on the aggregate investment collectively made by the group of investors. In particular, the return on a bank's investment is lower when the aggregate investment in the bank decreases. Each individual investor relies on her own private information and public information disclosed by banks to determine her investments in the two banks. Summing individual investments gives rise to the total amount of investment made by each bank. A key assumption in my model is that the investment in a bank is not directly controlled by the bank itself but is driven by individual investment decisions.[3] Instead, the bank manages the bank-level investment by choosing a disclosure policy and its vulnerability to liquidity risk. These two choices in turn coordinate investment decisions at the individual level.

The presence of the liquidity risk has important implications for individual investment decisions. Since the return on investment decreases when the group of investors invests less, investors are confronted with a coordination problem. As a result, an investor adopts an investment strategy that matches not only the fundamentals but others' strategies as well. Because others' strategies are motivated by their own beliefs, the investor must conjecture the beliefs held by other investors, other investors' beliefs about others and even higher-order beliefs. The need to form higher-order beliefs alters the investor's use of information significantly. In deciding individual investments, public information is given disproportionately high weight that is incommensurate with its precision. This result of overweighting public information often appears in the literature of higher-order beliefs; the reason is that public information, as a common information source, is more effective in guessing beliefs of others (Morris and Shin, 2002). Departing from the previous literature, my paper highlights the effect of higher-order beliefs in the presence of

[3] I make this assumption to capture an important feature in the banking industry. Non-banking firms usually have almost perfect control over the size of their investments. Banks, however, do not enjoy the same degree of discretion. The reason is that, after a bank makes its investment, investors at the bank are allowed to withdraw their investments. These withdrawal requests in turn force the bank to liquidate some of its projects and shrink its investment size. It is these withdrawals (runs) that cause the bank to lose the absolute control over its investment.

two production technologies (banks) competing for individual investors. I find that the competition between banks reinforces the role of higher-order beliefs in determining individual investments. This is because the competition prompts investors to reallocate their investments between banks. When liquidity risk is present, it is of critical importance for an investor to predict others' reallocation decisions because these reallocations cause banks' returns to vary, which in turn influences the investor's own decision. Since others' reallocating decisions are motivated by their beliefs, the investor relies more on higher-order beliefs about others in determining her investment. This reinforcing effect of competition on higher-order beliefs yields two implications for individual use of information: (i) more intense competition makes the individual investment more sensitive to investors' information; (ii) competition also exacerbates each investor's overweighting public information.

These competition-driven results at the individual level are important in understanding the trade-off at the bank level. In managing its liquidity risk, each bank faces a trade-off between aligning the bank-level investment with fundamentals and reducing volatility in the investment. This trade-off hinges on variations of the investment at each bank which are in turn driven by individual investment decisions. The linkage between individual investment decision and the banks' trade-off provides an indirect channel for competition to influence the bank's payoff, in addition to the direct channel by which competition erodes profit margin. That is, competition alters (higher-order) beliefs and actions at the individual level, and thus indirectly affects the trade-off for the bank. It is this indirect effect of competition that drives my main result that the entry of the shadow bank might benefit the traditional bank. Specifically, competition with the shadow bank reinforces the role of higher-order beliefs, which improves the informational sensitivity of individual investment in the traditional bank. As each individual becomes more sensitive to her information, the aggregate of individual investments (that is, the investment in the traditional bank) becomes better aligned with the fundamentals. In other words, the entry of the shadow bank helps the traditional bank to manage its liquidity risk by strengthening the alignment between its investment and fundamentals. When managing liquidity risk is of a central concern for the traditional bank, the traditional bank chooses to induce the entry of the shadow bank, despite the direct effect that competition impairs profit margin.

The second key finding of my paper is that when the incumbent bank prefers and facilitates the entry of a competitor, the entrant bank is induced to be opaque and fragile so it is endogenously a "shadow" bank. Specifically, the entrant bank's disclosure hurts the traditional bank due to the effect of the disclosure on individual investments. As the entrant bank discloses more precise information, it prompts each investor to rely more on this public information, which has already been overweighted relative to its precision in the higher-order-beliefs context. Investors overreact to public information, which injects magnified noise in this public information into individual investments. This added impact of noise at the individual level injects more volatility into the bank-level investments of both the entrant and the traditional bank, which lowers the traditional bank's payoff. In addition, the traditional bank also prefers the entrant bank to be fragile and more vulnerable to liquidity risk. This is because the reinforcing effect of competition on higher-order beliefs, which is the primary driver for the traditional bank to prefer entry, depends critically on the entrant bank's exposure to liquidity risk. In fact, if the entrant bank were immune to any liquidity risk, its entry would not improve the traditional bank's payoff. Combined, the analyses suggest that the traditional bank has a strong incentive to induce the entrant bank to be opaque and fragile. Indeed, my model shows that the traditional bank is able to induce the opacity and fragility of the entrant bank by lowering its own disclosure precision, through the same indirect channel of affecting investment decisions at the individual level.

2.1.1. Literature Review

The extant literature in accounting and economics has examined extensively the effects of public disclosure in both the product and the financial market (Darrough and Stoughton, 1990; Wagenhofer, 1990; Diamond and Verrecchia, 1991; Gigler, 1994; Dye and Sridhar, 1995; Hwang and Kirby, 2000; Kanodia, Singh and Spero, 2005; Vives, 2006). Some recent papers examine different aspects of public disclosure. For example, Hughes and Williams (2008) examine uses of pre-production commitments by firms in oligopoly markets and disclosure of these commitments. Baiman and Baldenius (2009) examine the use of non-financial performance measures to facilitate coordination across multiple divisions. Bagnoli and Watts (2010) study a Cournot competition environment in which firms misreport production costs. Bertomeu, Beyer and Dye (2011) examine a setting in which firms' capital structure, voluntary disclosure decision and cost of capital are jointly determined. Beyer and Guttman (2012) examine the interdependencies between disclosure and investment decisions and find that firms' disclosure strategy is sometimes characterized by two distinct nondisclosure intervals. Arya and Mittendorf (2013) illustrate that in the presence of dual distribution channels, retailers may be more willing to disclose favorable information to induce entry by competitors, which improves the supply terms for these retailers. Gao and Liang (2013) show that disclosure by firms can reduce the informational feedback from the stock market to real decisions. My paper extends this literature of discretionary disclosure decisions to a banking context. The banking feature I consider is the liquidity mismatch between banks' assets and liabilities, which helps to provide liquidity to the economy while, at the same time, exposing banks themselves to liquidity risk (Diamond and Dybvig, 1983; Goldstein and Pauzner, 2005; Allen and Carletti, 2008; Plantin, Sapra, and Shin, 2008; Sapra, 2008). I find that the interaction between public disclosure and liquidity risk provides a novel role of public disclosure in competition that differs from previous literature. Specifically, in my setting, public disclosure is used to coordinate individual actions, which affects the aggregate liquidity risk borne by each bank. This change in the liquidity risk, in return, shifts competing strategies and competitive outcomes.

This paper is related to the literature on higher-order beliefs and global games (Morris and Shin, 2007). Several studies focus on the effect of public information in games with incomplete information. In a seminal work, Morris and Shin (2002) show that, in a Keynesian beauty contest economy, increasing public disclosure might reduce social welfare by magnifying volatility. In contrast, several other studies argue that more precise public disclosure is necessarily welfare improving (Angeletos and Pavan, 2004, 2007). There are also some studies in the accounting literature that apply the theory of higher-order beliefs and global games. For example, Plantin, Sapra, and Shin (2008) study sales of securitized loans in an illiquid market and show that mark-to-market accounting injects artificial volatility into prices, which distorts real decisions. In addition, Gao (2008) examines the market efficiency of accounting disclosure in a beauty-contest economy and finds that more precise public disclosure always improves market efficiency in spite of its commonality role. More recently, Gigler, Kanodia and Venugopalan (2013) study a setting in which customers are concerned about the firm's total wealth and find that although fair-value accounting provides more precise information, it also magnifies the volatility of the firm's income and wealth. This increase in the volatility in turn distorts the firm's assets allocating decision and makes the firm worse off. The study that is closest to mine is Angeletos and Pavan (2007), which examines the efficient use of information from a social welfare perspective. In particular, they focus on the optimal degree of coordination (i.e., the level of complementarity or substitutability) under which the equilibrium allocation would coincide with the socially efficient allocation. In a similar spirit, I study the use of information in a competitive environment. In my setting, two competing production technologies determine the degree of coordination and the information structure in order to achieve the best competitive outcome.

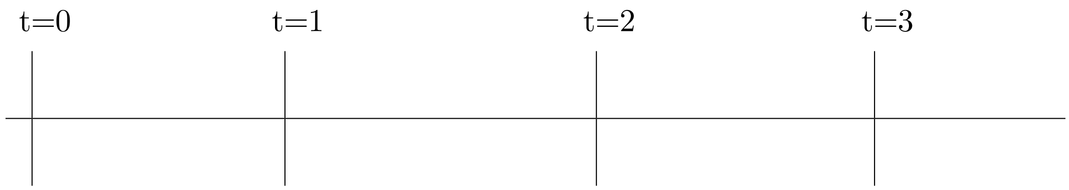
This paper is also related to the extensive literature on shadow banking and securitization. Some earlier studies argue that the business of shadow banking, by pooling and tranching risky assets, helps generate liquid and safe assets for uninformed investors, which alleviates the adverse selection problems in the banking market (Gorton and Pennacchi, 1990). Several other studies focus on the "regulatory arbitrage" obtained by the business of shadow banking (Acharya, Schnabl, and Suarez, 2013). According to these studies, banks conduct off-balance-sheet shadow banking activities in order to circumvent regulatory capital requirements. Some recent studies examine what might have caused the fragility and collapse of the shadow banking system in the 2007-08 crisis. Gennaioli, Shleifer and Vishny (2013), for example, argue that investors' negligence of tail risks contributed to the fragility of the shadow banking system, which would have been stable under rational expectations. Brunnermeier (2009) stresses that the liquidity mismatch between assets and liabilities, combined with runs by short-term investors, might serve as triggers for the meltdown of the shadow banking system (see also Shin, 2009; Gorton and Metrick, 2012). My paper is related to these studies in the sense that I also examine the fragility and opacity of the shadow banking system. Nevertheless, I depart from the literature by assuming that the shadow banking system has the discretion to choose its level of opacity and vulnerability to liquidity risk, in anticipation of competition with the traditional banking system. Therefore, in my setting, the opaque and fragile nature of shadow banking arises endogenously as a result of the competition.

The paper is organized as follows. In Section 2, I describe the main model and analyze the resulting equilibrium. Section 3 provides an extension of my model that has a competitive traditional banking system. Section 4 discusses the empirical implications of the results. Section 5 concludes the paper.

2.2. Model

2.2.1. Setup

I examine a four-date model in which an incumbent traditional bank, indexed by bank 1, occupies a banking market and a shadow bank, indexed by bank 2, decides whether to enter. At date 0, the traditional bank decides the precision of the information that it will disclose to the public, m_1. At date 1, the shadow bank makes the entry decision. Upon entering, the shadow bank chooses the precision of its disclosure, m_2, and the exposure to liquidity risk, a_2. At date 2, each investor receives public and private information on the quality of banks' projects and makes the investment decisions. Each bank thereafter invests these funds in a loan project. Finally, at date 3, the outcomes of the investments are realized. The time line of the model is shown below.



The traditional bank chooses the precision of public information, m_1.	The shadow bank makes the entry decision and chooses the precision of information, m_2, and the exposure to liquidity risk, a_2.	Public and private signals are realized. Investors decide the investments. Bank invests funds in a project.	The outcomes of the investments are realized.

Figure 2.1: Time line.

I now describe and explain the decisions and events at each date in more detail.

Date 0

At date 0, each bank is endowed with an investment project (a loan) that yields a stochastic per-unit return, R_i. The two banks finance the projects by competing for a common group of investors, indexed by the unit interval $[0, 1]$, in Bertrand competition. Each investor j's investment in the traditional bank is denoted as k_{1j}, and investment in the shadow bank is denoted as k_{2j}. Without loss of generality, when the entry of bank 2 is deterred, I set $k_{2j} \equiv 0$ and $R_2 \equiv 0$. I let $K_1 = \int_0^1 k_{1j} dj$

and $K_2 = \int_0^1 k_{2j} dj$ denote the aggregate level of investments in the two banks, respectively.

To account for the liquidity risk borne by the bank, following Plantin, Sapra, and Shin (2008), I assume that the return to the investment, R_i, is linear in an exogenous shock, θ_i, which represents the fundamentals of the bank's project, and the aggregate investment, K_i, such that:

$$R_i = 2\,(\theta_i + a_i\, K_i), \tag{2.1}$$

where $a_i \in [0, \frac{1}{2}]$ is publicly observable and interpreted as a measure of the bank's exposure to liquidity risk.[4] In Appendix A, I show that this linear reduced-form representation of the return can be derived from a model in which banks conduct liquidity transformation and incur liquidity risk. The random shock θ_i is normally distributed with mean $\bar{\theta} > 0$ and variance, $\frac{1}{q} > 0$. I assume that θ_1 and θ_2 are independent of each other. Following Morris and Shin (2002), I assume that investors' prior precision on the fundamentals, q, is sufficiently low such that investors have little prior knowledge about the fundamentals before receiving private and public information. I also assume that the fundamentals are not observable to either banks or investors until date 3.

[4]This is to ensure that the bank's payoff is concave in the investment, K_i. Otherwise, volatility in K_i would be desirable to the bank. This is also sufficient to make the equilibrium unique.

An important assumption about my model is that the investment return depends on the aggregate amount of investment by investors. In particular, the investment return is lower when the aggregate investment decreases. One can think of the decrease in the bank's investment as equivalent to investors' withdrawal of previous investments from the bank.[5] These withdrawals result in liquidity risk for the bank as a result of the liquidity mismatch between the bank's assets and liabilities: when investors withdraw from the bank (decrease their investments), the bank is forced to liquidate a portion of its illiquid project at a loss to meet the withdrawal request, leading to a lower investment return. When $a_i = 0$, the project is infinitely liquid so that the bank can always liquidate a portion of the project without liquidity losses to satisfy withdrawal requests. As a result, the investment return does not depend on the aggregate investment. When $a_i > 0$, the investment return is sensitive to the aggregate investment. The higher the a_i, the more illiquid is the bank's project. As the bank liquidates a portion of the project to meet investors' withdrawal requests, the bank incurs liquidity losses, which lower its investment return.

At date 0, the traditional bank decides the precision of the public signal of θ_1, denoted by $m_1 > 0$, which the bank will disclose to investors at date 2. Specifically,

[5] One can consider a modified setting in which before receiving any new information, investors make some initial investments, $\bar{K}$, in each of the two banks. Banks thereafter invest these funds in their own projects. Investors later receive new information on the banks' projects and the new information motivates investors to adjust (withdraw) their investments in banks. These withdrawals in turn cause banks to liquidate their illiquid projects and result in lower investment returns.

the public signal, z_1, is equal to:

$$z_1 = \theta_1 + \varepsilon_1, \tag{2.2}$$

where ε_1 is normally distributed, independent of θ_1, with mean 0 and variance $\frac{1}{m_1}$. I interpret m_1 as the precision of the public information disclosed by the traditional bank. I assume that the choice of m_1 is committed by the traditional bank.[6] It is also publicly observable by the shadow bank and investors. I also assume that to build an information system with the precision m_1, the traditional bank incurs a cost, $c_1(m_1)$, which is increasing and convex in m_1.[7]

Date 1

At date 1, the shadow bank decides whether to enter the banking market. Let a binary variable, $\Delta \in \{0, 1\}$, denote the shadow bank's entry decision, such that $\Delta = 1$ when the bank enters and $\Delta = 0$ otherwise. If the shadow bank chooses not to enter, it earns a payoff, $\overline{U}$. Otherwise, the shadow bank earns the investment proceeds after paying investors. I assume that $\overline{U}$ is sufficiently low such that the entry is not blockaded. Upon entering, the shadow bank makes two decisions: the precision of the public information that will be disclosed, m_2, and the exposure to

[6] A bank's ability to commit to a disclosure precision can either arise from the stickiness of disclosure or the installation of an information system upfront. In particular, Arya, Glover and Sivaramakrishnan (1997) show that building an imprecise information system can help firms to commit to disclose less information. Some empirical studies (Healy, Hutton and Palepu, 1999; Bushee, Matsumoto and Miller, 2003) find that disclosure decisions are often sticky and firms tend not to alter their earlier disclosure practices.

[7] The disclosure costs for the two banks are not essential to my results. They are employed only to guarantee an interior equilibrium. The main results are not affected qualitatively by costs.

liquidity risk, a_2. I assume that the choices of m_2 and a_2 are publicly observable by investors and committed by the shadow bank. Specifically, the shadow bank chooses the precision of the public signal z_2 about the fundamentals θ_2 such that

$$z_2 = \theta_2 + \varepsilon_2, \tag{2.3}$$

where ε_2 is normally distributed, independent of θ_2, with mean 0 and variance $\frac{1}{m_2}$. m_2 measures the precision of the public information. The shadow bank also incurs a cost, $c_2(m_2)$, which is increasing and convex in m_2. In addition, the shadow bank decides its exposure to the liquidity risk, a_2. In reality, the choice of a_2 may represent a set of actions taken by banks. For example, the shadow bank can achieve a level of liquidity risk exposure by investing in a portfolio of assets with different degrees of liquidity. I restrict the traditional bank from choosing its exposure to liquidity risk, a_1. I assume this asymmetric structure to capture the incremental regulation on traditional banks over shadow banks. In reality, traditional banks are under intensive regulatory oversights, such as liquidity reserve requirement, capital requirement, etc., and hence are severely restrained in taking liquidity risk; on the contrary, most prudential regulations do not extend to shadow banks, allowing shadow banks to choose the desired exposure to liquidity risk.[8]

[8]Timothy Geithner, the former Secretary of the Treasury, once commented that "a principal cause of the crisis was the failure to provide legal authority to constrain risk in this parallel banking system" (Geithner, 2010). Henry Paulson, the former Secretary of the Treasury also said "Compounding the problems at these financial institutions was a financial regulatory system that was archaic and outmoded" (Paulson, 2010). In fact, this view of the shadow banking system has been shared by many practitioners, government officials as well as academicians (Cox, 2010; Donaldson, 2010).

Date 2

At date 2, the two banks disclose the public signals, z_1 and z_2, in accordance with their choices of m_1 and m_2. Besides signals released by banks, each investor j also observes a pair of private signals, x_{1j} and x_{2j}:

$$\begin{aligned} x_{1j} &= \theta_1 + \eta_{1j}, \\ x_{2j} &= \theta_2 + \eta_{2j}, \end{aligned} \tag{2.4}$$

where the noises η_{1j} and η_{2j} are normally distributed, independent of θ_1 and θ_2, with mean zero and variance, $\frac{1}{n_1}$ and $\frac{1}{n_2}$, respectively. I also assume the noises are independent of each other across the population of investors. The pair of signals, x_{1j} and x_{2j}, are only privately observed by investor j. I also assume that n_1 and n_2 are large enough such that investors are sufficiently heterogeneous.

If the shadow bank enters, it competes with the traditional bank for investments from a common group of investors in Bertrand competition. I assume that a bank splits the investment return, R_i, equally with its investors.[9] Each individual

[9] My results remain valid qualitatively for other linear contracts in which the bank and investors share the investment proceeds proportionally. One may notice that under this assumption, investors become the equity holders of the bank. This assumption is often made in the literature of bank runs (Diamond and Dybvig, 1983; Goldstein and Pauzner, 2005). This is equivalent to assuming free entry within the traditional banking sector and the shadow banking sector. The bank's manager is offered a linear contract. After paying himself, the manager transfers all the remaining investment profits to investors so as to maximize investors' welfare. Otherwise, another competitor can offer a slightly higher return to investors and attract investors away. As a result, investors become equity holders of the bank. In reality, most investors in shadow banks are indeed equity holders of these banks. This is because, a majority of the shadow banking system is financed through issuing money market mutual funds to investors, who are ultimately equity holders of these funds (Pozsar et al., 2010). As for traditional banks, investors in the subordinated debts and equities are also close to be equity holders. These investors are of great

investor j's investments in the two banks, $\{k_{1j}, k_{2j}\}$, are given by:

$$
\begin{aligned}
k_{1j} &= E_j[\frac{1}{2}R_1] - b\,E_j[\frac{1}{2}R_2], \\
k_{2j} &= E_j[\frac{1}{2}R_2] - b\,E_j[\frac{1}{2}R_1],
\end{aligned}
\tag{2.5}
$$

where $b \in (0, 1]$ denotes the intensity of competition and $E_j[\cdot]$ denotes investor j's expectation of investment returns conditional on her information set. That is, an individual investor's investment in bank i is increasing in her share of the expected return of bank i and decreasing in her share of the expected return of the other. In Appendix B, I show that this reduced-form representation of individual investments can be derived from a model assuming that an investor either has a CARA utility or incurs a quadratic investment cost.

After raising funds for the aggregate investment, bank i invests these funds in its project. I assume that the bank incurs a convex cost in monitoring the project, $C_i(K_i) = \frac{1}{2}\,K_i^2$. In reality, this cost can arise because of banks' activities in monitoring borrowers, servicing mortgages, and supervising projects, etc. (see Diamond (1984) for a discussion of the costly monitoring of loan contracts by

importance in financing the traditional banking system. For example, according to a report issued by the Basel Committee (2003), subordinated debts issued by banks represent more than 50% of banking assets worldwide. This linear profit sharing assumption can also be seen as an approximation of the underlying optimal contract. Linear contracts are widely used in practice. Although not necessarily optimal, linear contracts often closely approximate the performance of optimal contracts. For example, Bose et al. (2011) examine the performance of linear contracts in a board class of economic settings and find that a linear contract can secure for the principal at least 90% of the proceeds obtained in a fully optimal contract as long as the agent is sufficiently productive.

banks). The payoff function for bank i is then given by:

$$U_i(K_i) = \frac{1}{2}\, R_i\, K_i - \frac{1}{2}\, K_i^2 - c_i(m_i), \tag{2.6}$$

where $\frac{1}{2}\, R_i\, K_i$ is bank i's share of investment profits.

Date 3

The investment returns are realized and the proceeds from the projects are distributed to the banks and investors.

2.2.2. The Equilibrium Definition

I consider a perfect rational expectation equilibrium defined as follows:

Equilibrium Definition: *I consider a perfect rational expectation equilibrium that satisfies:*

(1) *At date 2, each investor chooses the optimal investments conditional on her information set;*

(2) *At date 1, the shadow bank chooses the entry decision as well as decisions on disclosure and liquidity risk to maximize its payoff;*

(3) *At date 0, the traditional bank chooses the precision of public disclosure to maximize its payoff.*

I solve the equilibrium by backward induction. At each date, I characterize the equilibrium and derive its properties.

2.2.3. The Equilibrium at Date 2

I first solve for each investor's optimal investments conditional on the two banks' actions and the available information set, $I_j = \{x_{1j}, x_{2j}, z_1, z_2\}$, at date 2. An individual investor forms a conjecture on equilibrium investments, which is linear in all signals in the information set. The investor then decides her own optimal investments given this conjecture. In a rational expectation equilibrium, the investor's conjecture must be consistent with the optimal individual investments in equilibrium. Therefore, comparing the coefficients in the linear conjecture with the coefficients in the resulted optimal individual investment determines the unknown coefficients in the investor's conjecture. I further demonstrate that this linear equilibrium is the unique equilibrium using the higher-order-belief approach developed in Morris and Shin (2002). I summarize the individual investments in equilibrium, $\{k^*_{1j}(\cdot), k^*_{2j}(\cdot)\}$, in the following proposition.

Proposition 1. *Given the traditional bank's decision, m_1, and the shadow bank's decisions, $\{m_2, a_2, \Delta\}$, there exists a unique equilibrium of individual investments in which,*

(1) *When shadow bank enters the market ($\Delta = 1$), each investor makes the optimal investments $\{k^*_{1j}(\cdot), k^*_{2j}(\cdot)\}$ that satisfy*

$$k^*_{ij} = (\beta^*_i\, x_{ij} + \gamma^*_i\, z_1) - b\,(\omega^*_i\, z_k + \lambda^*_i\, x_{kj}) + h^*_i,\ \ (i,k) \in \{(1,2),(2,1)\}, \tag{2.7}$$

where:

$$\text{(2.8)} \qquad \begin{aligned} \beta_i^* &= \frac{\{q+m_i+[1-(1-b^2)a_k]n_i\}n_i}{T_i}, \\ \gamma_i^* &= \frac{\{[1-(1-b^2)a_k](q+m_i)+[1-(1-b^2)a_k(2-a_k)]n_i\}m_i}{\{1-a_k-a_i[1-(1-b^2)a_k]\}\,T_i}, \\ \omega_i^* &= \frac{\{q+m_k+[1-(1-b^2)a_ia_k]n_k\}m_k}{\{1-a_k-a_i[1-(1-b^2)a_k]\}\,T_k}, \\ \lambda_i^* &= \frac{(q+m_k+n_k)n_k}{T_k}, \\ T_i &= (q+m_i)^2+(2-a_i-a_k)(q+m_i)n_i \\ &\quad +\{1-a_k-a_i[1-(1-b^2)a_k]\}n_i^2; \end{aligned}$$

and the constant h_i^* is given in the proof.

(2) *When the entry of the shadow bank is deterred ($\Delta = 0$), each investor makes the optimal investments $k_{2j}^{**}(m_1, m_2, a_2) = 0$ and $k_{1j}^{**}(m_1)$ that satisfy*

$$\text{(2.9)} \qquad k_{1j}^{**} = \beta_1^{**}\, x_{1j} + \gamma_1^{**}\, z_1 + h_1^{**},$$

where:

$$\text{(2.10)} \qquad \begin{aligned} \beta_1^{**} &= \frac{n_1}{q+m_1+(1-a_1)n_1}, \\ \gamma_1^{**} &= \frac{m_1}{(1-a_1)[q+m_1+(1-a_1)n_1]}. \end{aligned}$$

and the constant h_i^{**} is given in the proof.

Proposition 1 characterizes each individual investor's use of information in determining her investments. My results show that each investor chooses an investment strategy that is linear in all signals in the information set. In particular, the investment in a bank is strictly increasing in the signals of the bank itself and decreasing in the signals of the other. Furthermore, relative to the private ones, public signals are given disproportionately high weights that are incommensurate with their respective precision.[10] To see this, I rewrite the individual investment in the traditional bank as:[11]

$$k^*_{1j} = \Gamma_1(E_j[\theta_1|z_1, x_{1j}] + \Phi_1(z_1 - x_{1j})) - \Gamma_2(E_j[\theta_2|z_2, x_{2j}] + \Phi_2(z_2 - x_{2j})), \tag{2.11}$$

where $\Gamma_1, \Gamma_2, \Phi_1, \Phi_2$ are four positive constants. The above equation illustrates that public information has an additional impact on individual investments when the liquidity risk is present. In addition to the information role of signals in forming the conditional expectations, there are two additional terms that assign positive weights to the public signals z_1 and z_2 and negative weights to the private ones x_{1j} and x_{2j}. Investors overuse public information due to the liquidity risk exposure and the need to form higher-order beliefs. Recall that the presence of the liquidity risk causes the investment return for an individual to be lower when others

[10]This result often shows up in the higher-order belief literature (e.g., Morris and Shin, 2002; Angeletos and Pavan, 2004; Gao, 2008).

[11]This is similar to the derivation in Morris and Shin (2002). I show only the case when q is close to zero.

invest less. This renders a strategic complementarity between individual investments and forces each individual to choose an investment strategy that matches the investments of others. Since others' investments are motivated by their beliefs, each individual must take accounts of the beliefs held by other investors, others' beliefs about others and even higher-order beliefs. Public information is of extra importance in guessing higher-order beliefs because it is used by every individual in her decisions and hence can serve as a better predictor of others' beliefs. As a result, each individual assigns to public signals higher weights than the weights given by the Bayesian updating.

I also examine how individual investments are affected by the intensity of the competition between the traditional and the shadow bank as summarized in the corollary below.

Corollary 2. *Given $0 < a_1, a_2 < \frac{1}{2}$ and $0 < b < 1$, when the intensity of the competition b increases, the following holds:*

(1) *Individual investors become more sensitive to all signals,*

$$\frac{\partial \beta_i^*}{\partial b}, \frac{\partial \gamma_i^*}{\partial b}, \frac{\partial \omega_i^*}{\partial b}, \frac{\partial \lambda_i^*}{\partial b} > 0,\ i \in \{1, 2\}; \tag{2.12}$$

(2) *The additional weights on public signals increase,*

$$\frac{\partial \Phi_i}{\partial b} > 0,\ i \in \{1, 2\}. \tag{2.13}$$

Corollary 2 suggests that as the competition becomes more intense, investors become more sensitive to information, assigning larger weight to both public and private signals in making investment decisions. In addition, competition also exacerbates each investor's overweighting public information. These results arise because the competition between banks reinforces the role of higher-order beliefs in determining individual investments. Specifically, the competition prompts investors to reallocate investments between banks. When liquidity risk is present, it is of critical importance for an investor to predict others' reallocation decisions because these reallocations cause banks' returns to vary, which in turn influences the investor's own decision. Since others' reallocating decisions are motivated by their beliefs, the investor relies more on higher-order beliefs about others in determining her investment. This reinforcing effect of competition on higher-order beliefs yields two implications for individual use of information. First, each investor becomes more sensitive to her information, which helps herself to better second-guess others' beliefs. Second, each investor overweights public information even more since public information is more effective than the private one in conjecturing others' beliefs.

2.2.4. The Equilibrium at Date 1

At date 1, the shadow bank decides whether to enter the banking market. Upon entering, the shadow bank also decides the precision of public information, m_2, and the exposure to liquidity risk, a_2. To solve for the shadow bank's decisions, I substitute investors' investments in equilibrium into banks' payoffs. Let Π_1 and Π_2 denote the traditional bank and the shadow bank's payoffs given the optimal investments respectively. I first summarize the result regarding the entry of the shadow bank in the proposition below.

Proposition 3. *There exists a threshold* $0 < \hat{a} < \frac{1}{2}$*, such that,*

(1) *When* $a_1 < \hat{a}$*, the shadow bank is deterred from entry, as long as the disclosure cost for the traditional bank is not too high;*[12]

(2) *When* $a_1 > \hat{a}$*, the traditional bank always accommodates the shadow bank's entry.*

Proposition 3 suggests that the liquidity risk borne by the traditional bank plays an important role in determining the entry of the shadow bank. When the traditional bank's exposure to liquidity risk is low (i.e., $a_1 < \hat{a}$), the traditional bank is better off when it deters the shadow bank from entry. When the traditional bank is highly vulnerable to liquidity risk (i.e., $a_1 > \hat{a}$), the traditional bank always chooses to accommodate the entry of the shadow bank. It is important to notice that the traditional bank's decision to accommodate entry is not due to the prohibitively high cost of deterrence, which is often the case in prior studies (see Chapter 8, Tirole, 1988, for a comprehensive review). In fact, the traditional bank

[12]When the disclosure cost is sufficiently high, the traditional bank will also choose to accommodate entry for $a_1 < \hat{a}$. The reason is different from the case for $a_1 > \hat{a}$. In this case, the traditional bank accommodates entry because the cost to deter entry is too high; the traditional bank still prefers to deter entry. However, in the case of $a_1 > \hat{a}$, the traditional bank actually benefits from the entry of the shadow bank.

is better off when it shares the banking market with the shadow bank than when it deters entry. There is a "symbiotic relation" between the traditional bank and the shadow bank, especially when the traditional bank is sufficiently vulnerable to liquidity risk.

To explain the intuition behind this result, I rewrite bank i's expected payoffs as follows:[13]

$$
\begin{aligned}
\Pi_i &= \frac{1}{2}\,E[R_i\,K_i] - \frac{1}{2}\,E[K_i^2] \\
&= Cov(\frac{1}{2}R_i, K_i) - \frac{1}{2}Var(K_i) \\
&= Cov(\theta_i + a_i\,K_i, K_i) - \frac{1}{2}Var(K_i) \\
&= \underbrace{Cov(\theta_i, K_i)}_{\text{Procyclicality}} - \frac{1}{2}(1-2a_i)\,\underbrace{Var(K_i)}_{\text{Volatility}}.
\end{aligned} \tag{2.14}
$$

The first component, $Cov(\theta_i, K_i)$, in equation (2.14) is the covariance between the fundamentals and the aggregate investment. It shows that the bank prefers to align the aggregate investment in its project with the fundamentals. Intuitively, when the fundamentals improve, the bank prefers to induce more investments from individual investors; however, when the fundamentals deteriorate, the bank benefits from a decrease of investments by investors.[14] For convenience, I denote

[13]Notice that I drop a few terms concerning first-order moments (i.e., terms related to the mean of the fundamentals, $\bar{\theta}$). This is because when the prior precision of the fundamentals, q is sufficiently low (close to zero), these first-order moments take only very small weights in a bank's payoff, compared to the weights of second-order moments.

[14]This force is similar to Allen and Gale (1998) which shows that efficient and inefficient bank runs can help to achieve the first-best allocation by producing the right risk contingencies.

this component as the *procyclicality.* The second component in equation (2.14), $Var(K_i)$, is the volatility in the bank's investment. It shows that the bank is averse to volatility in the aggregate investment. The aversion to volatility arises because of the convex monitoring cost borne by banks, which makes the bank's payoff concave in the aggregate investment. For convenience, I denote this component as the *volatility.* It is important to notice that the aggregate investment is not directly controlled by banks but is driven by individual investment decisions. Instead, banks manage aggregate investment indirectly by choices of public disclosure and liquidity risk.

Equation (2.14) shows that the bank's payoff increases with the procyclicality and decreases with the volatility, given $a_i < \frac{1}{2}$. Moreover, the relative weight on the volatility, $\frac{1}{2}(1-2a_i)$, is strictly decreasing in bank i's exposure to the liquidity risk, a_i. This is because an increase in the liquidity risk exposure raises the convexity of the bank's payoff in the investment which makes the bank less averse to the volatility in K_i. Specifically, the gross proceeds from the bank's project depend on K_i in two ways. First, an increase in the investment expands the size of the bank's project. Second, an increase in the investment also raises the per-unit project return, $R_i = 2\,(\theta_i + a_i\,K_i)$, due to the presence of liquidity risk. Recall that the bank faces liquidity risk because liquidating illiquid assets causes losses to the bank. Therefore, increasing the bank's investment allows the bank to liquidate fewer amounts of illiquid assets, which saves the liquidation losses and boosts the return of the investment. These two effects of K_i on the bank's project proceeds are complementary to each other, resulting in the convexity of the bank's payoff in K_i. When the bank's exposure to liquidity risk a_i increases, this convexity is even stronger, since an increase in the bank's investment boosts the investment return with a larger magnitude. As the bank's payoff becomes more convex, the bank is less averse to volatility in K_i, making the relative weight on volatility decrease in the bank's exposure to liquidity risk.

I now explain how the trade-off between the procyclicality and the volatility determines the net effect of the shadow bank's entry on the payoff of the traditional bank. As characterized in Corollary 2, competition makes individual investments more sensitive to investors' information and exacerbates overweighting public information. These two changes in individual investments affect both the volatility and the procyclicality of the traditional bank. On one hand, as each individual becomes more sensitive to her information, this reinforces the covariance between individual investments and the fundamentals, $Cov(\theta_1, k_{1j})$. At an aggregate level, this improvement in informational sensitivity helps to better align the aggregate investment of the traditional bank with the fundamentals of its project (i.e., increase $Cov(\theta_1, K_1)$), which increases the procyclicality. On the other hand, the volatility of the traditional bank also increases. This is because as an investor responds to changes in her signals more sensitively, her investments also vary with a greater magnitude. Moreover, the entry of the shadow bank also exacerbates investors' overweighting public information. This further raises the volatility of the traditional bank by magnifying the impact of the public information noise on the aggregate investment.

The net effect of the shadow bank's entry on the traditional bank's payoff is determined by comparing the gain in the procyclicality with the increase in the volatility. When the liquidity risk exposure of the traditional bank is sufficiently high (i.e., $a_1 > \hat{a}$), the relative weight on the volatility, $\frac{1}{2}(1 - 2a_1)$, is small and the procyclicality component dominates. This encourages the traditional bank to accommodate the entry of the shadow bank in order to obtain the gain in the procyclicality. However, when the liquidity risk exposure for traditional bank is low, the volatility component takes a large weight. As a result, the volatility component dominates and motivates the traditional bank to deter entry in order to avoid the associated increase in the volatility.

Perhaps a more illuminating intuition about why the traditional bank prefers entry is obtained by considering a benchmark case in which the traditional bank is the monopoly and has direct control over its investment. Thus in this benchmark, the bank-level investment is no longer plagued by the coordination problem among individual investors. The traditional bank determines the bank-level investment K_1, contingent on its own signal z_1, to maximize its expected payoff:

$$E[\frac{1}{2} R_1 K_1 - \frac{1}{2} K_1^2 | z_1]. \tag{2.15}$$

Solving the first order condition gives the optimal investment K_1^* as:

$$K_1^* = \frac{E[\theta_1|z_1]}{1-2\,a_1} = \frac{m_1 z_1 + q\bar{\theta}}{(1-2\,a_1)(m_1+q)} = \frac{m_1(\theta_1+\varepsilon_1)+q\bar{\theta}}{(1-2\,a_1)(m_1+q)}, \tag{2.16}$$

where the sensitivity of the traditional bank's investment to the fundamentals θ_1 is $\frac{m_1}{(1-2\,a_1)(m_1+q)}$. On the other hand, when the traditional bank's investment is driven by individual investments as in my setting, this sensitivity is determined by the sum of the weights on the information z_1 and x_{1j}:

$$\beta_1^{**} + \gamma_1^{**} = \frac{m_1 + (1-a_1)n_1}{(1-a_1)[m_1+(1-a_1)n_1+q]} < \frac{m_1}{(1-2\,a_1)(m_1+q)}, \tag{2.17}$$

for q is sufficiently small. Therefore, equation (2.17) shows that when the traditional bank controls its investment by itself, the investment is more responsive to information and the fundamentals than when the bank-level investment is driven by individual investments. An individual investor is less sensitive to information than the traditional bank would prefer because she fails to internalize all the gains and losses associated with changing her investment: the investor's change of investment alters the investment return and hence affects other investors' payoff as well. In this light, Corollary 2 suggests that the traditional bank can boost informational sensitivity in individual investments towards its preferred level by accommodating the entry of the shadow bank. Indeed, when the traditional bank's exposure to liquidity risk is sufficiently high (i.e., a_1 is high), changes of individual investments have a large impact on the investment return. Hence there are a great number of gains and losses that individual investors fail to internalize, making investors even less sensitive to information compared to the level preferred by the traditional bank. As a result, the traditional bank decides to induce the entry of the shadow bank, even though competition impairs profit margin.

When the shadow bank enters, I also characterize how its decisions of public disclosure and liquidity risk in equilibrium are contingent on the traditional bank's choice of public disclosure, which is summarized in the proposition below.

Proposition 4. *When the shadow bank enters (i.e., when a_1 is sufficiently large), and private precision, n_1 and n_2 are sufficiently large, there exist two thresholds, $0 < \hat{b}_1, \hat{b}_2 < 1$, such that, in equilibrium,*

(1) *If $b > \hat{b}_1$, the shadow bank's exposure to liquidity risk $a_2^*(m_1)$ is strictly decreasing in the traditional bank's precision of public information (i.e., $\frac{\partial a_2^*}{\partial m_1} < 0$);*

(2) *If $b > \hat{b}_2$, the shadow bank's precision of public information $m_2^*(m_1)$ is strictly increasing in the traditional bank's precision of public information (i.e., $\frac{\partial m_2^*}{\partial m_1} > 0$).*

Proposition 4 suggests that when the competition between the two banks is sufficiently intense, the traditional bank's disclosure precision is a strategic substitute to the shadow bank's decision of liquidity risk exposure and a strategic complement to the shadow bank's decision of disclosure precision.

I first explain the substitute relation between the disclosure decision by the traditional bank and the liquidity risk decision by the shadow bank. The disclosure by the traditional bank amplifies the volatility of the shadow bank while leaving the shadow bank's procyclicality unchanged. The procyclicality of the shadow bank is not affected because of the independence between the fundamentals θ_1 and θ_2.[15] Intuitively, the disclosure by the traditional bank is not helpful in aligning the investment of the shadow bank with its fundamentals when the two banks' fundamentals are uncorrelated. However, the volatility of the shadow bank increases for two reasons. First, as the disclosure by the traditional bank becomes more precise, each individual becomes more sensitive to this public information in making her investments in both the traditional bank and the shadow bank. This increase in the informational sensitivity in turn raises the volatility of the aggregate investment in the shadow bank. Second, the volatility of the shadow bank is further magnified due to investors' overreaction to public information in the higher-order-belief context. Specifically, as the public disclosure by the traditional bank becomes more precise, this information is also used more by investors in estimating the fundamentals. Therefore, knowing that others use the public information more, an individual will assign even larger weight to the public information since this information is more effective in second-guessing others' actions. As the public information is further overweighted relative to its precision, this magnifies

[15] I numerically examine a model with two correlated fundamentals and find that my results hold qualitatively for a wide range of parameters.

the impact of the public information noise on the investment in the shadow bank, which injects additional volatility.

The increase in the volatility of the shadow bank affects the shadow bank's choice of liquidity risk exposure in two ways. On one hand, it forces the shadow bank to increase its liquidity risk exposure in order to reduce the relative weight on the volatility component, which helps to alleviate the damage by the increase in the volatility. I call this effect a *weighting effect*. On the other hand, recall that more public disclosure amplifies volatility because it exacerbates investors' overreaction to public information, due to the presence of liquidity risk. This observation suggests that the shadow bank can reduce its exposure to liquidity risk, which dampens investors' overreaction and alleviates the increase in the volatility. I call this effect an *overreaction effect*. The relation between m_1 and a_2 is determined by the trade-off between the strategic complementarity induced by the weighting effect and the strategic substitutability induced by the overreaction effect. In particular, competition plays a critical role in weighting this trade-off because competition exacerbates investors' overweighting public information. When the competition is sufficiently intense (i.e., $b > \hat{b}_1$), the issue of overweighting public information becomes a central concern for the shadow bank, forcing the bank to reduce its liquidity risk exposure to dampen investors' overreaction. The overreaction effect dominates and leads to the strategic substitutability between m_1 and a_2.

The intuitions for the relation between the two banks' disclosure can be gleaned similarly. Observe that the disclosure decision of the traditional bank has no direct effect on that of the shadow bank ($\frac{\partial^2 \Pi_2}{\partial m_1 \partial m_2} = 0$), because of the independence between the fundamentals θ_1 and θ_2.[16] In my model, the traditional bank's disclosure decision m_1 influences the shadow bank's disclosure decision m_2 indirectly through affecting the shadow bank's liquidity risk a_2. Specifically, notice first that when b is large, m_2 and a_2 are strategic substitutes to each other, which is similar to the relation between m_1 and a_2. Therefore, as the precision of the traditional bank's public information deteriorates, the shadow bank is motivated to take more liquidity risk (the strategic substitutability between m_1 and a_2), which in turn induces it to disclose less precise information (the strategic substitutability between a_2 and m_2). Overall this chain of reasoning results in the strategic complementarity between the two banks' disclosure decisions.

2.2.5. The Equilibrium at Date 0

In this section, I solve for the traditional bank's disclosure decision, m_1, at date 0. As suggested by Proposition 3, when the traditional bank's liquidity risk exposure is large ($a_1 > \hat{a}$), the traditional bank prefers and encourages the entry of the shadow bank. When the liquidity risk exposure of the traditional bank is

[16] I check the robustness of my results by examining a model with correlated fundamentals. It is analytically intractable, but the numerical analysis suggests that when the fundamentals are correlated positively, the cross-partial derivative $\frac{\partial^2 \Pi^2}{\partial m_1 \partial m_2} > 0$, which strengthens the strategic complementarity between m_1 and m_2 as shown in my current setting.

small ($a_1 < \hat{a}$), the traditional bank deters entry. In accordance with this result, I examine the decision of the traditional bank separately for the case when it accommodates the entry and the case when it deters.

Accommodation Case. In this section, I examine the traditional bank's disclosure decision when it accommodates entry. Before I fully characterize the equilibrium, I describe how the payoff of the traditional bank depends on the decisions of the shadow bank. This helps me to better explain the disclosure decision by the traditional bank in equilibrium. I summarize the results in the lemma below.

Lemma 5. *If the traditional bank accommodates the entry of the shadow bank,*

(1) *There exists a threshold, $\hat{a}(b) > 0$, such that, for $a_1 > \hat{a}(b)$, the traditional bank's payoff is strictly increasing in the shadow bank's exposure to liquidity risk,*

$$\frac{\partial \Pi_1}{\partial a_2} > 0; \tag{2.18}$$

(2) *The traditional bank's payoff is strictly decreasing in the shadow bank's disclosure precision,*

$$\frac{\partial \Pi_1}{\partial m_2} < 0. \tag{2.19}$$

Lemma 5 suggests that the traditional bank prefers the shadow bank to be both fragile (high a_2) and opaque (low m_2). I first explain why a higher liquidity risk taken by the shadow bank might benefit the traditional bank. The entry of the shadow bank reinforces the role of higher-order beliefs. As the shadow bank takes on more liquidity risk, it becomes more important for the individual to form higher-order beliefs since the per-unit investment return is more sensitive to the aggregate investments. This reinforcing effect of a_2 on higher-order beliefs benefits the traditional bank in a way similar to the intuition in Proposition 3. Concisely, the increase of a_2 makes investors more sensitive to information, which benefits the traditional bank since the equilibrium level of the informational sensitivity is lower than the level preferred by the traditional bank. Therefore, when the liquidity risk exposure of the traditional bank is sufficiently high (i.e., $a_1 > \hat{a}(b)$), the traditional bank prefers the shadow bank to take more liquidity risk. I now explain why the traditional bank also prefers the shadow bank to be opaque. This is due to the concern of reducing the volatility, similar to the discussions in Proposition 4. In short, the more precise disclosure by the shadow bank increases the sensitivity of investors to this public information and exacerbates the overweighting of the public information, both of which cause the aggregate investment in the traditional bank to be more volatile. Therefore, the traditional bank prefers the shadow bank to disclose less to avoid the associated increase in volatility.

The traditional bank's preference for the entry of an opaque and fragile shadow bank plays a central role in shaping its disclosure decision. To better characterize the properties of the equilibrium, I consider a benchmark case in which the traditional bank's disclosure decision is unobservable to the shadow bank.[17] Therefore, in the benchmark the shadow bank's decisions cannot be contingent on the traditional bank's actual disclosure decision. Comparing banks' equilibrium decisions in my model with those in the benchmark helps to better understand how the competition between the traditional and the shadow bank shapes the characteristics of these two banks. I summarize the comparison results in the proposition below.

Proposition 6. *When the shadow bank enters the market (a_1 is sufficiently large), the private precision n_1 and n_2 are sufficiently large, and $b > \max(\hat{b}_1, \hat{b}_2)$, the two banks' decisions in equilibrium $\{m_1^*, m_2^*, a_2^*\}$ and banks' decisions in the unobservable benchmark $\{m_1^c, m_2^c, a_2^c\}$ satisfy:*

(1) *The traditional bank discloses less precise public information than in the benchmark,*

$$m_1^* < m_1^c; \tag{2.20}$$

(2) *The shadow bank discloses less precise public information and takes more liquidity risk than in the benchmark,*

$$m_2^* < m_2^c \text{ and } a_2^* > a_2^c. \tag{2.21}$$

[17] This benchmark was suggested by Tirole (1988). Tirole defines the equilibrium in which the first mover's actions are not observed by the second mover as an "open-loop solution" and the one in which the first mover's actions are observed by the second mover as a "close-loop solution."

Proposition 6 suggests that when the traditional bank accommodates entry, the entrant is induced to be both opaque (low m_2) and fragile (high a_2). However, inducing the opacity and fragility of the shadow bank is costly to the traditional bank, which forces it to lower its own disclosure transparency. To see this, I rewrite the first-order condition on m_1 as follows:

$$\frac{d\Pi_1}{dm_1} = \frac{\partial \Pi_1}{\partial m_1} + \frac{\partial \Pi_1}{\partial m_2}\frac{\partial m_2^*}{\partial m_1} + \frac{\partial \Pi_1}{\partial a_2}\frac{\partial a_2^*}{\partial m_1}. \tag{2.22}$$

The first term captures the traditional bank's disclosure incentive without considering the interaction with the shadow bank, which corresponds to the benchmark case. The remaining two terms reflect how the traditional bank's disclosure decision is distorted by its motive to alter the shadow bank's decisions to its advantage. In particular, the second term in equation (2.22) characterizes the traditional bank's use of the disclosure to affect the shadow bank's disclosure decision. From Proposition 4 and Lemma 5, this term is negative with $\frac{\partial \Pi_1}{\partial m_2} < 0$ and $\frac{\partial m_2^*}{\partial m_1} > 0$. Similarly, the third term in equation (2.22) describes how the traditional bank alters the shadow bank's choice of liquidity risk exposure through its disclosure. Observe that from Proposition 4 and Lemma 5, $\frac{\partial \Pi_1}{\partial a_2} > 0$ and $\frac{\partial a_2^*}{\partial m_1} < 0$, which makes the third term negative. Therefore, the incentives to decrease the disclosure and to increase the liquidity risk exposure of the shadow bank jointly induce the traditional bank to disclose less precise information, compared to the situation in which these incentives are absent.

Deterrence Case. I now complete the analysis by examining the traditional bank's disclosure decision when it deters entry. Lemma 7 suggests that the traditional bank's disclosure of public information can be detrimental to the shadow bank's profit, which is summarized below. The intuitions for this result are similar to the one explained in Lemma 5.

Lemma 7. *The shadow bank's profit is strictly decreasing in the traditional bank's precision of public information,*

$$\frac{d\Pi_2(m_2^*(m_1), a_2^*(m_1), m_1)}{dm_1} < 0. \tag{2.23}$$

Lemma 7 implies that the traditional bank can deter the entry of the shadow bank by providing more precise disclosure. Indeed, I find that, in the deterrence case, the traditional bank maintains a higher level of transparency, than when the traditional bank is the monopoly, which is summarized in the proposition below.[18]

Proposition 8. *When the shadow bank is deterred from entry ($a_1 < \hat{a}$), denote the traditional bank's decision in equilibrium as m_1^{D*}, and the traditional bank's decision when it is the monopoly as m_1^M. When the private precision n_1 and n_2 are sufficiently large,*

$$m_1^{D*} > m_1^M. \tag{2.24}$$

[18] I use the monopolist's decision as a benchmark for the deterrence case following Fudenberg and Tirole (1984).

2.3. Extension: A Competitive Traditional Banking System

In the main setup, I consider a simplified traditional banking system that includes only a traditional bank. In this extension, I consider a competitive traditional banking system that has two traditional banks, indexed by bank 1 and 2, competing with each other, to check the robustness of my results. Each traditional bank is endowed with a project that yields a return to the investment, R_i, such that:

$$R_i = 2\,(\theta_i + a_1\,K_i),\ i \in \{1, 2\} \tag{2.25}$$

For simplicity, I assume that the two traditional banks have the same exposure to liquidity risk, a_1. At date 0, each traditional bank i decides the precision of its public signal z_i concerning θ_i, denoted by $m_i > 0$, which the bank will disclose to investors at date 2.

If the shadow bank, indexed by bank 3, enters, it competes with the two traditional banks for investments from the individual investors in Bertrand competition. I assume that a bank splits the investment return, R_i, equally with its investors. Each individual investor j's investments in the three banks, $\{k_{1j}, k_{2j}, k_{3j}\}$, are given by:

$$
\begin{aligned}
k_{1j} &= E_j[\frac{1}{2}R_1] - b_0\, E_j[\frac{1}{2}R_2] - b_1\, E_j[\frac{1}{2}R_3], \\
k_{2j} &= E_j[\frac{1}{2}R_2] - b_0\, E_j[\frac{1}{2}R_1] - b_1\, E_j[\frac{1}{2}R_3], \\
k_{3j} &= E_j[\frac{1}{2}R_3] - b_1\, E_j[\frac{1}{2}R_1] - b_1\, E_j[\frac{1}{2}R_2],
\end{aligned} \tag{2.26}
$$

where $b_0 \in (0,1]$ denotes the intensity of competition within the traditional banking system and $b_1 \in (0,1]$ denotes the intensity of competition between the shadow bank and the traditional banks.

Following similar approaches as in the main setup, I verify that my main results hold qualitatively, which is summarized in the proposition below:

Proposition 9. *There exists a threshold* $0 < \hat{a}' < \frac{1}{2}$*, such that,*

(1) *When* $a_1 < \hat{a}'$*, the shadow bank is deterred from entry, as long as the disclosure cost for the traditional banks is not too high;*

(2) *When* $a_1 > \hat{a}'$*, the traditional banks always accommodate the shadow bank's entry.*

This extension with a competitive traditional banking sector also allows me to analyze how the intensity of competition within the traditional banking system b_0 affects the entry of the shadow bank. This analysis, however, leads to analytical intractability. I thus conduct some numerical analysis to obtain some patterns as summarized in the following observation.

Observation 1: *The threshold $\hat{a}'$ for the shadow bank to enter is decreasing in the competitiveness of the traditional banking system b_0.*

This observation suggests that the traditional banks have a stronger incentive to accommodate the entry of the shadow bank when the traditional banking system is more competitive. Hence this extension seems to imply that a (perhaps unintended) consequence of exacerbating the competition among traditional commercial banks is to induce the emergence of the shadow banking system.

2.4. Empirical Implications

In this section, I describe the empirical implications of my model. As shown in the figure below, my model suggests that, depending on the risk profile of the traditional bank, two types of banking market structures might emerge: a single-banking regime in which only the traditional bank sustains and a parallel-banking regime in which the shadow bank operates in parallel to the traditional bank. In particular, when the traditional bank is more subject to the fundamental than to the liquidity risk, it chooses to deter the shadow bank from entry by disclosing highly precise information. However, when the liquidity risk plays a more important role in the risk profile of the traditional bank, the entry of the shadow bank is preferred and accommodated by the traditional bank. Indeed, the shadow bank enters the banking market and competes with the traditional bank. Moreover, the shadow bank is induced to be more opaque and fragile than it would be in absence of the competition with the traditional bank. In addition, the traditional bank also lowers its own disclosure precision when it prefers to coexist with the shadow bank.

The Parallel-Banking Regime	**The Single-Banking Regime**
The liquidity risk exposure of the traditional bank is high.	The liquidity risk exposure of the traditional bank is low.
The traditional bank discloses less precise information; the shadow bank enters, takes more liquidity risk, and discloses less precise information.	The traditional bank discloses more precise information; the shadow bank is deterred from entry.

Figure 2.2: Empirical Implications.

These regimes characterized by my model may provide us additional insights about several dramatic transformations in the banking industry. First, the phenomenal growth of the shadow banking system began only in recent years around the deregulation. In a Federal Reserve staff report, Pozsar et al. (2010) argue that "while the seeds of shadow banking have been sown over 80 years ago, the crystallization of shadow banking activities into a full-fledged system is a phenomenon of the past 30 years." Indeed, according to the flow of funds report,[19] the shadow banking system was stagnant and almost non-growing from 1950s to 1990s (see Figure 1, Pozsar et al., 2010). It was only after the deregulation that the shadow banking system boomed and grew sharply in the 2000s, "exceeding the traditional banking system in the years before the crisis" (see Figure 2.1, FCIC Final Report). Second, the shadow banking system has been keeping itself in shadow, providing almost no public disclosure to either investors or regulators. For example, the prospectus of mortgage-backed securities, a type of assets commonly held by shadow banks, provided only summary statistics about the underlying assets (Pagano and Volpin, 2012). In fact, in his testimony before the Financial Crisis Inquiry Commission, Timothy Geithner, the former Secretary of the Treasury, called for "more extensive disclosure, including loan-level data for asset-back securities," in order to "ensure that investors have the information they need to make informed decisions" (Geithner, 2010). Third, the shadow banking system is inherently fragile. Its reliance on short-term liquid claims, such as money market mutual funds, to fund long-term illiquid assets, such as securitized assets, causes a huge liquidity gap and exposes itself to substantial amounts of liquidity risk (Pozsar et al., 2010; Cox, 2010). Indeed, in the middle of the financial crisis, the runs on Bear Stearns,

[19] It is available at http://www.federalreserve.gov/releases/z1/current/. The size of shadow banking is measured as the sum of total commercial papers, bankers' acceptance, repos, net securities loaned, liabilities of ABS issuers, total GSE liabilities, and money market mutual funds assets.

and thereafter on Lehman Brothers and others, highlighted the fragility of shadow banking (Schwartz, 2010). Finally, although traditional banks are required to make more mandatory disclosures, the quality of financial information disclosed has considerably deteriorated. For example, in a federal reserve staff report, Mehran et al. (2011) argue that "the business of banks has become more complex and more opaque...since the passage of the Gramm-Leach-Bliley Act in 1999" Using the disagreement between rating agencies over bond ratings on banks and non-financial institutions as a proxy, Morgan (2002) also reports that banks have become more opaque than non-financial institutions since the mid-1980s. In addition, Flannery et al. (2010) show that the opacity of both big and small banking firms was further exacerbated in the middle of the crisis.

In my model, these changes can be explained by a shift between the two regimes. My model suggests that the structure of the banking market could have been transformed from a single-banking regime to a parallel-banking regime. The shift of the regime thereby contributes to the massive growth of the shadow banking system, the opaque and fragile nature of shadow banking as well as the increase in the opacity of traditional banks. My model also suggests that this regime shift could have been triggered by an increase in the liquidity risk exposure of traditional banks (i.e., the increase in a_1), which could be driven by regulatory changes. This result seems to be consistent with several observations and conjectures by regulators. For example, in a Federal Reserve staff report, Pozsar et al. (2010) argue that "The principal drivers of the growth of the shadow banking system have been the transformation of the largest (traditional) banks since the early 1980s... In conjunction with this transformation, the nature of banking changed from a credit-risk intensive...process to a less credit-risk intensive, but more market-risk intensive...process." My results complement these findings by providing a theoretical analysis.

2.5. Conclusion

This paper presents a model of shadow banking in which the shadow and the traditional banking systems share a symbiotic relationship. I examine a setting in which a shadow bank determines whether to enter a banking market occupied by an incumbent traditional bank. In this setting, banks face liquidity risk stemming from collective actions, such as runs, by investors who fund these banks. I find that competition with an opaque and fragile shadow bank can be beneficial to the traditional bank. This is because the opacity and fragility of the shadow bank help to coordinate (higher-order) beliefs and actions of individual investors, which improve the management of liquidity risk faced by the traditional bank. Two types of banking market structures can prevail in my model. When the liquidity risk exposure of the traditional bank is low, the traditional bank deters the shadow bank from entry by disclosing highly precise public information. However, when the liquidity risk exposure of the traditional bank is sufficiently high, the traditional bank prefers and encourages the entry of the shadow bank. In addition, in this parallel banking equilibrium, the shadow bank is induced to be both opaque and fragile, consistent with the empirically observed characteristics of shadow banks; both features are preferred and facilitated by the traditional bank lowering its own disclosure precision.

An important caveat concerning my study is that it rests on a set of simplifying assumptions to ensure tractability. This study also leaves many interesting characteristics concerning the banking sector outside the model for simplicity. Although I numerically examine some of the simplifying assumptions and find that my results remain valid qualitatively, a more comprehensive analysis is beyond the scope of this paper.

CHAPTER 3

Accounting Information Quality, Interbank Competition, and Banks' Risk Taking

ABSTRACT:[1] We study the interaction between interbank competition and accounting information quality and their effects on banks' risk-taking behavior. In our setting, banks may be forced to sell assets to meet the regulatory capital requirement. We identify an endogenous false-alarm cost of assets sales for the banks and show that this cost plays an important role in the relation between accounting information quality and the banks' risk taking decisions. Surprisingly, we find that when the interbank competition is not too fierce, an improvement in the quality of accounting information actually induces the banks to take more risk. We find that, keeping the banks' investments in loans constant, the provision of high-quality accounting information reduces the false-alarm cost of assets sales and improves the discriminating efficiency of the capital requirement policy. However, if we consider the banks' endogenous investment decisions, it is precisely this improvement in discriminating efficiency that causes excessive risk-taking. This is because banks respond by competing more aggressively in the deposit market and the resulting increase in deposit costs motivates banks to take more risk. Bank

[1]This essay is a joint work with Carlos Corona and Lin Nan.

regulators may believe that competition should be restricted by regulation to enhance bank stability. Separately, better accounting disclosure is often posited as an important market disciplining device for banks. Our paper, however, shows that there is an interaction between the two mechanisms, where improving information quality actually increases risk taking with mild competition while it has no effect under fierce competition. The results imply that these mechanisms cannot be evaluated in isolation.

3.1. Introduction

Before the financial meltdown of 2008, regulators and academia focused mainly on capital requirements as means to restrain banks' risk-taking decisions. In the United States, the Federal Deposit Insurance Corporation Improvement Act sets the capital standards in the hope that requiring banks to hold additional capital restrains them from taking too much leverage. Regulators also consider the competitiveness of the banking industry as an important contributor to more aggressive risk taking and to banks' failures. A previous official in the central bank stated that "in order to preserve the stability of the banking and financial industry, competition had to be restrained" (Padoa-Schioppa, 2001, pg. 14). This view is in fact supported by some previous research studies such as Keeley (1990), Suarez (1994), and Matutes and Vives (1996). More recently, however, accounting information quality has drawn considerable attention as a complementary regulatory tool to preserve financial stability. For instance, a 2010 report by the European

Central Bank commented that "the provision of more detailed information would help the market to assess the risks associated with asset-backed securities. ... (and) it would unquestionably benefit all types of investors."

In this paper, we intend to shed some light on the role that accounting information plays in restraining banks' risk-taking behavior. We directly extend the theory literature on the relation between bank competition and bank risk-taking behavior by examining two fundamental disciplinary mechanisms: minimum capital requirements and accounting disclosure quality. We show that the existence of capital requirements creates a key role for disclosure quality in influencing bank risk-taking behavior via the opportunity costs of false negative signals from the accounting system. Most importantly, we show that the impact of disclosure quality on risk-taking depends directly on the level of competition in the banking market. Specifically, we find that when the competition in the deposit market is not too fierce, risk-taking incentives are increasing in the quality of disclosure. However, this positive relation between disclosure quality and risk-taking becomes more muted as competition increases; when the competition is sufficiently fierce, disclosure quality has no impact on risk-taking incentives. We also show that, as intended by regulators, requiring banks to hold a minimum amount of capital restrains their risk-taking behavior. However, this disciplining effect is weakened if information quality is increased. Thus, while the banking literature posits capital requirements, competition policy and disclosure as key policy tools to discipline bank risk-taking, we show that these policies cannot be examined in isolation as the interaction among them plays a key role in determining risk-taking incentives.

We examine a setting in which N banks compete in the deposit market. Each bank decides the amount of capital raised through deposits and the level of risk at which this capital is invested in loans. After all banks take these decisions simultaneously, a public accounting signal issued by each bank provides information about the quality of its loan investment. This accounting information is used by a regulator to monitor whether banks meet a regulatory capital requirement. If a bank fails to meet the requirement based on the accounting information, it is forced to sell a portion of its risky assets to boost its capital ratio. This setting, although parsimonious, allows us to examine the interaction between two banking regulatory tools: capital requirements and accounting information. Indeed, since in reality the capital-ratio requirement is calculated based on accounting information, the ability of a capital-requirement policy to deter banks' risk-taking behavior should be examined jointly with the financial accounting information properties. In this paper, we examine this interaction assuming that banks improve their capital ratio through the sale of a portion of their risky assets. This is a frequently observed measure taken by banks to fulfill the capital requirement. During the 2008–2009 financial crisis, following huge write-downs and severe capital impairments, banks were often forced to sell a considerable amount of their risky assets in the secondary market (i.e., deleveraging), even at a distressed or fire-sale price (Shleifer and Vishny, 2011). For instance, First Financial Network, an Oklahoma

City-based loan sale advisor on behalf of the FDIC, planned to sell 150 million dollars in loan participation from four failed banks in November, 2009. More recently, BNP Paribas, one of the largest French banks, sold 96 billion dollars of assets to shore up capital and cut funding needs.

The results in our paper stem mainly from the emergence of an endogenous "false-alarm" cost that banks incur when they are forced to sell their risky assets, even if the assets are sold at their fair price. This cost is borne only by a bank that receives a bad accounting signal but stays solvent in the end. It arises because, when the bank sells its assets, neither the bank nor the market knows the future outcome. Consequently, the fair price that the market offers reflects the expected cash flows considering the possibility of both good and bad outcomes. In the case that a bad investment outcome is realized, the bank is insolvent and has to use all the selling proceeds to repay depositors. Since insolvency happens regardless of whether assets are sold or not, asset sales have no net effect on the final payoff, which is zero either way. However, if a good investment outcome is realized, the cash flow the assets yield is larger than the proceeds obtained from their sale. Therefore, the "early" assets sales triggered by a false alarm from the imperfect accounting information system results in an endogenous cost ex ante.

We show that the false-alarm cost of assets sales plays an important role in the relation between accounting information quality and banks' risk taking decisions. When the number of banks competing in the same market is not too large, we find that, surprisingly, improvement in accounting information quality induces more aggressive risk taking. More specifically, if we keep the amount of banks' investments in loans constant, the provision of high-quality accounting information reduces the false-alarm cost of assets sales and improves the discriminating efficiency of the capital requirement policy, which is consistent with conventional wisdom. However, if we consider the banks' investment decisions endogenous, it is precisely this improvement in discriminating efficiency that may cause excessive risk-taking. This is because the reduced endogenous false-alarm cost implies higher investment returns. As a result, banks respond by expanding investments which, through competition in the deposits market, leads to a higher deposit rate. The higher deposit rate, in turn, lowers the profit margin for banks, which induces them to take riskier loan investments to recover the margin. In contrast, when there are a sufficiently large number of banks, we find that accounting information quality has no impact on banks' risk-taking decisions. Upon a bad signal, a bank's profit margin is outweighed by the false-alarm cost, and that results in the bank's insolvency even if the bank's investment yields a high outcome. As a result, the bank only cares about its payoff after a good signal, upon which accounting information has no real consequence, and therefore this makes the risk decision independent from information quality.

We also study an extension of our main setting which examines the effect of accounting conservatism on banks' risk-taking decisions. We find that a more conservative accounting system restrains banks' risk-taking behavior when the interbank competition is not too fierce; when there are many banks competing, neither information quality nor conservatism influences banks' risk-taking decisions. Indeed, in our setting accounting information is only relevant through the capital requirement examination. Therefore, the quality of information only plays a role in the case of a bad signal. Since conservatism makes bad signals less informative, increasing conservatism in our setting is equivalent to decreasing information quality.

The paper is organized as follows. Section 2 provides a literature review. We describe the main model in Section 3 and explain the resulting equilibrium in Section 4. Section 5 provides an extension of our model to study accounting conservatism's effect on our results. Section 6 provides several robustness checks to our main results and discusses caveats. Section 7 concludes the paper.

3.2. Literature Review

The extant literature has examined the interaction between market competition and risk-taking behavior in the banking industry quite extensively. Some studies argue that a less competitive environment allows banks to enjoy higher rents that they are afraid to lose in case of failure. Therefore, lowering competition might improve economic efficiency by inducing banks to be more cautious in their risk-taking behavior to avoid failure (see for instance Allen and Gale, 2000; Keeley, 1990; Suarez, 1994; Matutes and Vives, 1996). This argument is also shared by some banking regulators. However, other studies reach different conclusions. For example, Boyd and Nicolò (2005) argue that banks can be more aggressive in risk taking as the market becomes more concentrated if the risk level is privately selected by borrowers but can be indirectly induced by a bank through the offer of a menu of contracts. The related empirical evidence on this matter is mixed. Beck et al. (2003) study panel data of 79 countries over 18 years and show that bank crises are less common in more concentrated markets. Keeley (1990) and Dick (2006) provide similar empirical evidence. However, Jayaratne and Strahan (1998) find that following the deregulation in the 1990s which exacerbated the competition in the banking industry, the banking industry experienced a significant decline in loan losses. However, in all this literature, the role of accounting disclosure in the interaction between market competition and risk-taking in the banking industry has often been neglected. In our paper, we try to shed some light on this interaction by assuming that banks, after taking their investment size and risk decisions, are subject to a capital requirement examination which is determined through the use of accounting information. We find that both harsher competition and more precise information increase risk. However, the effect of information quality on risk vanishes when competition is harsh enough.

A second stream of related literature examines the relationship between capital requirements and banks' risk-taking behavior. Buser et al. (1981) provide insight on how raising capital requirements may restrict banks' risk-taking behavior. Regulators seem to share this point of view and believe that a tightened capital requirement is an effective measure to restrain aggressive leverage taking. However, there are also studies indicating that the effect of a capital requirement on a bank's risk-taking behavior is not monotonic. By considering a bank's investment decision as a mean–variance portfolio-selection problem, an early study by Koehn and Santomero (1980) argues that a more stringent capital constraint may lead to a higher probability of bank failure. Gennotte and Pyle (1991) obtain similar results by analyzing a model in which, with the presence of a deposit guarantee, raising the capital requirement can increase the probability of bank failure and lead to financial instability. Empirical studies on the relation between capital requirements and banks' risk taking show mixed evidence. Aggarwal and Jacques (2001) show that the capital requirement effectively restricts banks' risk taking. Konishi and Yasuda (2004) find similar results using data in Japan. However, examining data on the banking industry from 1984 to 1994, Calem and Rob (1999) find that a tightened capital requirement may induce an ex-ante well-capitalized bank to take excessive risk. More recently, Laeven and Levine (2009) examine a database of 250 privately owned banks across 48 countries and show that a more stringent capital regulation can encourage more excessive risk-taking behavior for banks with a sufficiently large owner. In this paper we focus on the interaction between capital regulation and accounting information quality. In particular, we find that more precise information may weaken the disciplinary effect of capital regulation on risk-taking behavior.

There are also several studies on the implications of accounting measurement for risk-taking behavior. For example, Li (2009) compares banks' risk-taking behaviors under three different accounting regimes and finds that fair-value accounting may be less effective in controlling banks' risk level when compared to other regimes. In addition, Burkhardt and Strausz (2009) argue that lower-of-cost-or-market accounting may exacerbate the asset-substitution effect of debt. Christensen, Feltham, and Wu (2002) investigate the optimal cost of capital to motivate managers' investments, and they find that if the manager receives relatively precise pre-decision information, then it is optimal to charge him more than the riskless return to reduce the variability of his investment decisions. More recently, Bertomeu and Magee (2011) examine the interaction between accounting information quality regulation and the economic cycle. They show that a shift of accounting information quality driven by a downturn in economy may result in more bad loans. Another recent study by Bushman and Williams (2011) examines a large sample of banks from 27 countries, and finds evidence supporting that accounting discretion over loan-loss provisioning can have either positive or negative real consequences in disciplining of banks' risk taking depending on whether the discretion incorporates forward-looking judgements or is in the form of earnings smoothing. In contrast to these papers, our model illustrates how accounting information, capital regulation and market competition interact in their effects on banks' risk-taking behavior.

There are numerous previous studies on the effects of accounting information quality on firms' internal decisions. For instance, Arya and Mittendorf (2011) examine the role of information in evaluating manager's performance and career concerns. They find that more detailed information may not always be beneficial and sometimes aggregated information is efficient. Arya, Glover, and Liang (2004) examine interim performance measures and show that additional information is helpful only when other information sources abound. In a similar spirit, our paper also shows that the improvement of accounting information quality may not be beneficial. In a capital market setting, Dye and Sridhar (2007) examine the interaction between the choice of accounting information precision and investment decisions under different observability assumptions. In contrast to these studies, we examine the role of accounting information quality in a product market setting and we focus on accounting information's effect on banks' risk taking.

Not many studies have been done on the interactions among capital standards, risk taking and accounting rules. Among the few, Besanko and Kanatas (1996) study the effect of capital standards on bank safety in the presence of fair-value accounting rules. They assume that a bank satisfies the capital requirement by selling equities to outside investors and show that a more stringent capital requirement may raise the probability of bank failure. In contrast to our paper, the key factor driving their results comes from a dilution effect: increasing capital standards dilutes insiders' ownership which in turn reduces their incentive to exert effort in improving loan quality.

3.3. Model

3.3.1. Setup

We examine a three-date setting in which there are $N \geq 2$ identical risk-neutral banks competing in a market for deposits. At date 0, each bank i decides on how much deposit funds to obtain and chooses the risk level at which it invests these funds in loans. The outcome of all loans of bank i is described by a binary state, $\theta_i \in \{H, L\}$, where H stands for high and L stands for low, and this state is realized at date 2. At date 1, however, an imperfect accounting signal, η_i, which is informative about the future outcome of the loans, is mechanically generated for each bank i and observed publicly. The accounting signal is also binary, $\eta_i \in \{\mathrm{G}, \mathrm{B}\}$, where G stands for good and B stands for bad.[2] In case of a bad signal, the bank has to sell some of its assets (i.e., loans) to fulfill a capital requirement. Finally, at date 2, the outcome is realized. The time line of the model is shown below.

[2]This binary assumption simplifies our analysis without much loss of generality; to verify this, we examined a setting with a continuum of states and accounting signals, and found that the main results still hold qualitatively. Detailed analysis of this continuous-state setting is available upon request.

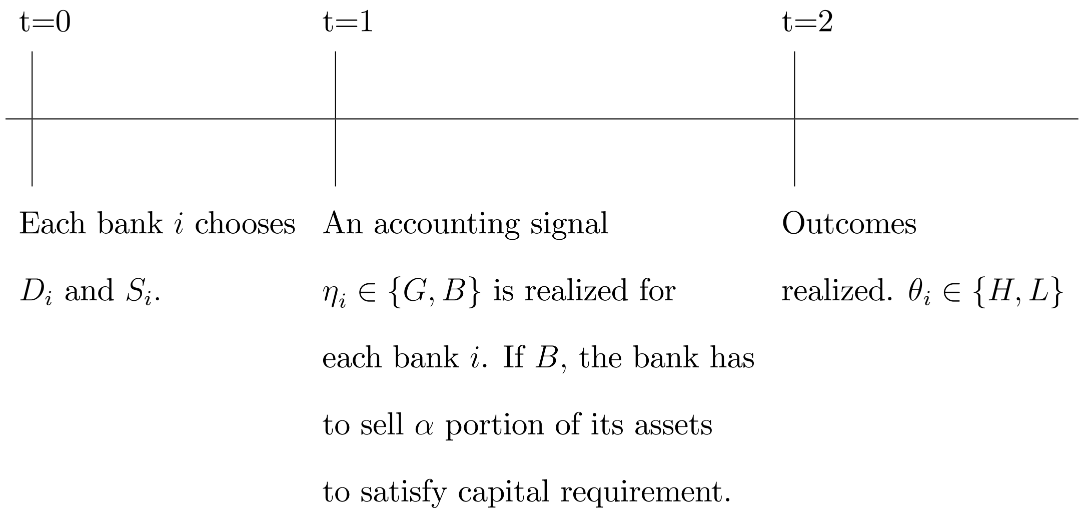


Figure 3.1: Time line.

More specifically, at date 0, all banks make two decisions simultaneously: the total amount of deposit funds, D_i, and the risk level at which they invest those funds, $S_i \in [0, 1]$. We assume that the banks' choices of S_i and D_i are not perfectly observed by outsiders. This assumption, which reflects quite realistically the real world and makes the model tractable, does not drive our results. In the robustness checks section we illustrate that the model with observable decisions provides qualitatively similar results. The deposit market is represented by an upward sloping inverse supply curve that yields the equilibrium gross deposit rate, $r_{\mathrm{D}}(D_A)$, as a function of the aggregate bank deposit amount, $D_A = \sum_{j=1}^{N} D_j$. For simplicity, we assume that r_{D} has the linear functional form:

$$r_{\mathrm{D}}(D_A) = bD_A + \varepsilon, \tag{3.1}$$

where $b > 0$, and ε is an unobservable random shock reflecting factors other than the aggregate deposit amount that influence the deposit rate. We assume $E[\varepsilon] = 0$, and that ε has a support with a positive measure but as small as needed. With this expression, we implicitly assume that deposit amounts are perfect substitutes and increase the gross deposit rate. Also, since all deposits are fully insured by the Federal Deposit Insurance Corporation (FDIC), the competitive gross deposit rate r_{D} depends on neither the individual nor the aggregate risk of all banks.[3]

We assume that each bank i invests all funds obtained from deposits in bank loans that in aggregate have an uncertain outcome, X_i. The outcome of these loans is characterized by the state, $\theta_i \in \{H, L\}$. That is, the loans can end up either in a high state (H), in which they yield a high outcome, or in a low state (L), in which they yield a low outcome which we normalize to zero. Neither the bank nor outsiders observe the realized state and outcome until date 2. The risk level of the loans, S_i, affects the expected return of the loans in two ways. First, given the loan amount, D_i, a higher loan risk yields a higher return in the H state. In particular, in the H state the loans yield a cash flow of $(1 + S_i)D_i$, while the loans yield a zero cash flow in the L state. Second, we follow Boyd and Nicolò

[3]The FDIC insurance is not a driving force for our main results, but it does simplify our analysis. Even if we assume that deposits are not insured and that r_{D} depends on the market's conjecture of total risk, banks' returns are only reduced in the H state, and our results remain valid.

(2005) in assuming that the probability that the loans end up in the H state, $P(S_i)$, decreases with their risk. In particular, we assume that $P(S_i)$ follows a linear function $P(S_i) = 1 - S_i$.[4] The outcome from the loan investment can be characterized as follows,

$$X_i = \begin{cases} (1+S_i)D_i & \text{if } \theta_i = H, \\ 0 & \text{if } \theta_i = L. \end{cases} \tag{3.2}$$

At date 2, bank i pays $r_D D_i = (bD_A + \varepsilon)D_i$ to depositors only in the H state. In the L state, the bank obtains a zero cash flow from the loan investment and does not pay depositors because banks have limited liability. Absent any capital requirement examination, bank i would expect a net cash flow of

$$P(S_i)(1 + S_i - E[r_D])D_i. \tag{3.3}$$

This expression reflects the basic risk-return trade-off for the bank: a higher level of risk decreases the probability of the H state, but increases the net loan cash flow if the H state is realized. This trade-off makes the expected net cash flow strictly concave in S_i, and ensures an interior maximum at $\frac{E[r_D]}{2}$. Also, notice that if banks were forced to bear the burden of covering defaults (i.e., pay depositors in the L state), they would expect a net cash flow of $(P(S_i)(1+S_i) - E[r_D])D_i =$

[4]We examined a more general functional form for the probability distribution in a continuous state setting, and we find that the main results qualitatively remain.

$((1-S_i)(1+S_i)-E[r_D])D_i$, and hence, would optimally choose a risk level of zero. In our model, as a result of limited liability, banks deviate from this "first-best" risk choice and take risk excessively.[5]

At date 1, an imperfect accounting signal η_i on the loan performance is generated and observed publicly. The quality of this accounting information is represented by an exogenous parameter, ϕ, which is the probability that the signal generated is correct. That is:

$$\Pr(\eta_i = \mathrm{G}|\theta_i = \mathrm{H}) = \Pr(\eta_i = \mathrm{B}|\theta_i = \mathrm{L}) = \phi. \tag{3.4}$$

We assume that the accounting signal is imperfectly informative: $\frac{1}{2} < \phi < 1$.

In the real world, upon a bad accounting signal, the market value of the bank's assets usually decreases. The bank may then fail to satisfy the capital-sufficiency examination by regulators. The capital sufficiency requirement can be described by the constraint,

$$\frac{\textit{Equity}}{\textit{Risk-Weighted Assets}} \geq \gamma, \tag{3.5}$$

where γ represents the minimal capital ratio required by the regulators. *Risk-Weighted Assets* is a weighted measure of the bank's assets for regulatory purposes, which uses a larger weight for riskier assets and a lower weight for less risky

[5]We thank an anonymous referee for bringing up this point. When there is no limited liability, the optimal choice of zero risk is in fact a normalization. By adjusting parameters in the model, we could potentially normalize the optimal risk choice to any arbitrary value.

assets (the weight on risk-free assets such as cash is zero).[6] According to current accounting regulations, the assets of a bank are recognized at the lower of cost or fair value.[7] Therefore, the asset's impairment upon a bad signal decreases the bank's asset value, while the associated impairment loss reduces its equity value. These two effects jointly result in a lower capital ratio. For example, suppose a bank's risky assets are worth 2 million dollars, its equity is recognized to be 1 million and the weight for risky assets in the calculation of the risk-weighted assets is 100%. The capital ratio is then 0.50. Let's say that, upon a bad accounting signal, the market value of the risky assets declines to 1.5 million. Then, the assets' value is marked to market and the impairment loss reduces the equity book value to 0.5 million. The capital ratio after the accounting signal, therefore, declines to 0.33. If with this capital ratio the bank fails the capital examination, it must take measures to satisfy the regulatory capital requirement. In particular, the bank can sell a part of its risky assets for cash. Suppose the bank sells 0.5 million of its risky

[6] In reality, regulators of the banking industry calculate the capital ratio by assigning different weights to different asset categories. There are only several categories of assets and the weight assigned to each category is fixed (Basel I Accord, 1988; Basel II Accord, 2004; FDIC Optional Regulatory Capital Worksheet, 2000). For example, almost all unsecured loans, in spite of their heterogeneous riskiness, are placed in the same category with a risk weight 100%. Therefore the risk is assessed only in a very gross manner and is not contingent on the actual risk of the assets contained in each category. In fact, a bank can change the risk of the asset portfolio with great flexibility without changing its capital ratio.

[7] Banks' loans can be either *held for investment* (HFI) or *held for sale* (HFS). HFS loans are reported at the lower of cost or fair value, with declines in fair value recognized in income (See SFAS No. 65, SFAS No. 5, SFAS No. 114, and SOP 03-3). Alternatively, a bank may utilize the fair-value option and choose to measure its loans at fair value regardless of whether they are HFI or HFS (See SFAS No. 159). Our model is able to accommodate both fair-value measurement and lower of cost or market, because we only assume that banks mark down their loan assets upon bad signals. We thank an anonymous referee for raising this point.

assets for cash. Since cash has zero weight in the calculation of risk-weighted assets, the new risk-weighted assets amount to 1 million and, as a result, the capital requirement ratio is boosted back to 0.50.

In our model, after S_i and D_i are chosen by bank i, the satisfaction of the capital requirement is determined by the realization of the accounting signal. We consider the nontrivial scenario in which a bank fails to meet the capital requirement if and only if a bad signal is generated. Essentially, if the accounting signal realization is good, the bank meets the capital requirement and does not need to sell assets. For expositional purposes, we disregard the bank's possibility to sell assets after a good signal realization. This is without loss of generality because, as we will show, the bank incurs an endogenous cost when selling the assets and therefore it is not willing to sell unless it is forced to. Thus, the bank's cash flow net of payments to depositors, denoted by π_i, has an expected value upon a good accounting signal of,

$$E[\pi_i|G] = P_{\mathrm{H|G}} Max\{(1 + S_i - E[r_D])D_i, 0\}, \tag{3.6}$$

where $P_{\mathrm{H|G}}$ denotes the conditional probability of the H state given a good signal. The expressions for all conditional probabilities can be found in the appendix. In this expression, the maximum operator reflects the fact that the bank has limited liability and therefore cannot have a negative terminal value. If the realization of the net cash flow in the H state is positive, it reflects the loan outcome, $(1+S_i)D_i$, net of expected payments to depositors, $E[r_D]D_i$.

If the accounting signal realization is B, the bank violates the capital requirement and must sell a portion of its risky assets for cash. Selling assets helps to boost the capital ratio because it shrinks the bank's balance of risk-adjusted assets. For simplicity, we assume that the proportion of assets that needs to be sold is a constant, $\alpha \in (0,1)$, which henceforth we refer to as the "assets sales portion." The market price of the bank's assets, $Asset_i^B$, equals the market's conditional expectation of the loans future value:

$$(3.7) \quad Asset_i^B = E[X_i(S_i^c, D_i^c, D_{-i}^c)|B] = \left[\frac{(1-\phi)(1-S_i^c)}{(1-\phi)(1-S_i^c)+\phi S_i^c}\right](1+S_i^c)\,D_i^c.$$

In this expression, the term in square brackets is the conditional probability of the H state given a bad signal, and the rest is the loan outcome in the H state. Note that the assets price $Asset_i^B$ is only a function of the investors' risk conjectures and, therefore, it is ex-ante independent of the bank's actual choices. To avoid trivial cases, we assume that once a capital-deficient bank ends up in the L state, the cash proceeds from the assets sale are not sufficient to repay depositors. However, by the virtue of limited liability, the bank is not liable for the outstanding balance. It can be shown that this assumption is satisfied if $\alpha < \frac{1}{2}$ and thus we henceforth assume $\alpha \in (0, \frac{1}{2})$.

Now we are ready to characterize the expected net cash flow for the bank upon a bad signal, which is

$$E[\pi_i|B] = P_{\mathrm{H|B}} Max\{(1-\alpha)(1+S_i)D_i + \alpha\, Asset_i^B - E[r_D]D_i, 0\}. \tag{3.8}$$

In the above expression, the maximum operator reflects the fact that the bank has limited liability. The bank obtains a positive value only when the H state is realized and the net cash flow is positive. In this expression, the term $(1-\alpha)(1+S_i)D_i$ is obtained from the unsold portion of the loans, the term $\alpha\, Asset_i^B$ is obtained from the sold portion of the loans, and the term $E[r_D]D_i$ is the payment to depositors. With these conditional expected payoffs for different signals, we can now specify the bank's objective function. At date 0, each bank i chooses the deposit quantity D_i and the loan risk S_i to maximize its expected net cash flow:

$$\max_{S_i, D_i} \; P_G E[\pi_i|G] + (1-P_G)E[\pi_i|B]. \tag{3.9}$$

3.4. Equilibrium

In this section, we define the equilibrium and explain the derivation of the main results. We define the equilibrium in our model as follows:

Definition 10. ***Equilibrium:*** *a Perfect Bayesian Equilibrium in this game is a triple* $\{S_i^*, D_i^*, Asset_i^\eta\}$ *for each bank* $i \in \{1, .., N\}$ *such that:*

- *At date 0, each bank i chooses the optimal risk and loan amount, $\{S_i^*, D_i^*\}$, to maximize its expected future cash flow, $E[\pi_i] = P_G E[\pi_i|G] + (1 - P_G)E[\pi_i|B]$.*
- *The market price of bank i's assets at date 1 contingent upon the accounting signal, $Asset_i^\eta$, is equal to the market's updated expectation of the loans' outcome:*

$$Asset_i^\eta = E[X_i(S_i^c, D_i^c, D_{-i}^c)|\eta], \quad \eta \in \{G, B\}, \tag{3.10}$$

where S_i^c, D_i^c, D_{-i}^c represent the market's conjectures of bank i's risk level, bank i's deposit amount, and the total deposit amount of all other banks, respectively.

- *In equilibrium, the market's conjectures of each bank i's risk-taking and investing decisions equal the bank's actual decisions; i.e., $(S_i^c, D_i^c) = (S_i^*, D_i^*)$ for all $i \in \{1, .., N\}$.*

We derive the equilibrium as follows. At date 0, each bank i chooses the deposit quantity D_i and the loan risk S_i to solve

(3.11)

$$\max_{S_i, D_i} P_{\mathrm{G}} P_{\mathrm{H|G}} Max\{(1+S_i-bD_A)D_i, 0\}+(1-P_{\mathrm{G}})P_{\mathrm{H|B}}\, Max\{(1-\alpha)(1+S_i)D_i+\alpha\, Asset_i^{\mathrm{B}}-bD_A D_i, 0\}.$$

For expositional purposes, we assume that the realization of the net cash flow in the H state after a good signal is always positive. That is,

$$(1 + S_i - bD_A)D_i > 0. \tag{3.12}$$

Nevertheless, this condition is always satisfied in the equilibrium. Also, we need to consider two cases: first, the case in which the bank obtains a positive net cash flow in H state after a bad accounting signal; second, the case in which this net cash flow is negative. In the appendix we prove that there exists a threshold $\hat{N}$ such that, if $N < \hat{N}$, the first case applies, and otherwise the second case applies. Formally, we must take into consideration the condition,

$$(1 - \alpha)(1 + S_i)D_i + \alpha\, Asset_i^{\mathrm{B}} - bD_A D_i > 0 \text{ for all } N < \hat{N}. \tag{3.13}$$

Let's first consider the case in which $N < \hat{N}$. The bank's program can be expressed as:

(3.14)

$$\max_{S_i, D_i} P_{\mathrm{G}} P_{\mathrm{H|G}} \left[(1 + S_i - bD_A)D_i\right] + (1 - P_{\mathrm{G}}) P_{\mathrm{H|B}} \left[(1 - \alpha)(1 + S_i)D_i + \alpha\, Asset_i^{\mathrm{B}} - bD_A D_i\right].$$

Taking derivatives with respect to the two choice variables, we obtain two first-order conditions:

$$b\,(D_{-i}+D_i)D_i - 2\,[\phi + (1-\phi)(1-\alpha)]S_i D_i + \alpha(\phi-1)Asset_i^{\mathrm{B}} = 0, \tag{3.15}$$

$$\left(1 + S_i - \frac{b\,(D_{-i}+2D_i)}{1-\alpha(1-\phi)}\right)(1-S_i) = 0. \tag{3.16}$$

In equilibrium, the market's conjectures are true; i.e., $(S_i^c, D_i^c) = (S_i, D_i)$ for all $i \in \{1, 2, \ldots, N\}$. Therefore, the above equations become:

$$D_i\left(b\,(D_{-i}+D_i) - 2\,[\phi + (1-\phi)(1-\alpha)]S_i + \alpha(\phi-1)\left(\frac{(1-\phi)(1-S_i)}{(1-\phi)(1-S_i)+\phi S_i}\right)(1+S_i)\right) = 0, \tag{3.17}$$

$$\left(1 + S_i - \frac{b\,(D_{-i}+2D_i)}{1-\alpha(1-\phi)}\right)(1-S_i) = 0. \tag{3.18}$$

Solving the system of equations for all banks simultaneously, one can derive the decisions for each bank in equilibrium. Notice that $D_i = 0$ and $S_i = 1$ are obvious solutions to equations 3.18 and 3.17 respectively. However, these solutions do not satisfy the second-order conditions and therefore are discarded. Also, from equation 3.18, it is apparent that there is a linear relation between the optimal risk and investment choices. Indeed, solving for S_i we have,

$$S_i = \frac{b\,(D_{-i}+2D_i)}{1-\alpha(1-\phi)} - 1. \tag{3.19}$$

Therefore, if the loan assets size were exogenous, an increase in the size of a bank's loan assets would imply an increase in their risk. The rest of the equilibrium derivation for the case of $N < \hat{N}$ can be found in the appendix. The resulting equilibrium expressions for the assets market price and banks' decisions are stated below in Proposition 11.

On the other hand, for $N \geq \hat{N}$, condition (3.12) tells us that if H state is realized after a bad signal, the realization of the net cash flow is non-positive. Therefore, the bad accounting signal already announces the bank's insolvency. The bank's program then reduces to:

$$\max_{S_i, D_i} \; P_{\mathrm{G}} P_{\mathrm{H|G}} (1 + S_i - bD_A) D_i. \tag{3.20}$$

Taking derivatives with respect to the two choice variables, we obtain two first-order conditions:

$$\left[b\left(D_{-i} + D_i\right) - 2\,S_i\right] D_i = 0, \tag{3.21}$$

$$\left(1 + S_i - b\,D_{-i} - 2\,b\,D_i\right)\left(1 - S_i\right) = 0. \tag{3.22}$$

As in the previous case, solving the system of equations for all banks simultaneously, we obtain the expressions for the equilibrium deposit amounts and loan risks. We can show that the equilibrium is always unique and symmetric.

Henceforth, we omit the firm index and denote the equilibrium strategy profile by $\{S^*, D^*, Asset^{\mathrm{B}}\}$. The following proposition describes the equilibrium.

Proposition 11. *There exists a unique and symmetric equilibrium in which,*

(i) • *each bank makes the optimal decisions S^* and D^* given by:*

$$S^* = \begin{cases} \frac{-k_2 - \sqrt{k_2^2 - 4\,k_1\,k_3}}{2\,k_1} & \text{if } N < \hat{N} \\ \frac{N}{N+2} & \text{if } N \geq \hat{N} \end{cases}, \text{ and} \tag{3.23}$$

$$D^* = \begin{cases} \frac{1-\alpha(1-\phi)}{b\,(N+1)}(1+S^*) & \text{if } N < \hat{N} \\ \frac{1}{b\,(N+1)}(1+S^*) & \text{if } N \geq \hat{N} \end{cases},$$

where the coefficients (k_1, k_2, k_3) are defined as functions of ϕ, α, and N:

$$\begin{aligned} k_1 &= (N+2)(1-2\,\phi) + \alpha(1-\ \phi)[(N+3)\phi - 1], \\ k_2 &= [1-\alpha(1-\phi)][(3N+2)\phi - 2(N+1)], \\ k_3 &= (1-\phi)[N - \alpha(1-\phi)(2N+1)], \end{aligned} \tag{3.24}$$

and $\hat{N} > 0$ is a threshold such that at $N = \hat{N}$ we have in equilibrium $(1-\alpha)(1+S^*)D^* + \alpha\, Asset_i^{\mathrm{B}} - bND^{*2} = 0$;

- *upon a bad accounting signal, the bank's assets market price,* $Asset^{\mathrm{B}}$*, is given by:*

$$Asset^{\mathrm{B}} = \frac{(1-\phi)(1-S^*)}{(1-\phi)(1-S^*)+\phi S^*}(1+S^*)D^*. \tag{3.25}$$

Proposition 11 describes the expressions for the equilibrium choices of the deposit and loan-risk amounts (S^*, D^*) for each bank in the market. In addition, it shows the expression for the equilibrium selling price of the banks' assets when the accounting signal is bad, $Asset^{\mathrm{B}}$. The asset price when the signal is good is not relevant because the bank does not sell assets in that case. The unique and symmetric equilibrium adopts two different characterizations, depending on whether the number of banks is below or above a threshold, $\hat{N}$. When $N < \hat{N}$, the equilibrium investment and risk decisions are contingent on the accounting information quality, ϕ, and the assets sales portion, α. However, when $N > \hat{N}$, ϕ and α do not affect the equilibrium investment and risk decisions. In the following subsections, we will examine and explain the results in these two cases.

3.4.1. The Case of $N < \hat{N}$

When the number of banks is sufficiently small ($N < \hat{N}$), banks' risk-taking decisions are contingent on both the accounting information quality and the capital requirement. By examining the comparative static properties of the equilibrium presented in Proposition 11, we find that a bank's risk-taking incentives are disciplined by a higher assets sale portion α. This is consistent with the intention of bank regulators in setting a capital requirement to induce less aggressive risk decisions by banks. However, our analysis also demonstrates that an improvement in the quality of accounting information actually strengthens a bank's risk-taking incentives. We summarize these results in the following proposition:

Proposition 12. *When $N < \hat{N}$,*

- $\frac{\partial S^*}{\partial \phi} > 0$;
- $\frac{\partial S^*}{\partial \alpha} < 0$;
- $\frac{\partial^2 S^*}{\partial \phi \partial \alpha} > 0$.

The results in Proposition 12 are driven by the trade-off between two effects: a false-alarm-cost effect and a deposit-market effect, which we will elaborate soon. To understand these effects and the trade-off between them, we first express a bank's objective function as follows:

$$\underbrace{P_H(X_i^H - E[r_D]D_i)}_{\text{Bank's expected cash flow with no assets sales}} \quad - P_B P_{\mathrm{H|B}} \quad \underbrace{\alpha(X_i^H - Asset_i^B)}_{\text{false-alarm cost of assets sales}} \quad , \tag{3.26}$$

where P_B denotes the probability of a bad signal.

Notice that the first component in the bank's objective function coincides with expression (3.3), the expected net cash flow the bank would obtain if there were no forced asset sales. This term shows that the bank expects to repay $E[r_D]D_i$ to depositors only if the H state is realized. As a consequence, the optimal level of risk implied by this first component is affected by an asset-substitution problem between the bank and the depositors. A larger expected payment $E[r_D]D_i$ reduces the marginal benefit of increasing the probability of the H state, P_H. As a result, banks turn to riskier investments, thereby reducing this probability, to recover a higher loan margin (i.e., larger $X_i^H - E[r_D]D_i$).

The second component in the bank's objective function represents an endogenous cost stemming from the sale of assets. The magnitude of the cost corresponds to the difference between the proceeds from assets sales, $\alpha Asset_i^B$, and the cash flows from the loan assets obtained in the H state, αX_i^H. This cost is not due to the illiquidity in the assets market since the assets in our model are sold at their fair price. It is borne only by a bank that receives a pessimistic accounting signal but stays solvent in the end. It arises because when the bank sells its assets, neither the bank nor the market knows the future outcome. The fair price that the market offers, therefore, reflects the expected cash flows considering the possibility of both good and bad outcomes. If a bad outcome is realized, the bank becomes insolvent, all the sale proceeds are paid to the depositors, and therefore the net value of the assets sale proceeds for the bank is zero. However, if a good outcome is realized, the cash flow generated by the investment, αX_i^H, is actually larger than the proceeds obtained from selling the assets, $\alpha Asset_i^B$. Therefore, the "early" assets sale results in an endogenous cost. Notice that this cost is incurred only if both a bad signal and the H state are realized (i.e., when the accounting system generates a false alarm), and that this cost captures an economic inefficiency arising from the imperfect accounting information. For notational convenience, we call this cost the *false-alarm cost* and denote it by c_S, $c_S = \alpha(X_i^H - Asset_i^B)$.

To illustrate how the false-alarm-cost affects the optimal risk choice, it is useful to rewrite the objective function in the following way:

$$P_H(X_i^H - E[r_D]\,D_i) - P_H(1-\phi)c_S. \tag{3.27}$$

Note that, same as the expected deposit payment $E[r_D]D_i$, the false-alarm cost is only incurred in the H state. Therefore, it plays an analogous role to the one played by $E[r_D]D_i$ in influencing the bank's risk decision. That is, an increase of c_S lowers the bank's net cash flow in the H state, which encourages the bank to pursue risky projects more aggressively.

Improving the quality of accounting information affects a bank's risk-taking decision in two ways. On the one hand, improving the information quality reduces the size of the expected false-alarm cost, $P_H(1-\phi)c_S$, and this is actually the result of two opposite effects: an increase in information quality increases the size of the false-alarm cost but reduces the probability that false alarm actually incurs. Indeed, as accounting information quality improves, the chance that a bank ends up in the H state after obtaining a bad signal decreases, and that makes the false-alarm cost less likely to be incurred. However, the lower H-state chance also reduces the assets-sales price, and that in turn yields a higher false-alarm cost. In total, the decrease in probability dominates, resulting in a lower expected false-alarm cost. This lower false-alarm cost mitigates the asset-substitution problem between the bank and the depositors and, as a result, induces the bank to take less risk. That is, keeping the bank investment decision fixed, increasing ϕ directly restrains the bank's risk-taking behavior. We call this disciplinary role of accounting information *the false-alarm-cost effect*. On the other hand, increasing the quality of accounting information also affects the bank's investment decisions. The decrease of the expected false-alarm cost induced by an increase in information quality increases the bank's marginal investment return. As a result, each bank responds by increasing its investment amount, D_i, and hence the resulting increase in aggregate investment leads to a higher deposit rate. The higher deposit rate, in turn, exacerbates the asset-substitution problem between the bank and the depositors, and motivates the bank to be more aggressive in risk taking. We call this risk-inducing role of accounting information *the deposit-market effect*.

In the trade-off between the two contrary effects of information quality described above, the risk-inducing deposit-market effect more than offsets the disciplinary false-alarm-cost effect. As a result, requiring a higher accounting information quality motivates banks to take more risk. Indeed, this result illustrates that, when examining the relation between information quality and banks' risk-taking decisions, it is important to consider the endogeneity of investment decisions. Improving the quality of accounting information improves the discriminating efficiency of the capital requirement policy, thereby reducing the chances of forcing solvent banks to liquidate assets. This restrains a bank's risk-taking incentive because the associated efficiency improvement raises the charter values for banks, and higher charter values motivate banks to make more prudent decisions. However, the role of accounting information quality is reversed once we consider the endogeneity of investment decisions. This is because banks respond to the improvement in discriminating efficiency by expanding investments, which raises the deposit rate. A higher deposit rate, in return, lowers the charter value and results in excessive risk-taking.

We can explain the disciplinary effect of an increase in the assets sales portion in a similar way. If bank regulators raise the capital requirement ratio, resulting in a higher α, this affects a bank's risk-taking decision in two ways. First, it forces a bank to sell more assets upon a bad signal to satisfy the capital requirement, which in turn leads to a higher expected false-alarm cost. Taking investment decisions as exogenous, a higher expected false-alarm cost strengthens the bank's asset-substitution incentive and encourages the bank to take risk more aggressively. However, the larger expected false-alarm cost leads to a lower marginal investment return. As a result, if we consider investment decisions to be endogenous, banks tend to invest less and compete less aggressively with each other in the deposit market. Therefore, a higher α softens the competition in the deposit market, thereby reducing the deposit rate. A lower deposit rate mitigates the asset-substitution problem between the bank and the depositors, and induces the bank to take less risk. Overall, this latter disciplinary effect dominates the former risk-inducing effect and, as a result, a higher α restrains banks from aggressive risk taking. That is, requiring banks to hold more capital not only builds an extra layer of protection for depositors, but also discourages banks from taking excessive risk.

Proposition 12 also shows that $\frac{\partial^2 S^*}{\partial\phi\partial\alpha} > 0$. That is, forcing capital-deficient banks to sell more assets can reinforce the risk-inducing effect of accounting information. The key driving force is that when banks are forced to sell a larger amount of their assets to satisfy the regulatory capital requirement, the false-alarm cost associated with the assets sales is also more substantial. Therefore, an improvement in the accounting information quality leads to a greater reduction in the false-alarm cost and further intensifies the competition in the deposit market, which causes banks to respond more aggressively in taking risk.

3.4.2. The Case of $N \geq \hat{N}$

When the number of banks is larger than $\hat{N}$, banks' investment and risk decisions are no longer affected by information quality or the assets sales portion. We state this result formally in the following proposition:

Proposition 13. *When $N \geq \hat{N}$, a bank's investment and risk-taking decisions are independent of ϕ and α.*

In particular, the expressions for the optimal decisions in the unique and symmetric equilibrium are:

$$
\begin{aligned}
S^* &= \frac{N}{N+2}, \quad \textit{and} \\
D^* &= \frac{2}{b\,(N+2)}.
\end{aligned} \tag{3.28}
$$

From the expressions for the equilibrium banks' decisions stated in Proposition 13, one can see that the risk taken by each bank is increasing in the number of banks in the market, N, and tends asymptotically to 1, the maximum level of risk, as $N \to \infty$. The investment of each bank, however, decreases with the number of banks, as they split the deposit market, and tends to zero as $N \to \infty$, as each bank becomes infinitesimally small. Nevertheless, the aggregate investment increases with the number of banks and tends to a constant $\frac{2}{b}$ as $N \to \infty$. The limit case as the number of banks approaches infinity is, in fact, the case of a perfectly competitive deposit market and deserves a formal statement, which we provide in the following corollary:

Corollary 14. *In the case of perfect competition, each bank makes the equilibrium decisions* (S^*, D^*) *that satisfy*

$$
\begin{aligned}
S^* &= 1, \quad \textit{and} \\
D_A^* &= \lim_{N \longrightarrow \infty} N D^* = \frac{2}{b}.
\end{aligned} \tag{3.29}
$$

Our results for the case with a sufficiently large number of banks (i.e., the case of $N \geq \hat{N}$, including the perfect competition case $N \to \infty$) extend the results of Allen and Gale (2000). Allen and Gale (2000) study a similar setting with N banks competing in the same market, but in their model banks are not subject to a capital requirement examination and accounting information plays no role. In conformity with our results, they find that banks choose to take more risk as N increases, and that banks choose the maximum level of risk in a perfectly competitive market. Our contribution is to state that a harsher competition induces banks to become more aggressive in risk taking even in the presence of a capital requirement examination based on accounting information. Moreover, we show that neither capital requirement nor information quality has any effect on the banks' decisions beyond a certain level of competitiveness.

To understand the intuition behind this result, notice that the payoff for a bank that receives a bad signal and ends up in the H state is:

$$(X_i^H - r_D\, D_i) - c_S. \tag{3.30}$$

As the number of banks increases, the increasing competition erodes the profit margin $X_H - r_D\, D_i$, and in the case of perfect competition, the profit margin is reduced to zero. However, the false-alarm cost c_S remains positive as N approaches infinity. This is because the false-alarm cost depends on the difference between the proceeds from assets sales and the cash flows from the loan assets obtained in the

H state, neither of which is net of the interest payment; therefore it is not affected by the profit margin and remains positive. When $N \geq \hat{N}$, upon a bad signal the profit margin $X_H - r_D\, D_i$ cannot cover the false-alarm cost and that results in the bank's insolvency even if the bank eventually ends up in the H state. As a result, the bank only cares about its payoff in the case of receiving a good signal. The net cash flow obtained in the H state decreases with N as the loan profit margin decreases, and therefore the bank becomes more aggressive in risk taking in trying to regain some of that margin.

Our analysis for both cases, $N < \hat{N}$ and $N \geq \hat{N}$, illustrates the interaction between interbank competition and accounting information quality and their effects on banks' risk-taking behavior. Bank regulators may believe that competition should be restricted by regulation to enhance bank stability. Separately, better accounting disclosure is often posited as an important market disciplining device for banks. Our paper, however, shows that there is an interaction between the two mechanisms: improving information quality may actually increase risk taking in an environment with mild competition while it may have no effect on risk decisions in an environment with fierce competition. Our results, therefore, imply that these two mechanisms cannot be evaluated in isolation and that regulators need to consider the interaction between them.

3.5. Extension: A Conservative Accounting Information System

In this section, we consider an extension of our main setting that incorporates accounting conservatism. To study how accounting conservatism affects our results, we model conservatism by assuming that the conditional probabilities of observing a good or a bad signal for a certain state of the loan are as follows:

$$\begin{aligned} \Pr(\eta_i &= \mathrm{G}|\theta_i = \mathrm{H}) = \phi - \lambda, \\ \Pr(\eta_i &= \mathrm{B}|\theta_i = \mathrm{L}) = \phi + \lambda, \end{aligned} \tag{3.31}$$

where $\phi \in [1/2, 1]$ and $\lambda \in [0, 1-\phi]$. The parameter ϕ measures the quality of the information as before, and the parameter λ captures the level of conservatism. As it has been modeled in previous studies, such as Chen et al. (2007), Gigler et al. (2009), Gao (2013), and Li (2013), conservatism shifts the conditional distribution of the accounting signal towards the bad signal, making the observation of a bad signal less informative. We present the results of our analysis in the following proposition.

Proposition 15. *There exists a N_c such that,*

(i) when $N < N_c$, $\frac{\partial S^*}{\partial \phi} > 0$ and $\frac{\partial S^*}{\partial \lambda} < 0$;

(ii) when $N \geq N_c$, S^* is independent of ϕ and α;

We find that, in general the effect of information quality on banks' risk decisions does not change qualitatively with the presence of accounting conservatism.

In particular, we still find that when the number of banks is small ($N < N_c$), the equilibrium risk chosen by banks strictly increases in the information quality, and that risk decisions are not affected when the number of banks is large ($N \geq N_c$). Moreover, in the latter case, the level of conservatism does not affect risk decisions either. However, the level of conservatism does affect risk decisions when the number of banks is small ($N < N_c$). In particular, a more conservative accounting system (higher λ) decreases the risk taken by banks. That is, conservatism plays a disciplinary role. Given the results in our main setting, the effect of conservatism on the risk decisions is quite intuitive. As mentioned above, a more conservative information system generates a downward bias on the signal, making a bad signal less informative about the underlying state of the loans. Since for the capital requirement examination purpose the informativeness of the accounting signal is only relevant upon the realization of a bad signal, conservatism effectively reduces the quality of information. Therefore, making the accounting information more conservative in our setting is effectively equivalent to lowering the quality of information, and thus induces banks to take less risk, as we know from the results in the main setting.

3.6. Robustness and Caveats

The results illustrated so far in this paper are obtained under some simplifying assumptions. One must make choices on what aspects of the real world to reflect in the model and, therefore, leave out some portions of reality that might have potentially affected the results had they been considered. In this section we try to assess the extent to which our results are contingent on our simplifying assumptions and, also, consider some unmodeled factors that may affect our results.

Perhaps the two main simplifying assumptions made in the model are: (i) the non-perfect observability of the banks decisions by the market, and (ii) the exogenous and constant assets sales portion α. To assess the robustness of our results to the relaxation of the former assumption, we examine an alternative specification to the main setup which assumes that the market can perfectly observe both the investment and risk decisions of each bank. This specification of the model leads to a high-degree polynomial in S_i that can only be analyzed numerically. However, we see a similar pattern of increasing equilibrium risk decisions with increasing information quality. This allows us to conclude with some confidence that the unobservability assumptions in isolation do not seem to drive our results.

We also analyze the effect of an endogenous α on our results by assuming that, after the accounting signals are released, each bank that obtains a bad signal sells a portion of its assets such that the capital ratio satisfies the capital requirement. This model specification is also difficult to examine analytically. However, numerical simulations facilitate the analysis and show that equilibrium risk decisions are still increasing in information quality for any capital requirement above a certain threshold. Below this threshold, however, risk decisions can decrease with information quality, especially when the number of firms is small.

We also examine the simultaneous relaxation of both simplifying assumptions. That is, we introduce the perfect observability of banks' decisions and the endogeneity of α in the same setting. Since, in our opinion, arguing that risk decisions are perfectly observable is quite unrealistic, we first examine a setting with an endogenous α, a perfectly observable D_i, and a non-perfectly observable S_i. Numerical simulations show that the qualitative nature of the results is similar to the one obtained with an endogenous α and unobservable decisions. That is, we still find a positive relation between banks' risk decisions and information quality for a capital requirement larger than a threshold and the opposite result below this threshold. For completeness, we also examine the most extreme case: an endogenous α and perfectly observable investment and risk decisions. In this case, one can still obtain a positive relation between risk and information quality for high capital requirements. Overall, the numerical examination of all these models drives us to believe that the positive relation between risk and information quality described in Proposition 11 is present in all specifications of the model and, therefore, quite robust.

There are aspects of the real world that we do not reflect in our model but that might potentially affect the results if considered. One such factor is that banks have the possibility of satisfying the capital requirement by raising capital through the issuance of new equity. Another such factor, examined by Boyd and Nicolò (2005), is allowing the risk level to be privately selected by borrowers, but indirectly induced by banks through the offer of menus of contracts. We analyzed the consideration of both factors separately, and are able to show that the revised models yield qualitatively similar results to the ones in Proposition 11.

Finally, although distressed banks sell risky assets with the purpose of increasing their capital ratio, ironically, it is often observed that, after obtaining the cash proceeds, they immediately pay bonuses to top executives and/or dividends to their shareholders. Regulators have taken actions to restrict this kind of "cash out" and investors can potentially claw back part of these executive bonuses through litigation. Nevertheless, it may be instructive to study the case in which at least a portion of the sales proceeds is appropriated by the decision makers in the bank. In such a setting, we find that our results in the main setting still remain when the information quality ϕ is low and/or the proportion of appropriated cash proceeds is small. However, when ϕ is sufficiently high and the proportion of appropriated cash proceeds is high, the introduction of this "cash out" makes the bank's risk-taking level decrease in the information quality. Intuitively, when the information quality is high, the assets price upon a bad signal is lower than when accounting information is noisy, which in turn diminishes the size of the benefit from "cash out." This, in turn, motivates the bank to take less risk. As the cash-out benefit joins the false-alarm-cost effect in disciplining banks' risk taking, the trade-off with the deposit-market effect becomes more balanced, and that yields a non-monotonic relation between the information quality and the risk taken by the bank.[8]

[8]Detailed analyses of our robustness checks are available upon request.

3.7. Conclusion

In this paper, we study the interaction between interbank competition and accounting information quality, and their effects on banks' risk-taking behavior. We examine a setting in which banks choose the risk level of their loan investments in a competitive environment. The banks are subject to a capital requirement, which is measured using accounting information. In case of capital deficiency, a bank is forced to sell a portion of its risky assets to boost its capital ratio. We identify a false-alarm cost of assets sales for banks and show that this cost, together with the imperfect competition among the banks, plays important roles in the relation between accounting information quality and the banks' risk taking. We find that an improvement in the quality of accounting information may induce the banks to take more risk when the competition is not too fierce. Bank regulators may believe that competition should be restricted by regulation to enhance bank stability. Separately, better accounting disclosure is often posited as an important market disciplining device for banks. Our paper shows that there is an interaction between the two mechanisms, where improving information quality actually increases risk taking with mild competition while it has no effect under fierce competition. The results imply that these mechanisms cannot be evaluated in isolation.

This study rests on a set of simplifying assumptions that ensure the tractability of the model. We numerically examine the consequence of relaxing each of these assumptions and confirm that our main findings are robust. However, a complete examination of all the possible combinations and variations of these assumptions is beyond the scope of a single paper.

CHAPTER 4

Conclusion

Banking institutions are crucial to numerous economic activities. This dissertation presents analytical models that seek to better understand the determinants and consequences of the information disclosure by banking institutions. I show that the unique nature of banking institutions helps to develop distinctive roles of information disclosure that are under-explored in the previous literature. Specifically, I examine two roles of information disclosure in the banking context. First, information plays a vital role in investors' formation of beliefs in bank runs, where the equilibrium outcome depends critically on how investors form beliefs about economic states and each other's beliefs. I show that the interplay between information and liquidity risk stemming from bank runs may lead to a symbiotic relationship between the shadow and the traditional banking systems. The analysis shows that competition with an opaque and fragile shadow bank can benefit the traditional bank, especially when the traditional bank is highly vulnerable to liquidity risk. The opacity and fragility of the shadow bank help to coordinate (higher-order) beliefs and actions of individual investors, which improve the management of liquidity risk faced by the traditional bank. In the parallel banking equilibrium, the traditional bank induces the shadow bank to be both opaque and fragile by lowering its own disclosure precision. Second, the information disclosed by banks is also widely used in the prudential bank regulation. I explore the use of accounting information in monitoring banks' satisfaction of the regulatory capital requirement. I find that sometimes an improvement in the quality of accounting information actually induces the banks to take more risk. The improvement of accounting information quality exacerbates the competition among banks, inducing banks to pursue more risky project in order to maintain the profit margin.

In their survey of the extant empirical research in the field of banking and accounting, Betty and Liao (2013) argue that the main challenge in much of the bank financial accounting research is in generating counterfactual forward-looking statements, which is of central importance to the provision of meaningful policy implications. Despite its popularity and soundness, the empirical approach alone seems to have difficulties in giving such statements because of the lack of suitable control groups and of the ability to predict changes in economic behaviors. In fact, Betty and Liao (2013) call for "a model to describe how banks will change their behavior in response to the proposed policy." I view such a call as an indicator of the lagging development in the analytical research of banking and accounting. This call, however, also suggests the abundance of potential research opportunities and thus can be read as an invitation for future research. In this light, this dissertation, despite of its limitations and simplifications, serves to at least throw a brick in order to attract a jade.

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Appendix

Appendix A

Chapter 2 assumes that the investment return is strictly increasing in the aggregate investment. In this appendix, I examine a model that explicitly considers the bank's role of liquidity transformation to better motivate this return structure.

Specifically, I consider a three-date model with one bank and a continuum of investors, indexed by the unit interval $[0, 1]$. The analysis for two banks is similar. The timeline is as follows. At date 0, each investor is endowed with an initial amount of wealth, $\bar{K}$. For simplicity, I assume that each investor j invests the endowment, $\bar{K}$, in the bank. The bank thereafter plunges all the investments it raised, $\bar{K} = \int_0^1 \bar{K} dj$, into a production technology which yields a stochastic return, θ, at date 2. The exogenous parameter θ is normally distributed, with mean $\bar{\theta} > 0$ and variance, $\frac{1}{q}$. To capture the bank's role in liquidity transformation, I assume that the investment is illiquid. That is, if the production is interrupted at date 1, the salvage value is λ per unit of interrupted investments, where $0 < \lambda < 1$. As with the main model, I assume that the investment profits are split equally between the bank and its investors. I also assume that the bank's liability is liquid, in the sense that investors can freely withdraw any amounts of their investments at the face value. At date 1, after the private and public signals concerning θ are realized, the investor decides the amount of the investment she wants to withdraw. I denote investor j's remaining investment as k_j and the aggregate investment remaining in the bank as K, where $K = \int_0^1 k_j dj$. To satisfy the withdrawal request, the bank is forced to liquidate its illiquid project at the rate, λ. To fulfill the withdraw requests $\bar{K} - K$, the amount of the bank's assets that needs to be liquidated is $\frac{\bar{K}-K}{\lambda}$ and the remaining amount of the investments becomes $\bar{K} - \frac{\bar{K}-K}{\lambda}$. The total investment profits from the project can be calculated as:

$$(\bar{K} - \frac{\bar{K} - K}{\lambda})\theta \tag{4.1}$$

The per-unit investment return of the project, R, is equal to:

$$[\frac{1}{\lambda} - \frac{(1-\lambda)\,\bar{K}}{\lambda\,K}]\,\theta \tag{4.2}$$

When the aggregate investment after withdrawal, K is sufficiently close to $\bar{K}$, I can approximate the investment return, R, by a first-order Taylor expansion around $K = \bar{K}$ and $\theta = \bar{\theta}$, such that:

$$R = \bar{\theta} + \frac{\partial R}{\partial K}(K - \bar{K}) + \frac{\partial R}{\partial \theta}(\theta - \bar{\theta}) \tag{4.3}$$

where at $K = \bar{K}$ and $\theta = \bar{\theta}$, $\frac{\partial R}{\partial K} = \frac{1-\lambda}{\lambda}\frac{\bar{\theta}}{\bar{K}} > 0$ which is a positive constant, and $\frac{\partial R}{\partial \theta} = 1$. Therefore, denoting $\frac{\partial R}{\partial K}$ as a, I have the linear return structure similar to the one used in the main setting:

$$R = \bar{\theta} + a\,(K - \bar{K}) + (\theta - \bar{\theta}) \tag{4.4}$$
$$= \theta - a\,(\bar{K} - K)$$
$$= \theta + a\,K - a\,\bar{K}$$

Notice that this linear approximation differs from the one I used in the main setting only by a constant, $-a\,\bar{K}$, and I verify that adding this constant doesn't bring any new insights to my model.

Appendix B

Chapter 2 assumes that each individual's investment in a bank is linearly increasing in the expected return of this bank and linearly decreasing in the expected return of the other bank. In this appendix, I show that this assumption can be motivated by assuming each investor either incurs a quadratic investment cost or has a CARA utility.

I first examine a model in which investors incur a quadratic investment cost, $c_j(k_{1j}, k_{2j})$, as follows:

$$c_j(k_{1j}, k_{2j}) = \frac{1}{2\,(1-b^2)}\,(k_{1j}^2 + k_{2j}^2 + 2\,b\,k_{1j}\,k_{2j}) \tag{4.5}$$

with $0 < b < 1$. The cross term, $2\,b\,k_{1j}\,k_{2j}$, makes each investor's investments in the two banks a strategic substitute to each other. The payoff function for investor j is then given by

$$u_j(k_{1j}, k_{2j}) = \frac{1}{2}\,R_1\,k_{1j} + \frac{1}{2}\,R_2\,k_{2j} - \frac{1}{2\,(1-b^2)}\,(k_{1j}^2 + k_{2j}^2 + 2\,b\,k_{1j}\,k_{2j}) \tag{4.6}$$

Each investor maximizes its expected payoff, which gives the optimal investments as:

$$\begin{aligned} k_{1j}^* &= E_j[\frac{1}{2}R_1] - b\,E_j[\frac{1}{2}R_2] \\ k_{2j}^* &= E_j[\frac{1}{2}R_2] - b\,E_j[\frac{1}{2}R_1] \end{aligned} \tag{4.7}$$

where each individual's investment in a bank is linearly increasing in the expected return of this bank and linearly decreasing in the expected return of the other bank, the same as the one used in the main setting.

Alternatively, I can also assume that each investor has a CARA utility such as:

$$u_j = -\frac{1}{\alpha} e^{-\alpha\, c_j} \tag{4.8}$$

where α measures each investor's relative risk aversion rate. An investor's consumption c_j, is equal to its share of investment profits from the two banks:

$$c_j = \frac{1}{2} R_1\, k_{1j} + \frac{1}{2} R_2\, k_{2j} \tag{4.9}$$

Each investor is also subject to a wealth constraint:

$$k_{1j} + k_{2j} \leq W \tag{4.10}$$

where W denotes each investor's total wealth. As shown in Proposition 1, the aggregate investment K_1 is normally distributed. Therefore, the return R_1, which is a linear combination of θ_1 and K_1, is also normally distributed and so is R_2. Applying the standard results for CARA utilities, each investor equivalently maximizes the following payoff:

$$E[c_j] - \frac{\alpha}{2} Var[c_j] \tag{4.11}$$

$$s.t.\; k_{1j} + k_{2j} \leq W$$

which gives the optimal investments as follows:

$$\begin{aligned} k_{1j}^* &= \frac{E_j[\frac{1}{2}R_1] - E_j[\frac{1}{2}R_2] + \alpha W(\sigma_2^2 - \rho\sigma_1\sigma_2)}{\alpha(\sigma_1^2 + \sigma_2^2 - 2\rho\sigma_1\sigma_2)} \\ k_{2j}^* &= \frac{E_j[\frac{1}{2}R_2] - E_j[\frac{1}{2}R_1] + \alpha W(\sigma_1^2 - \rho\sigma_1\sigma_2)}{\alpha(\sigma_1^2 + \sigma_2^2 - 2\rho\sigma_1\sigma_2)} \end{aligned} \tag{4.12}$$

where σ_1, σ_2, and ρ denote the standard deviation of R_1, the standard deviation of R_2 and the correlation between R_1 and R_2, respectively. I find that assuming a CARA utility for investors, the investment in a bank is linearly increasing in the expected return of this bank and linearly decreasing in the expected return of the other bank, similar to the assumption made in the main setting.

Appendix C

Derivations of Banks' Objective Function in Chapter 3

When a bad accounting signal is realized, the bank is forced to sell an α portion of its loan. The expected proceeds from the assets sale will be

$$\alpha\, P_{\mathrm{H|B}} Asset_i^{\mathrm{B}} + (1-\alpha)\, E(Loan|\mathrm{B}, S_i, D_i, D_{-i}) - P_{\mathrm{H|B}}\, b\left(\sum_i D_i\right) D_i, \tag{4.13}$$

where the first term is the expected proceeds of the assets sale since the bank can keep these cash proceeds only when the H state is later realized, the second is the expected cash flow from the remaining loan held by the bank, and the third is the bank's total expected deposit interest payment. We assume investors offer a fair price for the bank's assets given their conjectures:

$$Asset_i^{\mathrm{B}} = \frac{(1-\phi)\,(1-S_i^c)}{(1-\phi)\,(1-S_i^c)+\phi\, S_i^c}(1+\ S_i^c)\, D_i^c. \tag{4.14}$$

Conditional on the bad accounting signal, the expected proceeds from the loan equals

$$E(Loan|\mathrm{B}, S_i, D_i, D_{-i}) = \frac{(1-\phi)\,(1-S_i)}{(1-\phi)\,(1-S_i)+\phi\, S_i}(1+\ S_i)\, D_i. \tag{4.15}$$

When a good signal is realized, no assets sale is necessary and the bank receives $E(Loan|\mathrm{G}, S_i, D_i, D_{-i}) - P_{\mathrm{H|G}} b(\sum_i D_i)\, D_i$. Hence the bank's total expected payoff, which is also its objective function, is

$$P_{\mathrm{G}}\left[E(Loan|\mathrm{G},S_i,D_i,D_{-i})-P_{\mathrm{H|G}}b\left(\sum_i D_i\right)D_i\right] \tag{4.16}$$

$$+(1-P_{\mathrm{G}})\quad\left[\alpha P_{\mathrm{H|B}}Asset_i^{\mathrm{B}}+(1-\alpha)E(Loan|\mathrm{B},S_i,D_i,D_{-i})-P_{\mathrm{H|B}}b\left(\sum_i D_i\right)D_i\right].$$

Derivations of Bayesian Probabilities in Chapter 3

The conditional probability of the H state given a good signal is

$$P_{\mathrm{H|G}}=\frac{\phi\,(1-S_i)}{\phi\,(1-S_i)+(1-\phi)\,S_i}; \tag{4.17}$$

the conditional probability of the H state given a bad signal is

$$P_{\mathrm{H|B}}=\frac{(1-\phi)\,(1-S_i)}{(1-\phi)\,(1-S_i)+\phi\,S_i}; \tag{4.18}$$

the probability of a good signal is

$$P_{\mathrm{G}}=\phi\,(1-S_i)+(1-\phi)\,S_i; \tag{4.19}$$

the probability of a bad signal is

$$P_{\mathrm{B}}=1-P_{\mathrm{G}}. \tag{4.20}$$

Appendix D: Proofs

Proof of Proposition 1

Proof. The general idea is that I let an individual investor form a conjecture on equilibrium investments, which is linear in all signals in the information set. The investor then decides her own optimal investments given this conjecture. In a rational expectation equilibrium, the investor's conjecture must be consistent with the individual optimal investments in equilibrium. Therefore, comparing the coefficients in the linear conjecture with the coefficients in the individual optimal investment determines the unknown coefficients in the investor's conjecture. I further demonstrate that this linear equilibrium is the unique equilibrium using the higher-order-belief approach developed in Morris and Shin (2002). Thus, as a first step, each individual forms a linear conjecture on equilibrium investments

$$
\begin{aligned}
k_{1j} &= (\beta_1\, x_{1j} + \gamma_1\, z_1) - b\,(\omega_1\, z_2 + \lambda_1\, x_{2j}) + h_1, \\
k_{2j} &= (\beta_2\, x_{2j} + \gamma_2\, z_2) - b\,(\omega_2\, z_2 + \lambda_2\, x_{2j}) + h_2,
\end{aligned}
\tag{4.21}
$$

Then the aggregate investments become

$$
\begin{aligned}
K_1 &= (\beta_1 \theta_1 + \gamma_1\, z_1) - b\,(\omega_1\, z_2 + \lambda_1\, \theta_2) + h_1, \\
K_2 &= (\beta_2\, \theta_2 + \gamma_2\, z_2) - b\,(\omega_2\, z_2 + \lambda_2\, \theta_1) + h_2,
\end{aligned}
\tag{4.22}
$$

investor j's conditional estimates of the aggregate investment are

$$
\begin{aligned}
(4.23) \qquad E_j(K_1) &= \beta_1(\frac{m_1 z_1 + n_1 x_{1j} + q\bar{\theta}}{m_1 + n_1 + q}) + \gamma_1 z_1 \\
&\quad -b[\lambda_1(\frac{m_2 z_2 + n_2 x_{2j} + q\bar{\theta}}{m_2 + n_2 + q}) + \omega_1 z_2] + h_1, \\
E_j(K_2) &= \beta_2(\frac{m_2 z_2 + n_2 x_{2j} + q\bar{\theta}}{m_2 + n_2 + q}) + \gamma_2 z_2 \\
&\quad -b[\lambda_2(\frac{m_1 z_1 + n_1 x_{1j} + q\bar{\theta}}{m_1 + n_1 + q}) + \omega_2 z_1] + h_2,
\end{aligned}
$$

Therefore, the individual investments become

$$
\begin{aligned}
(4.24) \qquad k_{1j} &= E_j R_1 - b E_j R_2 \\
&= E_j[\theta_1] + a_1 E_j[K_1] - b(E_j[\theta_2] + a_2 E_j[K_2]) \\
&= (\frac{m_1 z_1 + n_1 x_{1j} + q\bar{\theta}}{m_1 + n_1 + q}) + a_1 E_j[K_1] \\
&\quad -b((\frac{m_2 z_2 + n_2 x_{2j} + q\bar{\theta}}{m_2 + n_2 + q}) + a_2 E_j[K_2]),
\end{aligned}
$$

and

$$
\begin{aligned}
(4.25) \qquad k_{2j} &= E_j R_2 - b E_j R_1 \\
&= E_j[\theta_2] + a_2 E_j[K_2] - b(E_j[\theta_1] + a_1 E_j[K_1]) \\
&= (\frac{m_2 z_2 + n_2 x_{2j} + q\bar{\theta}}{m_2 + n_2 + q}) + a_2 E_j[K_2] \\
&\quad -b((\frac{m_1 z_1 + n_1 x_{1j} + q\bar{\theta}}{m_1 + n_1 + q}) + a_1 E_j[K_1]),
\end{aligned}
$$

where $E_j[K_1]$ and $E_j[K_2]$ are given by equation (4.23). Comparing the coefficients in (4.21) and (4.24), I obtain the solutions for $\{\beta_i^*,\, \gamma_i^*,\, \omega_i^*,\, \lambda_i^*\}$ given in Proposition 1 and

$$h_1^* = (\frac{\gamma_1^*}{m_1} - \frac{b\omega_1^*}{m_2})\, q\bar{\theta}. \tag{4.26}$$

The other case when the shadow bank is deterred from entry can be derived similarly and

$$h_1^{**} = (\frac{\gamma_1^{**}}{m_1})\, q\bar{\theta}. \tag{4.27}$$

I now follow the higher-order-belief approach outlined in Morris and Shin (2002) and show that this linear equilibrium is indeed the unique equilibrium. I first show that the k-th order expectation of the fundamentals θ_i, by the group of investors, takes the following functional form, where $i \in \{1, 2\}$,

$$\bar{E}^k[\theta_i] = \delta_{ik}\, z_i + l_{ik}\, \theta_i + r_{ik}\, \bar{\theta}, \tag{4.28}$$

where

$$\begin{aligned} \delta_{ik} &= \frac{m_i}{m_i+q}[1-(\frac{n_i}{m_i+n_i+q})^k], \\ l_{ik} &= (\frac{n_i}{m_i+n_i+q})^k, \\ r_{ik} &= \frac{q}{m_i+q}[1-(\frac{n_i}{m_i+n_i+q})^k], \end{aligned} \tag{4.29}$$

This can be shown by induction. At $k = 1$, I know an individual j's expectation of θ_i is:

$$E_j(\theta_i) = \frac{m_i z_i + n_i x_{ij} + q\bar{\theta}}{m_i + n_i + q}, \tag{4.30}$$

Therefore, the expectation of θ_i by the group of investors becomes

$$\bar{E}[\theta_i] = \int_0^1 E_j(\theta_i) di = \frac{m_i z_i + n_i \theta_i + q\bar{\theta}}{m_i + n_i + q}, \tag{4.31}$$

Now Suppose (4.28) holds for $k - 1$. Then

$$\begin{aligned} E_j[\bar{E}^{k-1}[\theta_i]] &= E_j[\delta_{ik-1}\, z_i + l_{ik-1}\, \theta_i + r_{ik-1}\, \bar{\theta}] \\ &= \delta_{ik-1}\, z_i + r_{ik-1}\, \bar{\theta} + l_{ik-1}\, E_j[\theta_i] \\ &= \delta_{ik-1}\, z_i + r_{ik-1}\, \bar{\theta} + \frac{m_i z_i + n_i x_{ij} + q\bar{\theta}}{m_i + n_i + q}, \end{aligned} \tag{4.32}$$

Therefore,

$$\bar{E}^k[\theta_i] = \delta_{ik-1}\, z_i + r_{ik-1}\, \bar{\theta} + \frac{m_i z_i + n_i \theta_i + q\bar{\theta}}{m_i + n_i + q}, \tag{4.33}$$

and after a few simplifying steps, this gives

$$\bar{E}^k[\theta_i] = \delta_{ik}\, z_i + l_{ik}\, \theta_i + r_{ik}\, \bar{\theta}, \tag{4.34}$$

which concludes the proof on the linear form of $\bar{E}^k[\theta_i]$. In addition, notice also the individual optimal investments can be rewritten as:

$$\boldsymbol{k}_j = \boldsymbol{A}\,\boldsymbol{E}_j[\boldsymbol{\theta}] + \boldsymbol{B}\,\boldsymbol{E}_j[\boldsymbol{K}], \tag{4.35}$$

where

$$\begin{aligned} \boldsymbol{k}_j &= \begin{bmatrix} k_{1j} \\ k_{2j} \end{bmatrix}, \\ \boldsymbol{E}_j[\boldsymbol{\theta}] &= \begin{bmatrix} E_j[\theta_1] \\ E_j[\theta_2] \end{bmatrix}, \\ \boldsymbol{E}_j[\boldsymbol{K}] &= \begin{bmatrix} E_j[K_1] \\ E_j[K_2] \end{bmatrix}, \\ \boldsymbol{A} &= \begin{bmatrix} 1 & -b \\ -b & 1 \end{bmatrix}, \\ \boldsymbol{B} &= \begin{bmatrix} a_1 & -ba_2 \\ -ba_1 & a_2 \end{bmatrix}, \end{aligned} \tag{4.36}$$

Substituting in the individual j's expectation about the aggregate investment gives

$$\begin{aligned} \boldsymbol{k}_j &= \boldsymbol{A}\,\boldsymbol{E}_j[\boldsymbol{\theta}] + \boldsymbol{B}\,\boldsymbol{A}\,\boldsymbol{E}_j\bar{\boldsymbol{E}}[[\boldsymbol{\theta}]] + \boldsymbol{B}^2\,\boldsymbol{A}\,\boldsymbol{E}_j\,[\bar{\boldsymbol{E}}^{\boldsymbol{2}}[\boldsymbol{\theta}]] + \ \ldots \\ &= \sum_{k=0}^{\infty} \boldsymbol{B}^k\,\boldsymbol{A}\,\boldsymbol{E}_j[\bar{\boldsymbol{E}}^{\boldsymbol{k}}[\boldsymbol{\theta}]], \end{aligned} \tag{4.37}$$

where I have shown that

$$\bar{\boldsymbol{E}}^k\,[\boldsymbol{\theta}] = \begin{bmatrix} \delta_{1k}\,z_1 + l_{1k}\,\theta_1 + r_{1k}\,\bar{\theta} \\ \delta_{2k}\,z_2 + l_{2k}\,\theta_2 + r_{2k}\,\bar{\theta} \end{bmatrix}, \tag{4.38}$$

It can also be verified that given $0 < a_1 < \frac{1}{2}, 0 < a_2 < \frac{1}{2}$, and $0 < b < 1$, the eigenvalues of $\boldsymbol{B}$ are all between 0 and 1. Therefore, the sum $\sum_{k=0}^{\infty} \boldsymbol{B}^k\, \boldsymbol{A}\, \boldsymbol{E}_j[\bar{\boldsymbol{E}}^{\boldsymbol{k}}[\boldsymbol{\theta}]]$ is converging. After a few simplifying steps, this sum reduces to the exact linear forms as in Proposition 1 and hence I have verified the uniqueness of the linear equilibrium. □

Proof of Corollary 2

Proof. These can be shown by directly computing the derivatives. □

Proof of Proposition 3

Proof. The outline of the proof is as follows. I first show that the payoff of the traditional bank, Π_1, is continuous in a_1. Second, I show that when $a_1 = \frac{1}{2}$, the traditional bank always prefers to accommodate the entry of the shadow bank. Third, I show that when $a_1 = 0$, the traditional bank prefers to deter the entry of the shadow bank, as long as the disclosure cost is not too high. Lastly, I employ the intermediate value theorem to show the existence of the thresholds, $\hat{a}$.

As a first step, it is straightforward to verify the continuity of Π_1. Given $0 < a_1 < \frac{1}{2}, 0 < a_2 < \frac{1}{2}$, and $0 < b < 1$, all the coefficients $\{\beta_i^*,\, \gamma_i^*,\, \omega_i^*,\, \lambda_i^*,\, h_i^*\}$ in the individual optimal investments are continuous in a_1. Therefore, Π_1 is continuous in a_1.

Second, at $a_1 = \frac{1}{2}$, it can be shown that for any set of $\{m_1, m_2, a_2\}$, when $\bar{\theta} < \hat{\theta}$, the payoff of the traditional bank when it accommodates the entry of the shadow bank, $\Pi_1(\cdot|a_1 = \frac{1}{2})$, is strictly higher than its payoff when it deters entry, $\Pi_1^M(\cdot|a_1 = \frac{1}{2})$.[1] That is, for any set of $\{m_1, m_2, a_2\}$,

$$\Pi_1(\cdot|a_1 = \frac{1}{2}) > \Pi_1^M(\cdot|a_1 = \frac{1}{2}), \tag{4.39}$$

In addition, it can be also verified that

$$\lim_{q \to 0} \hat{\theta} = \infty, \tag{4.40}$$

Hence, when q is sufficiently close to zero, $\Pi_1(\cdot|a_1 = \frac{1}{2}) > \Pi_1^M(\cdot|a_1 = \frac{1}{2})$.

Third, at $a_1 = 0$, the following holds:

$$\lim_{q \to 0} [\Pi_1(\cdot|a_1 = 0) - \Pi_1^M(\cdot|a_1 = 0)] = -\infty, \tag{4.41}$$

Hence, when q is sufficiently close to zero, $\Pi_1(\cdot|a_1 = 0) < \Pi_1^M(\cdot|a_1 = 0)$.

Lastly, since $\Pi_1(\cdot|) - \Pi_1^M(\cdot|)$ is continuous in a_1, by the intermediate value theorem, in the compact set $a_1 \in [0, 1]$, there exists at least one a_x that makes

[1] Most of the inequalities in this proof are given by Mathematica. All the related code is available upon request.

$\Pi_1(\cdot|a_1 = a_x) - \Pi_1^M(\cdot|a_1 = a_x) = 0$. Define

$$f(a_1) = \Pi_1(\cdot) - \Pi_1^M(\cdot|), \tag{4.42}$$

I will show for any set of $\{m_1, m_2, a_2, b\}$, there is a unique root $\hat{a}$ that makes $f(\hat{a}) = 0$. When q is sufficiently close to zero, it can be verified that the derivative, $\frac{\partial f}{\partial a_1}$, has the same sign with the following polynomial:

$$C_1\, b^4 + C_2\, b^2 + C_3, \tag{4.43}$$

where,

$$\begin{aligned} C_1 &= (2\,a_1 - 1)\,[1 - (1 - a_1)\,a_1]\,a_2^3 < 0, \\ C_2 &= -(1 - a_1)\,a_2\,[(1 - a_1)^3 + (1 - 2\,a_1 + 4a_1^2)a_2(1 - a_2)] < 0, \\ C_3 &= (1 - a_1)^2(1 - a_2)\{(1 - a_2)a_2 - a_1^2 + a_1[1 + 2a_2(1 - a_2)]\} > 0, \end{aligned} \tag{4.44}$$

Define $x = b^2$, and $g(x) = C_1\,x^2 + C_2\,x + C_3$, where, given $b \in [0,1]$, $x \in [0,1]$. Notice that $g(x)$ has the same sign with $C_1\,b^4 + C_2\,b^2 + C_3$ and hence with $\frac{\partial f}{\partial a_1}$. Since $C_1 < 0$ and $C_3 > 0$, there exists a unique positive root for the quadratic function $g(x)$. Denote this positive root as $x^+(a_1, a_2)$. Notice also since $C_1 < 0$, $C_2 < 0$, $C_3 > 0$, the quadratic function $g(x)$ is strictly decreasing for $x > 0$. Therefore, $x^+ > 1$ if and only if $g(1) > g(x^+) = 0$. It can also be verified that $g(1) = C_1 + C_2 + C_3 > 0$ if and only if $a_1 > S_1(a_2)$, where $S_1(a_2) \in [0, \frac{1}{2}]$, is a function of a_2. When $a_1 > S_1(a_2)$, $g(1) > 0$ and since $g(x)$ is strictly decreasing for $x > 0$, for $x \in [0,1]$, $g(x) \geq g(1) > 0$. That is, for $a_1 > S_1(a_2)$, $\frac{\partial f}{\partial a_1} > 0$. Now consider the case when $a_1 \leq S_1(a_2)$. Notice that,

$$x^{+} = \frac{-C_2 - \sqrt{C_2^2 - 4\,C_1\,C_3}}{2\,C_1}, \tag{4.45}$$

and it can be verified that $\frac{\partial x^{+}}{\partial a_1} > 0$, that is, x^{+} is strictly increasing in a_1. As defined, at $a_1 = S_1(a_2)$, $x^{+} = 1 > b^2$. Consider two cases. First, given b, when at $a_1 = 0$, $x^{+}(a_1 = 0) > b^2$. In this case, for $0 \leq a_1 \leq S_1(a_2)$, $x^{+} > x^{+}(a_1 = 0) > b^2$, which makes $g(x = b^2) > g(x^{+}) = 0$, since $g(x)$ is strictly decreasing. That is, $\frac{\partial f}{\partial a_1} > 0$. Combined with the result that $\frac{\partial f}{\partial a_1} > 0$ for $a_1 > S_1(a_2)$, I verify that $\frac{\partial f}{\partial a_1} > 0$ for all $a_1 \in [0, \frac{1}{2}]$. Therefore, there is a unique root $\hat{a}$ that makes $f(\hat{a}) = 0$ since $f(a_1)$ is strictly increasing. Second, when at $a_1 = 0$, $x^{+}(a_1 = 0) \leq b^2$, then by the intermediate value theorem, since $x^{+}(a_1 = S_1(a_2)) = 1 > b^2$, there exists a unique solution, $S_2(a_2, b) \in (0, S_1(a_2))$, such that at $a_1 = S_2(a_2, b)$, $x^{+} = b^2$. In addition, for $a_1 > S_2(a_2, b)$, $x^{+} > x^{+}(a_1 = S_2(a_2, b)) = b^2$, since $\frac{\partial x^{+}}{\partial a_1} > 0$, which makes $g(x = b^2) > g(x^{+}) = 0$ and $\frac{\partial f}{\partial a_1} > 0$. On the other hand, for $a_1 \leq S_2(a_2, b)$, $x^{+} \leq b^2$, which makes $g(x = b^2) \leq g(x^{+}) = 0$ and $\frac{\partial f}{\partial a_1} \leq 0$. Combined with the result that $\frac{\partial f}{\partial a_1} > 0$ for $a_1 > S_1(a_2)$, I have $\frac{\partial f}{\partial a_1} > 0$ for $a_1 > S_2(a_2, b)$, and $\frac{\partial f}{\partial a_1} \leq 0$ for $a_1 \leq S_2(a_2, b)$. Recall that at $a_1 = 0$, $f(0) < 0$. Therefore, at any $a_1 \in [0, S_2(a_2, b)]$, $f(S_2(a_2, b)) < f(a_1) < f(0) < 0$. Thus there is no root for $f(a_1)$ in $[0, S_2(a_2, b)]$. For $a_1 > S_2(a_2, b)$, since $f(S_2(a_2, b)) < 0$ and $f(\frac{1}{2}) > 0$, by the intermediate value theorem, there exists a root $\hat{a}$ that makes $f(\hat{a}) = 0$. This root is also unique given $f(a_1)$ is monotonically increasing in a_1 for $a_1 > S_2(a_2, b)$. I thereby have verified that for any set of $\{m_1, m_2, a_2, b\}$, there is a unique root $\hat{a}$ that makes $f(\hat{a}) = 0$.

For any set of $\{m_1, m_2, a_2\}$, there exists an $\hat{a}$, when $a_1 > \hat{a}$,

$$\Pi_1(\cdot) > \Pi_1^M(\cdot|), \tag{4.46}$$

Let m_1^* be the optimal decision of the traditional bank when it accommodates the entry of the shadow bank and m_1^{*D} be the optimal decision when it deters. Let $(m_2^*(m_1), a_2^*(m_1))$ be the optimal decisions of the shadow bank contingent on the decision of m_1. I first have

$$\Pi_1(m_1^{*D}, m_2^*(m_1^{*D}), a_2^*(m_1^{*D})) > \Pi_1^M(m_1^{*D}), \tag{4.47}$$

In addition, since I rule out the blockaded case and by Proposition 8, the entry constraint for the shadow bank always binds, i.e.,

$$\Pi_2(m_1^{*D}, m_2^*(m_1^{*D}), a_2^*(m_1^{*D})) = \overline{U}, \tag{4.48}$$

therefore, the choice of m_1^{*D} is also within the feasible set of the accommodation case (marginally). Since m_1^* is the optimal decision by the traditional bank in the accommodation case, I in turn have

$$\Pi_1(m_1^*, m_2^*(m_1^*), a_2^*(m_1^*)) \geq \Pi_1(m_1^{*D}, m_2^*(m_1^{*D}), a_2^*(m_1^{*D})), \tag{4.49}$$

Thus

$$\Pi_1(m_1^*, m_2^*(m_1^*), a_2^*(m_1^*)) \geq \Pi_1(m_1^{*D}, m_2^*(m_1^{*D}), a_2^*(m_1^{*D})) > \Pi_1^M(m_1^{*D}), \tag{4.50}$$

which indicates that the traditional bank always deters the shadow bank's entry when $a_1 > \hat{a}$. For any set of $\{m_1, m_2, a_2\}$, there exists an $\hat{a}$, when $a_1 < \hat{a}$,

$$\Pi_1(\cdot) < \Pi_1^M(\cdot), \tag{4.51}$$

in particular,

$$\Pi_1(m_1^{*D}, m_2^*(m_1^{*D}), a_2^*(m_1^{*D})) < \Pi_1^M(m_1^{*D}), \tag{4.52}$$

However, in order to deter the shadow bank from entry, as shown in Proposition 8 the traditional bank needs to distort its disclosure precision upward and chooses m_1^{*D} instead of m_1^*, where $m_1^{*D} \geq m_1^*$. Therefore, if the traditional bank chooses to accommodate entry, it can choose m_1^* instead of m_1^{*D}, which saves the additional disclosure cost, measured by $\Pi_1(m_1^*, m_2^*(m_1^*), a_2^*(m_1^*)) - \Pi_1(m_1^{*D}, m_2^*(m_1^{*D}), a_2^*(m_1^{*D}))$. However, as long as the disclosure is not too costly and lower than the gain from the deterrence, i.e.,

$$\begin{aligned} & \Pi_1(m_1^*, m_2^*(m_1^*), a_2^*(m_1^*)) - \Pi_1(m_1^{*D}, m_2^*(m_1^{*D}), a_2^*(m_1^{*D})) \\ < \; & \Pi_1^M(m_1^{*D}) - \Pi_1(m_1^{*D}, m_2^*(m_1^{*D}), a_2^*(m_1^{*D})), \end{aligned} \tag{4.53}$$

I have[2]

$$\Pi_1^M(m_1^{*D}) > \Pi_1(m_1^*, m_2^*(m_1^*), a_2^*(m_1^*)), \tag{4.54}$$

That is, the traditional bank prefers to deter the shadow bank from entry. □

Proof of Proposition 4

Proof. In equilibrium, the first-order conditions for the shadow bank are given as follows:

$$\begin{aligned} \frac{\partial \Pi_2}{\partial m_2} &= 0, \\ \frac{\partial \Pi_2}{\partial a_2} &= 0, \end{aligned} \tag{4.55}$$

[2]It can be verified that this constraint gives a threshold on the disclosure cost of the traditional bank such that if the disclosure cost is lower than the threshold, this constraint is satisfied. Furthermore, I find that when q is sufficiently close to zero, this threshold approaches infinity, making the constraint always satisfied.

By the implicit function theorem, the following holds:

$$\begin{aligned}(4.56)\qquad \frac{\partial^2\Pi_2}{\partial m_2\partial m_1}+\frac{\partial^2\Pi_2}{\partial m_2^2}\frac{\partial m_2^*}{\partial m_1}+\frac{\partial^2\Pi_2}{\partial m_2\partial a_2}\frac{\partial a_2^*}{\partial m_1} &= 0,\\ \frac{\partial^2\Pi_2}{\partial a_2\partial m_1}+\frac{\partial^2\Pi_2}{\partial a_2^2}\frac{\partial a_2^*}{\partial m_1}+\frac{\partial^2\Pi_2}{\partial a_2\partial m_2}\frac{\partial m_2^*}{\partial m_1} &= 0,\end{aligned}$$

Hence,

$$\begin{aligned}(4.57)\qquad \frac{\partial a_2^*}{\partial m_1} &= -\frac{\frac{\partial^2\Pi_2}{\partial a_2\partial m_1}\frac{\partial^2\Pi_2}{\partial m_2^2}-\frac{\partial^2\Pi_2}{\partial a_2\partial m_2}\frac{\partial^2\Pi_2}{\partial m_2\partial m_1}}{\frac{\partial^2\Pi_2}{\partial a_2^2}\frac{\partial^2\Pi_2}{\partial m_2^2}-\frac{\partial^2\Pi_2}{\partial a_2\partial m_2}\frac{\partial^2\Pi_2}{\partial m_2\partial a_2}},\\ \frac{\partial m_2^*}{\partial m_1} &= -\frac{\frac{\partial^2\Pi_2}{\partial a_2^2}\frac{\partial^2\Pi_2}{\partial m_2\partial m_1}-\frac{\partial^2\Pi_2}{\partial a_2\partial m_1}\frac{\partial^2\Pi_2}{\partial m_2\partial a_2}}{\frac{\partial^2\Pi_2}{\partial a_2^2}\frac{\partial^2\Pi_2}{\partial m_2^2}-\frac{\partial^2\Pi_2}{\partial a_2\partial m_2}\frac{\partial^2\Pi_2}{\partial m_2\partial a_2}},\end{aligned}$$

Notice first that since (a_2^*, m_2^*) maximizes Π_2, the associated second-order condition requires that

$$\begin{aligned}(4.58)\qquad \frac{\partial^2\Pi_2}{\partial a_2^2}\frac{\partial^2\Pi_2}{\partial m_2^2}-\frac{\partial^2\Pi_2}{\partial a_2\partial m_2}\frac{\partial^2\Pi_2}{\partial m_2\partial a_2} &> 0,\\ \frac{\partial^2\Pi_2}{\partial a_2^2} &< 0,\\ \frac{\partial^2\Pi_2}{\partial m_2^2} &< 0,\end{aligned}$$

In addition, I verify that $\frac{\partial^2\Pi_2}{\partial m_2\partial m_1} = 0$. I also verify that when n_j and a_1 are sufficiently large, there exists a threshold $\hat{b}_1$ such that $b > \hat{b}_1$, $\frac{\partial^2\Pi_2}{\partial a_2\partial m_1} < 0$. In particular,

$$(4.59)\qquad \frac{\partial^2\Pi_2}{\partial a_2\partial m_1} = \frac{\partial^2(Cov(\theta_2, K_2) - \frac{1}{2}(1-2a_2)Var(K_2))}{\partial a_2\partial m_1},$$

It can be verified that $\frac{\partial^2(Cov(\theta_2,K_2))}{\partial a_2 \partial m_1} = 0$. Therefore,

$$(4.60)\quad \begin{aligned} \frac{\partial^2 \Pi_2}{\partial a_2 \partial m_1} &= \frac{\partial^2(-\frac{1}{2}(1-2a_2)Var(K_2))}{\partial a_2 \partial m_1} \\ &= \frac{\partial(Var(K_2))}{\partial m_1}\frac{\partial(-\frac{1}{2}(1-2a_2))}{\partial a_2} - \frac{1}{2}(1-2a_2)\frac{\partial^2(Var(K_2))}{\partial a_2 \partial m_1}, \end{aligned}$$

where the first term corresponds to the *weighting effect* and the second term corresponds to the *overreaction effect.* I verify that when n_j and a_1 are sufficiently large, there exists a threshold $\hat{b}_1$ such that $b > \hat{b}_1$, $\frac{\partial(Var(K_2))}{\partial m_1}\frac{\partial(-\frac{1}{2}(1-2a_2))}{\partial a_2} - \frac{1}{2}(1-2a_2)\frac{\partial^2(Var(K_2))}{\partial a_2 \partial m_1} < 0$, which makes $\frac{\partial^2 \Pi_2}{\partial a_2 \partial m_1} < 0$ and $\frac{\partial a_2^*}{\partial m_1} < 0$. Similarly, I also verify that when n_{2j} and a_1 are sufficiently large, there exists a threshold $\hat{b}_2$ such that $b > \hat{b}_2$, $\frac{\partial^2 \Pi_2}{\partial a_2 \partial m_2} < 0$ and $\frac{\partial^2 \Pi_2}{\partial a_2 \partial m_1} < 0$, which makes $\frac{\partial m_2^*}{\partial m_1} > 0$.[3] □

Proof of Lemma 5

Proof. That $\frac{\partial \Pi_1}{\partial m_2} < 0$ can be show by directly computing the derivative, when n_1 and n_2 are sufficiently large. In addition, when q is close to zero, it can be shown that $\frac{\partial \Pi_1}{\partial a_2} > 0$ when $a_1 > \hat{a}(b)$, where

$$(4.61)\qquad \hat{a}(b) = \frac{7 - b^2 - \sqrt{17b^4 + 2b^2 + 17}}{8 - 8b^2},$$

□

[3]All the related Mathematica code is available upon request.

Proof of Proposition 6

Proof. Observe first when the traditional bank's decision of m_1 is observable to the shadow bank, its equilibrium decision, m_1^* is characterized instead by the following first-order condition:

$$\frac{d\Pi_1(m_1^*, m_2^*(m_1^*), a_2^*(m_1^*))}{dm_1} = \frac{\partial \Pi_1}{\partial m_1} + \frac{\partial \Pi_1}{\partial m_2}\frac{\partial m_2^*}{\partial m_1} + \frac{\partial \Pi_1}{\partial a_2}\frac{\partial a_2^*}{\partial m_1} = 0, \tag{4.62}$$

However, in the benchmark case in which the traditional bank's decision is not observable to the shadow bank, its equilibrium decision, m_1^c, is characterized by the first-order condition such that:

$$\frac{\partial \Pi_1(m_1^c, m_2^*(m_1^c), a_2^*(m_1^c))}{\partial m_1} = 0, \tag{4.63}$$

where the shadow bank's decisions $(m_2^*(m_1), a_2^*(m_1))$ are identical with those in the main setting in which the traditional bank's decision is observable. This is because in a rational expectation equilibrium, the shadow bank correctly conjectures the decision by the traditional bank without observing the actual decision (see Bagwell, 1995). Recall that by Lemma 5, $\frac{\partial \Pi_1}{\partial m_2} < 0$ and $\frac{\partial \Pi_1}{\partial a_2} > 0$ given the conditions listed in Proposition 6. In addition, Proposition 4 also suggests that $\frac{\partial m_2^*}{\partial m_1} > 0$ and $\frac{\partial a_2^*}{\partial m_1} < 0$. Thus, in the unobservable case,

$$\frac{d\Pi_1(m_1^c, m_2^*(m_1^c), a_2^*(m_1^c))}{dm_1} = \frac{\partial \Pi_1}{\partial m_1} + \frac{\partial \Pi_1}{\partial m_2}\frac{\partial m_2^*}{\partial m_1} + \frac{\partial \Pi_1}{\partial a_2}\frac{\partial a_2^*}{\partial m_1} < 0, \tag{4.64}$$

this is because the last two terms in the first-order condition on m_1 are both negative and the first term is zero. Given the concavity of Π_1 in m_1, this implies that:

$$m_1^* < m_1^c, \tag{4.65}$$

In addition, since $\frac{\partial m_2^*}{\partial m_1} > 0$ and $\frac{\partial a_2^*}{\partial m_1} < 0$, thus,

$$\begin{aligned} m_2^* &= m_2^*(m_1^*) < m_2^*(m_1^c) = m_2^c, \\ a_2^* &= a_2^*(m_1^*) > a_2^*(m_1^c) = a_2^c. \end{aligned} \tag{4.66}$$

□

Proof Lemma 7

Proof. First, by the envelope theorem, evaluated at the optimal decisions by the shadow bank, $(m_2^*(m_1), a_2^*(m_1))$,

$$\frac{d\Pi_2(m_2^*(m_1), a_2^*(m_1), m_1)}{dm_1} = \frac{\partial \Pi_2(m_2, a_2, m_1)}{\partial m_1} \Big|_{m_2 = m_2^*(m_1), a_2 = a_2^*(m_1)}, \tag{4.67}$$

By computing the derivative, when n_1 and n_2 are sufficiently large, I verify that for any (m_2, a_2, m_1),

$$\frac{\partial \Pi_2(m_2, a_2, m_1)}{\partial m_1} < 0, \tag{4.68}$$

Therefore,

$$\frac{d\Pi_2(m_2^*(m_1), a_2^*(m_1), m_1)}{dm_1} < 0. \tag{4.69}$$

□

Proof of Proposition 8

Proof. Let m_1^D denote the solution to the following equation:

$$\Pi_2(m_1^D, m_2^*(m_1^D), a_2^*(m_1^D)) = \overline{U}, \tag{4.70}$$

where $\overline{U}$ denotes the outside payoff for the shadow bank. In addition, denote the traditional bank's decision when it is the monopoly as m_1^M. By Lemma 7, the payoff of the shadow bank, Π_2, is strictly decreasing in m_1. Thus, in the deterrence case, in order to deter the shadow bank from entry, the traditional bank needs to choose a disclosure decision, $m_1^{D*} \geq m_1^D$. Since I assume that the entry is not blockaded, it must be the case that $m_1^D > m_1^M$. Since the payoff of the traditional bank, Π_1, is concave in m_1 and when the entry is deterred, Π_1 is maximized at the monopoly choice, m_1^M, it is optimal for the traditional bank to set $m_1^{D*} = m_1^D$ since given $m_1^D > m_1^M$, a further deviation from m_1^M would impair the traditional bank's payoff. Therefore, $m_1^{D*} = m_1^D > m_1^M$. □

Proof of Proposition 9

Proof. The proof is similar to the proof of Proposition 3 and available upon request. $\square$

Proof of Proposition 11

Proof. Let's assume first that the bank is solvent when the bank receives a bad signal and ends up in the H state. That is, there exists a threshold $\hat{N}$ such that for $N < \hat{N}$ we must have in equilibrium

$$(1-\alpha)(1+S_i)D_i + \alpha\, Asset_i^{\mathrm{B}} - D_i b D_A > 0. \tag{4.71}$$

In this case, from equation (3.17) in the main text, we can state

$$b\,D_A - 2\,[\phi + (1-\phi)(1-\alpha)]S_i + \alpha[\phi(\delta+1)-1]\left(\frac{(1-\phi)(1-S_i)}{(1-\phi)(1-S_i)+\phi S_i}\right)(1+S_i) = 0. \tag{4.72}$$

Solving for S_i in the above equation, we obtain two solutions. One of them is obviously not a feasible solution because it is either negative or larger than 1 and, therefore, is discarded. For brevity, we call the feasible solution $S_i(D_A)$. Notice that $S_i(D_A)$ is only contingent on the basic parameters and the aggregate investment D_A. This already tells us that for a given aggregate investment there is a unique interior risk decision.

From equation (3.18) in the main text, we can state

$$(1 + S_i(D_A))(1 - \alpha(1 - \phi)) - b(D_A + D_i) = 0. \tag{4.73}$$

Since from the previous derivation we know that S_i is only contingent on D_A, we can aggregate this equation across all banks and obtain

$$N(1 + S_i)(1 - \alpha(1 - \phi)) - b(N + 1)D_A = 0. \tag{4.74}$$

Solving for D_A we obtain

$$D_A = \frac{N(1 + S_i)(1 - \alpha(1 - \phi))}{b(N + 1)}. \tag{4.75}$$

Substituting this expression into the expression for $S_i(D_A)$ gives us a quadratic equation, which has a unique solution between zero and one, and is given by:

$$S^* = \frac{-k_2 - \sqrt{k_2^2 - 4\,k_1\,k_3}}{2\,k_1}. \tag{4.76}$$

Therefore, given our assumptions on (α, ϕ, N), there exists a unique interior equilibrium (S^*, D^*). All we need to show is that the second-order conditions are also satisfied and that the corner solutions for S_i are never optimal. To show this, we start with showing that the second-order conditions are satisfied locally at the interior optimal choices:

$$\frac{\partial^2 E[\pi_i]}{\partial S_i^2} = -(1 - \alpha(1 - \phi))D_i < 0, \tag{4.77}$$

and

$$\frac{\partial^2 E[\pi_i]}{\partial D_i^2}\frac{\partial^2 E[\pi_i]}{\partial S_i^2} - \frac{\partial^2 E[\pi_i]}{\partial D_i \partial S_i}\frac{\partial^2 E[\pi_i]}{\partial S_i \partial D_i} \tag{4.78}$$
$$= -4b(1-\alpha(1-\phi))D_i(1-S_i) - (b(D_A + D_i)$$
$$-(1-\alpha(1-\phi))S_i)^2 > 0.$$

The first equation above is obviously satisfied. The second equation, using equation (3.18), can be reduced to the condition:

$$S^* > \frac{N-3}{N+5}. \tag{4.79}$$

This condition is always satisfied for all $N \geq 2$, $0 \leq \alpha \leq 1/2$, and $1/2 \leq \phi \leq 1$. Therefore, we can state that the interior solution is a local maximum. Since there is only one interior solution we just need to prove that $S_i = 0$ and $S_i = 1$ are not optimal. For $S_i = 1$, we have that $E[\pi_i] = 0$, and, therefore, it cannot be optimal. For $S_i = 0$, it can be proven that $\left.\frac{\partial E[\pi_i]}{\partial S_i}\right|_{S_i=0} > 0$. Thus, $S_i = 0$ cannot be optimal solution either. Therefore, we have proven that the interior solution for S_i given by expression (4.76) is the absolute maximum for $N < \hat{N}$.

Substituting (S^*, D^*) into constraint (4.71), it can be reduced to two conditions:

$$S^* < \frac{(1-\phi)^2}{1-2\phi(1-\phi)}, \tag{4.80}$$

or

$$N - \frac{1}{\alpha}\frac{1-\phi-[1-(2-\alpha)\phi]S^*}{[1-2(1-\phi)\phi]S^*-(1-\phi)^2} < 0. \tag{4.81}$$

The first condition can be further reduced to $N < \hat{N}_1$, where $S^*(\hat{N}_1) = \frac{(1-\phi)^2}{1-2\phi(1-\phi)}$, since S^* is strictly increasing in N. In addition, it can be verified that when $N > \hat{N}_1$, the LHS of the second condition is strictly increasing in S^* and hence increasing in N. Therefore, there exists another threshold $\hat{N}_2$, such that $\hat{N}_2 - \frac{1}{\alpha}\frac{1-\phi-[1-(2-\alpha)\phi]S^*(\hat{N}_2)}{[1-2(1-\phi)\phi]S^*(\hat{N}_2)-(1-\phi)^2} = 0$. Moreover, when $N < \hat{N}_2$, $N - \frac{1}{\alpha}\frac{1-\phi-[1-(2-\alpha)\phi]S^*}{[1-2(1-\phi)\phi]S^*-(1-\phi)^2} < 0$. Define $\hat{N} = \min(\hat{N}_1, \hat{N}_2)$. Combining these analyses, we have when $N < \hat{N}$, constraint (4.71) is satisfied. However, when $N \geq \hat{N}$, constraint (4.71) is violated, which makes the bank insolvent when the bank receives a bad signal but ends up in the H state. Solving the first-order conditions in this case gives,

$$\begin{aligned} S^* &= \frac{N}{N+2}, \text{ and} \\ D^* &= \frac{2}{b\,(N+2)}. \end{aligned} \tag{4.82}$$

We can prove that the second-order conditions for the case of $N \geq \hat{N}$ are also satisfied in an analogous way. $\square$

Proof of Proposition 12

Proof. When $N < \hat{N}$, the bank is solvent when the bank receives a bad signal but ends up in the H state. In the case, $\frac{\partial S^*}{\partial \phi}$ can be derived as follows:

$$\frac{\partial S^*}{\partial \phi} = -\frac{\frac{\partial k_1}{\partial \phi} S^{*2} + \frac{\partial k_2}{\partial \phi} S^* + \frac{\partial k_3}{\partial \phi}}{2\, k_1\, S^* + k_2}. \tag{4.83}$$

First, the denominator $2\, k_1\, S^* + k_2$ can be simplified as

$$\sqrt{k_2^2 - 4\, k_1\, k_3}, \tag{4.84}$$

which is positive given that the equilibrium exists. Hence, the sign of $\frac{\partial S^*}{\partial \phi}$ is solely determined by the numerator. With a few algebra steps, we can verify $\frac{\partial k_1}{\partial \phi} S^{*2} + \frac{\partial k_2}{\partial \phi} S^* + \frac{\partial k_3}{\partial \phi} < 0$, and as a result, $\frac{\partial S^*}{\partial \phi} > 0$.

Similarly, $\frac{\partial S^*}{\partial \alpha}$ can be derived as follows:

$$\frac{\partial S^*}{\partial \alpha} = -\frac{\frac{\partial k_1}{\partial \alpha} S^{*2} + \frac{\partial k_2}{\partial \alpha} S^* + \frac{\partial k_3}{\partial \alpha}}{2\, k_1\, S^* + k_2}. \tag{4.85}$$

As shown before, the numerator is positive given that the equilibrium exists. Hence, the sign of $\frac{\partial S^*}{\partial \alpha}$ is solely determined by the numerator. With more algebra steps, we can verify $\frac{\partial k_1}{\partial \alpha} S^{*2} + \frac{\partial k_2}{\partial \alpha} S^* + \frac{\partial k_3}{\partial \alpha} > 0$, and as a result, $\frac{\partial S^*}{\partial \alpha} < 0$.

$\frac{\partial^2 S^*}{\partial\phi\partial\alpha}$ can be derived as:

$$(4.86) \quad \begin{aligned} \frac{\partial^2 S^*}{\partial\phi\partial\alpha} &= -\frac{(\frac{\partial^2 k_1}{\partial\alpha\partial\phi}S^{*2} + 2\frac{\partial k_1}{\partial\alpha}S^*\frac{\partial S^*}{\partial\phi} + \frac{\partial k_2}{\partial\alpha\partial\phi}S^* + \frac{\partial k_2}{\partial\alpha}\frac{\partial S^*}{\partial\phi} + \frac{\partial k_3}{\partial\alpha\partial\phi})}{(2\,k_1\,S^* + k_2)} \\ &\quad + \frac{(\frac{\partial k_1}{\partial\alpha}\,S^{*2} + \frac{\partial k_2}{\partial\alpha}\,S^* + \frac{\partial k_3}{\partial\alpha})(2\frac{\partial k_1}{\partial\phi}S^* + 2\frac{\partial S^*}{\partial\phi}k_1 + \frac{\partial k_2}{\partial\phi})}{(2\,k_1\,S^* + k_2)^2} \\ &= \frac{m_1 S^{*3} + m_2 S^{*2} + m_3 S^* + m_4}{(2\,k_1\,S^* + k_2)^2}, \end{aligned}$$

where

$$(4.87) \quad \begin{aligned} m_1 &= 2(\frac{\partial k_1}{\partial\alpha}\frac{\partial k_1}{\partial\phi} - k_1\frac{\partial^2 k_1}{\partial\alpha\partial\phi}), \\ m_2 &= 2[\frac{\partial k_2}{\partial\alpha}\frac{\partial k_1}{\partial\phi} - k_1(\frac{\partial^2 k_2}{\partial\alpha\partial\phi} + \frac{\partial k_1}{\partial\alpha}\frac{\partial S^*}{\partial\phi})] + \frac{\partial k_1}{\partial\alpha}\frac{\partial k_2}{\partial\phi} - k_2\frac{\partial^2 k_1}{\partial\alpha\partial\phi}, \\ m_3 &= 2[\frac{\partial k_3}{\partial\alpha}\frac{\partial k_1}{\partial\phi} - (k_1\frac{\partial^2 k_3}{\partial\alpha\partial\phi} + k_2\frac{\partial k_1}{\partial\alpha}\frac{\partial S^*}{\partial\phi})] + \frac{\partial k_2}{\partial\alpha}\frac{\partial k_2}{\partial\phi} - k_2\frac{\partial^2 k_2}{\partial\alpha\partial\phi}, \\ m_4 &= \frac{\partial k_3}{\partial\alpha}(\frac{\partial k_2}{\partial\phi} + 2k_1\frac{\partial S^*}{\partial\phi}) - k_2(\frac{\partial^2 k_3}{\partial\alpha\partial\phi} + \frac{\partial k_2}{\partial\alpha}\frac{\partial S^*}{\partial\phi}). \end{aligned}$$

With more algebra steps, we can verify $m_1 S^{*3} + m_2 S^{*2} + m_3 S^* + m_4 > 0$, and as a result, $\frac{\partial^2 S^*}{\partial\phi\partial\alpha} > 0$. □

Proof of Proposition 13

Proof. As shown in the proof of Proposition 11, when $N \geq \hat{N}$,

$$(4.88) \quad \begin{aligned} S^* &= \frac{N}{N+2}, \text{ and} \\ D^* &= \frac{2}{b\,(N+2)}. \end{aligned}$$

From these expressions, it is clear that a bank's investment and risk-taking decisions in equilibrium, (S^*, D^*), are independent of ϕ and α. $\square$

Proof of Corollary 14

Proof. Perfect competition is a special case for $N \geq \hat{N}$. In this case,

$$\begin{aligned} S^* &= \frac{N}{N+2}, \text{ and} \\ D^* &= \frac{2}{b\,(N+2)}. \end{aligned} \tag{4.89}$$

When N goes to infinity, $S^* = 1$ and $D^* = 0$. The total deposit amount becomes $D^A = \frac{2}{b}$. Hence, S^* is independent of either α or ϕ. In this case, the second-order conditions become

$$\begin{aligned} \frac{\partial^2 E[\pi_i]}{\partial S_i^2} &= \lim_{N\to\infty} -\frac{4\phi}{b(N+2)} = 0, \\ \frac{\partial^2 E[\pi_i]}{\partial D_i^2}\frac{\partial^2 E[\pi_i]}{\partial S_i^2} - \frac{\partial^2 E[\pi_i]}{\partial D_i \partial S_i}\frac{\partial^2 E[\pi_i]}{\partial S_i \partial D_i} &= \lim_{N\to\infty} \frac{12\phi^2}{(N+2)^2} = 0. \end{aligned} \tag{4.90}$$

Hence, the second-order conditions are satisfied for any N arbitrarily large and by continuity, they are also satisfied when N goes to infinity in the case of perfect competition. $\square$

Proof of Proposition 15

Proof. Following similar steps as in Proposition 11, we can show there exists a threshold N_c, such that when $N < N_c$, the bank is solvent when the bank receives a bad signal but ends up in the H state. When $N \geq N_c$, the bank is always insolvent upon a bad signal. In this case, solving the first-order conditions gives

$$\begin{aligned} S^* &= \frac{N}{N+2} \text{ and} \\ D^* &= \frac{2}{b\,(N+2)}, \end{aligned} \tag{4.91}$$

which is independent of accounting information quality ϕ and conservatism λ. When $N < N_c$, solving first-order conditions gives

$$S^* = \frac{-l_2 - \sqrt{l_2^2 - 4\,l_1\,l_3}}{2\,l_1}, \tag{4.92}$$

where l_1, l_2, l_3 are functions of $(\lambda, \phi, N, \alpha)$. By computing the derivatives, it is straightforward to verify that $\frac{\partial S^*}{\partial \phi} > 0$ and $\frac{\partial S^*}{\partial \lambda} < 0$. $\square$