Competition and Opacity in the Financial System: An Equilibrium Analysis with Rollover Risk*

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Abstract

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Keywords: coordination, interbank competition, disclosure policies, rollover risk, financial institutions, bank opacity, higher-order beliefs

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Abstract

This paper presents a theory on how competition among financial institutions (FIs) may make them more opaque. The theory endogenizes the public disclosure decisions of two FIs when both are exposed to rollover risk while simultaneously competing against each other in attracting investment from a common group of investors. The analysis identifies a novel benefit of competition in improving the coordination outcome for the FIs. This benefit substitutes for and thus weakens the coordination role of public disclosure, inducing FIs to disclose less compared to a case in which the competitive interactions are absent.
1 Introduction

Financial institutions (FIs) are known to be opaque. Many argue that the opacity of FIs triggers severely adverse economic consequences, and “exposes the entire financial system to bank runs, contagion and other strains of ‘systemic’ risk.” (Morgan, 2002) Nonetheless, that why FIs are opaque remains unclear and is still under debate (e.g., Morgan, 2002; Dang, Gorton, Holmstrom and Ordonez, 2014). In this debate, the endogeneity of FIs’ transparency/opacity choice is usually absent. FIs have a fair amount of discretion to disclose information beyond those mandated by regulation; such discretionary disclosure (or lack thereof) plays an important role in determining FIs’ overall opacity. This endogeneity of FIs’ opacity cannot be ignored in understanding the effect of opacity on the stability of the overall financial system. In this paper, I examine the role of two economic factors underlying the disclosure decisions that endogenously determine the opacity of FIs: competition among FIs and their exposure to rollover risk.

Competition among FIs is often viewed as one of the causes for opacity (e.g., Bushman, 2014). Nevertheless, empirical evidence on the association between the opacity of FIs and competition is mixed and more importantly, relatively little is known about the mechanism through which competition may affect the opacity.\(^1\) Even though the literature on the role of competition in shaping non-financial firms’ disclosure choices is abundant (e.g., Verrecchia, 1983; Darrough and Stoughton, 1990; Wagenhofer, 1990; Feltham and Xie, 1992; Darrough, 1993; Newman and Sansing, 1993; Vives, 2006; Corona and Nan, 2013; Arya and Mittendorf, 2013), those analyses may not be directly applicable to FIs since they are mainly concerned with generic firms and thus in lack of special features of FIs. In this light, my paper provides a formal analysis of FIs’ disclosure decisions that may help uncover the economic rationale behind the empirically documented linkage between

\(^1\)See, for instance, Dou, Ryan and Zou (2015) and Bushman, Hendricks and Williams (2016) that provide evidence on a positive association between competition and bank opacity. In contrast, Jiang, Levine and Lin (2016) and Burks, Cuny, Gerakos and Granja (2016) report a negative association between competition and bank opacity. See Section 4 of the paper for a detailed discussion.
competition and the opacity of FIs. A distinct feature of FIs that my model incorporates is their exposure to the rollover risk. FIs often finance their long-term assets (e.g., loans) by regularly rolling over short-term instruments (e.g., commercial papers, repos, etc.). When investors of these instruments collectively decide not to roll over their investments, it causes disruptions to FIs and exposes them to runs.

This paper considers a model in which FIs make disclosure decisions in the face of both competition and rollover risk. I hope to shed light on some aspects of the following questions: what is the disclosure trade-off for FIs that are exposed to rollover risk? How does competition shift FIs’ rollover-risk-driven disclosure trade-off? Can competition and rollover risk jointly lead to less disclosure and more opacity?

More specifically, I examine a financial system with two FIs. Each FI is endowed with an investment project but must attract funding by competing for a common group of investors. Each FI decides the disclosure precision with regard to the public information about the fundamentals of the projects, which is then used jointly with private information by individual investors in making investment decisions. A key feature of the FIs I model is that their project return depends not only on the fundamentals of the projects, but also the rollover risk, which is driven by the aggregate investment funded by the group of investors and contingent on the coordination among them. In particular, the return on the FIs’ project is lower when a large number of investors collectively decide not to roll over their investments. The rollover risk in turn motivates investors to coordinate their investment decisions. Summing up individual investments gives rise to the total amount of investments made by the FIs. As such, the FIs effectively use disclosure to manage aggregate funding by investors and hence FI-level investments.

The paper first analyzes a model without competitive interactions among the FIs and identifies a disclosure trade-off driven solely by the FIs’ exposure to the rollover risk. In equilibrium, the FI
trades the benefit of improving coordination against the cost of heightened investment volatility stemming from noise in the disclosure. On one hand, the benefit of disclosure comes from its role in mitigating coordination inefficiencies among investors. I find that the FI’s exposure to the rollover risk results in two coordination inefficiencies. First, investors do not internalize the positive spillover of successful coordination that falls on others. Second, investors overweight the public information and underweight the private information, relative to the weights under Bayesian updating. In total, these coordination inefficiencies make investments less responsive to fundamentals, relative to the level preferred by the FI. In this regard, more precise disclosure by the FI induces investors to respond more promptly to the public information and hence the fundamentals, which mitigates the coordination inefficiencies and benefits the FI. On the other hand, more precise disclosure also hurts the FI because it prompts each investor to rely more on this public information, which has already been overweighted relative to its precision. The overweighing of public information magnifies the impact of the disclosure noise, which leads to heightened investment volatility and lowers the FI’s payoff. The trade-off between the coordination benefit and the volatility cost determines the FI’s equilibrium choices of disclosure precision. I find that a sufficient condition for the FI to disclose is that their exposure to the rollover risk is sufficiently large.

Next, I introduce the competitive interactions among the FIs and examine how the competition alters the disclosure trade-off. My analysis identifies a novel benefit of competition in improving the coordination outcome for the FIs, which in turn encourages the FIs to disclose less. This benefit arises because competition between the FIs produces a “multiplier” effect that improves investors’ responsiveness to the fundamentals. To fix ideas, suppose that FI 1’s disclosure improves. Thus, from an individual investor’s perspective, a favorable disclosure by FI 1 indicates not only better fundamentals, but also that others believe the fundamentals to be better. Because of competition, the investor conjectures that others are more likely to reallocate their investments from FI 2 to
FI 1. Since others’ reallocations reduce the FI 2’s return, this in turn induces the investor to make the same reallocating decision, transferring her investment from FI 2 to FI 1. Concisely, the competition-driven reallocations amplify investors’ responses to information and fundamentals, thus mitigating the coordination inefficiencies the FIs face. The coordination benefit of competition substitutes for and thus weakens the coordination role of disclosure, which induces the FIs to disclose less compared to the case in which the competitive interactions are absent.

That competition can be beneficial to FIs through facilitating coordination serves as the key mechanism through which competition reduces disclosure. While there is no direct empirical evidence on this mechanism, some casual observations by Goodfriend (2011) on commercial banks’ responses to the entrance of competing “shadow banks” may be suggestive. As noted by Pozsar, Adrian, Ashcraft and Boesky (2010), “growing competition from specialist non-banks put increasing pressure on banks’ profit margins.” It is intriguing that commercial banks, instead of engaging in fierce competition with shadow banks to drive them out of the market, actually assisted and supported the early development of shadow banks (Goodfriend, 2011). As pointed out by Goodfriend, for instance, commercial banks frequently back-stopped commercial paper programs sponsored by shadow banks with lines of credits. In this light, the coordination benefit of competition my paper identifies may potentially help to understand commercial banks’ favorable attitudes towards competing shadow banks.

Another empirical regularity that may help to motivate the beneficial role of competition lies in the empirical literature that examines the relation between interbank competition and bank stability. A recent advance in that literature based on cross-country studies points to overall positive effects of competition on banking system stability, with stability usually proxied by the likelihood of suffering systemic banking crisis (see Beck (2008) for a survey of the literature). To the extent that improving coordination among investors increases stability, the coordination benefit of competition
my paper identifies is consistent with the findings in the competition-stability literature.

The paper makes three contributions. First, the paper contributes to the literature on the information environment of financial institutions and its roles in financial stability. Due to the extensive size of this literature, I refer readers to three recent surveys by Goldstein and Sapra (2014), Beatty and Liao (2014), and Acharya and Ryan (2016). More specifically, some recent papers have examined the role of information disclosure when FIs face rollover risk. Bouvard, Chaigneau, and Motta (2015) find that a FI’s disclosure reduces the rollover risk in bad times but increases the risk in normal times. Gao and Jiang (2018) examine a FI’s decision on manipulating its report in the face of the rollover risk and find that the FI’s exposure to the rollover risk encourages it to increase the manipulation. Liang and Zhang (2018) examine the role of accounting objectivity in promoting financial stability and show that more objective disclosure by FIs helps to mitigate the rollover risk. This paper extends this literature by studying how competition interacts with FIs’ rollover risk in determining their disclosure decisions, which is absent in the prior literature.

Second, while the paper focuses on financial institutions’ disclosure, it may also shed some light on the joint effects of coordination and competition on firms’ choices of disclosure policies in general. The role of either feature has been extensively studied in the prior literature. The extant “beauty-contest” literature has examined the role of information in coordination settings and thus helps to shed light on optimal disclosure policies (e.g., Morris and Shin, 2002; Angeletos and Pavan, 2004, 2007; Gao, 2008; Plantin, Sapra, and Shin, 2008; Gigler, Kanodia and Venugopalan, 2013; Chen, Huang and Zhang, 2014; Chen, Lewis, Schipper and Zhang, 2016; Arya and Mittendorf, 2016). Competition has also been identified as a key determinant of disclosure policies. The vast oligopoly disclosure literature has demonstrated that firms rarely make disclosure decisions in isolation but need to take the competitive effect of disclosure into account (e.g., Verrecchia, 1983; Darrough and Stoughton, 1990; Wagenhofer, 1990; Feltham and Xie, 1992; Darrough, 1993; Newman and
Sansing, 1993; Vives, 2006; Corona and Nan, 2013; Arya and Mittendorf, 2013). Despite that the roles of coordination and competition have been separately promoted in two streams of disclosure literature with long and varied standings, an examination of their joint effect is under-explored in previous research. Nevertheless, such an examination is potentially important in improving our understanding of the determinants for disclosure policies. This paper may help to fill in this void. I characterize the interaction between coordination and competition and show that one consequence of such interaction is to induce firms to disclose less.

A concurrent paper by Galperti and Trevino (2017) also examines, in information markets, how competition among information providers affects their provision of information when information consumers want to coordinate their decisions. This paper is related to mine because both papers analyze the joint effects of competition and coordination on the supply of information. However, the two papers differ in two important aspects. First, a key focus of Galperti and Trevino is consumers’ allocations of attention to different information sources (i.e., information acquisitions). Information providers are only concerned with how much attention they receive. Thus information supply choices by the providers and competition matter only to the extent that they affect the amount of attention the providers receive. The assumption that the payoff to the information providers depends on the consumers’ attention but not on the coordination outcome of the consumers seems reasonable in Galperti and Trevino given their focus on information markets. In contrast, my paper intends to examine disclosure decisions by financial institutions whose payoff must depend on the rollover risk they are exposed to and thus the coordination outcome of FIs’ investors. Therefore, the key role played by disclosure and competition in my model is precisely that they affect the coordination among investors. The coordination benefit of competition is a key focus of my paper but not studied in Galperti and Trevino. Second, since Galperti and Trevino identify an economic force different from my paper, this leads to a different model implication from the implications
of mine. An interesting finding of Galperti and Trevino is that when the coordination motive is strong, the equilibrium supplies of information are the ones with high clarity. My paper obtains a different result that in the presence of coordination motives, competition makes FIs disclose less.

Lastly, this paper develops a new disclosure trade-off between mitigating coordination inefficiencies and amplifying investment volatility that has not been examined in the previous literature. In particular, the coordination-driven trade-off for disclosure in my model is different from trade-offs in the extant accounting literature built on either uncertain information endowment or proprietary disclosure cost (Verrecchia, 1983; Dye, 1985). In addition, this trade-off is also distinct from others developed in beauty-contest contexts. For instance, Morris and Shin (2002) discuss the heightened volatility induced by public disclosure in contexts where coordination has no social value. Angeletos and Pavan (2004) examine a trade-off between individual dispersion and aggregate volatility. These researches, however, do not consider the optimal responsiveness of actions to fundamentals (i.e., the covariance between actions and fundamentals), which is an essential element in this paper.

The rest of the paper is organized as follows. In Section 2, I describe the model setup. Section 3 analyzes the model. Section 4 discusses the implications of the paper. Section 5 concludes.

2 The Model

2.1 Model Setup

I examine a three-date model that contains two risk-neutral Financial Institutions (FIs), indexed by \(i \in \{1, 2\}\), and a continuum of risk-neutral investors, indexed by the unit interval \([0, 1]\). At date 0, each FI is endowed with a project and decides its disclosure precision. At date 1, FIs disclose information regarding the project returns. Investors choose their investments in the FIs based on

\[\text{The disclosure literature is extensive and I refer readers to three thorough surveys by Verrecchia (2001), Dye (2001), and Beyer, Cohen, Lys and Walther (2010).}\]
both their private information and FIs’ disclosure. At date 2, the outcomes of FIs’ projects are realized. The time line of the model is shown below.

\begin{align*}
t = 0 & \quad t = 1 & \quad t = 2 \\
\text{The FIs choose precision} & \quad \text{Public and private signals are realized.} & \quad \text{The outcomes of the} \\
\text{of public information.} & \quad \text{Investors decide investments.} & \quad \text{projects are realized.}
\end{align*}

Fig. 1: Time line.

Below, I describe and explain the decisions and events at each date in detail.

**Date 0** Each FI is endowed with an investment project that yields a stochastic per-unit terminal cash flow, \( R_i \). The two FIs finance the project by competing for a common group of investors, indexed by the unit interval \([0,1]\). I denote each investor \( j \)'s investment in FI \( i \) as \( k_{ij} \), and \( K_i \equiv \int_0^1 k_{ij} dj \) denotes the aggregate level of funding/investments in FI \( i \).

Following Angeletos and Pavan (2004), I assume that the per-unit terminal cash flow to the investment \( R_i \) is linear in an exogenous shock \( \theta_i \) and the aggregate investment \( K_i \), such that:

\[ R_i = 2 (\theta_i + aK_i). \tag{1} \]

\( \theta_i \) represents the fundamentals of the FI’s project (e.g., the quality and default risk of a loan). The common prior of \( \theta_i \) is normally distributed with mean \( \tilde{\theta} > 0 \) and variance \( \frac{1}{q} > 0 \). For simplicity, I also assume that \( \theta_1 \) and \( \theta_2 \) are independent of each other.\(^3\)

A key component in equation (1) is that FIs’ per-unit project returns are increasing in the aggregate investment funded by investors. As such, reductions in the aggregate investment are

\(^3\)This assumption isolates my results from the informational spillover effects studied in the prior literature (e.g., Admati and Pfeiderer, 2000).
costly to FIs’ project returns: if the aggregate investment decreases by 1 unit, the per-unit project return is reduced by \(a\). This structure is a reduced-form representation of the rollover risk FIs face and in Appendix I, I show that this structure can indeed be derived by extending a rollover-risk model laid out in Morris and Shin (2004). As I motivate later in the discussion of model assumptions, FIs face a considerable amount of rollover risk because they often finance their long-term illiquid assets (e.g., loans) by regularly rolling over short-term instruments (e.g., commercial papers, repos, etc.). When a large group of investors decide not to roll over their investments, it causes disruptions to FIs (e.g., forcing FIs to prematurely liquidate their assets) and impairs their investment returns. \(a \in [0, \frac{1}{2}]\) measures the FI’s exposure to the rollover risk.\(^4\)

Each FI \(i\) also decides the precision at which it will disclose a public signal of its fundamentals \(\theta_i\) at date 1. I assume that the precision choice is committed by the FI and publicly observable.\(^5\) The disclosed public signal \(z_i\) is given by:

\[
z_i = \theta_i + \varepsilon_i, \tag{2}
\]

where \(\varepsilon_i\) is normally distributed, independent of \(\theta_i\), with mean 0 and variance \(\frac{1}{m_i}\). Thus \(m_i\) measures the precision of FI \(i\)’s disclosure. In setting the precision \(m_i\), FIs incur a private disclosure cost \(C_m(m_i) = \frac{c_m}{2} m_i^2\) where \(c_m > \bar{c}_m > 0\). This cost can be interpreted as the building costs of the information system that gathers data to generate the report, the internal control system that safeguards the faithfulness of the report, etc. \(\bar{c}_m\) is a constant sufficiently large to guarantee that

\(^4\)Assuming \(a \leq \frac{1}{2}\) is to ensure that the FIs’ payoffs are concave in the investment, \(K_i\). Otherwise, volatility in \(K_i\) would be desirable to the FIs. This is also sufficient to make the equilibrium unique.

\(^5\)The disclosure precision chosen by FIs depends on the information system installed (Arya, Glover, and Sivaramakrishnan, 1997), the internal control procedures established, etc. These systems and procedures, once chosen, cannot be easily adjusted in a short horizon, which allows FIs to commit to their disclosure precision. Indeed, empirical studies (Bushee, Matsumoto, and Miller, 2003) find that disclosure decisions are often sticky and firms rarely alter their earlier disclosure practices.

Furthermore, I view FIs’ choices of disclosure precision are long-term decisions that are related to their design of reporting and internal control systems, the types of businesses they operate in (e.g., simple mortgages v.s. complicated structured finance), etc. To the extent that investors and FIs interact on a regular basis, it is reasonable to assume that investors may observe, to some degree, disclosure precision of FIs.
the FIs’equilibrium disclosure choices are unique.

**Date 1** The two FIs disclose the public signals, $z_1$ and $z_2$, in accordance with their choices of $m_1$ and $m_2$. In addition to the signals released by the FIs, each investor $j$ also observes a pair of private signals, $x_{1j}$ and $x_{2j}$:

$$x_{ij} = \theta_i + \eta_{ij},$$

(3)

where the noise $\eta_{ij}$ is normally distributed with mean 0 and variance $\frac{1}{\eta}$, and independent everywhere. Thus, each investor’s information set is given by $I_j = \{z_1, z_2, x_{1j}, x_{2j}\}$.

Conditional on her information set, an investor $j$ makes her investment decisions in the FIs by trading off the date-2 cash flow earned from the investments against her date-1 consumption. I capture such an intertemporal trade-off in a parsimonious manner. Specifically, I assume that investing in the two FIs with the amount of $\{k_{1j}, k_{2j}\}$ requires the investor to reduce her date-1 consumption by $d_j = k_{1j} + k_{2j}$. Reducing current consumptions generates a disutility to the investor, $C_d(d_j) = \frac{c_d}{2}d_j^2$ with $c_d > 0$. That is, the marginal disutility of cutting current consumptions is strictly increasing. Furthermore, I assume that the investor incurs an additional cost of investing in each FI’s project, $C_k(k_{ij}) = \frac{c_k}{2}k_{ij}^2$ with $c_k > 0$. The cost can be interpreted as investors’ cost of searching for investment opportunities, managing investments, etc. The cost $C_k(k_{ij})$ is employed to make the equilibrium solutions of $k_{ij}$ interior; absent $C_k(k_{ij})$, $k_{1j}$ and $k_{2j}$ would be perfect substitutes and investors would invest only in the FI with a higher expected project return.

In return for their investments, following Goldstein, Ozdenoren and Yuan (2013), I assume that investors obtain $\phi \in (0, 1)$ fraction of the terminal cash flows from FIs’ projects and FIs capture the rest $1 - \phi$ fraction. Later in the discussion of model assumptions, I motivate this payoff structure using a securitization example. Thus, each FI’s payoff from its project is $(1 - \phi) R_i K_i$ and investors share the remaining cash flows $\phi R_i k_{ij}$ on a pro-rata basis. That is, each investor receives $\phi R_i k_{ij}$
for each FI $i$. For simplicity, I set $\phi = \frac{1}{2}$ and my results hold qualitatively for other $\phi \in (0, 1)$. The investor’s payoff is thus given by

$$u_j(k_{1j}, k_{2j}) = \frac{R_1}{2} k_{1j} + \frac{R_2}{2} k_{2j} - \frac{c_k}{2} k_{1j}^2 - \frac{c_k}{2} k_{2j}^2 - \frac{c_d}{2} (k_{1j} + k_{2j})^2.$$ (4)

Each investor chooses $\{k_{1j}, k_{2j}\}$ to maximize her expected payoff. Taking the first-order condition gives the following linear investment rules:

$$k_{ij} = \frac{c_k + c_d}{c_k (c_k + 2c_d)} \left( E_j \left[ \frac{R_i}{2} \right] - \frac{c_d}{c_k + c_d} E_j \left[ \frac{R_{-i}}{2} \right] \right),$$ (5)

where $E_j[\cdot]$ denotes investor $j$’s expectation conditional on her information set $I_j$ and $-i$ refers to the FI other than FI $i$. To ease exposition, I normalize the coefficient in front of $E_j \left[ \frac{R_i}{2} \right], \frac{c_d}{c_k + c_d}$, to 1 and denote the relative weight on $E_j \left[ \frac{R_{-i}}{2} \right]$ by $\frac{c_d}{c_k + c_d} \equiv b$. Thus, equation (5) becomes:

$$k_{ij} = E_j \left[ \frac{R_i}{2} \right] - bE_j \left[ \frac{R_{-i}}{2} \right].$$ (6)

An investor’s investment in FI $i$ is increasing in her expected return of FI $i$ and decreasing in her expected return of the other FI. $b = \frac{c_d}{c_k + c_d} \in (0, 1)$ measures the intensity of the competition between the FIs. The higher the $b$, the stronger the adverse impact of increasing one FI’s project return on the investment in the other FI.

The FIs thereafter invest the funds from the investors in their projects. I assume that the FI incurs a private nonpecuniary cost from managing the project, $C_F(K_i) = \frac{1}{2} K_i^2$. One interpretation of this cost is the FI’s effort incurred in monitoring and servicing the project. Following the

\[\text{\footnote{Such a normalization is made without loss of generality because it only scales up/down the size of investments $k_{ij}$ but does not qualitatively alter how changes in the project return of one FI affect the investment in the other FI, which serves as the key driving force for my results. Furthermore, I verify that my results hold qualitatively without the normalization assumption.}}\]
literature (e.g., Goldstein, Ozdenoren and Yuan, 2013), such a nonpecuniary cost is not shared between the FI and the investors. Instead, the two parties only share the terminal cash flows from the FI’s project, as discussed previously. The payoff function for FI $i$ is thus given by:

$$E\left[\frac{R_i}{2}K_i - \frac{1}{2}K_i^2\right].$$

### Date 2

The project returns are realized and the proceeds from the projects are distributed to the FIs and investors. The table below summarizes the notations of the paper.

<table>
<thead>
<tr>
<th>Notation</th>
<th>Description</th>
</tr>
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<tbody>
<tr>
<td>$a$</td>
<td>Rollover-risk exposure</td>
</tr>
<tr>
<td>$b$</td>
<td>Intensity of competition between FIs</td>
</tr>
<tr>
<td>$c_m$</td>
<td>Cost of disclosure</td>
</tr>
<tr>
<td>$k_{ij}$</td>
<td>Investment by investor $j$ in FI $i$</td>
</tr>
<tr>
<td>$K_i$</td>
<td>Aggregate investment in FI $i$</td>
</tr>
<tr>
<td>$m_i$</td>
<td>Disclosure precision of FI $i$</td>
</tr>
<tr>
<td>$n$</td>
<td>Private information precision</td>
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<tr>
<td>$q$</td>
<td>Common prior precision</td>
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<tr>
<td>$R_i$</td>
<td>Project return of FI $i$</td>
</tr>
<tr>
<td>$\theta_i$</td>
<td>Fundamentals of FI $i$</td>
</tr>
<tr>
<td>$\bar{\theta}$</td>
<td>Common prior mean</td>
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<tr>
<td>$x_{ij}$</td>
<td>Private signal of investor $j$ about FI $i$</td>
</tr>
<tr>
<td>$z_i$</td>
<td>Public signal about FI $i$</td>
</tr>
</tbody>
</table>

**Table 1**: Notations.

### 2.2 Discussion of Model Assumptions

Several of my model assumptions warrant discussion. First, my model is built on two important assumptions that FIs share their project cash flows with their investors and simultaneously face rollover risk modeled as project returns increasing in the aggregate investment made by the investors. I argue that such a model setup is descriptive of FIs’ operations in the era of securitization. The following example may be illustrative. A FI originates a portfolio of loans (e.g., commercial or home mortgages). In order to finance these loans, the FI decides to securitize $\phi$ fraction of its loan portfolio and thus retains the remaining $1 - \phi$ fraction.$^7$ While the securitization process can take various forms, a typical practice is that the FI sets up some special purpose vehicles (SPVs) called

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$^7$It is noteworthy that the retention of a fraction of the loan portfolio is typical in the practice of securitization (Gorton and Souleles, 2007).
conduits and then sells $\phi$ fraction of its loan portfolio to these conduits. The conduits purchase the FI's assets by issuing asset-backed commercial papers (ABCPs) to outside investors. Since the conduits serve no other purposes than passing the loan cash flows to investors periodically (Acharya, Schnabl and Suarez, 2013), the FI effectively shares its loan cash flows proportionally with the ABCP investors via the conduits set up by the FI. In this securitization process, the FI exposes itself to a considerable amount of “rollover-risk” because the loans the FI originates are long-term whereas the ABCPs issued to investors are short-term.\footnote{It is noteworthy that FIs’ use of ABCP is not the only source of rollover risk. See Brunnermeier (2009) and Shin (2009) for many other examples in which FIs are exposed to rollover risk.} As documented by Acharya, Schnabl and Suarez (2013), “most conduits exhibit a significant maturity mismatch. They purchase medium- to long-term assets with maturities of 3-5 years and hold them to maturity. They finance these assets primarily by issuing ABCP with a maturity of 30 days or less. Conduits regularly roll over their liabilities and use proceeds from new issuances of ABCP to pay off maturing ABCP.” In some extreme events (e.g., during the 2007-2009 crisis) that a large group of investors collectively decide not to roll over maturing ABCP (i.e., runs in ABCP markets), it causes disruptions to FIs and impairs their investment returns. Acharya, Schnabl and Suarez (2013) show that in the narrow event window around the start of the financial crisis on August 9, 2007, ABCP runs cause the cumulative equity returns of exposed FIs to reduce by 1.1% in a 3-day window and 2.3% in a one-month window.

The decrease in FIs' abilities to roll over short-term securities may appear to resemble a traditional “bank run” triggered by retail depositors. Nonetheless, it is noteworthy that there are important differences between the depositors’ run and the rollover risk my model captures. A depositors’ run occurs when a large group of depositors withdraw their previous investments (i.e., deposits) from FIs. Such runs were completely eliminated thanks to the provision of deposit insurance to retail depositors. In contrast, short-term securities FIs issue in the securitization process...
(e.g., ABCPs) typically cannot be withdrawn before maturity. Thus FIs face rollover risk not because investors withdraw their previous investments but that investors choose not to purchase the newly issued securities.\(^9\) As a result, FIs are unable to use proceeds from new issuances of securities to pay off maturing ones, which appears like a “run.” Furthermore, securities created in the securitization process are usually not covered by deposit insurance, and thus are much riskier and more sensitive to the terminal cash flows of the underlying assets than traditional deposits.

For simplicity, I approximate the payoffs to investors in these securities as a fraction of the terminal cash flow from the FI’s project. Such an approximation has been commonly made in the literature of bank runs to simplify analyses and maintain tractability (e.g., Morris and Shin 2001, Gao and Jiang 2018, and Liang and Zhang 2018).

Another assumption I made is that the FI incurs a private nonpecuniary cost from managing the project. Using again the securitization example, the FI remains responsible for monitoring loans (loan servicing) after securitizing them. Ashcraft and Schuermann (2007) gave multiple examples of servicing activities, such as collection and remittance of loan payments, making advances of unpaid interest by borrowers to investors, accounting for principal and interest, customer service to the mortgagors, holding escrow or impounding funds related to payment of taxes and insurance, etc. These servicing activities take costly effort and I capture this through the nonpecuniary cost. It is noteworthy that in the securitization process, FIs only share the terminal cash flows from their loans with investors (by passing the cash flows via the conduits); however, FIs bear the nonpecuniary cost themselves.

Finally, I only allow investors to choose between investments in two FIs to simplify analyses. In reality, investors have access to a vast number of possible investment opportunities. My analyses can be extended to a setting with multiple investment opportunities. Consider that investors have

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\(^9\) In fact, the investors that decide not to purchase in the current period may not even be the same investors that purchased FIs’ securities in the last period.
access to \( N \) investment opportunities and each generates a per-unit terminal cash flow of \( R_i \) to the investors. As in the main model, I assume that making investments with the amount of \( \{k_{ij}\}_{i=1}^{N} \) requires the investors to reduce their date-1 consumption by \( d_j = \sum_{i=1}^{N} k_{ij} \), which generates a disutility of \( C_d (d_j) = \frac{c_d}{2} d_j^2 \). Furthermore, I assume that the investors incur an additional cost of investing in each project, \( C_k (k_{ij}) = \frac{c_k}{2} k_{ij}^2 \). Taking the first-order condition gives that

\[
    k_{ij} = \frac{c_k + (N - 1) c_d}{c_k (c_k + N c_d)} \left\{ E_j [R_i] - \frac{c_d}{c_k + (N - 1) c_d} \sum_{l \neq i} E_j [R_l] \right\}. \tag{8}
\]

Notice that with \( N \) investment opportunities, a key driving economic force of my model remains in that when investors’ expected return of investment opportunity \( l \) increases (i.e., a higher \( E_j [R_l] \)), they reallocate some of their investments from opportunity \( i \) to opportunity \( l \) (i.e., a lower \( k_i \) and a higher \( k_l \)). Since the reallocations of investments across FIs drive the coordination benefit of competition that my paper focuses on analyzing, I expect my main results extend qualitatively to a richer setting with more than two FIs.

3 The Analysis

3.1 Equilibrium Analysis without Competitive Interactions

In this section, I consider a case in which \( b = 0 \) such that there is no competitive interaction between the FIs in the funding market. This model allows me to identify a disclosure trade-off driven solely by FIs’ exposure to the rollover risk and, to isolate the effect of the rollover-risk exposure from that of competition. I only discuss the equilibrium actions related to FI 1 as the analysis of FI 2 is identical.
3.1.1 Coordination Inefficiencies in Investment Decisions

I first characterize each investor’s optimal investment. This analysis illustrates how investors utilize their information in making investment decisions and importantly, emphasizes that investors’ use of information suffers coordination inefficiencies. I summarize the equilibrium investments $k^{NC}_{ij}$ in the following lemma.

**Lemma 1** Given $b = 0$, there exists a unique equilibrium in which investors choose

$$k^{NC}_{ij} (m_1) = \beta^{NC}_{1} x_{ij} + \gamma^{NC}_{1} z_{1} + h^{NC}_{1},$$

(9)

with $\beta^{NC}_{1} = \frac{n}{q + m_1 + (1-a)n}$, $\gamma^{NC}_{1} = \frac{m_1}{(1-a)(q+m_1+(1-a)n)}$ and $h^{NC}_{1} = \frac{q^{\theta}}{(1-a)(q+m_1+(1-a)n)}$.

Lemma 1 characterizes how investors utilize information in the face of the rollover risk. Two equilibrium features of $k^{NC}_{ij} (m_1)$ are noteworthy. The first is investors’ overweighting of public information, i.e., relative to the private information, the public information (the public signal $z_1$ and the common prior $\theta$) is given disproportionately high weights that are incommensurate with their respective precision (e.g., $\frac{\gamma^{NC}_{1}}{\beta^{NC}_{1}} = \frac{m_1}{n(1-a)} > \frac{m_1}{n}$). This result is consistent with findings in the prior coordination literature and, in my model, arises because FIs’ exposure to the rollover risk induces a strategic complementarity between investors’ investment decisions. If an investor expects others not to roll over their investments, she also anticipates, from equation (1), a decrease in the return to the FI’s project, and thus a lower return for her to invest in the FI. This, in turn, encourages her not to roll over the investment. The strategic complementarity between investment decisions motivates investors to coordinate them. Since investments by others are motivated by their beliefs, each individual must take account of these beliefs that are held by other investors, others’

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10In equilibrium the optimal investment $k^{NC}_{ij}$ is a linear combination of the normally-distributed signals and thereby can be negative. To avoid interpreting negative investments, I assume $\theta$ to be sufficiently large such that the probability that equilibrium investments turn negative is sufficiently small. In addition, the notation “NC” stands for “no competitive interaction.”
beliefs about others and even higher-order beliefs. Public information, as a common information source known to every investor, is more effective in forecasting the higher-order beliefs of others.

The second feature of $k_{1j}^{NC}(m_1)$, which serves a key role in my model but is less emphasized in the prior literature, is that investors coordinate less efficiently in utilizing their information to make investment decisions, compared to what the FI would prefer. As I will show later, these coordination inefficiencies create an incentive for FIs to disclose. To illustrate the coordination inefficiencies, consider the following benchmark in which FI 1 determines the investment by itself and thus the FI’s investment is not plagued by the coordination inefficiencies among investors. I further assume that in the benchmark, FI 1 has the same amount of information $\{x_{1j}, z_1\}$ as any individual investor. Therefore, examining this benchmark allows me to separate the effect of the coordination inefficiencies from other effects. First, when investors make investment decisions, the equilibrium individual investment is:

$$k_{1j}^{NC} = E \left[ \frac{R_1}{2} | x_{1j}, z_1 \right] = \beta_1^{NC} x_{1j} + \gamma_1^{NC} z_1 + h_1^{NC}. \quad (10)$$

Aggregating all the individual investments gives the equilibrium aggregate investment $K_1^{NC} = \int_0^1 k_{1j}^{NC} dj$. The sensitivity of $K_1^{NC}$ to the fundamentals $\theta_1$ is equal to the sum of the weights on $z_1$ and $x_{1j}$:

$$\beta_1^{NC} + \gamma_1^{NC} = \left( \frac{1}{1 - a} \right) \frac{m_1 + (1 - a)n}{m_1 + (1 - a)n + q}. \quad (11)$$

Second, in the FI benchmark, FI 1 determines the aggregate investment $K_1$ to maximize its expected payoff, $E \left[ \frac{R_1}{2} K_1 - \frac{1}{2} K_1^2 | x_{1j}, z_1 \right]$. The first-order condition is:

$$K_1 = E \left[ \frac{R_1}{2} | x_{1j}, z_1 \right] + \frac{\partial E \left[ \frac{R_1}{2} | x_{1j}, z_1 \right]}{\partial K_1} K_1. \quad (12)$$
Comparing (12) with the first-order condition (10) for investors reveals a coordination inefficiency. The two differ by a term \( \frac{\partial E \left\{ \theta_1 | x_{1j}, z_1 \right\}}{\partial K_1} K_1 > 0 \), i.e., each individual does not internalize the positive spillover of successful coordination that falls on others. Intuitively, when an investor decides to roll over her investment, this increases the project return and thus results in gains to all other investors. Nevertheless, these positive externalities are not fully accounted for by the investor. Solving equation (12) gives the optimal investment \( K_{FI}^{FI} \) in the FI benchmark:

\[
K_{FI}^{FI} = \frac{E[\theta_1|x_{1j}, z_1]}{1 - 2a} = \frac{1}{1 - 2a} \left( \frac{n x_{1j} + m_1 z_1}{m_1 + n + q} + \frac{1}{1 - 2a} \right) \frac{q \hat{\theta}}{m_1 + n + q},
\]

where the sensitivity of \( K_{FI}^{FI} \) to \( \theta_1 \) is \( \frac{1}{1 - 2a} \frac{m_1 + n}{m_1 + n + q} \). Comparing this sensitivity with the one chosen by investors, I have

\[
\left( \frac{1}{1 - 2a} \right) \frac{m_1 + n}{m_1 + n + q} > \left( \frac{1}{1 - a} \right) \frac{m_1 + (1 - a)n}{m_1 + (1 - a)n + q}.
\]

That is, as long as \( a \neq 0 \), investors are less responsive to the fundamentals than the level preferred by FI 1. Inequality (14) shows that the investors' low responsiveness to the fundamentals is caused by two reasons. First, the individual investors do not internalize the positive spillover of successful coordination that falls on others. This can be seen in the coefficients multiplying the sensitivities to the fundamentals, \( \frac{1}{1 - a} \) and \( \frac{1}{1 - 2a} \). The second reason is the investors’ overweighting of the public information. As previously discussed, to better coordinate, investors put too much weight on the common prior and is less responsive to the private information, i.e., in the individual investment, the private information is discounted by a factor \( 1 - a \). The underweighting of private information further attenuates the sensitivity of individual investments to the fundamentals. I summarize the coordination inefficiency result in the proposition below.
Proposition 1 For \( a > 0 \), the investment chosen by individual investors is less sensitive to the fundamentals than in a benchmark in which FI 1 decides the investment itself; for \( a = 0 \), the individual sensitivity is equal to the FI’s preferred sensitivity.

3.1.2 Disclosure Trade-off: Coordination Benefit and Volatility Cost

I now discuss the disclosure trade-off for FI 1. Let \( \Pi_1^{NC} \) denote FI 1’s payoff given the optimal individual investment and substituting the expressions for \( k_1^{NC} \) into \( \Pi_1^{NC} \) gives that

\[
\Pi_1^{NC} (m_1) = \left[ (\beta_1^{NC} + \gamma_1^{NC}) - \frac{1 - 2a}{2} (\beta_1^{NC} + \gamma_1^{NC})^2 \right] \frac{1}{q} - \frac{1 - 2a (\gamma_1^{NC})^2}{2} \frac{1}{m_1} - \frac{c_m}{2} m_1^2 + \frac{\bar{\theta}^2}{2 (1 - a)^2},
\]

Equation (15) illustrates the disclosure trade-off for FI 1 driven only by the rollover risk. The first term in the equation represents a benefit of disclosure in improving coordination. As shown in equation (11), the total sensitivity to the fundamentals \( \beta_1^{NC} + \gamma_1^{NC} \) is strictly increasing in the disclosure precision \( m_1 \). More precise disclosure by the FI helps investors to better assess the quality of the FI’s project and the rollover risk triggered by others’ investment decisions. As a result, the investors respond more promptly to the disclosure and to the fundamentals. This in turn benefits the FI because, by Proposition 1, investors are less sensitive to the fundamentals than the FI’s preferred level.

The second term in equation (15) represents an endogenous cost of disclosure in amplifying the non-fundamental volatility in \( K_1^{NC} \). Specifically, since individual investments vary with the public signal \( z_1 \), they also vary with the noise in \( z_1 \). In aggregating individual investments, this public noise is not diversified away as the noises in the private information, leading to the non-fundamental volatility in \( K_1^{NC} \). A key economic force behind the result that more precise disclosure may amplify the non-fundamental volatility is investors’ over-weighting of public information. In
fact, had investors observed only \( z_1 \) (or the private signal precision \( n = 0 \)), increasing the precision of \( z_1 \) would always reduce the non-fundamental volatility. This is because increasing \( m_1 \) reduces the size of the public noise, which in turn reduces the amount of noises in \( K_1^{NC} \) and thus makes \( K_1^{NC} \) less volatile. However, when investors also observes \( x_{1j} \) (or \( n > 0 \)), increasing \( m_1 \) produces an additional effect. When \( m_1 \) increases, \( z_1 \) is used more by every investor in estimating the fundamentals (i.e., a higher \( \gamma_1^{NC} \)). Anticipating that others use \( z_1 \) more, an investor will assign an even larger weight to \( z_1 \) since this information is more effective in forecasting others’ actions. As \( z_1 \) is further overweighted relative to its precision, this magnifies the impact of the noise in \( z_1 \) on \( K_1^{NC} \), thus increasing the non-fundamental volatility. When \( n \) is sufficiently large, the problem of overweighting public information becomes severe and increasing \( m_1 \) leads to a higher non-fundamental volatility and lowers FI 1’s payoff.

FI 1 decides its disclosure precision by trading off the coordination benefit against the volatility cost. I characterize the equilibrium disclosure precision \( m_1^{NC} \) in the proposition below.

**Proposition 2** Given \( b = 0 \):

1. for \( a \geq \frac{5}{8} - \frac{1}{8} \sqrt{\frac{16q}{n} + 9} \), FI 1 chooses a unique disclosure precision \( m_1^{NC} > 0 \) that solves

\[
\frac{\partial \Pi_1^{NC}(m_1)}{\partial m_1} = 0;
\]

2. for \( a < \frac{5}{8} - \frac{1}{8} \sqrt{\frac{16q}{n} + 9} \), FI 1 does not disclose \( (m_1^{NC} = 0) \).

Proposition 2 suggests that a sufficient condition for the FI to disclose is that it faces a sufficiently large amount of rollover risk (i.e., a high \( a \)). To understand how the rollover risk affects the FI’s disclosure decision, consider first an extreme case in which the FI faces a large amount of rollover risk (i.e., \( a \) is close to \( \frac{1}{2} \)). Inequality (14) shows that FI 1’s preferred sensitivity to the fundamentals approaches infinity and thus FI 1 always wants to increase the sensitivity through disclosure. Intuitively, when the FI’s project return depends to a great extent on investors’ collec-
tive decisions to roll over their investments, the FI finds it crucial to disclose in order to facilitate the coordination among investors and mitigate the coordination inefficiencies. One the other hand, when FI faces little rollover risk (i.e., $a$ is close to 0). Inequality (14) shows that individual sensitivity to the fundamentals is equal to the sensitivity preferred by FI 1. That is, absent the rollover risk, there is no need for the FI to coordinate investors’ rollover decisions and the coordination benefit of disclosure vanishes. As a result, the FI stops disclosing.

### 3.2 Equilibrium Analysis with Competitive Interactions

In this section, I analyze the full model with both the rollover risk and competitive interactions (i.e., $b > 0$). The analyses highlight how competition alters the rollover-risk-driven disclosure trade-off, and derive conditions under which competition and rollover risk jointly lead to less disclosure by the FIs.

#### 3.2.1 Benefit of Competition in Coordinating Investment Decisions

I first solve for each investor’s optimal investments conditional on the two FIs’ decisions and the available information set, $I_j = \{x_{1j}, x_{2j}, z_1, z_2\}$, at date 2. The main objective of this analysis is to highlight a benefit of competition in improving coordination among investors. I summarize the equilibrium individual investments, $\{k_{ij}^*(\cdot), k_{2j}^*(\cdot)\}$, in the following lemma.

**Lemma 2** Given $b > 0$, there exists a unique equilibrium in which investors choose

$$k_{ij}^* = \beta_1^* x_{ij} + \gamma_1^* z_i - b(\lambda_1^* x_{-ij} + \omega_1^* z_{-i}) + h_1^*, \tag{16}$$

where $\beta_1^* = \beta_i^{NC}(1 + \kappa_i)$, $\gamma_1^* = \gamma_i^{NC}(1 + \nu_i)$, $\lambda_1^* = \beta_i^{NC}(1 + \kappa_{-i})$, and $\omega_1^* = \gamma_i^{NC}(1 + \nu_{-i})$, with $\nu_i > \kappa_i > 0$. In addition, $\frac{\partial \beta_1^*}{\partial m_{-i}} = \frac{\partial \gamma_1^*}{\partial m_{-i}} = \frac{\partial \beta_i^{NC}}{\partial m_i} = \frac{\partial \omega_i^{NC}}{\partial m_i} = 0$. The expressions of $\{\kappa_i, \nu_i, h_1^*\}$ are given in the appendix.
Lemma 2 characterizes how competition affects investors’ use of information, in addition to the effect of the rollover risk characterized in Lemma 1. First, there is a direct effect. Because of their competitive interactions in the funding market, investments in a FI vary with not only the information about the FI, but also with the information about the other FI.

Aside from the direct effect, competition also has an indirect effect that mitigates the coordination inefficiencies stemming from FIs’ exposure to the rollover risk. Compared to the model without competitive interactions, competition between the FIs amplifies investors’ responses to the information and thus the fundamentals (i.e., \( \gamma_i^* > \gamma_i^{NC} \) and \( \beta_i^* > \beta_i^{NC} \)). As I will show in later analysis, this indirect effect of competition is a key channel to understand how competition affects the FIs’ disclosure decisions. For future reference, I define the indirect effect as a “multiplier effect of competition” and characterize its properties in the following proposition.

**Proposition 3** Given \( a > 0 \) and \( b > 0 \):

1. competition produces a multiplier effect that the equilibrium responses of the FIs’ investments to their signals \( \{x_{ij}, z_i\} \) with competitive interactions \( (b > 0) \) exceed the responses without competitive interactions \( (b = 0) \), i.e., \( \gamma_i^* > \gamma_i^{NC} \), \( \beta_i^* > \beta_i^{NC} \);

2. the sizes of multipliers are increasing in the rollover risk \( a \), and the intensity of competition \( b \), i.e., \( \frac{\partial}{\partial a} \left( \gamma_i^* \right) > \frac{\partial}{\partial a} \left( \frac{\beta_i^*}{\gamma_i^{NC}} \right) > 0 \), and \( \frac{\partial}{\partial b} \left( \gamma_i^* \right) > \frac{\partial}{\partial b} \left( \frac{\beta_i^*}{\gamma_i^{NC}} \right) > 0 \);

3. the multiplier effect is stronger on the sensitivity to the public signal than the private one, i.e., \( \frac{\gamma_i^*}{\gamma_i^{NC}} > \frac{\beta_i^*}{\beta_i^{NC}} \).

I now explain the intuition behind the multiplier effect. To fix ideas, suppose FI 1’s disclosure \( z_1 \) increases. I need to explain how \( k_{1j}^* \) responds to the increase in \( z_1 \) and, how competition affects
such response. Writing out the sensitivity of $k_{1j}^*$ to $z_1$ gives that:

$$
\frac{dk_{1j}^*}{dz_1} = \frac{\partial k_{1j}^*}{\partial E_j[R_1]} \frac{\partial E_j[R_1]}{\partial z_1} + \frac{\partial k_{1j}^*}{\partial E_j[R_2]} \frac{\partial E_j[R_2]}{\partial z_1} + \frac{\partial k_{1j}^*}{\partial E_j[K_2]} \frac{\partial E_j[K_2]}{\partial z_1} + \frac{\partial k_{1j}^*}{\partial E_j[e_j[R_1]]} \frac{\partial e_j[R_1]}{\partial z_1} \tag{17}
$$

$E_{-j}[]$ denotes the expectations by the investors other than investor $j$. The signal $z_1$ affects the investment $k_{1j}^*$ via two channels. The first term represents a direct informational effect of $z_1$. A higher $z_1$ improves the investor’s expectations about the project return, which in turn encourages the investor to roll over her investment. The second term captures the multiplier effect of competition that amplifies the response of $k_{1j}^*$ to $z_1$. A key to generate this effect is that competition prompts investors to reallocate investments between FIs. Upon receiving a higher $z_1$, an investor rationally anticipates that other investors also hold more optimistic beliefs about FI 1’s project return, and moreover, these investors are more likely to reallocate their investments from FI 2 to FI 1 (i.e., $E_j[K_2]$ is lower). Since others’ decisions of not rolling over their investments reduce the return to FI 2’s project, the investor lowers her expectation of FI 2’s return $E_j[R_2]$ and thus prefers to make the same reallocating decision from FI 2 to FI 1. This chain of reasoning sets into motion a loop of feedbacks and through this loop, the effect of FI 1’s disclosure on its investors’ investments is amplified. This explains part 1 of Proposition 3.

Next, since the FIs’ exposure to the rollover risk and the competition-driven reallocations are two essential ingredients in the feedback loop, a necessary condition for the multiplier effect is $a > 0$ and $b > 0$. In fact, had the FIs faced no rollover risk ($a = 0$), the multiplier effect of competition would not exist. Furthermore, the multiplier effect gets stronger when $a$ and $b$ increases. This explains part 2 of Proposition 3.

Finally, the feedback loop also highlights that investors’ (higher-order) beliefs about others’ beliefs play a vital role in producing the multiplier effect of competition. Since public signals
have a larger impact on investors’ forming of higher-order beliefs \( \left( \frac{\partial E_j[E_{-j}[R_i]]}{\partial z_i} > \frac{\partial E_j[E_{-j}[R_i]]}{\partial x_{ij}} \right) \), the multiplier effect is stronger in amplifying the response of investments to the public signal than the private signal. As a result, competition further exacerbates the investors’ overweighting of the public information. The public information is overweighted even more when the competition becomes more intense or the FIs’ rollover risk increases. This is because improvements in both measures reinforce the multiplier effect and hence the role of the higher-order beliefs, inducing the investors to place a larger weight on the public signal. This explains part 3 of Proposition 3.

### 3.2.2 Effect of Competition on Disclosure Decisions

In this section, I address my main research question on how competition affects FIs’ disclosure decisions. I first characterize FIs’ disclosure decisions given their competition for investors and then compare the equilibrium disclosure precision with that in the model without competitive interactions. From Lemma 2, the equilibrium aggregate investment is given by \( K_i^* = \int_0^1 k_{ij}(i) \, di = (\beta_i^* \theta_i + \gamma_i^* z_i) - b(\lambda_i^* \theta_{-i} + \omega_i^* z_{-i}) + h_i^* \). Let \( \Pi_i^* \) denote FI \( i \)’s payoff and substituting the expressions for \( K_i^* \) into \( \Pi_i^* \) gives that

\[
\Pi_i^* = \left[ (\beta_i^* + \gamma_i^*) - \frac{1 - 2a}{2} (\beta_i^* + \gamma_i^*)^2 \right] \frac{1}{q} - \frac{1 - 2a}{2} \frac{(\gamma_i^*)^2}{m_i} - \frac{c^m}{2} \frac{m_i^2}{m_i},
\]

Equation (18) illustrates the FIs’ disclosure trade-offs driven by both their exposure to the rollover risk and the competition between them. Notice first that since the FIs’ fundamentals are independent of each other, the signals of one FI contain no information about the fundamentals of the other FI. As a result, the weight an investor places on the signals of one FI only depends on the
disclosure precision of the FI itself and is independent of the disclosure precision of the other FI, i.e., \( \frac{\partial \beta^*_i}{\partial m_{-i}} = \frac{\partial \gamma^*_i}{\partial m_{-i}} = \frac{\partial \lambda^*_i}{\partial m_i} = \frac{\partial \omega^*_i}{\partial m_i} = 0 \). This in turn implies that, the two FIs’ disclosure precision affects a FI’s payoff through two separate channels. The disclosure precision of the other FI, \( m_{-i} \), affects \( \Pi^*_i \) only through the second line of equation (18). Recall that competition between the FIs makes investments in FI 1 respond to disclosure by FI 2 and thus vary with both FI 2’s fundamentals and disclosure noise. From an ex ante perspective, such variations introduce an additional volatility cost and lowers FI 1’s expected payoff. On the other hand, a FI’s own disclosure decision \( m_i \) affects \( \Pi^*_i \) only through the first line of equation (18). Notice that these terms are similar to the ones in the model without competitive interactions (i.e., equation (15)): with competition, the FI still contemplates a similar disclosure trade-off between the coordination benefit and the volatility cost.

I solve for the FI’s optimal choice of \( m_i \) by taking the first-order condition:

\[
\frac{\partial \Pi^*_i}{\partial m_i} = \frac{1}{q} \left( 1 - (1 - 2a)(\beta^*_i + \gamma^*_i) \right) \frac{\partial (\beta^*_i + \gamma^*_i)}{\partial m_i} - \frac{1 - 2a}{2} m_i \left( \frac{(\gamma^*_i)^2}{m_i} \right) - m_i = 0, \tag{19}
\]

which determines the FIs’ choices of disclosure precision \( m^*_i \). Since the focus of my paper is to analyze the role of competition in affecting disclosure, I now compare \( m^*_i \) with the FIs’ disclosure choices in the model without competitive interactions, \( m^{NC}_i \). The following proposition summarizes the main result of the paper: competition between the FIs may make them more opaque by reducing their choices of disclosure precision.

**Proposition 4** There exists a unique equilibrium of disclosure precision \( m^*_i \) chosen by each FI, such that:

1. when \( a = 0 \), the FIs’ choices of disclosure precision with competitive interactions (i.e., \( b > 0 \)) are the same as those without competitive interactions (i.e., \( b = 0 \)), i.e., \( m^*_i = m^{NC}_i \);
2. When $a > 0$, there exist two thresholds $\hat{b} > 0$ and $\hat{n} > 0$ defined in the appendix, such that for $b > \hat{b}$ and $n > \hat{n}$, the FIs disclose less precise public information with competitive interactions than without competitive interactions, i.e., $m_i^* \leq m_i^{NC}$, with the inequality strict if $m_i^* > 0$.

The key driving force behind Proposition 4 is the multiplier effect of competition driven by the FIs’ exposure to the rollover risk. In fact, if there were no rollover risk (i.e., $a = 0$), the multiplier effect would not exist, competition would have no effect on the disclosure trade-off, and as a consequence, the FIs’ disclosure choices under competition would coincide with those under no competition. However, when the FIs face some rollover risk (i.e., $a > 0$), competition alters both the coordination benefit and the volatility cost of disclosure through its multiplier effect, thus shifting the FIs’ disclosure trade-off.

Specifically, competition affects the coordination benefit through two channels. On one hand, since the multiplier effect of competition improves the sensitivity of investments to the fundamentals, the coordination inefficiencies become less severe (i.e., in equation (19), $1 - (1 - 2a)(\beta_i^* + \gamma_i^*)$ decreases towards zero) and as a result, the marginal benefit of disclosure in increasing $\beta_i^* + \gamma_i^*$ becomes smaller. In other words, the multiplier effect of competition substitutes the effect of disclosure in mitigating coordination inefficiencies, leading to less disclosure by the FI. I call this effect of competition a disclosure-substituting effect. On the other hand, competition also complements and amplifies the effect of $m_i$ in increasing $\beta_i^* + \gamma_i^*$ (i.e., in equation (19), $\frac{\partial(\beta_i^* + \gamma_i^*)}{\partial m_i}$ gets larger with competition). As a result, the FIs will disclose more when competing with each other. The reason for this effect is that when facing a decision to invest in two competing FIs, an investor finds an improvement in a FI’s disclosure precision more informationally valuable, since the disclosed signal helps the investor to make not only better investment decisions in the FI but also better allocation decisions between the FIs. Therefore, the investor responds more sensitively to information and $\beta_i^* + \gamma_i^*$ increases by a larger extent than the case without competition. I call this effect of
Next, I explain how competition affects the volatility cost. Recall that when the private information precision is sufficiently large, disclosure amplifies the non-fundamental volatility because of investors’ overweighting of public information. Since the multiplier effect of competition further exacerbates investors’ overweighting, increasing competition magnifies the volatility cost for $n$ sufficiently large. I call this effect of competition a \textit{volatility-amplifying effect}.

The overall effect of competition on the FI’s optimal choice of disclosure precision depends on the trade-off between the aforementioned effects. When $b$ is sufficiently large, $\beta_i^* + \gamma_i^*$ becomes sufficiently large and close to $\frac{1}{1-2n}$. That is, the multiplier effect of competition has almost completely eliminated the coordination efficiencies, making the benefit of disclosure minimal. In addition, when $n$ is sufficiently large, competition also leads to a higher volatility cost of disclosure. Overall, for $b$ and $n$ sufficiently large, the disclosure-substituting effect and the volatility-amplifying effect dominate the disclosure-complementing effect and thus FIs disclose less compared to the case in which the competitive interactions are absent.

4 Discussion and Implications

In this section, I discuss the implications of the paper and, more specifically, will focus on elaborating how my analyses may help to uncover determinants of bank opacity. Banks have often been alleged to be opaque (e.g., Morgan, 2002; Hirtle, 2006; Jones, Lee and Yeager, 2012). For example, using disagreement among bond raters on bonds issued by banks as a proxy for bank opacity, Morgan (2002) shows that banks had become more opaque than non-banking firms since 1986 (Fig. 2, top; Morgan, 2002). Many argue that bank opacity “exposes the entire financial system to bank runs, contagion, and other strains of ‘systemic’ risk,” (Morgan, 2002) and prevents effective market discipline and regulatory monitoring (Acharya and Ryan, 2016), thus severely impairing financial
stability. In fact, opacity (or lack of information) was argued to be one of the root causes of the 2008-2009 financial crisis (Gorton, 2008).

The determinants of bank opacity, however, remain unclear and under debate. For instance, Morgan (2002) argue that opacity of banks can be traced to their assets and thus to some extent inherent to their business. In particular, in lending to small opaque borrower, banks must monitor and acquire private information about those borrowers, which makes banks themselves less transparent to outsiders. In addition, Dang, Gorton, Holmstrom and Ordonez (2014) argue that opacity is central to banks’ role in liquidity provision and money creation and therefore “banks are optimally opaque institutions.”

In this debate, the increase in competition among banks is viewed as one of the causes for bank opacity (Bushman, 2014; Dou, Ryan and Zou, 2015; Bushman, Hendricks and Williams, 2016). A number of recent empirical studies utilize the interstate bank deregulation in U.S. during the last quarter of the 20th century as an exogenous shock to competition to examine the relation between competition and banks’ disclosure transparency (opacity). The empirical findings are mixed. On one hand, Bushman, Hendricks and Williams (2016) report that banks’ propensity to delay recognition of expected loan losses (DELR) is positively associated with competition. To the extent that the reduction in the timeliness of loan loss recognition contributes to bank opacity (Bushman and Williams, 2012), this finding is consistent with the hypothesis that competition leads to opacity. Similarly, Dou, Ryan and Zou (2015) find that when entry threat increases, incumbent banks decrease their levels of loan loss provisions. If one interprets a lower level of loan loss provision as banks’ downward manipulation of provision to prop up earnings which arguably decreases disclosure transparency, this result also suggests that competition increases opacity. On the other hand, Jiang, Levine and Lin (2016) report that competition reduces banks’ abnormal loan loss provisions and frequency of restating financial statements. The results thus suggest that
competition reduces bank opacity. In addition, Burks, Cuny, Gerakos and Granja (2016) find a positive association between competition and voluntary disclosure (press releases by FIs), suggesting that competition leads to more disclosure and reduces opacity.

In addition to the apparent difficulty in reconciling the conflicting empirical evidence, more importantly, relatively little is known about the exact mechanism through which competition among banks affects their disclosure transparency. While there are some informal arguments laid out in the empirical studies above, these arguments are not derived in a formal model and are mostly based on the oligopoly disclosure literature which studies generic firms and considers no bank-specific features. In this light, my paper may help us to better understand how competition affects opacity in the banking industry, to the extent that the rollover-risk component considered in my model is a key feature of banks (Diamond and Dybvig, 1983). Specifically, my analyses identify the following mechanism on how competition leads to bank opacity. Banks’ exposure to rollover risk leads to coordination inefficiencies in their investors’ investment decisions. Both disclosure and competition help to mitigate these coordination inefficiencies. When competition increases, it substitutes for and thus weakens the coordination benefit of disclosure, inducing banks to disclose less.

The prediction of my paper seems broadly consistent with observations on bank opacity during the deregulation period. As documented by Morgan (2002), banks had become more opaque than non-banking firms since mid-1980s. This pattern of the increase in opacity roughly matches two observations that occurred around the same time: 1) an increase in banks’ fragility to rollover risk and 2) an increase in the intensity of interbank competition stemming from deregulation.

More specifically, as for the first observation, a number of changes in regulatory policies and banks’ funding structure may have contributed to the increase in bank fragility. The first is the demise of the “too big to fail” policy around 1986. As discussed in Flannery and Sorescu (1996), before 1986, the federal government implicitly guaranteed all the liabilities of the very largest U.S.
banks, not just the deposits, as partly evidenced by the Continental Illinois bank bailout in 1984. With the implicit guarantee, neither banks nor their investors face any risk of runs. Beginning in 1986, regulators sought ways through which they could save the bank without either sparing its holding company or even protecting (non-deposit) creditors of the bank, as observed in the failures of the First National bank of Oklahoma City in 1986 and the First Republic bank Corporation in 1988.

The loss of the government guarantees substantially increased the risks borne by banks and their investors which arguably exacerbates banks’ vulnerability to runs. Second, since mid-1980s, banks had become increasingly relying on wholesale funding markets (or “shadow banking markets”) such as asset-backed commercial papers, repos, etc., instead of traditional deposit funding (see Fig. 1 of Pozsar, Adrian, Ashcraft and Boesky (2010) for the sharp growth of the shadow bank liabilities in mid-1980s). This transformation in banks’ funding structure has fundamentally changed the nature of banking. For example, in a Federal Reserve staff report, Pozsar, Adrian, Ashcraft and Boesky (2010) argue that “in conjunction with this transformation, the nature of banking changed from a credit-risk intensive, deposit-funded, spread-based process to a less credit-risk intensive, but more market-risk intensive, wholesale funded, fee-based process.” Arguably, tapping into shadow banking markets exposed banks to significant rollover risks since these markets were beyond the reach of federal safety net which covers mostly traditional deposit-funding.

For the second observation, a number of policy changes in the interstate bank deregulation from 1980s to early 1990s loosened restrictions on interbank competition. The passage of the Garn-St. Germain Act in 1982 allowed thrifts to engage in commercial loans up to 10 percent of assets, thus making thrifts able to act like banks and compete directly with banks. Since then, the regulation on interbank competition had been loosened considerably (Johnson and Rice, 2008; Sherman, 2009). The effort on relaxing regulation of interbank competition peaked with the passage of Riegle-Neal Interstate Banking and Branching Efficiency Act (IBBEA) in 1994. IBBEA essentially eliminated
federal restrictions on interstate branching, which greatly increased the competitiveness in the banking industry.

My model may provide a coherent explanation for the three observations above (i.e., higher bank opacity, higher bank fragility and more intense competition). Looking through the lens of my model, when banks face significant rollover risks, relaxing constraints on the competition among them can produce a benefit of improving coordination, which weakens the benefit of disclosure, makes banks disclose less and leads to higher bank opacity.

5 Conclusion

This paper studies how competition between financial institutions (FIs) may affect their disclosure decisions when the FIs are vulnerable to rollover risk. In a model without competitive interactions, I first identify a disclosure trade-off, driven solely by the rollover risk, between the benefit of mitigating coordination inefficiencies and the cost of induced excess volatility. This rollover-risk-driven disclosure trade-off is then embedded in a competition model in which two FIs compete for a group of investors. I find that the competition produces a benefit for the FIs in improving the coordination among their investors. This coordination benefit of competition in turn substitutes for and thus weakens the coordination role of disclosure, inducing FIs to disclose less compared to the case in which the competitive interactions are absent.

References


Appendix I: Micro-foundation for FIs’ Project Return

In this appendix, I consider an extension of the rollover-risk model laid out in Morris and Shin (2004) that can micro-found the reduce-form return structure used in my main model. The model contains 3 dates. At date 0, each FI sets up \( N \) conduits, indexed by \( i \in \{1, 2, ..., N\} \), with \( N \) sufficiently large. Each conduit begins with an asset of 1 unit and is financed by a group of investors. At date 1, the investors have a choice of either rolling over the investment at the FI until the maturity at date 2, or not rolling over and seizing the investment at the face value 1. I denote the fraction of investors who roll over their investment as \( \delta \) and the rest as \( l \). Therefore, the total amount of investments that are rolled over in the FI is \( \delta N \) and the total short-term claims from investors who decide not to roll over are \( lN \).

I model the return of each conduit following Morris and Shin (2004). The outcome of each conduit’s investment is binary, either success or failure. Upon success, a conduit \( i \) generates \( V \) per-unit terminal cash flow and upon failure, it generates 0. Each conduit succeeds if \( zl \leq \omega_i \) (or equivalently, \( z(1 - \delta) \leq \omega_i \)) and fails if \( zl > \omega_i \). That is, the value of the project upon maturity depends on two factors – the underlying fundamentals of each conduit \( \omega_i \), and the degree of disruption caused to the conduit by the fraction of investors who decide not to roll over, \( l \).

\( z > 0 \) is a parameter that determines the severity of disruption caused by investors’ decisions. I assume that the distribution of \( \omega_i \) in the FI’s portfolio is characterized by a uniform distribution \([\omega - b, \omega + b]\), where \( \omega \) is a normally-distributed random variable. One can interpret \( \omega \) as some characteristics of the FI that affects the return of every conduit set up by the FI.

As discussed in Morris and Shin (2004), an interpretation of the conduit’s payoff structure is as follows. The total short-term claims from investors are \( lN \). The FI can tap into each of its conduits to meet these claims. Suppose that the FI allocates an equal fraction \( \frac{1}{N} \) of the total claims for every conduit to meet, which is \( lN \frac{1}{N} = l \). \( \frac{\omega_i}{z} \) is a measure of the ability of the conduit \( i \) to meet short-term claims, which may depend on the type of the conduit’s assets, market liquidity, etc. The conduit \( i \) thus remains in operation provided that \( \frac{\omega_i}{z} \) is large enough to meet \( l \). Otherwise, the conduit is pushed into bankruptcy and returns 0.

For \( N \) sufficiently large, an application of the law of large numbers shows that, the per-unit terminal cash flow to the FI’s conduits can be approximated by the expected per-unit return from a single conduit conditional on \( \omega \):

\[
\Pr(z(1 - \delta) \leq \omega_i \mid \omega) V = \left[ \frac{\omega + b - z(1 - \delta)}{2b} \right] V = \left( \frac{\omega + b - z}{2b} \right) V + \frac{zV\delta}{2b}.
\]

I can redefine the FIs’ fundamentals \( \theta \equiv \left( \frac{\omega + b - z}{4b} \right) V \) (which remains normally distributed), the total
investment \( K \equiv \delta N \), and \( a \equiv \frac{\gamma}{4N_0} \). This gives the same FI’s per-unit terminal cash flow as in the main model:

\[
R = 2(\theta + aK).
\]

**Appendix II: Proofs**

**Proof**. of Proposition 2: The optimal disclosure precision \( m_1^{NC} \) is given by the following first-order condition:

\[
\frac{\partial \Pi_1^{NC}}{\partial m_1} = \left[1 - (1 - 2a)(\beta_1^{NC} + \gamma_1^{NC})\right] \frac{\partial (\beta_1^{NC} + \gamma_1^{NC})}{\partial m_1} \frac{1}{q} - \frac{1 - 2a}{2} \frac{\partial}{\partial m_1} \left[ \frac{(\gamma_1^{NC})^2}{m_1} \right] = 0. \tag{20}
\]

Given the expressions for \( \beta_1^{NC} \) and \( \gamma_1^{NC} \) in Lemma 1, I have

\[
\beta_1^{NC} + \gamma_1^{NC} = \frac{m_1 + (1 - a)n}{(1 - a)(q + m_1 + (1 - a)n)} < \frac{1}{1 - 2a}, \tag{21}
\]

\[
\frac{\partial (\beta_1^{NC} + \gamma_1^{NC})}{\partial m_1} = \frac{q}{(1 - a)(q + m_1 + (1 - a)n)^2} > 0,
\]

\[
\frac{\partial}{\partial m_1} \left[ \frac{(\gamma_1^{NC})^2}{m_1} \right] = \frac{2}{m_1^2} \frac{\partial}{\partial m_1} \left[ \frac{(\gamma_1^{NC})^2}{m_1} \right] = \frac{2m_1}{(1 - a)(q + m_1 + (1 - a)n)^2} \frac{q + (1 - a)n}{m_1} - \frac{1}{m_1^2} \frac{m_1^2}{(1 - a)^2 [q + m_1 + (1 - a)n]^2}
\]

That is, increasing \( m_1 \) always increases \( \beta_1^{NC} + \gamma_1^{NC} \). In addition, increasing \( m_1 \) increases the volatility \( \frac{(\gamma_1^{NC})^2}{m_1} \) if and only if \( n > \frac{m_1}{1-a} - d \). Substituting these expressions into \( \frac{\partial \Pi_1^{NC}}{\partial m_1} \) gives

\[
\frac{\partial \Pi_1^{NC}}{\partial m_1} = \left[1 - (1 - 2a)\frac{m_1 + (1 - a)n}{(1 - a)(q + m_1 + (1 - a)n)}\right] \frac{1}{(1 - a)(q + m_1 + (1 - a)n)^2}
\]

\[
- \frac{1 - 2a}{2} \frac{q + (1 - a)n}{m_1} - m_1 \frac{1 - 2a}{2} \frac{(1 - a)(1 - 4a)n}{2(1 - a)^2 [q + m_1 + (1 - a)n]^3} - c_m m_1
\]

\[
= \frac{m_1 + q - (1 - a)(1 - 4a)n}{2(1 - a)^2 [q + m_1 + (1 - a)n]^3} - c_m m_1. \tag{22}
\]

Notice that at \( m_1 = \infty, \lim_{m_1 \to \infty} \frac{\partial \Pi_1^{NC}}{\partial m_1} = -\infty < 0 \). At \( m_1 = 0, \lim_{m_1 \to 0} \frac{\partial \Pi_1^{NC}}{\partial m_1} = \frac{q - (1 - a)(1 - 4a)n}{2(1 - a)^2 [q + (1 - a)n]^3} \)

which is positive if and only if \( q - (1 - a)(1 - 4a)n > 0 \) \( (a \geq \frac{5}{8} - \frac{1}{8}\sqrt{\frac{16a}{n} + 9}) \). In addition, the
Then the aggregate investments become

\[
\begin{align*}
    k_{1j} &= \beta_1 x_{1j} + \gamma_1 z_1 - b(\omega_1 z_2 + \lambda_1 x_{2j}) + h_1, \\
    k_{2j} &= \beta_2 x_{2j} + \gamma_2 z_2 - b(\omega_2 z_2 + \lambda_2 x_{2j}) + h_2.
\end{align*}
\]

The sign of \( \frac{\partial^2 \Pi_{j}^N C}{\partial m_1^2} \) is dominated by the size of \( c_m \). For \( c_m \) sufficiently large, \( \frac{\partial^2 \Pi_{j}^N C}{\partial m_1^2} < 0 \). These conditions jointly imply that there exists a unique and finite \( m_1^{-1} \Pi_{j}^N C \) that maximizes \( \Pi_{j}^N C \). If \( a \geq 5 \frac{8}{9} - \frac{1}{8} \sqrt{\frac{16q}{n} + 9} \), then \( \lim_{m_1 \to 0} \frac{\partial \Pi_{j}^N C}{\partial m_1} > 0 \) and an application of the intermediate value theorem implies that \( \Pi_{j}^N C > 0 \). If \( a < \frac{5}{8} - \frac{1}{8} \sqrt{\frac{16q}{n} + 9} \), then \( \lim_{m_1 \to 0} \frac{\partial \Pi_{j}^N C}{\partial m_1} < 0 \). From \( \frac{\partial^2 \Pi_{j}^N C}{\partial m_1^2} < 0 \), \( \frac{\partial \Pi_{j}^N C}{\partial m_1} < 0 \) for all \( m_1 \geq 0 \), which implies that \( m_1^{-1} \Pi_{j}^N C = 0 \). 

**Proof.** of Lemma 1 and Lemma 2: 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

\[
\begin{align*}
    k_{1j} &= (\beta_1 x_{1j} + \gamma_1 z_1) - b(\omega_1 z_2 + \lambda_1 x_{2j}) + h_1, \\
    k_{2j} &= (\beta_2 x_{2j} + \gamma_2 z_2) - b(\omega_2 z_2 + \lambda_2 x_{2j}) + h_2.
\end{align*}
\]

Then the aggregate investments become

\[
\begin{align*}
    K_1 &= (\beta_1 \theta_1 + \gamma_1 z_1) - b(\omega_1 z_2 + \lambda_1 \theta_2) + h_1, \\
    K_2 &= (\beta_2 \theta_2 + \gamma_2 z_2) - b(\omega_2 z_2 + \lambda_2 \theta_1) + h_2.
\end{align*}
\]

Investor j’s conditional expectations of the aggregate investment are

\[
\begin{align*}
    E_j[K_1] &= \beta_1 \left( \frac{m_1 z_1 + nx_{1j} + q \theta}{m_1 + n + q} \right) + \gamma_1 z_1 - b \left[ \lambda_1 \left( \frac{m_2 z_2 + nx_{2j} + q \theta}{m_2 + n + q} \right) + \omega_1 z_2 \right] + h_1, \\
    E_j[K_2] &= \beta_2 \left( \frac{m_2 z_2 + nx_{2j} + q \theta}{m_2 + n + q} \right) + \gamma_2 z_2 - b \left[ \lambda_2 \left( \frac{m_1 z_1 + nx_{1j} + q \theta}{m_1 + n + q} \right) + \omega_2 z_1 \right] + h_2.
\end{align*}
\]

Substituting equation (26) into investors’ linear investment rules (5), one can simplify the individual investments into

\[
\begin{align*}
    k_{1j} &= \frac{E_j R_1 - b E_j R_2}{2} \\
    &= E_j[\theta_1] + a E_j[K_1] - b(E_j[\theta_2] + a E_j[K_2]) \\
    &= \left( \frac{m_1 z_1 + nx_{1j} + q \theta}{m_1 + n + q} \right) + a E_j[K_1] - b \left[ \left( \frac{m_2 z_2 + nx_{2j} + q \theta}{m_2 + n + q} \right) + a E_j[K_2] \right], \\
    k_{2j} &= \left( \frac{m_2 z_2 + nx_{2j} + q \theta}{m_2 + n + q} \right) + a E_j[K_2] - b \left[ \left( \frac{m_1 z_1 + nx_{1j} + q \theta}{m_1 + n + q} \right) + a E_j[K_1] \right],
\end{align*}
\]
where $E_j[K_1]$ and $E_j[K_2]$ are given by equation (26). Comparing the coefficients in (24) and (27), I obtain

$$
\beta^*_i = \beta^{NC}_i \left( 1 + \frac{n(1+\beta^{NC}_a)}{q+m_i+(1-a)n} a^2 b^2 \right),
$$

$$
\gamma^*_i = \gamma^{NC}_i \left( 1 + \frac{a^2 b^2}{(1-a)^2} \right) \left( 1 + \frac{n(1+\beta^{NC}_a)}{q+m_i+(1-a)n} \right) + \frac{1-a}{1-\frac{n(1+\beta^{NC}_a)}{q+m_i+(1-a)n} a^2 b^2},
$$

$$
\lambda^*_i = \beta^{NC}_{-i} \left( 1 + \frac{n(1+\beta^{NC}_a) a^2 b^2}{q+m_i+(1-a)n} \right),
$$

$$
\omega^*_i = \gamma^{NC}_{-i} \left( 1 + \frac{a^2 b^2}{(1-a)^2} \right) \left( 1 + \frac{n(1+\beta^{NC}_a) a^2 b^2}{q+m_i+(1-a)n} \right) + \frac{1-a}{1-\frac{n(1+\beta^{NC}_a) a^2 b^2}{q+m_i+(1-a)n}},
$$

$$
h^*_i = \left( \frac{\gamma^{NC}_{-i}}{m_i} - \frac{b \omega^{NC}_{-i}}{m_{-i}} \right) q \tilde{r},
$$

where $\beta^{NC}_1 = \frac{n}{q+m_i+(1-a)n}$, $\gamma^{NC}_1 = \frac{m_i}{q+m_i+(1-a)n}$, $\beta^{NC}_2 = \frac{m_2}{q+m_2+(1-a)n}$ and $\gamma^{NC}_2 = \frac{m_2}{q+m_2+(1-a)n}$.

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 $\theta_i$ by the group of investors takes the following functional form,

$$
E^k[\theta_i] = \delta_{ik} z_i + l_{ik} \theta_i + r_{ik} \tilde{r},
$$

where

$$
\delta_{ik} = \frac{m_i}{m_i + q} \left[ 1 - \left( \frac{n}{m_i + n + q} \right)^k \right],
$$

$$
l_{ik} = \left( \frac{n}{m_i + n + q} \right)^k, \quad r_{ik} = \frac{q}{m_i + q} \left[ 1 - \left( \frac{n}{m_i + n + q} \right)^k \right].
$$

This can be shown by induction. At $k = 1$, I show an individual $j$’s expectation of $\theta_i$ is:

$$
E_j(\theta_i) = \frac{m_i z_i + n x_{ij} + q \tilde{\theta}}{m_i + n + q}.
$$

Therefore, the expectation of $\theta_i$ by the group of investors becomes

$$
E[\theta_i] = \int_0^1 E_j(\theta_i) di = \frac{m_i z_i + n \theta_i + q \tilde{\theta}}{m_i + n + q}.
$$
Now suppose (29) holds for \( k - 1 \). Then
\[
E_j[E^{k-1}[\theta_j]] = E_j[\delta_{ik-1}z_i + l_{ik-1}\theta_i + r_{ik-1}\pi] \\
= \delta_{ik-1}z_i + r_{ik-1}\pi + l_{ik-1}E_j[\theta_i] \\
= \delta_{ik-1}z_i + r_{ik-1}\pi + \frac{m_iz_i + n\pi_{ij} + q\pi}{m_i + n + q}.
\]

Thus the aggregate expectation is given by
\[
E^k[\theta_j] = \delta_{ik-1}z_i + r_{ik-1}\pi + \frac{m_iz_i + n\pi_i + q\pi}{m_i + n + q}.
\]

After a few simplifying steps, \( E^k[\theta_j] \) becomes
\[
E^k[\theta_i] = \delta_{ik}z_i + l_{ik}\theta_i + r_{ik}\pi,
\]
which concludes the proof on the linear form of \( E^k[\theta_i] \).

Second, I verify that the linear equilibrium derived previously is indeed the unique equilibrium. Notice that the individual optimal investments can be rewritten as:
\[
k_j = AE_j[\theta] + BE_j[K],
\]
where
\[
k_j = [k_{1j}]
E_j[\theta] = \begin{bmatrix} E_j[\theta_1] \\ E_j[\theta_2] \end{bmatrix},
E_j[K] = \begin{bmatrix} E_j[K_1] \\ E_j[K_2] \end{bmatrix},
\]
\[
\begin{aligned}
A &= \begin{bmatrix} 1 & -b \\ -b & 1 \end{bmatrix},
B &= \begin{bmatrix} a & -ba \\ -ba & a \end{bmatrix}.
\end{aligned}
\]

The aggregate investment can be similarly written as:
\[
K = A\bar{E}[\theta] + B\bar{E}[K].
\]

Substituting the aggregate investment into the individual investment gives
\[
k_j = AE_j[\theta] + BA E_j[\bar{E}[\theta]] + B^2 AE_j[\bar{E}^2[\theta]] + \ldots
\]
\[
= \sum_{k=0}^{\infty} B^k A E_j[\bar{E}^k[\theta]],
\]
where I have shown that
\[
\bar{E}^k[\theta] = \begin{bmatrix} \delta_{1k}z_1 + l_{1k}\theta_1 + r_{1k}\pi \\ \delta_{2k}z_2 + l_{2k}\theta_2 + r_{2k}\pi \end{bmatrix}.
\]

Given \( 0 < a < \frac{1}{2} \), and \( 0 < b < 1 \), the eigenvalues of \( B \) are \( a(1-b) \) and \( a(1+b) \), both of which are between 0 and 1. Therefore, the sum \( \sum_{k=0}^{\infty} B^k A E_j[\bar{E}^k[\theta]] \) converges. After a few simplifying steps, this sum reduces to the exact linear forms as in Lemma 2 and hence I have verified the uniqueness of the linear equilibrium. □

**Proof.** of Proposition 3: From the expressions of \( \{\beta_i^*, \gamma_i^*\} \), I have
\[
\frac{\beta_i^*}{\beta_i^{NC}} = 1 + \frac{n(1+\beta_i^{NC}a)}{q+m_i(1-a)n} - \frac{n}{q+m_i(1-a)n}a^2b^2ab^2 > 1,
\]

39
which is strictly increasing in $a$ and $b$, i.e.,

\[
\frac{\partial}{\partial a} \left( \beta_*^{iNC} \right) = \frac{b^2 n (q + m_i + n) \left( (q + m_i)^2 + 2(q + m_i) n + (1 - a^2)(1 - b^2) n \right)}{(q + m_i + (1 - a)(1 - b)) n^2 (q + m_i + (1 - a - ab) n)^2} > 0,
\]

\[
\frac{\partial}{\partial b} \left( \beta_*^{iNC} \right) = \frac{2abn (q + m_i + n) (q + m_i + (1 - a)^2)}{(q + m_i + (1 - a)(1 - b)) n^2 (q + m_i + (1 - a - ab) n)^2} > 0.
\]

Similarly,

\[
\frac{\gamma_*^{i}}{\gamma_*^{iNC}} = \left( 1 + \frac{a^2 b^2}{(1 - a)^2} \right) \left( 1 + \frac{n(1 + (1 - a)\beta_*^{iNC})}{(1 - a)(q + m_i + (1 - a) n)} \right) - \frac{1-a}{1-a} \frac{n(a^2 b^2)}{1-a} \frac{1}{a^2 b^2} > \frac{\beta_*^{iNC}}{\beta_*^{iNC}}.
\]

In addition, by computing the derivatives, I verify that $\frac{\gamma_*^{i}}{\gamma_*^{iNC}}$ is strictly increasing in $a$ and $b$. \(\blacksquare\)

**Proof.** of Proposition 4: If $b = 0$, a FI's disclosure decision $m_i^{NC}$ is given by

\[
\frac{\partial \Pi_i^{NC}}{\partial m_i} = \frac{1}{q} \left[ 1 - (1 - 2a) (\beta_*^{iNC} + \gamma_*^{iNC}) \right] \frac{\partial (\beta_*^{iNC} + \gamma_*^{iNC})}{\partial m_i} - \frac{1 - 2a}{2} \frac{\partial}{\partial m_i} \left( \frac{(\gamma_*^{iNC})^2}{m_i} \right) - c_m m_i = 0.
\]

If $b > 0$, the equilibrium $m_i^*$ is given by,

\[
\frac{\partial \Pi_*^i}{\partial m_i} = \frac{1}{q} \left[ 1 - (1 - 2a) (\beta_*^{i} + \gamma_*^{i}) \right] \frac{\partial (\beta_*^{i} + \gamma_*^{i})}{\partial m_i} - \frac{1 - 2a}{2} \frac{\partial}{\partial m_i} \left( \frac{(\gamma_*^{i})^2}{m_i} \right) - c_m m_i = 0. \tag{45}
\]

I verify that at $m_i = \infty$, \( \lim_{m_i \to \infty} \frac{\partial \Pi_*^i}{\partial m_i} = -\infty \). In addition, the second-order condition is given by

\[
\frac{\partial^2 \Pi_*^i}{\partial m_i^2} = \frac{1}{q} \left[ 1 - (1 - 2a) (\beta_*^{i} + \gamma_*^{i}) \right] \frac{\partial^2 (\beta_*^{i} + \gamma_*^{i})}{\partial m_i^2} - \frac{1 - 2a}{2} \frac{\partial}{\partial m_i} \left( \frac{(\gamma_*^{i})^2}{m_i} \right) - c_m \tag{46}
\]

The sign of $\frac{\partial^2 \Pi_*^i}{\partial m_i^2}$ is dominated by the size of $c_m$. For $c_m$ sufficiently large, $\frac{\partial^2 \Pi_*^i}{\partial m_i^2} < 0$. These conditions jointly imply that there exists a unique and finite $m_i^*$ that maximizes $\Pi_*^i$. If $\frac{\partial \Pi_*^i}{\partial m_i} |_{m_i = 0} > 0$, an application of the intermediate value theorem implies that $m_i^*>0$ whereas if $\frac{\partial \Pi_*^i}{\partial m_i} |_{m_i = 0} < 0$, then from $\frac{\partial^2 \Pi_*^i}{\partial m_i^2} < 0$, $\frac{\partial \Pi_*^i}{\partial m_i} < 0$ for all $m_i \geq 0$, which implies that $m_i^* = 0$.

Now I compare $m_i^*$ with $m_i^{NC}$. At $a = 0$, from Lemma 1 and Lemma 2, $\beta_*^{i} = \beta_*^{iNC} = \frac{n}{q + m_i + n}$ and $\gamma_*^{i} = \gamma_*^{iNC} = \frac{m_i}{q + m_i + n}$. As a result, $\frac{\partial \Pi_*^i}{\partial m_i} = 0$ coincides with $\frac{\partial \Pi_*^{iNC}}{\partial m_i} = 0$ and thus $m_i^* = m_i^{NC}$.
For $a > 0$, the detailed expression of $\frac{\partial \Pi_i^*}{\partial m_i}$ is too complex for analysis of any $b \in [0,1]$. I will thus focus on comparing $m_i^*$ and $m_i^{NC}$ at $b = 1$. At $b = 1$, I can compute each term in $\frac{\partial \Pi_i^*}{\partial m_i}$ as follows.

$$\beta_i^* + \gamma_i^* = \frac{m_i + (1 - 2a)n}{(1 - 2a)[q + m_i + (1 - 2a)n]} > \beta_i^{NC} + \gamma_i^{NC},$$

$$\frac{\partial(\beta_i^* + \gamma_i^*)}{\partial m_i} = \frac{q}{(1 - 2a)[q + m_i + (1 - 2a)n]^2} > \frac{\partial(\beta_i^{NC} + \gamma_i^{NC})}{\partial m_i},$$

$$\frac{\partial}{\partial m_i} \left[ \frac{(\gamma_i^*)^2}{m_i} \right] = \frac{2\gamma_i^*}{m_i} \frac{\partial m_i}{\partial m_i} - \frac{(\gamma_i^*)^2}{m_i^2},$$

$$= \frac{q}{(1 - 2a)^2[q + m_i + (1 - 2a)n]^3}.$$

where $\frac{\partial}{\partial m_i} \left[ \frac{(\gamma_i^*)^2}{m_i} \right] > 0$ if and only if $n > \frac{m_i - q}{1 - 2a}$. In addition, in the expression of $\frac{\partial}{\partial m_i} \left[ \frac{(\gamma_i^*)^2}{m_i} \right]$, $\frac{2\gamma_i^*}{m_i} \frac{\partial m_i}{\partial m_i} > \frac{2\gamma_i^{NC}}{m_i^{NC}} \frac{\partial m_i}{\partial m_i}$ and $\frac{(\gamma_i^*)^2}{m_i^2} > \frac{(\gamma_i^{NC})^2}{m_i^{NC}}$. Thus the comparison between $\frac{\partial}{\partial m_i} \left[ \frac{(\gamma_i^*)^2}{m_i} \right]$ and $\frac{\partial}{\partial m_i} \left[ \frac{(\gamma_i^{NC})^2}{m_i^{NC}} \right]$ is ambiguous. Plugging these expressions into $\frac{\partial \Pi_i^*}{\partial m_i}$, I obtain that:

$$\frac{\partial \Pi_i^*}{\partial m_i} = \frac{m_i + q - (1 - 2a)n}{(1 - 2a)[q + m_i + (1 - a)n]^3} - c_m m_i. \quad (47)$$

Notice that at $m_i = 0$, $\lim_{m_i \to 0} \frac{\partial \Pi_i^*}{\partial m_i} = \frac{q}{2(1 - 2a)[q + (1 - a)n]^3}$ which is negative if and only if $n > \frac{q}{1 - 2a}$.

If $m_i^* = 0$, then trivially $m_i^* \leq m_i^{NC}$. If $m_i^{NC} = 0$, then as long as $n > \frac{q}{1 - 2a}$, $m_i^* = 0 \leq m_i^{NC}$.

Next I focus on the more interesting case that $m_i^{NC} > 0$ and $m_i^* > 0$. Since $\frac{\partial \Pi_i^*}{\partial m_i} |_{m_i = m_i^*} = 0$ and $\frac{\partial \Pi_i^*}{\partial m_i}$ is strictly decreasing in $m_i$, to show that $m_i^* < m_i^{NC}$, it suffices to show that $\frac{\partial \Pi_i^*}{\partial m_i} |_{m_i = m_i^{NC}} < 0$. Specifically,

$$\frac{\partial \Pi_i^*}{\partial m_i} |_{m_i = m_i^{NC}} = \frac{1}{q} \left[ 1 - (1 - 2a)(\beta_i^* + \gamma_i^*) \right] \frac{\partial (\beta_i^* + \gamma_i^*)}{\partial m_i} - \frac{1 - 2a}{2} \frac{\partial}{\partial m_i} \left[ \frac{(\gamma_i^*)^2}{m_i} \right] - c_m m_i^{NC} \quad (48)$$

$$= \frac{1}{q} \left[ 1 - (1 - 2a)(\beta_i^* + \gamma_i^*) \right] \frac{\partial (\beta_i^* + \gamma_i^*)}{\partial m_i} - \frac{1}{q} \left[ 1 - (1 - 2a)(\beta_i^{NC} + \gamma_i^{NC}) \right] \frac{\partial (\beta_i^{NC} + \gamma_i^{NC})}{\partial m_i} - \frac{1 - 2a}{2} \frac{\partial}{\partial m_i} \left[ \frac{(\gamma_i^{NC})^2}{m_i} \right].$$

The second equality uses $\frac{1}{q} \left[ 1 - (1 - 2a)(\beta_i^{NC} + \gamma_i^{NC}) \right] \frac{\partial (\beta_i^{NC} + \gamma_i^{NC})}{\partial m_i} - \frac{1 - 2a}{2} \frac{\partial}{\partial m_i} \left[ \frac{(\gamma_i^{NC})^2}{m_i} \right] = c_m m_i^{NC}$. 

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Plugging in the expressions for the coefficients gives that

\[
\frac{\partial \Pi^*_i}{\partial m_i} \bigg|_{m_i = m_i^{NC}} = \frac{q}{(1-2a) [q + m_i^{NC} + (1-2a)n]^3} - \frac{q + \frac{a}{1-a}m_i^{NC} + an}{(1-a) [q + m_i^{NC} + (1-a)n]^3} - \frac{1}{2} \left[ \frac{q + (1-2a)n - m_i^{NC}}{(1-2a)^2 [q + m_i^{NC} + (1-2a)n]^3} - \frac{q + (1-a)n - m_i^{NC}}{(1-a)^2 [q + m_i^{NC} + (1-a)n]^3} \right]
\]

\[
= \frac{m_i^{NC} + q - (1-2a)n}{2 (1-2a) [q + m_i^{NC} + (1-2a)n]^3} - \frac{m_i^{NC} + q - (1-a)(1-4a)n}{2 (1-a) [q + m_i^{NC} + (1-a)n]^3}.
\]

(49)

I now verify that for \( n \) sufficiently large, \( \frac{\partial \Pi^*_i}{\partial m_i} \bigg|_{m_i = m_i^{NC}} < 0 \). Specifically, at \( n = 0 \),

\[
\lim_{n \to 0} \frac{\partial \Pi^*_i}{\partial m_i} \bigg|_{m_i = m_i^{NC}} = \frac{a^2}{2 (1-2a) (1-a)^2 (q + m_i^{NC})^2} > 0.
\]

(50)

At \( n = \infty \), \( \lim_{n \to \infty} \frac{\partial \Pi^*_i}{\partial m_i} \bigg|_{m_i = m_i^{NC}} = 0 \). In addition, I verify that \( \frac{\partial \Pi^*_i}{\partial m_i} \bigg|_{m_i = m_i^{NC}} = 0 \) can be reduced into a fourth-order polynomial of \( n \) which has 1 sign change in its coefficients. Thus \( \frac{\partial \Pi^*_i}{\partial m_i} \bigg|_{m_i = m_i^{NC}} = 0 \) has a unique positive root \( \hat{n} > 0 \). For \( n > \hat{n} \), \( \frac{\partial \Pi^*_i}{\partial m_i} \bigg|_{m_i = m_i^{NC}} < 0 \). Since \( \frac{\partial \Pi^*_i}{\partial m_i} \bigg|_{m_i = m_i^{NC}} \) is continuous in \( \hat{n} \), then there exists a \( \tilde{\hat{n}} \in (0,1) \), such that for \( b > \tilde{\hat{n}} \) and \( n > \hat{n} \), \( \frac{\partial \Pi^*_i}{\partial m_i} \bigg|_{m_i = m_i^{NC}} < 0 \). Thus \( m_i^{NC} > m_i^* \).