

# ON THE SOCIAL VALUE OF ACCOUNTING OBJECTIVITY IN FINANCIAL STABILITY\*

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## Abstract

In this paper, we analyze the social value of accounting objectivity in maintaining financial stability. Building on an early, influential accounting study by Ijiri and Jaedicke (1966), we operationalize two informational properties, accuracy (free of collective bias) and objectivity (degree of consensus), in a correlated information structure and embed them into a model of runs on financial institutions. We show that, when compared with the accuracy property, the objectivity property exhibits an advantage in mitigating inefficient, panic-based runs. In fact, it is possible that improving objectivity discourages such runs whereas improving accuracy encourages them. Our model also sheds light on the design of optimal accounting systems to enhance objectivity. We find that, to generate a more objective accounting report, accounting systems should be designed to be less subject to intentional managerial intervention.

**Keywords:** financial stability, accounting objectivity, higher-order beliefs, differential interpretation, correlated signals

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In this paper, we analyze the social value of accounting objectivity in maintaining financial stability. Building on an early, influential accounting study by Ijiri and Jaedicke (1966), we operationalize two informational properties, accuracy (free of collective bias) and objectivity (degree of consensus), in a correlated information structure and embed them into a model of runs on financial institutions. We show that, when compared with the accuracy property, the objectivity property exhibits an advantage in mitigating inefficient, panic-based runs. In fact, it is possible that improving objectivity discourages such runs whereas improving accuracy encourages them. Our model also sheds light on the design of optimal accounting systems to enhance objectivity. We find that, to generate a more objective accounting report, accounting systems should be designed to be less subject to intentional managerial intervention.

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# 1 Introduction

The recent turmoil in the financial markets revealed the fragility of financial institutions to risk of runs. Runs not only led to failures of traditional banks with notable examples, such as Northern Rock, WaMu and IndyMac, but also caused disruption in shadow banking markets, such as markets of repos, asset-backed commercial papers, and money market mutual funds. Opacity was attributed to be a major cause of financial instability (Gorton, 2008). In response, regulators took a series of actions to improve financial market information environments. One key regulatory action is the stress-test disclosure mandated by the Dodd-Frank act, which “provided anxious investors with credible information,” and “helped restore confidence in the banking system.” (Bernanke, 2013)

Accounting measurements are a key determinant of financial market information environments. Both regulatory disclosure, including stress tests and bank capital analysis (such as CCAR), and financial institutions’ own disclosure, including Tangible Common Equity and loan loss reserves, are based on GAAP accounting measurements designed for financial reporting. In this light, the properties of accounting measurement have important implications for financial stability and examining these implications can shed light on regulatory policies on financial institutions and accounting standards.

We examine the social value of two key accounting measurement properties, objectivity and accuracy, in maintaining financial stability. In an influential accounting measurement work by Ijiri and Jaedicke (1966), accounting measurement’s objectivity, defined as the degree of consensus among observers, is made distinct from its accuracy, defined as being free of measurement bias collectively. This distinction is of great importance to accounting because in various contexts of financial reporting, the significance of accounting measurements often lies in their impact on the level of agreement/consensus they generate (or eliminate) among observers, in addition to being accurate or inaccurate about fundamentals. A current banking disclosure example is illustrative. In determining the reported assets and liabilities stemming from banks’ collateralized borrowing and lending, a critical accounting recognition issue is the application for “sales” accounting and “secured borrowing.” This application requires substantial amounts of managerial judgment, which may in turn invite disagreements among outside observers in interpreting the reported accounting numbers. Exploiting the now infamous “Repo 105” product, Lehman Brothers recorded repo transactions of

assets as sales and removed \$38 to \$50 billion from its reported liabilities, thus reducing the reported leverage ratios. This accounting treatment was entirely based on judgment by Lehman that it did not have the ability to fund all the cost of repurchasing the assets because of the difference – via the larger haircut at 5% – between the value of the assets transferred and the funding Lehman borrowed in a Repo 105 transaction. Such a variation in the implementation of sales accounting will lead to differences in opinions among outside observers about Lehman’s true leverage (even if they all observe the same reported leverage), stemming from different inferences about managers’ intentions in their private use of controversial products like Repo 105 to manipulate reported leverage ratios.<sup>1</sup>

We place the objectivity-accuracy distinction in a model of financial institution runs to study its implications for financial stability. We hope to shed light on some aspects of the following questions. Do improvements in accuracy always lead to higher financial stability? Does the distinction matter in runs, that is, can improving objectivity play a distinct role from improving accuracy? What is the optimal design of accounting measurement systems to enhance financial stability?

The main message of the paper is that, in promoting financial stability, the Ijiri-Jaedicke objectivity-accuracy distinction matters. Higher accuracy does not always lead to higher stability. In particular, although improving objectivity always discourages panic-based inefficient runs, improving accuracy may actually encourage runs, especially when investors’ prior information is sufficiently precise. To the extent that “modern-day” runs incurred in the recent crisis were primarily by institutional investors equipped with precise prior knowledge, objectivity has a higher social value in enhancing stability than accuracy. The social value of objectivity also has implications for the design of accounting systems. We show that the optimal accounting system should minimize noise stemming from intentional managerial intervention, thereby suggesting a new benefit of reducing earnings manipulations based on grounds of objectivity and stability.

Specifically, we expand the Ijiri-Jaedicke framework into a correlated information structure in which each investor’s private signal contains a common noise and an idiosyncratic noise. Within this structure, the precision of the common noise captures the collective knowledge about the funda-

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<sup>1</sup>To fix the idea, suppose that Lehman reports a debt-to-equity leverage ratio of 30, and 1 unit use of Repo 105 reduces the reported leverage ratio by 1. Outsiders may disagree on to what extent Repo 105 has been used in Lehman’s report for the purpose of reducing the reported leverage ratios. For instance, a skeptical investor may believe that Lehman has used 3 units of Repo 105 and thus conjecture upon observing a report of 30 that the true leverage ratio is 33. However, an optimistic investor may believe Lehman has used no Repo 105 and that the true leverage ratio is equal to the reported 30. Notice while they disagree with each other in their opinions about Lehman’s true leverage, both investors are rational but simply hold heterogeneous beliefs.

mentals while, separately, the precision of the idiosyncratic noise captures the degree of consensus. Following Ijiri and Jaedicke, we define accuracy as the amount of collective knowledge and objectivity as interpersonal consensus/agreement. The key idea of Ijiri-Jaedicke is that a more objective information source causes fewer disagreements and a higher consensus among the same group of decision-makers, which does not necessarily make them collectively more or less knowledgeable about the fundamentals. We thereafter embed the correlated private information structure into a simple model of runs on a financial institution (FI) in the spirit of Morris and Shin (2001). Each investor makes the withdraw decision (or run the FI) based on a signal she receives. Critically, each investor rationally uses the signal to infer both (1) the underlying fundamental health of the FI (the fundamental value of information) and (2) the likely signal other investors have received to gauge the likelihood they would run the FI (the strategic value of information).

Our analyses show that, although improvements in both the precision of the idiosyncratic and common noises increase the fundamental value of the investors' signals, improving the precision of the idiosyncratic noise enhances the strategic value, whereas improving the precision of the common noise impairs the strategic value. The key economic force behind this asymmetry result is that changing the precision of the idiosyncratic noise alters the correlation between investors' signals differently from changing the precision of the common noise. Specifically, from an individual investor's perspective, she knows that her signal is driven by three components, the fundamentals, a common noise, and an idiosyncratic noise. When the precision of the common noise increases, the common variation in the signal decreases and thus the signal is driven more by the idiosyncratic variation. As a result, the signal becomes less correlated with others' signals and has a lower strategic value in forecasting others' beliefs. In contrast, an increase in the precision of the idiosyncratic noise reduces the idiosyncratic variation of the signal and increases its correlation with others' signals, thus improving its strategic value. Because of their different roles regarding the strategic value of information, improving the precision of the idiosyncratic noise (objectivity) exhibits a comparative advantage in mitigating panic-based runs relative to improving the precision of the common noise (accuracy). In fact, increasing objectivity always discourages such runs, whereas increasing accuracy may encourage them.

The social value of objectivity calls for the adoption of objectivity-based accounting rules. To shed light on how to design accounting systems to improve the objectivity of financial reporting, we

build a micro-model of the accounting measurement process that produces the exogenous “correlated private information structure” in Ijiri and Jaedicke. More specifically, an accounting system generates a report about the fundamentals and the report is subject to noise associated with a measurement error in the accounting system and an opportunistic manager’s intervention. The measurement error introduces a common noise in the report, the precision of which corresponds to accuracy. In addition, different outsiders hold different beliefs about the manager’s intervention incentive. As a result, outsiders disagree on interpreting the same accounting report because they disagree on how much the manager may have intervened. Such disagreement in turn leads to an idiosyncratic noise in each outsider’s interpretation of the report, the precision of which corresponds to objectivity. Our analyses show that the objectivity and the accuracy can be derived endogenously as the primitive properties of the measurement system and the heterogeneity among the outsiders. The key message is that, to generate a more objective report that helps to enhance financial stability, accounting systems should be designed to be less subject to managerial intervention. In this light, our model suggests a new benefit of avoiding earnings manipulations from the perspective of coordination and stability, in addition to the existing ones based on grounds of stewardship and reliability.

To the extent that restoring stability is a key motivation behind various actions taken by regulators and financial institutions towards improving financial market information environments, considering the stability-enhancing role of objectivity may help us to understand observed mandatory and voluntary disclosure practices and the related costs-benefits trade-offs. In particular, our results suggest that the recently implemented stress-test disclosure helps to improve financial stability and restore market confidence only when it is perceived to be objective. We argue in Section 5 that the stress-test disclosure is highly quantitative and transparent compared with traditional regulatory disclosure. To the extent that these features limit the room for alternative interpretations and thus invite fewer disagreements, the stress-test disclosure is more objective. This claim seems consistent with the finding of an empirical paper by Ellahie (2013), who shows that the stress-test disclosure in Europe reduces informational difference among market participants. Furthermore, we discuss in Section 5 that the accuracy-objectivity trade-off is also relevant in examining many choices among accounting methods, such as accounting for loan losses and disclosure of bank capital.

## 1.1 Contributions and the Literature Review

Our paper makes three contributions. First, we contribute to the literature on the information environment of financial markets and its roles in financial stability. Because of the extensive size of this literature, we refer readers to three recent surveys by Goldstein and Sapra (2014), Beatty and Liao (2014), and Acharya and Ryan (2015). In our model, we focus on examining how an accounting measurement process (i.e., the Ijiri-Jaedicke measurement model) contributes to the overall information environments of financial markets, through which channel the derived accounting properties (i.e., objectivity and accuracy) play important roles in promoting financial stability. Some studies have examined the interactions between stability and other accounting measurement rules, such as mark-to-market versus historical cost. For instance, Allen and Carletti (2008) show that when financial institutions are subject to liquidity risk, using market-based accounting information to assess financial institutions' solvency is undesirable, compared with historical-cost-based information. In addition, Plantin, Sapra, and Shin (2008) study sales of securitized loans in an illiquid market and show that mark-to-market accounting injects artificial volatility into prices, which distorts real decisions. Lastly, Gao and Jiang (2015) examine the role of reporting discretion in a bank run setting. They show that reporting discretion reduces panic-based runs but excessive discretion may weaken market discipline.

Along the lines of the same broad literature, our paper is also related to disclosure studies because we examine the economic consequences of disclosure through influencing collective knowledge and disagreement in the underlying information environment. In particular, a number of studies have examined differential interpretations of firms' disclosures by outside investors. For instance, Indjejikian (1991) shows that investors' differential interpretations of disclosures can produce a risk-sharing benefit, thus encouraging firms to disclose. Kim and Verrecchia (1997) and Kondor (2012) deploy disagreement over how to interpret firms' disclosures to explain why trading volume increases with disclosure. Fischer and Stocken (2001) examine a cheap-talk model in which a receiver of information may interpret the credibility of disclosure by a sender differently. Because of this differential interpretation, improving the quality of the sender's information may actually reduce the quality of information communicated to the receiver. Suijs (2007) studies a disclosure setting in which there is uncertainty about how investors respond to disclosure, partly because investors

can interpret the disclosure in different ways. An interesting result of considering the uncertain investor response is that it can potentially break the standard unraveling argument, thus allowing partial disclosure to be supported as an equilibrium. In line with Suijs, Thakor (2015) finds that a firm’s disclosure of qualitative strategic information may lead to disagreement between the firm and its investor, thus reducing the probability of obtaining financing.<sup>2</sup> Our paper contributes to this literature by identifying a coordination benefit of agreement in mitigating panic runs on financial institutions, which has not been studied previously.

Second, our paper contributes to the accounting literature of objectivity. The concept of objectivity has a long and varied history in accounting theory going back to at least the famous Paton-Littleton 1940 monograph (p. 18). Accounting scholars have since studied objectivity extensively. Ijiri and Jaedicke (1966) make a seminal contribution, framing objectivity within a statistical sampling setting as interpersonal agreement and making it distinct from collective bias.<sup>3</sup> Ijiri and Jaedicke decompose accounting reliability, defined as the inverse of the distance between the true state and measurements of the state by different measurers, into two components. One is the distance between the true state and the average measurements, termed bias (the inverse of which we define as accuracy). The other is the distance between the average measurements and measurements by different measurers, the inverse of which is termed objectivity. We discuss the details in footnote 14 of Section 4. However, explicit economic considerations are not given under this more narrowly defined measurement approach to accounting.

Starting in the late 1960s and early 1970s, accounting researchers began linking accounting concepts to information economics concepts (see AAA monographs by Feltham, 1972 and Mock, 1976). The agenda is to build on the traditional approach under a purely measurement perspective and to tie the accounting measurement concepts to economic trade-offs in decision making under

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<sup>2</sup>There are three important differences between our paper and Thakor (2015). First, whereas Thakor studies the disagreement between a firm that needs financing and its investor, we examine the disagreement among investors of a financial institution. Second, the main insight of Thakor is that the firm discloses if the disagreement between the firm and the investor is sufficiently *high*; in contrast, our main finding is that the benefit of disclosure is high when the disagreement among investors is *low*. Lastly, from a modeling perspective, Thakor models disagreement as heterogeneous priors, whereas we model disagreement as correlated private signals.

<sup>3</sup>Defining objectivity operationally as “agreement” among different individuals can be traced at least to Guilford (1957), who declares “objectivity is one of the major goals of science. ... ‘objectivity’ means interpersonal agreement. Where many persons reach agreement as to observations and conclusions, the descriptions of nature are more likely to be free from the biases of particular individuals.” (as quoted by Bierman 1963, p. 502). Also see Burke (1964), Chambers (1964), and Wagner (1965) for additional discussions and see Ashton (1977) for some extensions of the Ijiri-Jaedicke formulation of objectivity and a brief description of the contrast between operational and conceptual definitions of objectivity.



uncertainty.<sup>4</sup> For example, Feltham (1972) formalized many informational properties, such as informativeness, timeliness, accuracy, all within a single-person decision context. In addition, the relevance and reliability trade-off have been studied by Kirshenheiter (1997), Dye and Sridhar (2004), and Glover and Levine (2015). More recently, a small but emerging strand of work in accounting, such as Gao (2008), Plantin, Sapra and Shin (2008), Gigler, Kanodia and Venugopalan (2013), Chen, Huang and Zhang (2014), and Arya and Mittendorf (2016), has begun to address issues of interest to accounting scholars within economic coordination settings where individuals care not only about information’s fundamental value but also its strategic value.

Our paper contributes to this literature by providing a single economic framework in which both accuracy and objectivity have the potential to play an economic role. Extending earlier measurement-based accounting research tradition, we place the objectivity into a multiple-person decision-making context and analyze its economic role in coordinating group behavior (such as runs on financial institutions). Extending the post-70’s information-based accounting research tradition, we expand the dimensions of information properties and open a different research avenue to study how accounting information affects economic outcome. That is, beyond providing accurate or inaccurate inference about the state-of-nature, our study of objectivity’s distinctive role shows that accounting measurements may add much value to a society by improving decision-makers’ knowledge about each other’s beliefs, leading to better coordination in the economy.

Lastly, our paper contributes to the economics and accounting literature on the role of (incomplete) information in a decentralized economy in which each individual is strategically interdependent.<sup>5</sup> A majority of the literature adopts a standard information structure with purely public and purely private signals. From a modeling perspective, two sufficient statistics describing an information environment are collective knowledge of all individuals and the disagreement among the individuals. Under the standard information structure, collective knowledge is perfect through aggregating purely private signals, and the precision of private and public signals only

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<sup>4</sup>Beaver and Demski (1979), in their seminal work, clearly articulated the shift in perspective. They argue that income measurement loses its economic foundation in a world with imperfect and incomplete markets. They offer a reinterpretation of income reporting and accrual notions in terms of a “cost-effective” communication procedure (Beaver and Demski 1979, p. 38). Therefore, under this new information economics approach, the logical function for accounting in such a world is to carry information. The usual connotations attached to these accounting labels are of less significance. What is important are their informational properties.

<sup>5</sup>See Carlsson and van Damme (1993), Morris and Shin, (1998, 2002), Angeletos and Pavan, (2004, 2007), Goldstein, Ozdenoren, and Yuan (2011), Chen, Huang and Zhang (2014), and Arya and Mittendorf (2016). For specific applications in bankrun settings, see Morris and Shin (2001) and Goldstein and Pauzner (2005).

contribute to the disagreement, making a decomposition of collective knowledge and disagreement infeasible. Our paper departs from the standard structure by considering a correlated private information structure. This information structure, by contrast, provides a parsimonious structure of modeling collective knowledge and agreement separately wherein the precision of the common noise (accuracy) captures collective knowledge and the precision of the idiosyncratic noise (objectivity) captures agreement. We use the correlated information structure to model accounting objectivity as an independent property from the accuracy property, thus shedding light on the distinct social value of accounting objectivity in promoting financial stability.

The rest of paper is organized as follows. Section 2 discusses the information environment in our model. Section 3 presents the main analytic results of the paper. Section 4 provides a micro-foundation of objectivity property based on the accounting measurement process. Section 5 discusses our empirical implications and, in particular, how the paper may shed light on the current debates on financial fragility and regulation-mandated and accounting disclosure by financial institutions. Section 6 concludes.

## 2 Information Environment

In this section, we describe in detail the information environment in which each decision-maker operates in our main model of Section 3. We focus on two distinct properties of the environment, accuracy and objectivity, and give an explicit account of how our information model differs from the standard information structure.

### 2.1 Accuracy and Objectivity of Accounting Measures

Consider a continuum of decision-makers, indexed by  $i \in [0, 1]$ , facing decision under uncertainty. Suppose the payoff-relevant state-of-nature (or fundamentals) is denoted  $\tilde{r} \sim N(\bar{r}, \frac{1}{\alpha})$ . Each decision-maker receives a private signal, denoted  $\tilde{x}_i$ , with the following information property:

$$\tilde{x}_i = \tilde{r} + \tilde{\eta} + \tilde{\varepsilon}_i, \tag{1}$$

where  $\tilde{\eta} \sim N(0, \frac{1}{\gamma})$  and  $\tilde{\varepsilon}_i \sim N(0, \frac{1}{\beta})$  for all  $i$ . In Section 4, we show that this information structure can arise endogenously from an accounting measurement process which derives such signal  $\tilde{x}_i$  as a result of each decision-maker optimally combining a public announcement (common to all decision-makers) and his own private knowledge (heterogeneous among decision-makers). Accordingly, precision parameters  $\gamma$  and  $\beta$  are endogenously derived as the properties of the measurement system and the heterogeneity among the decision-makers. In Appendix III, we provide an alternative micro-foundation based on the framework of imperfect communication in Morris and Shin (2007).<sup>6</sup>

The information environment of the economy is described completely by  $X$ , the collection of all private signals, where

$$X = \{\tilde{x}_i = \tilde{r} + \tilde{\eta} + \tilde{\varepsilon}_i | i \in [0, 1]\}. \quad (2)$$

The informational properties of environment- $X$  are completely described by the parameter set  $\{\tilde{r}, \alpha, \gamma, \beta\}$ . Notice that at the economy level, the collective knowledge about the underlying state  $\tilde{r}$  is equivalent to an aggregate signal  $\tilde{x}_p \equiv \tilde{r} + \tilde{\eta}$  as all idiosyncratic noises sum to zero at the limit.

Our information structure is related to the standard information structure in two aspects. First, at the individual signal level, the semi-public signal in our information structure can approach, in extremes, either the purely private signal or the purely public signal in the standard information structure. To see this, consider the standard structure (Morris and Shin, 2002; Angeletos and Pavan, 2004) where each agent receives a public signal  $\tilde{z} = \tilde{r} + \tilde{\eta}'$ , where  $\tilde{\eta}' \sim N(0, \frac{1}{\gamma'})$  and a private signal  $\tilde{x}'_i = \tilde{r} + \tilde{\varepsilon}'_i$ , where  $\tilde{\varepsilon}'_i \sim N(0, \frac{1}{\beta'})$ . Notice that, in our information structure, when  $\beta = +\infty$ , the signal becomes  $\tilde{z}$  while when  $\gamma = +\infty$ , the signal becomes  $\tilde{x}'_i$ . Second, at the aggregate information level, our information structure departs from the standard structure in a substantive manner. Consider two features of the aggregate information environment: (1) How much do the agents in the economy collectively know about the fundamental (i.e.,  $E[\tilde{r}|X]$ )? (2) How much do their private posterior beliefs (i.e.,  $E[\tilde{r}|\tilde{x}_i]$ ) disagree among themselves? The following table summarizes the collective knowledge and disagreements within the standard information structure

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<sup>6</sup>Similar information structure to ours also appears in the literature on correlated private signals (see the web-appendix to Morris and Shin, 2002). This structure can be micro-founded in a number of ways. For example, Kondor (2012) motivates the structure with multi-dimensional fundamentals. In an information-acquisition context, Myatt and Wallace (2012) motivate the structure with a “sender noise” and a “receiver noise.” In accounting literature (e.g., Kim and Verrecchia, 1997, and references therein), the same structure is motivated by the so-called event-period information (i.e., private information useful in conjunction with public earnings announcements).

and our structure, respectively.

	Collective knowledge	Disagreement of posteriors
Standard structure	infinitely precise	indexed by $\beta'$ and $\gamma'$
Our structure	indexed by $\gamma$ only	indexed by $\beta$ only

The table shows that our formulation provides a parsimonious structure of modeling the economy’s collective knowledge, captured by the common noise precision  $\gamma$ , independently from the degree of disagreement among individual decision-makers in the economy, captured by the idiosyncratic noise precision  $\beta$ . Conversely, in the standard information structure, collective knowledge is perfect through aggregating all the private signals and the disagreement is jointly determined by the public and the private precision.

More specifically, on the one hand, a higher  $\gamma$  places the beliefs of all decision-makers closer to the payoff-relevant state-variable ( $\tilde{r}$ ). When  $\gamma = +\infty$ , the consensus of all decision-makers’ beliefs would perfectly reveal  $\tilde{r}$ , but each decision-maker remains unsure about the beliefs of the others. On the other hand, a higher  $\beta$  places the beliefs of different decision-makers closer to one another. When  $\beta = +\infty$ , all decision-makers agree on their private posterior beliefs about the fundamentals  $\tilde{r}$ ; however, aggregating all the signals does not reveal  $\tilde{r}$  perfectly.

We use the term objectivity to label  $\beta$ , the precision of *idiosyncratic* noise and the term accuracy to label  $\gamma$ , the precision of the *common* noise. The terminology we adopt follows both classic accounting and recent information-economics work. The objectivity term originates from Ijiri and Jaedicke (1966) and the accuracy term originates from Myatt and Wallace (2012). Specifically, as discussed in the introduction, Ijiri and Jaedicke (1966) define “objectivity” as interpersonal agreement (as opposed to agreement with the “true” state), a position with earlier origins in psychology. Myatt and Wallace (2012) define the accuracy of an information source as “how precisely it identifies the state” (p. 340). For the rest of the paper, we stipulate these usages of the terms objectivity and accuracy.

## 2.2 The Statistical Distinction between Accuracy and Objectivity

Before moving to our exact economic model, it is instructive to explore the statistical distinction between objectivity and accuracy and its implication in decision-making generally. We describe how

accuracy  $\gamma$  and objectivity  $\beta$  assist decision-maker  $i$  in making inferences about the fundamentals ( $\tilde{r}$ ) and about the beliefs of other decision-makers ( $E[\tilde{r}|\tilde{x}_j]$ ). Statistically, how well signal  $\tilde{x}_i$  informs  $\tilde{r}$  is measured by the conditional precision of  $\tilde{r}$  given  $\tilde{x}_i$ , which is given by

$$\frac{1}{\text{Var}[\tilde{r}|\tilde{x}_i]} = \alpha + \frac{\beta\gamma}{\beta + \gamma}. \quad (3)$$

Intuitively, objectivity and accuracy affect the fundamental value of the signal  $\frac{1}{\text{Var}[\tilde{r}|\tilde{x}_i]}$  in a *symmetric* manner. The conditional precision is unchanged between measurement system with  $\langle\beta = c_1, \gamma = c_2\rangle$  and another measurement system  $\langle\beta = c_2, \gamma = c_1\rangle$  for any  $c_1$  and  $c_2$ . This symmetry implies that objectivity plays no distinct and separate role from accuracy in a single-person decision setting in which each decision-maker makes a decision only based on her own belief about the fundamentals  $\tilde{r}$ , not on others' beliefs about  $\tilde{r}$ .

Now consider how well signal  $\tilde{x}_i$  informs others' beliefs about the fundamentals  $E[\tilde{r}|\tilde{x}_j]$ . The relevant measure here is the conditional precision of estimating  $E[\tilde{r}|\tilde{x}_j]$  given  $\tilde{x}_i$ :

$$\frac{1}{\text{Var}[E[\tilde{r}|\tilde{x}_j]|\tilde{x}_i]} = \frac{1}{\left(\frac{\frac{1}{\alpha}}{\frac{1}{\alpha} + \frac{1}{\beta} + \frac{1}{\gamma}}\right)^2 (1 - \rho^2) \left(\frac{1}{\alpha} + \frac{1}{\beta} + \frac{1}{\gamma}\right)}, \quad (4)$$

where  $\rho = \frac{\frac{1}{\alpha} + \frac{1}{\gamma}}{\frac{1}{\alpha} + \frac{1}{\beta} + \frac{1}{\gamma}}$  denotes the correlation between different signals. Notice that objectivity and accuracy affect the strategic value of the signal  $\frac{1}{\text{Var}[E[\tilde{r}|\tilde{x}_j]|\tilde{x}_i]}$  in an *asymmetric* manner through  $\rho$ :  $\beta$  increases  $\rho$  while  $\gamma$  decreases  $\rho$ . Fixing the total informativeness of  $\tilde{x}_i$ ,  $\frac{1}{\text{Var}[\tilde{r}|\tilde{x}_i]}$ , increasing  $\beta$  increases the strategic value of information by increasing  $\rho$  while increasing  $\gamma$  decreases the strategic value by decreasing  $\rho$ . This asymmetry implies that objectivity can play a divergent role from accuracy in settings with strategic interactions in which each decision-maker makes a decision not only based on her own belief about the fundamentals  $\tilde{r}$ , but also on others' beliefs about  $\tilde{r}$ .

To better explain the roles played by objectivity and accuracy in our information structure, it may also be helpful to compare them with the roles played by the private signal precision  $\beta'$  and the public signal precision  $\gamma'$  in the standard information structure. In the standard information model, the fundamental value of the information  $\{\tilde{x}'_i, \tilde{z}\}$  is measured by the conditional precision

of  $\tilde{r}$ :

$$\frac{1}{\text{Var}[\tilde{r}|\tilde{x}'_i, \tilde{z}]} = \alpha + \beta' + \gamma'. \quad (5)$$

That is, both  $\beta'$  and  $\gamma'$  play symmetric roles in improving the fundamental value of information, similar to the implications in our information model. However, the implications from the standard model and our model differ once we analyze the strategic value of information. In the standard model, the strategic value of information is measured by the conditional precision of estimating others' beliefs  $E[\tilde{r}|\tilde{x}'_j, \tilde{z}]$ :

$$\frac{1}{\text{Var} \left[ E[\tilde{r}|\tilde{x}'_j, \tilde{z}] | \tilde{x}'_i, \tilde{z} \right]} = \frac{1}{\frac{\beta'^2}{(\alpha + \beta' + \gamma')^2} \left( \frac{1}{\beta'} + \frac{1}{\alpha + \beta' + \gamma'} \right)}. \quad (6)$$

Holding the fundamental value of information  $\text{Var}[\tilde{r}|\tilde{x}'_i, \tilde{z}] = \frac{1}{\alpha + \beta' + \gamma'}$  fixed, increasing the public signal precision  $\gamma'$  improves while increasing the private signal precision  $\beta'$  decreases the strategic value of information, an insight often discussed in the literature (e.g., Angeletos and Pavan, 2004). Notice that, however, this insight is opposite to the roles played by  $\beta$  and  $\gamma$  in our model. We summarize the role of information properties in our model and that in the standard model in the following proposition.

**Proposition 1** *Holding the total informativeness constant ( $\frac{\beta\gamma}{\beta+\gamma}$  and  $\beta' + \gamma'$  fixed), in the standard information model with a public and a private signals, increasing the public signal precision increases while increasing the private signal precision decreases the strategic value of information:*

$$\frac{d\text{Var} \left[ E[\tilde{r}|\tilde{x}'_j, \tilde{z}] | \tilde{x}'_i, \tilde{z} \right]}{d\beta'} > 0 > \frac{d\text{Var} \left[ E[\tilde{r}|\tilde{x}'_j, \tilde{z}] | \tilde{x}'_i, \tilde{z} \right]}{d\gamma'}. \quad (7)$$

*In the model with correlated signals,  $\tilde{x}_i = \tilde{r} + \tilde{\eta} + \tilde{\varepsilon}_i$ , improving objectivity (the precision of the idiosyncratic noise) increases while improving accuracy (the precision of the common noise) decreases the strategic value of information:*

$$\frac{d\text{Var} \left[ E[\tilde{r}|\tilde{x}_j] | \tilde{x}_i \right]}{d\beta} < 0 < \frac{d\text{Var} \left[ E[\tilde{r}|\tilde{x}_j] | \tilde{x}_i \right]}{d\gamma}. \quad (8)$$

The distinction between the standard model and our model is a result of the different mech-

anisms through which the informational properties influence posterior beliefs. In the standard information model, the information properties  $\beta'$  and  $\gamma'$  affect the posterior through changing the Bayesian weights each individual allocates to the two signals. When the private information precision  $\beta'$  increases, each individual places relatively more weight on the private signal and less weight on the public signal, which makes the individual beliefs more heterogeneous. As a result, it becomes more difficult to forecast others' beliefs and the strategic value of information decreases. The positive role of the public information precision  $\gamma'$  on the strategic value can be understood similarly.

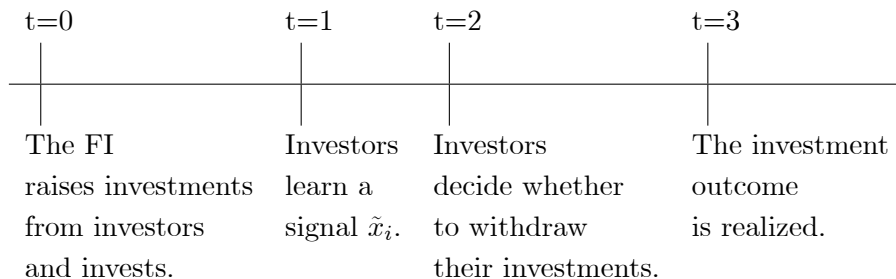
In our model, the key economic force is that changing the information properties,  $\beta$  and  $\gamma$ , alters the sizes of the common and idiosyncratic noises, which affects the correlation between different decision-makers' signals. Specifically, from an individual decision-maker's perspective, she knows that her signal is driven by three components, the fundamentals, a common noise, and an idiosyncratic noise. When the accuracy of the signal  $\gamma$  increases, the variation in the common noise decreases and thus the signal is driven more by the variation in the idiosyncratic noise. As a result, the signal becomes less correlated with others' signals and has a lower strategic value in forecasting others' beliefs. In contrast, a higher  $\beta$  makes the signal driven more by the variation in the common noise, increases the correlation between the signals, and improves the strategic value of each signal in forecasting others' beliefs.

### 3 Model

#### 3.1 Model Setup

In this section, we analyze the role of objectivity and accuracy in a model of runs on a financial institution (FI) in which multiple investors need to coordinate with each other. We show that with the strategic interaction among the investors, the distinction between objectivity and accuracy becomes critical because of their different effects on the strategic value of information. The model has four dates, a continuum of investors, and an FI endowed with an illiquid investment project. At date 0, the FI finances the project by attracting investments from the investors. At date 1, investors learn an intermediate signal  $\tilde{x}_i$ . At date 2, investors decide whether to withdraw their investments from the FI. At date 3, the project yields a stochastic payoff that depends on both the

fundamentals of the project and the amount of investments withdrawn. The time line of the model is shown in Figure 1.



**Figure 1:** Time line.

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

### Date 0

At date 0, the FI is endowed with an investment project that yields a stochastic gross rate of return,  $\tilde{R} = e^{\tilde{r}}$  realized on date-3 where  $\tilde{r}$  is normally distributed with a mean  $\bar{r}$  and a variance  $\frac{1}{\alpha}$ .  $\alpha$  measures the precision of investors' common prior about  $\tilde{r}$ . We assume that  $0 < \bar{r} \leq \frac{1}{2}$ .<sup>7</sup> The FI finances the project by attracting investments from a group of investors, with unit mass indexed by the unit interval  $[0, 1]$ , each of whom contributes 1 unit of the consumption good. All investors have the log utility function such as:

$$u_i = \log(c_{i2} + c_{i3}), \tag{9}$$

where  $c_{i2}$  and  $c_{i3}$  denote investor  $i$ 's consumption at date 2 and at date 3 respectively. The FI invests all the investments attracted in its project.

### Date 1

<sup>7</sup>As we will show later, assuming  $\bar{r} \leq \frac{1}{2}$ , the FI's disclosure of information helps to reduce the risk of runs. However, when the common prior about the FI's project is sufficiently good (i.e.,  $\bar{r} > \frac{1}{2}$ ), the release of information actually exacerbates the risk of runs, which prevents the FI from disclosing in the first place. This is because, in such cases, the FI prefers investors to rely more on the favorable prior than to respond to new information, which is likely to be worse than the prior. In the proof of Corollary 3, we verify that, in the absence of any information, investors always choose to stay if and only if the prior  $\bar{r} > \frac{1}{2}$ .



At date 1, each investor  $i$  bases the withdraw decision on an individual signal  $\tilde{x}_i$  with the following informational properties:<sup>8</sup>

$$\tilde{x}_i = \tilde{r} + \tilde{\eta} + \tilde{\varepsilon}_i, \tag{10}$$

where the various noise terms are all independently distributed with  $\tilde{\eta} \sim N(0, \frac{1}{\gamma})$  and  $\tilde{\varepsilon}_i \sim N(0, \frac{1}{\beta})$ . As previously described, we use the term objectivity to label  $\beta$ , and the term accuracy to label  $\gamma$ .

**Date 2**

Based on the information  $\tilde{x}_i$ , investor  $i$  updates her beliefs about the project’s fundamentals and other investors’ beliefs and decides whether to withdraw her investment. Following Morris and Shin (2001), we assume that if investor  $i$  withdraws, she is repaid at the face value, 1 unit of the consumption good. Further, the FI’s project is illiquid and the net rate of return obtainable at date 3 is decreasing in the proportion of investments withdrawn at date 2, as denoted by  $l \in [0, 1]$ . Specifically, we assume that at date 3, the net rate of return is  $e^{\tilde{r}-l}$ . The term  $e^{-l} < 1$  captures the cost of liquidating the illiquid project to meet the investors’ withdrawals.

**Date 3**

The net rate of return is realized and distributed to the investors.

**3.2 The First-Best Benchmark**

We first solve for the first-best in our model as a benchmark. Consider a situation in which the FI’s project is financed by only one investor whose information set contains all of the private signals,  $\tilde{x}_i$ .<sup>9</sup> Aggregating all of the private signals removes all idiosyncratic noises and perfectly reveals the

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<sup>8</sup>As with other models in the higher-order-belief literature, we do not allow investors to communicate their information among themselves. As argued in Hayek (1945), Radner (1962), and more recently Angeletos and Pavan (Footnote 6; p. 1114, 2007), information is often dispersed in an economy and cannot be easily communicated to a “center.” In our specific context of runs on financial institutions, there are three reasons that make communication among investors very difficult. First, the private information known to each investor can be highly subjective and qualitative. For instance, such information can be related to investors’ personal beliefs and judgments on an FI’s financial conditions, which cannot be easily explained or conveyed to others. Second, runs occur instantaneously and require investors to respond promptly, which then leaves little time for investors to first communicate and integrate their private information. Third, the usual price mechanism that aggregates and communicates dispersed private information is lacking or, at least, far from perfect in our context of FI runs (Gorton, 2008).

<sup>9</sup>We can also interpret this benchmark as a situation in which a regulator acquires all the information from the investors and provides them with full insurance. Upon receiving the information, the regulator decides whether to liquidate the FI.

common underlying signal  $\tilde{x}_p = \tilde{r} + \tilde{\eta}$ , because

$$\int_0^1 \tilde{x}_i di = \tilde{r} + \tilde{\eta} + \int_0^1 \tilde{\varepsilon}_i di = \tilde{x}_p. \quad (11)$$

$\tilde{x}_p$  is also a sufficient statistic to the investor's liquidating decision. For expositional purposes, denote the "demeaned" value of the signal  $\tilde{x}_p$  as  $\tilde{y}_p \equiv \tilde{x}_p - \bar{r}$ . It is straightforward to verify that, without loss of generality, only one kind of strategy, a switching strategy, needs to be considered, where the investor chooses to withdraw if and only if she observes a  $\tilde{y}_p$  below some threshold  $y^{FB}$ :

$$s(\tilde{y}_p) = \begin{cases} \text{Withdraw} & \text{if } \tilde{y}_p \leq y^{FB}, \\ \text{Not to Withdraw} & \text{if } \tilde{y}_p > y^{FB}. \end{cases} \quad (12)$$

Consider a marginal investor whose signal  $\tilde{y}_p$  is exactly equal to  $y^{FB}$ . If the investor withdraws, her expected utility is  $\log(1) = 0$ . If she chooses not to withdraw, her expected utility conditional upon the signal  $\tilde{y}_p = y^{FB}$  is:

$$E[\log(e^{\tilde{r}}) | \tilde{y}_p = y^{FB}] = E[\tilde{r} | \tilde{y}_p = y^{FB}] = \bar{r} + \frac{\frac{1}{\alpha}}{\frac{1}{\alpha} + \frac{1}{\gamma}} y^{FB}. \quad (13)$$

In equilibrium, the marginal investor is indifferent between staying and withdrawing. This gives,

$$y^{FB} = -\frac{\left(\frac{1}{\alpha} + \frac{1}{\gamma}\right) \bar{r}}{\frac{1}{\alpha}} = -\left(1 + \frac{\alpha}{\gamma}\right) \bar{r}. \quad (14)$$

We summarize the equilibrium in the first-best benchmark in the lemma below.

**Lemma 1** *In the first-best benchmark, the investor withdraws if and only if  $\tilde{y}_p \leq y^{FB} = -\frac{\left(\frac{1}{\alpha} + \frac{1}{\gamma}\right) \bar{r}}{\frac{1}{\alpha}}$ .*

### 3.3 The Equilibrium

We now solve for the equilibrium in our model. As shown in Morris and Shin (2001), it suffices to consider only the switching strategy in which the investor chooses to withdraw if and only if she

observes a  $\tilde{y}_i$  below some threshold  $y^*$ :

$$s(\tilde{y}_i) = \begin{cases} \text{Withdraw} & \text{if } \tilde{y}_i \leq y^*, \\ \text{Not to Withdraw} & \text{if } \tilde{y}_i > y^*. \end{cases} \quad (15)$$

Consider a marginal investor whose signal  $\tilde{y}_i$  is exactly equal to  $y^*$ . If she withdraws, her expected utility is 0. If she chooses not to withdraw, her expected utility is equal to:

$$E[\log(e^{\tilde{r}-l})|\tilde{y}_i = y^*] = E[\tilde{r} - l|\tilde{y}_i = y^*]. \quad (16)$$

The investor's updated belief of  $\tilde{r}$  conditional upon the signal  $\tilde{y}_i = y^*$  is:

$$E[\tilde{r}|\tilde{y}_i = y^*] = \bar{r} + \frac{\frac{1}{\alpha}}{\frac{1}{\alpha} + \frac{1}{\beta} + \frac{1}{\gamma}} y^* = \bar{r} + k_1 y^*, \quad (17)$$

where  $k_1 \equiv \frac{\frac{1}{\alpha}}{\frac{1}{\alpha} + \frac{1}{\beta} + \frac{1}{\gamma}}$ .

We now compute, from the marginal investor's perspective, the portion of investors who choose to withdraw  $E[l|\tilde{y}_i = y^*]$ . Because the noises are all independently distributed, the expected portion of investors who withdraw is equal to the probability that a particular investor  $j$  withdraws. Because investor  $j$  also follows the same switching strategy, she withdraws if and only if her signal  $\tilde{y}_j \leq y^*$ .

Thus we have

$$E[l|\tilde{y}_i = y^*] = \Pr(\tilde{y}_j \leq y^*|\tilde{y}_i = y^*). \quad (18)$$

Given the marginal investor's signal  $\tilde{y}_i = y^*$ , she thinks that investor  $j$ 's signal is normally distributed with a mean  $\rho y^*$  and a variance  $(1 - \rho^2) \left( \frac{1}{\alpha} + \frac{1}{\beta} + \frac{1}{\gamma} \right)$ , where  $\rho = \frac{\frac{1}{\alpha} + \frac{1}{\gamma}}{\frac{1}{\alpha} + \frac{1}{\beta} + \frac{1}{\gamma}}$  denotes the correlation between the signals of the marginal investor and investor  $j$ .<sup>10</sup> Therefore,

$$\begin{aligned} \Pr(\tilde{y}_j \leq y^*|\tilde{y}_i = y^*) &= \Pr \left( \frac{\tilde{y}_j - \rho y^*}{\sqrt{(1 - \rho^2) \left( \frac{1}{\alpha} + \frac{1}{\beta} + \frac{1}{\gamma} \right)}} \leq \frac{y^* - \rho y^*}{\sqrt{(1 - \rho^2) \left( \frac{1}{\alpha} + \frac{1}{\beta} + \frac{1}{\gamma} \right)}} \middle| \tilde{y}_i = y^* \right) \\ &= \Phi(k_2 y^*), \end{aligned} \quad (19)$$

---

<sup>10</sup>The derivations regarding the conditional distribution are included in Appendix I.

where  $k_2 \equiv \sqrt{\frac{1-\rho}{1+\rho} \frac{1}{\frac{1}{\alpha} + \frac{1}{\beta} + \frac{1}{\gamma}}}$ .

In equilibrium, the investor who observes a  $\tilde{y}_i$  equal to  $y^*$  is indifferent between staying and withdrawing. This in turn gives:

$$\bar{r} + k_1 y^* = \Phi(k_2 y^*). \quad (20)$$

In the following proposition, we show that for a sufficiently small  $\alpha$ , there exists a unique equilibrium in our model.

**Proposition 2** *Define  $\alpha_H$  as the unique positive solution to  $k_1 = k_2 \sqrt{\frac{1}{2\pi}}$ . Given that  $\alpha \leq \alpha_H$ , there exists a unique equilibrium such that every investor withdraws if and only if  $\tilde{y}_i < y^*$ , where  $y^*$  is the unique solution to Equation (20).*

Proposition 2 shows that when the common prior among investors is sufficiently diffuse, the equilibrium in a game of FI runs becomes unique, which often appears in the higher-order beliefs and global game literature (Morris and Shin, 1998, 2001, 2002; Plantin, Sapra and Shin, 2008). This result shows that the occurrence of runs depends critically on the information disclosed by the FI: an investor withdraws upon receiving a bad signal about the FI's project. In addition, we find that the investor tends to withdraw more often in equilibrium than in the first-best benchmark. That is,  $y^* > y^{FB}$ , as summarized in the following corollary.

**Corollary 1** *Given that  $\alpha \leq \alpha_H$ , in equilibrium, every investor tends to withdraw more often than in the first-best benchmark, i.e.,  $y^* \geq 0 > y^{FB}$ .*

Corollary 1 depicts the coordination failure in the FI run. Because an investor is concerned with the risk of runs by other investors, she will withdraw when anticipating that others will withdraw, even if the FI's project yields an expected payoff higher than its liquidation value. As a result, in equilibrium, the project is liquidated more often than what is optimal in the first-best ( $y^* > y^{FB}$ ). This observation also suggests that because all investors hold a common pessimistic prior  $\bar{r} \leq \frac{1}{2}$ , an investor will choose not to withdraw only when she receives an updated signal that is sufficiently more favorable than her prior (that is,  $\tilde{y}_i = \tilde{x}_i - \bar{r} > y^* \geq 0$ ). This point turns out to be of critical importance in understanding the roles of improving the accuracy and objectivity in affecting the risk of runs.

### 3.4 Equilibrium Analysis

Identifying the unique equilibrium in the FI-run game allows us to analyze the properties of the equilibrium. We focus on studying the roles of two important properties of information, the accuracy  $\gamma$  and the objectivity  $\beta$ , in affecting the threshold for withdrawals  $y^*$ . We believe such analyses can shed light on the optimal design of information systems to reduce the occurrences of inefficient runs (i.e., runs where  $y \in (y^{FB}, y^*)$ ).

We first show that improving both the accuracy and the objectivity properties can help to reduce the risk of runs in the following proposition.

**Proposition 3** *Given that  $\alpha \leq \alpha_H$ , the following holds:*

1. *Improving the objectivity always decreases the threshold for withdrawals, i.e.,  $\frac{\partial y^*}{\partial \beta} < 0$ ;*
2. *There exists a threshold  $\alpha_L \in [0, \alpha_H]$ , such that for  $\alpha < \alpha_L$ , improving the accuracy decreases the threshold for withdrawals, i.e.,  $\frac{\partial y^*}{\partial \gamma} < 0$ .*

Proposition 3 suggests that improving the objectivity always reduces the withdrawal threshold. It also identifies a sufficient condition for the accuracy to reduce inefficient runs: the common prior  $\alpha$  needs to be sufficiently imprecise. Whereas Proposition 3 points to the similarity between objectivity and accuracy, the next two focus on their differences. Specifically, Proposition 4 shows that improving the objectivity is more effective than improving the accuracy in terms of reducing runs, *ceteris paribus*. In Proposition 5, we show improving the accuracy can actually increase the risk of runs when the common prior is sufficiently precise.

**Proposition 4** *For  $\beta \leq \gamma$ , the marginal effect of improving the objectivity in reducing the withdrawal threshold is stronger than improving the accuracy, i.e.,*

$$\frac{\partial y^*}{\partial \beta} < \frac{\partial y^*}{\partial \gamma}; \tag{21}$$

*for  $\beta > \gamma$ , there exists a  $\Delta > 1$ , such that  $\frac{\partial y^*}{\partial \beta} < \frac{\partial y^*}{\partial \gamma}$  if  $\frac{\beta}{\gamma} < \Delta$ .*

Proposition 4 highlights a difference between objectivity and accuracy in a setting of FI runs. All else being equal, improving the objectivity exhibits a greater marginal benefit than improving

the accuracy in mitigating the risk of runs, as long as the objectivity of the information is not too large such that the marginal benefit of further improving the objectivity becomes minimal.<sup>11</sup> To understand the intuition behind the results in Proposition 3 and 4, it is illuminating to return to the equation that determines the threshold for withdrawal:

$$\bar{r} + k_1 y^* = \Phi(k_2 y^*). \quad (22)$$

Equation (22) illustrates well that, from the marginal investor's standpoint, her information  $\tilde{y}_i = y^*$  serves two purposes: on the left-hand side of the equation,  $y^*$  is used to estimate the fundamentals of project (the fundamental value of information), where the importance of this usage is characterized by  $k_1$ ; on the right-hand side,  $y^*$  is used to forecast the probability that other investors will withdraw, i.e., the risk of runs (the strategic value of information), where the importance of this usage is characterized by  $k_2 = \sqrt{\frac{1-\rho}{1+\rho} \frac{1}{\frac{1}{\alpha} + \frac{1}{\beta} + \frac{1}{\gamma}}}$ , which depends crucially on the correlation between different investors' signals,  $\rho$ .

The effects of improving the two informational properties on the risk of runs depends critically on their effects on the two usages of the information. First, as we discussed in Section 2 of information environment, improving the accuracy and the objectivity are symmetric in affecting the fundamental value of the information. Improving either of the two increases the precision of the marginal investor's signal and, as a result, the marginal investor places a larger weight (a higher  $k_1$ ) on the signal. Recall that in our model, the marginal investor holds a pessimistic prior and will choose not to withdraw only upon receiving a new signal that is sufficiently more favorable than the prior (that is,  $y^* = x^* - \bar{r} \geq 0$ ). Therefore, as the marginal investor places a larger weight on the favorable signal  $y^*$ , she forms a more optimistic expectation about the project's return. As a result, at the previous withdrawal threshold  $y^*$ , she now prefers to leave her money within the FI, which means the solvency threshold needs to lower for the investor to be indifferent. These analyses show that through magnifying the fundamental value of the marginal investor's favorable information, both improving the objectivity and the accuracy reduce the withdrawal threshold.

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<sup>11</sup>Notice that this comparison result between objectivity and accuracy stands in contrast to the result under the standard information structure that improving the precision of public information is superior to improving the precision of private information (Morris and Shin, 2001). In their original 2001 paper, only a pure private signal is available for each investor. One can show that when adding a pure public signal in their setting, increasing the precision of the public signal is superior to increasing the precision of the private signal in reducing panic-based runs, holding the realization of the public signal equal to the withdrawal threshold of the private signal.

Second, improving the accuracy and the objectivity have the opposite impacts on the strategic value of the information. Recall that, as discussed in Section 2, the disclosure of more objective information facilitates the investor's ability to forecast others' actions while more accurate information impairs her forecasting ability. This is because improving the accuracy decreases while improving the objectivity increases the correlation  $\rho = \frac{\frac{1}{\alpha} + \frac{1}{\gamma}}{\frac{1}{\alpha} + \frac{1}{\beta} + \frac{1}{\gamma}}$ . Now consider how these changes in the strategic value of the information affect the withdrawal threshold. For a marginal investor with a more favorable signal than her prior, when improving the objectivity enhances the value of the information in forecasting others' actions, her signal indicates that a larger portion of the other investors also receive favorable signals and hence will choose to stay. As a result, from the marginal investor's perspective, the risk of runs is lower and hence she prefers to stay at the previous threshold before the improvement in the objectivity. That is, improving the objectivity, through amplifying the strategic value of the marginal investor's favorable information, reduces the withdrawal threshold. On the contrary, improving the accuracy decreases the strategic value of the marginal investor's favorable signal and increases the withdrawal threshold.

When combined, our analyses suggest that improving the objectivity increases both the fundamental and the strategic value of the information, which collectively reduce the withdrawal threshold; however, the effect of improving the accuracy can be non-monotonic and depend on the trade-off between the increase in the fundamental value of the information and the decrease in its strategic value. This non-monotonicity implies that there may exist a region in which improving the objectivity yields the opposite effect on the risk of FI runs to improving the accuracy, which we show in the following proposition.

**Proposition 5** *Consider a case where  $\bar{r}$  is sufficiently close to  $\frac{1}{2}$ , the following holds:*

1. *For  $\alpha < \alpha_L$ , improving both the objectivity and the accuracy decreases the threshold for withdrawals, i.e.,  $\frac{\partial y^*}{\partial \beta} < \frac{\partial y^*}{\partial \gamma} < 0$ ;*
2. *for  $\alpha_L < \alpha \leq \alpha_H$ , improving the objectivity decreases the threshold for withdrawals, while improving the accuracy increases the threshold for withdrawals, i.e.,  $\frac{\partial y^*}{\partial \beta} < 0 < \frac{\partial y^*}{\partial \gamma}$ .*

Proposition 5 shows that in a case where the investor's prior is sufficiently close to  $\frac{1}{2}$ , when the investors' prior information about the FI is poor ( $\alpha < \alpha_L$ ), improvements in the objectivity

and the accuracy both decrease the risk of runs. However, when the investors have good prior information ( $\alpha > \alpha_L$ ), there is a *qualitative* difference between the effects of the objectivity and the accuracy on runs: making the disclosed information more objective reduces runs while more accurate disclosure actually increases runs. The intuition behind this result is as follows. When the investors' prior is sufficiently diffuse, their signals are primarily driven by the common variations (more specifically, the variation associated with the fundamentals  $\frac{1}{\alpha}$ ) and thus highly correlated with each other (i.e., the correlation  $\frac{\frac{1}{\alpha} + \frac{1}{\gamma}}{\frac{1}{\alpha} + \frac{1}{\beta} + \frac{1}{\gamma}}$  close to 1). Changes in the accuracy/objectivity hence will not substantially affect the correlation, and their impacts on the strategic value of the information are small. As a result, with the fundamental value of the information as the dominant force, the roles of the objectivity and the accuracy are similar. It is until the investors' prior becomes sufficiently precise that changing the accuracy/objectivity has considerable impacts on the strategic value of the information. Only with this additional effect do the roles of the objectivity and the accuracy differ from each other qualitatively.

The two cases characterized in Proposition 5 can be interpreted as the descriptions of two types of runs. The case of poor prior information ( $\alpha < \alpha_L$ ) can be viewed as depicting “old-fashioned,” ordinary investors' runs on traditional commercial banks, such as the ones that occurred repeatedly in the 19th century (Allen and Gale, 1998). Our results imply that in terms of mitigating these runs, it makes no qualitative difference between improving the objectivity and accuracy of FIs' disclosures; the trade-off between objectivity and accuracy hence may seem moot. The other case in which the investors hold much better prior information ( $\alpha > \alpha_L$ ) can be related to the “modern-day” runs on financial institutions in shadow banking markets (Shin, 2009). The group of “investors” in these shadow banking markets is primarily contained with sophisticated institutional investors, such as mutual funds, investment banks and hedge funds. Different from ordinary investors, these investors are trained professionals well equipped with prior knowledge about operations in shadow banking markets. In the recent financial turmoil, shadow banking markets had experienced catastrophic runs by their investors, which led to severe liquidity dry-ups and economic downturns. Our results suggest that in dealing with these modern-day runs, it is important to understand the trade-off between objectivity and accuracy. While the disclosure of highly objective information helps to stabilize investors' runs, our results also send a cautionary note regarding regulatory initiatives that aim solely at improving the accuracy of disclosure, because such initiatives may have the



unintended consequence of triggering runs.

Lastly, it is noteworthy that we only focus on comparing the effects of objectivity and accuracy in reducing runs and do not consider other differences between the two. Importantly, the cost of improving accuracy is likely to differ from that of improving objectivity. In situations in which improving objectivity is much more expensive than improving accuracy, it can be cost-benefit effective to disclose a more accurate report instead of a more objective one, despite the larger marginal benefit of objectivity in mitigating runs.

Another effect of improving the objectivity/accuracy of disclosure that we do not formally examine is that these changes may discourage investors from acquiring private information (e.g., Goldstein and Sapra, 2014). Boot and Thakor (2001) show that when the disclosed information is a substitute for investors' private information, the disclosure reduces investors' incentive to acquire information, whereas when the disclosed information is a complement, it encourages information acquisition. The following examples may help to shed some light on how objectivity/accuracy may affect complementarity/substitutability between the disclosure and investors' private information. Consider first a variation of our model in which investors can acquire a noisy signal  $\tilde{s}^l = \tilde{l} + \tilde{\xi}^l$  about the portion of investors who withdraw  $\tilde{l}$ . Notice that when the disclosure is fully objective ( $\beta = \infty$ ), each investor receives the same signal  $\tilde{x}_i = \tilde{r} + \tilde{\eta}$ . As a result, investors can perfectly conjecture others' decisions and thus forecast  $\tilde{l}$ , making the noisy signal  $\tilde{s}^l$  redundant. However, when the disclosure is less than fully objective, investors can no longer perfectly forecast others' actions, which makes  $\tilde{s}^l$  useful. That is, reducing objectivity decreases the substitutability between the disclosure and investors' information. To illustrate how accuracy may affect the complementarity/substitutability, consider another variation of our model in which investors can acquire a noisy signal  $\tilde{s}^\eta = \tilde{\eta} + \tilde{\xi}^\eta$  about the common error in the FI's disclosure  $\tilde{\eta}$ .<sup>12</sup> Notice that when the disclosure is fully accurate ( $\gamma = \infty$ ),  $\tilde{\eta} \equiv 0$  and thus  $\tilde{s}^\eta$  is not useful with or without disclosure. However, when the disclosure is not fully accurate, it complements investors' information in the sense that  $\tilde{s}^\eta$  is useful only when the FI discloses. In other words, reducing accuracy increases the complementarity between the disclosure and investors' information.

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<sup>12</sup>The example is constructed following the "event-period information" modeled in Kim and Verrecchia (1997).

### 3.5 Additional Analysis

In this section, we supplement our main analysis by deriving two additional results. First, we expand our analysis on the different effects of accuracy and objectivity on the risk of runs by studying their effects on social welfare. Second, in our main model, we do not consider the discretion in disclosure decisions. In practice, bank regulators may have some discretion to withhold or disclose information (Leitner, 2014). We thus consider an extension of our model in which a regulator can voluntarily disclose information regarding the FI.

#### 3.5.1 Social Welfare Analysis

We first analyze the effects of accuracy and objectivity on social welfare. Because we are mostly interested in comparing the effects of improving the accuracy and the objectivity, we focus on the case  $\beta = \gamma$  to “level the playing field.” We also numerically verify that as long as  $\beta$  is not too large relative to  $\gamma$ , our comparison result holds qualitatively.

The social welfare of our economy  $W = \int_0^1 u_i di$  is equal to the aggregate of the investors’ utilities. The  $l$  portion of investors who withdraw obtain a utility of  $\log(1) = 0$ , and the rest of the investors who stay obtain a utility of  $\log(e^{\tilde{r}-l}) = \tilde{r} - l$ . Therefore, conditional on the fundamental  $\tilde{r}$ , the social welfare is:

$$W(\tilde{r}) = l(\tilde{r}) 0 + (1 - l(\tilde{r})) (\tilde{r} - l) = (1 - l(\tilde{r})) (\tilde{r} - l(\tilde{r})), \quad (23)$$

and the ex-ante social welfare is  $W = E_{\tilde{r}}[W(\tilde{r})]$ . In the following corollary, we identify a condition in which improving objectivity dominates accuracy in terms of increasing social welfare. In addition, numerical analysis shows that this condition holds for a large set of parameter values.

**Corollary 2** *Consider a symmetric case  $\beta = \gamma$ . The marginal effect of improving the objectivity on social welfare is greater than improving the accuracy,  $\frac{\partial W}{\partial \beta} > \frac{\partial W}{\partial \gamma}$ , if and only if*

$$\bar{r} > 2 \Phi \left( \frac{\sqrt{\frac{\beta\gamma}{\beta+\gamma}} y^*}{\sqrt{(\tau^2 + 1)(2\tau^2 + 1)}} \right) - \frac{\tau \sqrt{\frac{\beta\gamma}{\beta+\gamma}} y^*}{\sqrt{\alpha}(\tau^2 + 1)} - 1, \quad (24)$$

where  $\tau = \sqrt{\frac{\beta\gamma}{\alpha(\beta+\gamma)}}$ . In particular, this condition holds for either 1)  $\bar{r}$  close to  $\frac{1}{2}$  or 2)  $\alpha$  close to 0.

### 3.5.2 Voluntary Disclosure Extension

We now consider an extension of our main model in which a regulator observes the FI's fundamentals  $\tilde{r}$  and decides whether to disclose it to investors with some noise. We denote the regulator's decision to disclose by  $d = 1$  and decision to withhold by  $d = 0$ . If the regulator chooses  $d = 1$ , each investor observes the same signal as in our main model,  $\tilde{x}_i = \tilde{r} + \tilde{\eta} + \tilde{\varepsilon}_i$ . If the regulator chooses  $d = 0$ , investors do not observe the private signals. In addition, because in our model, runs are always excessive compared with the first-best, we assume for simplicity that the regulator minimizes the portion of investors who withdraw  $l$ .<sup>13</sup> That is, conditional on  $\tilde{r}$  and the disclosure choice  $d$ , the regulator's payoff is given by  $V(d, r) = -l(d, r)$ .

**Costless Voluntary Disclosure** We first examine a case in which disclosure is costless and find that our main results are robust to adding voluntary disclosure decisions. Even if the regulator has the discretion to withhold information, we obtain an “unravelling” type of result such that in equilibrium the regulator always discloses and upon disclosure, investors' withdrawal decisions are the same as in the main model. This is because in our model, the prior about the FI's fundamentals is sufficiently pessimistic (i.e.,  $\bar{r} \leq \frac{1}{2}$ ) such that all investors will always withdraw in absence of disclosure. As a result, the regulator will always disclose to avoid runs. We summarize these results in the following corollary.

**Corollary 3** *When the disclosure cost is zero, there exists an equilibrium in which the regulator always discloses  $d^* = 1$ . Upon disclosure, investors withdraw if and only if  $\tilde{y}_i \leq y^*$ , where the withdrawal threshold  $y^*$  is as in the main model.*

**Costly Voluntary Disclosure** We now introduce a disclosure cost  $c > 0$  to break the “unravelling” result. Analysis in such a model is intractable because it requires us to work with truncated normal distributions in a model of runs. However, when  $c$  is close to zero, we are able to compare the effects of improving the accuracy and the objectivity on the regulator's disclosure decision. We again focus on the symmetric case  $\beta = \gamma$ . We find that there exists a partial disclosure equilibrium in which the regulator discloses if and only if  $r \geq \hat{r}(\beta, \gamma)$ . In addition, because improving the objectivity has a stronger effect than improving the accuracy on reducing runs, improving the

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<sup>13</sup>Other papers in the literature have made similar assumptions, e.g., Gao and Jiang (2015).

objectivity also has a stronger effect on decreasing the disclosure threshold  $\hat{r}$ . In other words, the regulator has a stronger incentive to disclose information voluntarily when such a disclosure is perceived to be objective than when perceived to be accurate. We summarize these results in the following corollary.

**Corollary 4** *When the disclosure cost  $c$  is close to zero, there exists a partial disclosure equilibrium in which the regulator discloses if and only if  $r \geq \hat{r}(\beta, \gamma)$ . In a symmetric case  $\beta = \gamma$ , the marginal effect of improving the objectivity on decreasing the disclosure threshold  $\hat{r}$  is stronger than improving the accuracy, i.e.,  $\frac{\partial \hat{r}}{\partial \beta} < \frac{\partial \hat{r}}{\partial \gamma}$ .*

## 4 Accounting Measurement Micro-foundation of Information Environment

The accuracy-objectivity trade-off discussed previously has important implications for the optimal design of accounting systems and the social value of objectivity in improving coordination calls for the adoption of more objectivity-based accounting rules. This implication may be suggestive about the underlying rationale for banking regulators to resist certain GAAP treatments based on objectivity grounds, to the extent that banking regulators are arguably more sensitive than accounting standard setters to coordination problems associated with FIs under their supervision. For example, GAAP fair-value treatments of certain balance sheet items are disallowed under regulatory accounting principles (RAP). For the purpose of computing Tier-I capital, unrealized gains/losses due to available-for-sales (AFS) securities are removed from GAAP bank equity as well as unrealized gains/losses due to mark-to-market treatment of FIs' own long-term debt and certain excess amounts of servicing assets. One could argue that these GAAP fair value treatments contain relevant information for estimating FI's fundamentals and so excluding them in RAP may make the resulting bank equity measures less accurate. However, to the extent that the unrealized gains and losses caused by fair value treatments invite more disagreement in interpretations among investors (e.g., when and how much of the unrealized gains/losses will be realized), removing them can enhance the objectivity of bank equity measures.

To derive policy implications for designing accounting measurement systems, we offer a micro-

model of the accounting measurement process which gives rise to the information properties modeled in the main setup (i.e., Equation (1) on p. 8). Analyzing this accounting measurement model sheds light on possible measures to affect the objectivity and accuracy properties.<sup>14</sup>

Consider a simple model of the accounting measurement system.<sup>15</sup> Suppose that the payoff-relevant state-of-nature (or fundamentals) is denoted by  $\tilde{r} \sim N(\bar{r}, \frac{1}{\alpha})$ . The accounting measurement process generates a piece of evidence about the fundamentals. If the accounting measurement process is not intervened by the manager, the piece of evidence, denoted by  $\tilde{s}$ , is given by

$$\tilde{s} = \tilde{r} + \mu\tilde{\epsilon}, \quad (25)$$

where  $\tilde{\epsilon} \sim N(0, \phi)$  denotes an *uninfluenced* noise stemming from measurement errors in the imperfect accounting system and  $\phi > 0$  measures the size of the errors.  $\mu \geq 0$  measures the extent to which the evidence is affected by the errors. In addition, the manager can also intervene and influence the realization of the evidence by an action  $b$ . After the intervention, the influenced evidence, denoted by  $\tilde{X}$ , becomes

$$\tilde{X} = \tilde{s} + \lambda b, \quad (26)$$

where  $\lambda \geq 0$  measures the extent to which the evidence is affected by the intervention.  $\tilde{X}$  is thereafter disclosed as the public report.

To rule out a perfect report, we assume  $\mu\lambda > 0$ . The  $\{\mu, \lambda\}$  parameter-pair regulates how

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<sup>14</sup>The first measurement model of objectivity is given by Ijiri and Jaedicke (1966). In their influential work on reliability, Ijiri and Jaedicke proposed a simple, elegant model that decomposes the so-called reliability property (of accounting measurement system) into two components: objectivity and bias. Suppose that  $n$  measurers are asked to measure an object (e.g., the performance of a firm) using a given measurement system  $\eta$ . Let  $x^*$  be the true value of the object (e.g., the economic income of the firm) and  $x_i^\eta$  be the outcome (e.g., the net income of the firm) reported by measurer  $i$  by operating the measurement system  $\eta$  (e.g., a historical-cost based measurement system). Ijiri and Jaedicke propose that the reliability of the measurement system  $\eta$  is given as

$$R_\eta = \frac{1}{n} \sum_{i=1}^n (x_i^\eta - x^*)^2 = \frac{1}{n} \sum_{i=1}^n (x_i - \bar{x}^\eta)^2 + (\bar{x}^\eta - x^*)^2 = V_\eta + B_\eta,$$

where  $\bar{x}^\eta$  is the average outcome among  $n$  measurers. Accordingly,  $V_\eta \equiv \frac{1}{n} \sum_{i=1}^n (x_i^\eta - \bar{x}^\eta)^2$  is defined as the inverse of the objectivity of the measurement system  $\eta$  and  $B_\eta \equiv (\bar{x}^\eta - x^*)^2$  is defined as the bias of the measurement system  $\eta$ . Two points are worth noting. First, in our information model, objectivity  $V_\eta = \int_0^1 (\tilde{x}_i - \tilde{x}_p)^2 di = \int_0^1 \tilde{\epsilon}_i^2 di = \frac{1}{\beta}$ . That is,  $\beta$  exactly corresponds to the notion of objectivity in Ijiri and Jaedicke. Second, the Ijiri-Jaedicke measurement model is agnostic about the source of measurement bias and disagreement among measurers. Our measurement model gives rise to these dimensions by examining accounting system errors and managerial influences.

<sup>15</sup>Our accounting measurement model can be readily expanded to a more general one in which the accounting system generates multiple pieces of evidence and some measurement rules are applied by a reporting entity to the set of evidence to create a public report. In developing this measurement model, we owe our inspiration to the accounting measurement framework in Gao (2013).

the report ( $\tilde{X}$ ) reveals information about the fundamentals. We interpret a parameter pair  $\{\mu \neq 0, \lambda = 0\}$  as representing a completely *uninfluenced* report. Think of transactional data such as the amount of loans that are actually fully repaid, and the amount and length of time of loans that are past due. Although not perfectly descriptive of the true underlying economic state, this measurement provides non-discretionary indications about a firm’s prospects. When  $\lambda \neq 0$ , the report is *influenced* by the intervention action  $b$ . For instance, in the Repo 105 example of the introduction, Lehman privately employed the Repo 105 products to qualify the sales accounting treatment, thus biasing its reported leverage ratio downward from the true one.

We assume that, in choosing her intervention, the manager always prefers a higher report  $\tilde{X}$  and incurs a cost of intervention,  $\frac{1}{2} (b - \tilde{\theta})^2$ .<sup>16</sup> This cost can be interpreted as potential litigation costs, manager’s mental suffering from misreporting, and so on. Importantly, the intervention cost depends on a parameter  $\tilde{\theta}$ , which is privately known only to the manager, and it captures the uncertainty of outsiders regarding the manager’s private reporting intentions. Linking back to the Repo 105 example, outsiders may not be even aware of Lehman’s use of Repo 105 or at least uncertain about to what extent Repo 105 has been used in influencing financial reporting.<sup>17</sup> Given the nature of  $\tilde{\theta}$ , we assume that it has an improper prior. The manager’s payoff is then given by  $\tilde{X} - \frac{1}{2} (b - \tilde{\theta})^2$ . The FOC on  $b$  gives the manager’s equilibrium intervention  $b^*$  as

$$b^* = \tilde{\theta} + \lambda. \tag{27}$$

Notice that in a rational expectation equilibrium, the functional form of  $b^*$  is perfectly conjectured by outsiders and thus to estimate  $b^*$ , one only needs to estimate  $\tilde{\theta}$ . We assume that, in processing a public report  $\tilde{X}$ , a decision-maker  $i$  “interprets” the public report by combining the report  $\tilde{X}$  with her own private signal/belief about  $\tilde{\theta}$ , denoted by

$$\tilde{s}_i^\theta = \tilde{\theta} + \tilde{\xi}_i, \tag{28}$$

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<sup>16</sup>Our modeling of the cost follows Dye and Sridhar (2004).

<sup>17</sup>In fact, Lehman’s use of Repo 105 was never publicly disclosed. As stated in the bankruptcy examiner report of Lehman, “a careful review of Lehman’s Forms 10-K and 10-Q would not reveal Lehman’s use of Repo 105 transactions.” In addition, “Lehman affirmatively misrepresented in its financial statement that the firm treated all repo transaction as financing transactions – i.e., not sales – for financial reporting purposes.” For details, see <http://documents.nytimes.com/lehman-brothers-repo-105-valukas-report#p=1>.

where  $\tilde{\xi}_i \sim N(0, \delta)$  is the noise in the decision-maker  $i$ 's signal and independent of  $\tilde{\theta}$ .  $\delta > 0$  is a parameter that measures the degree of heterogeneity among decision-makers. Relating to the Repo 105 example, because of the uncertainty regarding Lehman's reporting intentions, outsiders rely on their own private assessments (based on their different education, experience and familiarity with the reporting issues, etc.) to draw inferences, thus disagreeing with each other.

From the decision-maker  $i$ 's perspective, given the improper prior of  $\tilde{\theta}$ , her belief of  $\tilde{\theta}$  given  $\tilde{s}_i^\theta$  is  $E[\tilde{\theta} | \tilde{s}_i^\theta] = \tilde{s}_i^\theta$  and her inference of the managerial bias  $\hat{b} = \tilde{s}_i^\theta + \lambda$ . Using  $\hat{b}$ , the decision-maker  $i$  can (partially) undo the bias in the report  $\tilde{X}$  and her interpretation of the "de-biased" report  $\tilde{x}_i$  is equal to

$$\tilde{x}_i = \tilde{X} - \lambda \hat{b} = \tilde{r} + \mu \tilde{\epsilon} + \lambda (b - \hat{b}) = \tilde{r} + \mu \tilde{\epsilon} - \lambda \tilde{\xi}_i. \quad (29)$$

Let  $\tilde{\eta} = \mu \tilde{\epsilon}$  and  $\tilde{\epsilon}_i = -\lambda \tilde{\xi}_i$ , and we have

$$\tilde{x}_i = \tilde{r} + \tilde{\eta} + \tilde{\epsilon}_i. \quad (30)$$

Notice that  $\tilde{x}_i$  resembles the signals received by investors in our main setting. The accounting measurement process generates a public report which, when interpreted by each decision-maker privately, contains a common noise  $\tilde{\eta}$  with precision  $\gamma = \frac{1}{\mu^2 \phi}$  (accuracy) and an idiosyncratic noise  $\tilde{\epsilon}_i$  with precision  $\beta = \frac{1}{\lambda^2 \delta}$  (objectivity). Furthermore, although each decision-maker only observes  $\tilde{x}_i$  in our main setting but observes a set of signals  $\{\tilde{X}, \tilde{s}_i^\theta, \tilde{x}_i\}$  in the accounting measurement model, we show in Appendix II that  $\tilde{x}_i$  is a sufficient statistic for  $\{\tilde{X}, \tilde{s}_i^\theta, \tilde{x}_i\}$  given that  $\tilde{\theta}$  follows an improper prior. To see this, notice first that because  $\tilde{x}_i = \tilde{X} - \lambda \hat{b} = \tilde{X} - \lambda (\tilde{s}_i^\theta + \lambda)$ ,  $\tilde{X}$  contains no incremental information given  $\tilde{s}_i^\theta$  and  $\tilde{x}_i$ . In addition,  $\tilde{s}_i^\theta$ , *by itself*, is of no use in estimating either the fundamentals or others' beliefs unless used *in conjunction with* the report  $\tilde{X}$  to help interpret the report and "de-bias"  $\tilde{X}$  into  $\tilde{x}_i$ . What is relevant in a decision-maker's information set is her interpretation of the report ( $\tilde{x}_i$ ), rather than the disclosed report *per se*.<sup>18</sup>

<sup>18</sup>Holthausen and Verrecchia (1990) and Kim and Verrecchia (1997) have examined similar information models on agents' different interpretations of the same reported earnings. For instance, Holthausen and Verrecchia (1990) argue that "what is relevant is not the earnings number *per se*, but the implications of the earnings release for the value of the firm. Moreover, the earnings signal *per se* does not contain a direct statement about the value of the firm which is known by all agents prior to their idiosyncratic assessment." In addition,  $\tilde{s}_i^\theta$  in our model is related to the "event-period" information in Kim and Verrecchia (1997), which "can only be used in conjunction with the announcement itself: in effect, only in the event-period," and "is used in all announcements to provide a context or interpretation to the disclosure."

In practical terms, our model setup can be interpreted as individual investors regarding a public report (Lehman’s reported leverage of 30) as un-interpretable unless being supplemented by their own private information about the managerial intent. In this light, the accounting measurement model provides a micro-foundation for the information structure studied in our main setting.

Importantly, objectivity and accuracy are functions of (1) the properties of the measurement system,  $\lambda$ ,  $\phi$  and  $\mu$ , and (2) the heterogeneity among decision-makers,  $\delta$ . To investigate how different measures can affect accuracy and objectivity, we compute the comparative statics of  $\beta$  and  $\gamma$  in the following proposition.

**Proposition 6** *The comparative statics of accuracy and objectivity are such that:*

1. *Information accuracy  $\gamma$  is strictly decreasing in the size of the measurement errors  $\phi$ , and the degree to which the evidence is affected by the measurement errors  $\mu$ ;*
2. *Information objectivity  $\beta$  is strictly decreasing in the heterogeneity among decision-makers  $\delta$  and the degree to which the evidence is affected by the managerial influence  $\lambda$ .*

Proposition 6 can shed some light on the optimal design of accounting systems from the perspective of the objectivity-accuracy trade-off. Given our previous result that high objectivity is socially desirable, our measurement model implies that accounting systems should be designed to be less subject to managerial influence but be more tolerant of random errors. In this light, our model suggests a novel benefit of reducing earnings manipulations from the perspective of coordination and stability, in addition to the existing ones based on grounds of stewardship and reliability.

## 5 Discussions and Empirical Implications

In this section, we provide a discussion of empirical evidence and examples to supplement our analyses and arguments. We focus on discussing the vulnerability of financial institutions to the risk of runs, the role played by the information environments of financial markets in runs, and examples of both regulation-mandated and accounting disclosure by financial institutions wherein the objectivity and accuracy properties are key determinants of the information environments. Lastly, we also discuss our empirical implications.



## 5.1 Vulnerability of Financial Institutions to Runs

Financial institutions are known to be vulnerable to the risk of runs because of their roles in liquidity transformation. A seminal contribution by Diamond and Dybvig (1983) is that to provide liquidity to the economy, financial institutions (banks) hold illiquid assets and borrow liquid liabilities. This liquidity mismatch between assets and liabilities exposes financial institutions to the risk of runs in which excessive withdrawal requests of short-term investors cannot be entirely satisfied by liquidating illiquid assets. Runs were frequent until the establishment of the Federal Deposit Insurance Corporation and the provision of deposit insurance in the 1930s.

The recent turmoil in the financial markets, however, revealed the vulnerability of financial institutions to runs despite the deposit insurance. In the 2008-2009 crisis, 165 banks failed with runs as a notable cause, compared with only 27 banks from 2000 to 2007 (FDIC bank failure list, 2016). Runs not only caused failures of traditional banks, such as Northern Rock, WaMu, and IndyMac, but also disrupted shadow banking markets, such as markets for repos, asset-backed commercial papers and money market mutual funds.<sup>19</sup> The reason deposit insurance cannot prevent runs is that these “modern-day” runs are fundamentally different from the “old-fashioned” runs by “retail” depositors (e.g., households). The modern-day runs are enacted by “sophisticated institutional investors,” such as hedge funds, investment banks, and non-retail depositors, none of which are covered by the deposit insurance. Take Northern Rock as an example. As noted in Shin (2009), during its expansion in early 2000s, Northern Rock became increasingly reliant on non-retail funding as its traditional funding based on retail deposits could not keep up with its growth. By the summer of 2007, only 23 percent of its liabilities were in the form of retail deposits with the rest from “a combination of short-term borrowing in the capital markets and securitized notes and other longer-term funding sources” (Shin, 2009), none of which were insured. Unsurprisingly, during the run on Northern Rock, these uninsured liabilities took the largest hit (see Figure 3 of Shin, 2009). It is also important to note that in the age of securitization, it is not at all uncommon for financial institutions to rely on uninsured “wholesale” funding. For example, the median U.K. bank’s non-retail funding percentage doubled from 27.8 percent in December 2000 to 47.8 percent

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<sup>19</sup>See Shin (2009) for a discussion of the run on Northern Rock, He and Manela (2016) for a discussion of the run on WaMu, Brunnermeier (2009) for a discussion of the run on repo and asset-backed commercial papers, and Wermers (2012) for a discussion of the run on money market mutual funds.

by December 2007 (Financial Stability Report, The Bank of England, 2008, Figure 4).<sup>20</sup>

Runs occur even more frequently in shadow banking markets, although the exact form may differ from traditional runs in which depositors withdraw demand deposits. For instance, as noted by Brunnermeier (2009), “not rolling over commercial paper is, in effect, a run on the issuer of asset-backed commercial paper.” In addition, Bear Sterns experienced a run by hedge funds which pulled out their liquid assets, which are typically parked with their primary brokers. Runs may also take the form of a large “haircut” in the repo markets or a “margin” call as faced by AIG in September 2008. Finally, runs also occur on money market mutual funds in the form of “breaking the buck.” For example, one large money market fund, the Reserve Primary Fund, disclosed that it had broken the buck, following which a total of \$300 billion flowed out of the fund (Wermers, 2012).

The model in our paper can be readily adapted to understand the runs in shadow banking markets. Consider first the runs on money market mutual funds. Under Rule 2a-7 of the Investment Company Act, each share of mutual funds is redeemed at \$1 each, as assumed in our model. In addition, assets held by mutual funds are less liquid and can be risky. For example, the runs on the Reserve Primary Fund was triggered by its holding of \$750 million in commercial paper issued by Lehman Brothers, which, at that time, was on the verge of bankruptcy. Mutual funds pay their (equity) investors out of the returns on their assets, which depends on the fundamentals of the assets (denoted by  $\tilde{r}$  in our model) and the fraction of investors who decide to redeem their shares  $l$ . The payoff to investors decreases in  $l$  because the more investors redeem, the more assets the mutual funds need to sell to meet the redemption, which results in liquidity losses and lower returns on remaining assets. One can capture these features by specifying the return to each share of mutual funds to be  $e^{\tilde{r}-l}$ . Note that the resulting model is the same as ours.

Our model can also represent runs stemming from not rolling over short-term lending, such as asset-backed commercial papers and repos, following a roll-over-risk model laid out in Morris and Shin (2004). More specifically, consider a group of small creditors deciding whether to roll over their short-term lending to a financial institution. If the creditors decide not to roll over (foreclosure), each creditor keeps the face value of the lending, \$1. If the creditors decide to roll over, the final payoff to each creditor depends on two factors: the underlying state of the financial institution’s

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<sup>20</sup>See <http://www.bankofengland.co.uk/publications/Pages/fsr/2008/fsr24.aspx>.

project  $\tilde{r}$  and the portion of the creditors who foreclose on the lending  $l$ . As discussed in Morris and Shin (2004), because foreclosure causes disruption in the project, a higher  $l$  reduces the return to the remaining creditors. If one specifies the return to remaining creditors to be  $e^{\tilde{r}-l}$ , the resulting model is the same as ours.

## 5.2 The Role of Information Environments in Runs

The information environment occupied by financial institutions plays a key role in runs. One of the most prominent examples is the run on IndyMac Bancorp in June 2008 which immediately followed the public release of letters by Senator Charles Schumer (Banking Committee) commenting on the health of IndyMac.<sup>21</sup> As noted by Hertzberg, Liberti and Paravisini (2011), regulatory agencies responded by requiring regulators not to publicly comment on conditions of financial institutions because of concerns that the release of information may produce unintended consequences of undermining market confidence and triggering panic runs. A similar example is the run on Bear Sterns, which was initially started by the information on Goldman Sachs' delay of entering a new contract with Bear (Brunnermeier, 2009). Lastly, information that WaMu may not have been able to secure funds from the Fed also played a key role in triggering the run on WaMu.<sup>22</sup>

An empirical study by Hertzberg, Liberti and Paravisini (2011) highlights the interaction between information environments and coordination failure in runs. Consistent with what is predicted in the higher-order belief literature (e.g., Morris and Shin, 2001, 2002), they find that public information exacerbates the coordination failure among lenders, which increases the incidence of financial distress. Although there is no direct evidence yet on how disagreement (objectivity) affects runs, a number of empirical studies show that there indeed exists a substantial amount of disagreement/information differences regarding conditions of financial institutions. Most notably, an influential study by Morgan (2002) on bank opacity reports a higher disagreement among bond rating agencies over bank bond issues, compared with non-financial institutions. In line with our arguments, Morgan argues that the high disagreement arises because “there is no objective standard in” assessing a bank’s asset quality and thus an outsider “must exercise his or her judgment using what can only be impressionistic information.” To the extent that disagreement is an integral part

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<sup>21</sup>See [http://latimesblogs.latimes.com/money\\_co/2008/07/sen-charles-e-s.html](http://latimesblogs.latimes.com/money_co/2008/07/sen-charles-e-s.html).

<sup>22</sup>See Footnotes 9 and 10 in He and Manela (2016) for detailed discussions.

of bank opacity which arguably plays a key role in runs, examining the objective/subject nature of the information environments seems quite relevant.

### **5.3 Objectivity-Accuracy in Disclosure Examples**

In this section, we discuss the objectivity and accuracy properties in the context of specific disclosure examples. We discuss examples of both regulatory disclosure and (general) accounting disclosure.

#### **5.3.1 Regulatory Disclosure: Stress Test versus CAMELS**

In our discussion of regulation-mandating disclosure, we focus on comparing the newly mandated stress-test disclosure under the Dodd-Frank Act with the traditional regulatory disclosure policy, most notably, the CAMELS rating. The stress-test disclosure was proposed and implemented in the wake of the recent financial crisis. The disclosure serves to inform financial institutions themselves and the general public “how the institutions’ capital ratios might change during a hypothetical set of adverse economic conditions.”<sup>23</sup> It is also noteworthy that the disclosure of stress-test results is mandated. In particular, the Dodd-Frank Act requires that, on an annual basis the Federal Reserve must generate stress test results under three “supervisory” scenarios for all U.S. bank holding companies with at least \$50 billion in total assets, and disclose a summary of the results. As a result, the Fed cannot choose whether to disclose strategically.

The disclosure of stress-test results brought a major change to the information environments of financial markets because it differs substantially from traditional regulatory disclosure policy, such as the CAMELS rating. We argue that compared with the CAMELS rating, two new features of the stress-test disclosure may make it more objective. First, the stress-test disclosure is highly quantitative, as noted by Hirtle and Lehnert (2014). By design, stress testing is a “*quantitative* evaluation of the impact of stressful economic and financial market conditions.” More specifically, (severely) adverse scenarios are defined quantitatively: for instance, the scenarios include that the unemployment rate rises to 10 percent, the level of real GDP by the end of 2015 is 4.5 percent lower than its level in the third quarter of 2014, and that equity prices fall 60 percent from the third quarter of 2014 through the fourth quarter of 2015 (Dodd-Frank Act Stress Test, 2015, Figures 2 to

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<sup>23</sup>See the preface page, Dodd-Frank Act Stress Test 2015: Supervisory Stress Test Methodology and Results, Board of Governors of the Federal Reserve System, March, 2015. See Goldstein and Sapra (2014) and Leitner (2014) for detailed discussions of the stress-test disclosure.

7). In addition, the process of preparing stress-test reports is also quantitative. The Fed estimates the effect of the adverse scenarios on regulatory capital ratios by “projecting the balance sheet, RWAs, net income and resulting capital” (Dodd-Frank Act Stress Test, 2015, Figure 8). Lastly, the disclosed results of stress tests are also quantitative, and include projections of losses, loan loss provisions, balance-sheet items and regulatory capital ratios, etc. (Dodd-Frank Act Stress Test 2015, pp. 17-39). In contrast, traditional supervisory disclosure is more qualitative. Take the CAMELS rating as an example. Even the weights assigned to the six composite ratings are not defined but determined instead at the discretion of the regulator. As expressly mentioned in the policy document of the FDIC, the weight of “each component rating is based on a *qualitative* analysis of the factors comprising that component and its interrelationship with the other components. When assigning a composite rating, some components may be given more weight than others depending on the situation at the institution.”<sup>24</sup>

Second, the transparency of stress-test disclosure is unprecedented. For instance, Peristiani, Morgan and Savino (2010) note that the stress-test disclosure “was unusually transparent. Not only were the outputs—projected losses and necessary capital buffers—publicized, so too were the inputs, the modeling assumptions, and the processes involved in producing the outputs. Ordinary inspections are opaque by comparison, with both the inputs and outputs kept confidential.” Indeed, in the disclosure of stress-test results, the Fed discloses not only outputs, such as projections of loan losses, RWAs, and capital ratios, etc., in great detail (including both BHC-specific and aggregate results), but also the underlying procedure used to compute the projections, such as supervisory scenarios used, and models to project net income and stressed capital, etc. (Dodd-Frank Act Stress Test, 2015). In contrast, all exam materials related to the CAMELS rating are highly confidential. As noted by Lopez (1999), “a bank’s CAMELS rating is directly known only by the bank’s senior management and the appropriate supervisory staff. CAMELS rating is never released by supervisory agencies, even on a lagged basis.” While the public may infer some of the outputs in the CAMELS rating based on subsequent regulatory actions and bank disclosure,<sup>25</sup> the detailed outputs and the inputs used to compute the rating (such as the rating for each component) are

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<sup>24</sup>See <https://www.fdic.gov/regulations/laws/rules/5000-900.html>.

<sup>25</sup>As noted in Jordan, Peek and Rosengren (2000), “the announcement of a formal action reveals to the public that bank supervisors believe that the financial institution is deeply troubled, requiring remedial action to deal with its financial problems. In addition, these announcements, in effect, reveal the likely confidential supervisory rating of the bank.”

never revealed to the public.

To the extent that its quantitative and transparent features limit the room for alternative interpretations and thus invite fewer disagreements, the stress-test disclosure is arguably more objective than traditional regulatory disclosure policy, such as the CAMELS rating. This claim seems consistent with the finding of an empirical paper by Ellahie (2013), which shows that the stress-test disclosure in Europe reduces informational difference among market participants. In light of our results on the social value of objectivity, we argue that disclosing the stress-test results, which are perceived to be objective, may help to restore market confidence and improve financial stability. In addition, to the extent that the stress-test disclosure is more transparent than the CAMELS rating, we argue that it is also more accurate.

### **5.3.2 Accounting Disclosure by Financial Institutions**

In our discussion of accounting disclosure by financial institutions, we focus on discussing two examples: one related to the accounting for loan losses and the other related to the disclosure of bank capital. We show in the two examples that choices among accounting methods are confronted with the accuracy and objectivity trade-off.

**Accounting for Loan Losses** One of the recent key changes in bank accounting is on the accounting for loan losses in which the FASB, in June 2016, issued its new loan loss accounting framework requiring the “current expected credit loss” (CECL) model, which differs substantially from the current standard, the “incurred loss” model. More specifically, under the incurred loss model, only expected losses over a specific time horizon that pass a “probable” threshold are recognized. The new CECL model removes the “probable” threshold and expands the time horizon of the expected losses. Under the CECL model, the expected credit loss is “an estimate of all contractual cash flows not expected to be collected from a recognized financial asset (or group of financial assets) or commitment to extend credit.”

It is natural to believe that the CECL model may be more accurate than the incurred loss model because the CECL model requires the estimated loan losses to be based on relevant information about not only past events and current conditions (as also required in the incurred loss model) but also “reasonable and supportable forecasts that affect the expected collectability of the

financial assets' remaining contractual cash flows," which is more forward-looking information than is permitted under the incurred loss model. For example, in addition to evaluating the borrowers' current creditworthiness, the CECL model also requires an evaluation of the forecasted direction of the economic cycle. In addition, because of the expanded time horizon, the estimate utilizes the time value concept such that expected losses are discounted at the asset's effective interest rate. Furthermore, estimates should reflect both the possibility that a credit loss results and the possibility that no credit loss results.

However, one may also argue that the CECL model is less objective from the Ijiri-Jaedicke perspective than the incurred loss model because outsiders must subjectively interpret the additional judgments/estimations made under CECL and thus disagree more on interpreting the reported loan loss provisions. On the contrary, the incurred loss model can be more objective because one may find fewer disagreements about incurred losses among reasonably trained professional accountants.

Through the lens of our results on the social value of objectivity, moving toward the CECL model may produce an unintended consequence of reducing financial stability. Although the CECL model may provide more accurate information than the incurred loss model, it may be perceived to be less objective, thus magnifying disagreements among market participants and potentially disrupting coordination.

**Disclosure of Bank Capital** Our results may also shed light on the disclosure of bank capital when financial institutions face the risk of runs. Two alternative disclosure practices of bank capital came to the limelight: Tier-I capital and Tangible Common Equity (TCE). Arguably, Tier-I capital may be a more accurate measure of bank equity than TCE for a number of reasons. For instance, some intangible assets, such as mortgage servicing rights, which are partly included in Tier-I capital but entirely excluded from TCE, contribute to the value of banks and should be recognized as a component of bank capital. Moreover, TCE includes unrealized gains and losses, which are removed from the Tier-I capital. However, TCE is more likely to induce fewer disagreements among investors given its simplicity (i.e., more objective from an Ijiri-Jaedicke perspective), whereas Tier-I capital may be subject to different interpretations given its many-layered construction. In the comparison between Tier-I capital and TCE, our model predicts that the more objective, albeit less accurate, disclosure of TCE can help to stabilize runs. One phenomenon, which then could be consistent

with the spirit of our findings, is that financial institutions have begun to voluntarily emphasize TCE measures toward their shareholders. For example, Citigroup began formally disclosing and commenting its TCE measures in their 10K reports for fiscal year 2008.<sup>26</sup>

## 5.4 Empirical Implications

We collect and summarize the empirical implications from our previous analyses in this section. Proposition 3, Proposition 4, and Proposition 5 provide the empirical implications regarding the relationship between informational properties and the risk of runs. Specifically, our model first predicts a negative association between agreement among investors (objectivity) and the risk of runs. Second, our model also predicts an ambiguous sign on the association between the precision of collective knowledge (accuracy or the reciprocal of average bias) and the risk of runs, which depends on the precision of prior knowledge. If the prior is sufficiently imprecise, the association is negative, whereas if the prior is sufficiently precise, the association can be positive. Lastly, our model predicts a comparative advantage of improving agreement over reducing average bias in reducing the risk of runs. An implication is that if an information environment incurs a one-to-one swap of decreases in agreement for reductions in average bias, the risk of runs will increase.

Our empirical predictions on the effects of objectivity and accuracy can be tested using proxies of disagreement and average bias developed in the literature. For instance, Barron, Kim, Lim and Stevens (1998) show that measures of average bias and disagreement can be constructed as functions of analyst forecast dispersion and error in the mean analyst forecast. To illustrate the idea, consider a simple case in which there are a large number ( $N$  sufficiently large) of analysts' forecasts. Each analyst's forecast is  $x_i = r + \eta + \varepsilon_i$  and thus the mean analyst forecast is  $\bar{x} = \frac{1}{N} \sum_{i=1}^N x_i = r + \eta$ . Note that a proxy for disagreement is given by the dispersion in analysts' forecasts, i.e.,  $\frac{1}{\beta} = \frac{1}{N} \sum_{i=1}^N (x_i - \bar{x})^2 = \frac{1}{N} \sum_{i=1}^N \varepsilon_i^2$ . A proxy for average bias is given by the average/expected square error of the mean forecast (difference between the mean earnings forecast and the actual earnings reported later), i.e.,  $\frac{1}{\gamma} = E(\bar{x} - r)^2 = E\eta^2$ . Other than proxies based on analysts' forecasts, another proxy for disagreement among investors is short-interests (Miller, 1977) or breadth of ownership, i.e., the ratio of investors holding long positions (Chen, Hong and Stein, 2002). In addition, average bias can also be proxied using delayed expected loan loss recognition (DELRL), to the extent that

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<sup>26</sup>See an example of TCE reporting by Citibank at <http://online.wsj.com/news/articles/SB123577012189796905>.



this proxy is shown to capture some aspects of overall transparency regarding financial institutions (Bushman and Williams, 2015).

The recent financial crisis provides two potential empirical settings to test how informational properties may affect risk of runs. The first setting is the runs on asset-backed commercial paper (ABCP) programs, which constitute a major source of short-term funding for financial institutions. Covitz, Liang and Suarez (2013) provide some initial evidence on ABCP runs. With a run defined as occurring when short-term creditors refuse to roll their position, they find that one-third of ABCP programs experienced a run within weeks of the ABCP crisis onset. The second setting is the runs in the repo market. Dealer banks, i.e., investment banks and commercial banks with an investment banking subsidiary, rely heavily on repos for financing. Gorton and Metrick (2012) examine repo runs and use high repo haircuts and the cessation of repo lending as proxies for runs.

## 6 Conclusion

In this paper, we analyze the roles of two information properties, objectivity and accuracy, in improving financial stability. We show that in a model of runs on a financial institution, objectivity exhibits a comparative advantage in mitigating inefficient, panic-based runs compared with accuracy. In fact, it is possible that improving objectivity discourages runs while improving accuracy encourages such runs. Our model also sheds light on the design of optimal accounting systems. Our analyses identify a new benefit of reducing earnings manipulation from the perspective of improving the objectivity of financial reporting.

This study proposes a new line of accounting research that explores the role of accounting measurement properties in settings featuring coordination as the key economic tension. We hope that future work will use our results as the building blocks to develop a theory of corporate disclosure based on the need to encourage or discourage coordination. Given that public information plays a special role in coordination-based games, we believe there is much to learn about the role of accounting disclosure in these settings, including what makes accounting special compared to other information sources, such as share price. This new line of research would complement current disclosure theories built on moral hazard and adverse selection tensions.

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## Appendix I: Derivations of the Conditional Distribution of $\tilde{y}_j$ Given $\tilde{y}_i = y^*$

In this Appendix, we derive the conditional distribution of an investor  $j$ 's signal  $\tilde{y}_j$ , given the marginal investor's signal  $\tilde{y}_i = y^*$ . The two signals are:

$$\begin{aligned}\tilde{y}_i &= \tilde{x}_i - \bar{r} = \tilde{r} - \bar{r} + \tilde{\eta} + \tilde{\varepsilon}_i, \\ \tilde{y}_j &= \tilde{x}_j - \bar{r} = \tilde{r} - \bar{r} + \tilde{\eta} + \tilde{\varepsilon}_j.\end{aligned}\tag{31}$$

Since the random variables  $\tilde{r} - \bar{r}$ ,  $\tilde{\eta}$ ,  $\tilde{\varepsilon}_i$ , and  $\tilde{\varepsilon}_j$  are independently normally distributed, their linear combinations  $\tilde{y}_i$  and  $\tilde{y}_j$  are jointly normally distributed such as,

$$\begin{bmatrix} \tilde{y}_i \\ \tilde{y}_j \end{bmatrix} \sim N \left[ \begin{bmatrix} 0 \\ 0 \end{bmatrix}, \begin{bmatrix} \frac{1}{\alpha} + \frac{1}{\beta} + \frac{1}{\gamma} & \rho \left( \frac{1}{\alpha} + \frac{1}{\beta} + \frac{1}{\gamma} \right) \\ \rho \left( \frac{1}{\alpha} + \frac{1}{\beta} + \frac{1}{\gamma} \right) & \frac{1}{\alpha} + \frac{1}{\beta} + \frac{1}{\gamma} \end{bmatrix} \right],\tag{32}$$

where the correlation between the two signals  $\rho = \frac{\frac{1}{\alpha} + \frac{1}{\gamma}}{\frac{1}{\alpha} + \frac{1}{\beta} + \frac{1}{\gamma}}$ . As a result, the conditional distribution of  $\tilde{y}_j$  given  $\tilde{y}_i = y^*$  is also normally distributed with the conditional expectation

$$E[\tilde{y}_j | \tilde{y}_i = y^*] = 0 + \frac{\rho \left( \frac{1}{\alpha} + \frac{1}{\beta} + \frac{1}{\gamma} \right)}{\frac{1}{\alpha} + \frac{1}{\beta} + \frac{1}{\gamma}} (y^* - 0) = \rho y^*,\tag{33}$$

and the conditional variance

$$Var[\tilde{y}_j | \tilde{y}_i = y^*] = (1 - \rho^2) \left( \frac{1}{\alpha} + \frac{1}{\beta} + \frac{1}{\gamma} \right).\tag{34}$$

## Appendix II: A Proof for $x_i$ as a Sufficient Statistic in the Accounting Measurement Micro-foundation

In this Appendix, we show that  $x_i$  is a sufficient statistic of  $\{X, s_i^\theta\}$  in estimating either  $\tilde{x}_{-i}$  or  $\tilde{r}$ , i.e.,  $f(\tilde{x}_{-i}|x_i) = f(\tilde{x}_{-i}|x_i, X, s_i^\theta)$  and  $f(\tilde{r}|x_i) = f(\tilde{r}|x_i, X, s_i^\theta)$ . We only present the proof for  $f(\tilde{x}_{-i}|x_i) = f(\tilde{x}_{-i}|x_i, X, s_i^\theta)$  as the proof for  $f(\tilde{r}|x_i) = f(\tilde{r}|x_i, X, s_i^\theta)$  is similar. Given our joint normal distribution assumption, we only need to verify that the means and variances of  $f(\tilde{x}_{-i}|x_i)$  and  $f(\tilde{x}_{-i}|x_i, X, s_i^\theta)$  are equal, i.e.,  $E[\tilde{x}_{-i}|x_i] = E[\tilde{x}_{-i}|x_i, X, s_i^\theta]$  and  $var(\tilde{x}_{-i}|x_i) = var(\tilde{x}_{-i}|x_i, X, s_i^\theta)$ .

We first prove that  $E[\tilde{x}_{-i}|x_i] = E[\tilde{x}_{-i}|x_i, X, s_i^\theta]$ . Notice that since  $x_i \equiv X - \lambda\hat{b} = X - \lambda(s_i^\theta + \lambda)$ , the report  $X$  is redundant given  $s_i^\theta$  and  $x_i$ . Thus, we only need to verify that  $E[\tilde{x}_{-i}|x_i] = E[\tilde{x}_{-i}|x_i, s_i^\theta]$ . Standard Bayesian updating implies that,

$$E[\tilde{x}_{-i}|x_i, s_i^\theta] = E[\tilde{x}_{-i}|x_i] + \frac{cov(\tilde{x}_{-i}, \tilde{s}_i^\theta|x_i)}{var(\tilde{s}_i^\theta|x_i)} [s_i^\theta - E[\tilde{s}_i^\theta|x_i]]. \quad (35)$$

The conditional covariance  $cov(\tilde{x}_{-i}, \tilde{s}_i^\theta|x_i)$  is given by

$$\begin{aligned} cov(\tilde{x}_{-i}, \tilde{s}_i^\theta|x_i) &= cov(\tilde{x}_{-i}, \tilde{s}_i^\theta) - cov(E[\tilde{x}_{-i}|x_i], E[\tilde{s}_i^\theta|x_i]) \\ &= cov(\tilde{x}_{-i}, \tilde{s}_i^\theta) - cov\left(\frac{cov(\tilde{x}_{-i}, \tilde{x}_i)}{var(\tilde{x}_i)}\tilde{x}_i, \frac{cov(\tilde{x}_i, \tilde{s}_i^\theta)}{var(\tilde{x}_i)}\tilde{x}_i\right) \\ &= cov(\tilde{x}_{-i}, \tilde{s}_i^\theta) - \frac{cov(\tilde{x}_{-i}, \tilde{x}_i)cov(\tilde{x}_i, \tilde{s}_i^\theta)}{var(\tilde{x}_i)} \\ &= \lambda\delta \frac{\frac{1}{\alpha} + \mu^2\phi}{\frac{1}{\alpha} + \mu^2\phi + \lambda^2\delta} \\ &> 0. \end{aligned} \quad (36)$$

which is positive and finite. The first step uses the law of total covariances. The second step uses  $E[\tilde{x}_{-i}|x_i] = E[\tilde{x}_{-i}] + \frac{cov(\tilde{x}_{-i}, \tilde{x}_i)}{var(\tilde{x}_i)}(x_i - E[\tilde{x}_i])$  and  $E[\tilde{s}_i^\theta|x_i] = E[\tilde{s}_i^\theta] + \frac{cov(\tilde{x}_i, \tilde{s}_i^\theta)}{var(\tilde{x}_i)}(x_i - E[\tilde{x}_i])$ . The fourth step uses

$$\begin{aligned} cov(\tilde{x}_{-i}, \tilde{s}_i^\theta) &= cov(\tilde{r} + \mu\tilde{\epsilon} - \lambda\tilde{\xi}_{-i}, \tilde{\theta} + \tilde{\xi}_i) = 0, \\ cov(\tilde{x}_i, \tilde{s}_i^\theta) &= cov(\tilde{r} + \mu\tilde{\epsilon} - \lambda\tilde{\xi}_i, \tilde{\theta} + \tilde{\xi}_i) = -\lambda\delta, \\ cov(\tilde{x}_{-i}, \tilde{x}_i) &= cov(\tilde{r} + \mu\tilde{\epsilon} - \lambda\tilde{\xi}_{-i}, \tilde{r} + \mu\tilde{\epsilon} - \lambda\tilde{\xi}_i) = \frac{1}{\alpha} + \mu^2\phi, \\ var(\tilde{x}_i) &= var(\tilde{r} + \mu\tilde{\epsilon} - \lambda\tilde{\xi}_i) = \frac{1}{\alpha} + \mu^2\phi + \lambda^2\delta. \end{aligned} \quad (37)$$

The conditional variance  $\text{var}(\tilde{s}_i^\theta|x_i)$  is given by

$$\begin{aligned}\text{var}(\tilde{s}_i^\theta|x_i) &= \text{var}(\tilde{s}_i^\theta) - \text{var}(E[\tilde{s}_i^\theta|x_i]) \\ &= \text{var}(\tilde{s}_i^\theta) - \frac{\text{cov}(\tilde{s}_i^\theta, \tilde{x}_i)^2}{\text{var}(\tilde{x}_i)} \\ &= \infty.\end{aligned}\tag{38}$$

The first step uses the law of total variances. The second step uses  $E[\tilde{s}_i^\theta|x_i] = E[\tilde{s}_i^\theta] + \frac{\text{cov}(\tilde{x}_i, \tilde{s}_i^\theta)}{\text{var}(\tilde{x}_i)}(x_i - E[\tilde{x}_i])$ . The last step holds because  $\tilde{\theta}$  follows an improper prior (i.e.,  $\text{var}(\tilde{\theta}) = \infty$ ),  $\text{var}(\tilde{s}_i^\theta) = \text{var}(\tilde{\theta}) + \text{var}(\tilde{\xi}_i) = \infty$  and  $\frac{\text{cov}(\tilde{s}_i^\theta, \tilde{x}_i)^2}{\text{var}(\tilde{x}_i)} = \frac{\lambda^2 \delta^2}{\frac{1}{\alpha} + \mu^2 \phi + \lambda^2 \delta}$ . With  $\text{var}(\tilde{s}_i^\theta|x_i) = \infty$ ,  $\frac{\text{cov}(\tilde{x}_i, \tilde{s}_i^\theta|x_i)}{\text{var}(\tilde{s}_i^\theta|x_i)} = 0$  and  $E[\tilde{x}_{-i}|x_i] = E[\tilde{x}_{-i}|x_i, s_i^\theta]$ . Intuitively, the private signal  $\tilde{s}_i^\theta$ , by itself, is of no use in estimating either the fundamentals or others' beliefs, unless used in conjunction with the report  $\tilde{X}$  to help interpret and “de-bias”  $\tilde{X}$  into  $\tilde{x}_i$ .

Second, we prove that  $\text{var}(\tilde{x}_{-i}|x_i) = \text{var}(\tilde{x}_{-i}|x_i, X, s_i^\theta)$ . Applying the law of total variances gives,

$$\begin{aligned}\text{var}(\tilde{x}_{-i}|x_i, X, s_i^\theta) &= \text{var}(\tilde{x}_{-i}) - \text{var}(E[\tilde{x}_{-i}|x_i, X, s_i^\theta]) \\ &= \text{var}(\tilde{x}_{-i}) - \text{var}(E[\tilde{x}_{-i}|x_i]) \\ &= \text{var}(\tilde{x}_{-i}|x_i).\end{aligned}\tag{39}$$

The second step uses  $E[\tilde{x}_{-i}|x_i, X, s_i^\theta] = E[\tilde{x}_{-i}|x_i]$  and the last step uses the law of total variances. In sum, we have shown that  $f(\tilde{x}_{-i}|x_i) = f(\tilde{x}_{-i}|x_i, X, s_i^\theta)$ .



### Appendix III: A Micro-foundation Based on Imperfect Communication

Our information structure can also be micro-founded in the framework of imperfect communication laid out by Morris and Shin (2007). Suppose that the FI discloses a set of  $n$  signals about its fundamentals. The signals are imperfectly correlated,

$$\tilde{z}_i = \tilde{r} + \tilde{\zeta} + \tilde{\psi}_i, \quad (40)$$

where  $\tilde{\zeta} \sim N\left(0, \frac{1}{\chi}\right)$  and  $\tilde{\psi}_i \sim N\left(0, \frac{1}{\nu}\right)$ . All the random variables are independent of each other. The set of  $\tilde{z}_i$  can be thought as different line items/discussions in the financial statement such as the disclosure of liquidity risk, market risk, net interest income, etc. Each  $\tilde{z}_i$  is subject to a common error and an idiosyncratic error. The common error may depend on institution-wide factors such as the quality of the accounting information system, the overall strength of internal control, etc. The idiosyncratic error may depend on the individual attribute of each  $\tilde{z}_i$ . For example, the measurement error in liquidity risk disclosure is likely to be driven by factors that differ from those cause the measurement error in net interest income disclosure. In addition, we assume that the communication of accounting information from the FI to investors is imperfect, possibly due to investors' limited attention, complexity of accounting numbers and fragmented communication channels. In particular, following Morris and Shin (2007), we model the imperfect communication by assuming that each investor can only understand and observe precisely one of the signals disclosed by the FI. Each signal  $\tilde{z}_i$  is observed by proportion  $\frac{1}{n}$  of the population of investors. For instance, some investors may focus on analyzing the discussion of liquidity risk in the FI's financial statement while others focus on the report of the FI's activities in structured finance.

The variance of each investor's signal  $\tilde{z}_i$  is given by

$$\text{var}(\tilde{z}_i) = \frac{1}{\alpha} + \frac{1}{\chi} + \frac{1}{\nu}. \quad (41)$$

The average covariance between an investor's signal  $\tilde{z}_i$  and other investors' signals  $\tilde{z}_j$  is given by

$$\begin{aligned} \sum_{j=1}^n \frac{1}{n} \text{cov}(\tilde{z}_i, \tilde{z}_j) &= \frac{\sum_{j=1, j \neq i}^n \text{cov}(\tilde{z}_i, \tilde{z}_j) + \text{var}(\tilde{z}_i)}{n} \\ &= \frac{1}{\alpha} + \frac{1}{\chi} + \frac{1}{n\nu}. \end{aligned} \quad (42)$$

The average correlation between investors' signals is then given by

$$\frac{\sum_{j=1}^n \frac{1}{n} \text{cov}(\tilde{z}_i, \tilde{z}_j)}{\text{var}(\tilde{z}_i)} = \frac{\frac{1}{\alpha} + \frac{1}{\chi} + \frac{1}{n\nu}}{\frac{1}{\alpha} + \frac{1}{\chi} + \frac{1}{\nu}} < 1. \quad (43)$$

That is, the imperfect communication between the FI and investors gives rise to a correlated private information structure similar to the one used in our main setting. Due to the possibility that the signals observed by different investors may not always coincide, they disagree with each other in the sense that the average correlation between their signals is positive but imperfect.

Given our joint-normal-distribution assumption, the information structure in our main setting is ultimately characterized by two moments,  $var(\tilde{x}_i)$  and  $cov(\tilde{x}_i, \tilde{x}_j)$ , with that in this micro-foundation also characterized by the variance and the average covariance of investors' signals,  $var(\tilde{z}_i)$  and  $\sum_{j=1}^n \frac{1}{n} cov(\tilde{z}_i, \tilde{z}_j)$ . Therefore, we can derive the "effective" objectivity and accuracy  $(\hat{\beta}, \hat{\gamma})$  in our micro-foundation by equating  $var(\tilde{x}_i) = var(\tilde{z}_i)$  and  $cov(\tilde{x}_i, \tilde{x}_j) = \sum_{j=1}^n \frac{1}{n} cov(\tilde{z}_i, \tilde{z}_j)$ , which reduces into:

$$\begin{aligned} \frac{1}{\alpha} + \frac{1}{\hat{\beta}} + \frac{1}{\hat{\gamma}} &= \frac{1}{\alpha} + \frac{1}{\chi} + \frac{1}{\nu}, \\ \frac{1}{\alpha} + \frac{1}{\hat{\gamma}} &= \frac{1}{\alpha} + \frac{1}{\chi} + \frac{1}{n\nu}. \end{aligned} \tag{44}$$

As a result,

$$\begin{aligned} \hat{\beta} &= \frac{\nu}{1 - \frac{1}{n}}, \\ \hat{\gamma} &= \frac{1}{\frac{1}{\chi} + \frac{1}{n\nu}}. \end{aligned} \tag{45}$$

Equation (45) suggests that objectivity is determined solely by the size of the idiosyncratic measurement error  $\frac{1}{\nu}$ . In addition, when  $n$  is sufficiently large, accuracy is determined primarily by the size of the common measurement error  $\frac{1}{\chi}$ . In fact, at  $n = \infty$ , there is a one-to-one correspondence between  $\{\hat{\beta}, \hat{\gamma}\}$  and  $\{\nu, \chi\}$ , i.e.,  $\hat{\beta} = \nu$  and  $\hat{\gamma} = \chi$ . Furthermore, we verify that if the information structure under this micro-foundation is employed in our FI-run model, there exists a unique threshold  $z^*(\nu, \chi)$  such that each investor chooses to withdraw if and only if  $z_i - \bar{r} \geq z^*(\nu, \chi)$ . In addition, for  $n = \infty$ ,  $z^*(\nu, \chi) = y^*(\beta, \gamma)$  as long as  $\nu = \beta$  and  $\chi = \gamma$ . The policy implication from this micro-foundation is also straightforward. In order to enhance objectivity, FI should minimize the measurement error in each idiosyncratic measurement process.

## Appendix IV: Proofs

### Proof of Proposition 2

**Proof.** As shown in the main text, the equilibrium threshold  $y^*$  is given by the following equation,

$$\bar{r} + k_1 y^* = \Phi(k_2 y^*). \quad (46)$$

It is straightforward to verify that  $\frac{k_1}{k_2}$  is strictly decreasing in  $\alpha$ . Thus when  $\alpha \leq \alpha_H$ ,  $\frac{k_1}{k_2} \geq \frac{k_1}{k_2}|_{\alpha=\alpha_H} = \sqrt{\frac{1}{2\pi}}$ . Therefore,

$$k_1 \geq k_2 \sqrt{\frac{1}{2\pi}} \geq k_2 \phi(k_2 y^*), \quad (47)$$

that is, the slope of the LHS of equation (46),  $\bar{r} + k_1 y^*$ , is always greater than the slope the RHS of equation (46),  $\Phi(k_2 y^*)$ , which guarantees a unique solution to the equation. As a result, for  $\alpha \leq \alpha_H$ , there exists a unique equilibrium such that every investor withdraws if and only if  $\tilde{y}_i < y^*$ .

■

### Proof of Corollary 1

**Proof.** Given  $y^{FB} = -\frac{(\frac{1}{\alpha} + \frac{1}{\gamma})\bar{r}}{\frac{1}{\alpha}}$ ,  $y^{FB} < 0$ . In addition, it can be verified that given  $\bar{r} \leq \frac{1}{2}$ ,  $y^* \geq 0$ . To see this, consider the function  $f(y)$ :

$$f(y) = \bar{r} + k_1 y - \Phi(k_2 y), \quad (48)$$

$f(y)$  is continuous in  $y$ ,  $f(0) = \bar{r} - \frac{1}{2} \leq 0$ , and  $f(\frac{1-\bar{r}}{k_1}) > 0$ . Therefore, by the intermediate value theorem, the unique root of the equation  $f(y) = 0$ ,  $y^*$ , must be between 0 and  $\frac{1-\bar{r}}{k_1}$ . That is,  $y^* \geq 0$ .

■

### Proof of Proposition 3

**Proof.** Since  $y^*$  solves,

$$\bar{r} + k_1 y^* = \Phi(k_2 y^*), \quad (49)$$

using the implicit function theorem and taking the derivative with respect to  $\beta$  and  $\gamma$  on the both sides of the equation, we have,

$$k_1 \frac{\partial y^*}{\partial m} + y^* \frac{\partial k_1}{\partial m} = \phi(k_2 y^*) \left( k_2 \frac{\partial y^*}{\partial m} + y^* \frac{\partial k_2}{\partial m} \right), \quad m \in \{\beta, \gamma\}, \quad (50)$$

which gives,

$$\frac{\partial y^*}{\partial m} = \frac{y^* \left( \phi(k_2 y^*) \frac{\partial k_2}{\partial m} - \frac{\partial k_1}{\partial m} \right)}{k_1 - k_2 \phi(k_2 y^*)}, \quad m \in \{\beta, \gamma\}. \quad (51)$$

Since  $\alpha \leq \alpha_H$ ,

$$k_1 \geq k_2 \sqrt{\frac{1}{2\pi}} \geq k_2 \phi(k_2 y^*), \quad (52)$$

and we have shown that  $y^* \geq 0$  in Corollary 1, thus the denominator of  $\frac{\partial y^*}{\partial m}$  is always positive.

It remains to check the sign of several derivatives,  $\left\{ \frac{\partial k_1}{\partial \beta}, \frac{\partial k_2}{\partial \beta}, \frac{\partial k_1}{\partial \gamma}, \frac{\partial k_2}{\partial \gamma} \right\}$ . Denote  $\frac{1}{q} = \frac{1}{\alpha} + \frac{1}{\beta} + \frac{1}{\gamma}$  as the variance of the private signal and  $\rho = \left( \frac{1}{\alpha} + \frac{1}{\gamma} \right) q = 1 - \frac{q}{\beta}$  the correlation among the private signals. As a result,  $k_1 = \frac{1}{\alpha} q$  and  $k_2 = \sqrt{\frac{1-\rho}{1+\rho}} q$ . Notice that improving  $\gamma$  and  $\beta$  affects  $k_1$  and  $k_2$  only through affecting  $q$  (the fundamental value of information) and  $\rho$  (the strategic value of information). We have

$$\begin{aligned} & \phi(k_2 y^*) \frac{\partial k_2}{\partial \beta} - \frac{\partial k_1}{\partial \beta} \\ &= \left[ \phi(k_2 y^*) \frac{\partial k_2}{\partial \rho} - \frac{\partial k_1}{\partial \rho} \right] \frac{\partial \rho}{\partial \beta} + \left[ \phi(k_2 y^*) \frac{\partial k_2}{\partial q} - \frac{\partial k_1}{\partial q} \right] \frac{\partial q}{\partial \beta} \\ &= -\phi(k_2 y^*) \frac{\sqrt{q} \frac{1}{(1+\rho)^2} q^2}{\sqrt{\frac{1-\rho}{1+\rho}}} \beta^2 \left( \frac{1}{q} - \frac{1}{\beta} \right) + \left( \frac{k_2}{2} \phi(k_2 y^*) - k_1 \right) \frac{q}{\beta^2} < 0, \end{aligned} \quad (53)$$

the last inequality is due to  $k_1 \geq k_2 \phi(k_2 y^*) > \frac{k_2}{2} \phi(k_2 y^*)$ . That is, improving  $\beta$  increases both  $\rho$  and  $q$ , leading to a lower  $y^*$ . As a result,  $\frac{\partial y^*}{\partial \beta} < 0$ . Similarly,

$$\begin{aligned} & \phi(k_2 y^*) \frac{\partial k_2}{\partial \gamma} - \frac{\partial k_1}{\partial \gamma} \\ &= \left[ \phi(k_2 y^*) \frac{\partial k_2}{\partial \rho} - \frac{\partial k_1}{\partial \rho} \right] \frac{\partial \rho}{\partial \gamma} + \left[ \phi(k_2 y^*) \frac{\partial k_2}{\partial q} - \frac{\partial k_1}{\partial q} \right] \frac{\partial q}{\partial \gamma} \\ &= \phi(k_2 y^*) \frac{\sqrt{q} \frac{1}{(1+\rho)^2} q^2}{\sqrt{\frac{1-\rho}{1+\rho}}} \frac{1}{\gamma^2} \beta + \left( \frac{k_2}{2} \phi(k_2 y^*) - k_1 \right) \frac{q}{\gamma^2}, \end{aligned} \quad (54)$$

where the first term is positive due to  $\frac{\partial \rho}{\partial \gamma} < 0$  (improving  $\gamma$  reduces the strategic value) and the second term is negative due to  $\frac{\partial q}{\partial \gamma} > 0$  (improving  $\gamma$  increases the fundamental value). Therefore, the sign of  $\frac{\partial y^*}{\partial \gamma}$  is ambiguous and depends on the trade-off between the strategic and the fundamental value of information. For  $\frac{\partial y^*}{\partial \gamma} < 0$ , we must have  $\phi(k_2 y^*) \frac{\partial k_2}{\partial \gamma} - \frac{\partial k_1}{\partial \gamma} < 0$ , which can be reduced into

$$g(\alpha) = \alpha \left( \frac{\sqrt{q} \frac{1}{(1+\rho)^2} \frac{1}{\beta}}{\sqrt{\frac{1-\rho}{1+\rho}}} + \sqrt{\frac{1-\rho}{1+\rho}} \frac{1}{q} \right) < \frac{1}{\phi(k_2 y^*)}. \quad (55)$$

One can verify that the LHS  $g(\alpha)$  is strictly increasing in  $\alpha$ . In addition, at  $\alpha = 0$ , the LHS is zero, i.e.,

$$g(0) < \sqrt{2\pi} < \frac{1}{\phi(k_2 y^*)}, \quad (56)$$

while at  $\alpha = \alpha_H$ , we verify that  $g(\alpha_H) > \sqrt{2\pi}$ . Therefore, by the intermediate value theorem, there exists an  $\alpha_L \in [0, \alpha_H)$  such that  $g(\alpha_L) = \sqrt{2\pi}$ . For  $\alpha < \alpha_L$ ,

$$g(\alpha) < g(\alpha_L) = \sqrt{2\pi} < \frac{1}{\phi(k_2 y^*)}, \quad (57)$$

and thus we have  $\frac{\partial y^*}{\partial \gamma} < 0$ . ■

### Proof of Proposition 4

**Proof.** From the proof of Proposition 3,

$$\begin{aligned} & \frac{\partial y^*}{\partial \beta} - \frac{\partial y^*}{\partial \gamma} \\ &= \frac{y^*}{k_1 - k_2 \phi(k_2 y^*)} \left[ \phi(k_2 y^*) \frac{\partial k_2}{\partial \beta} - \phi(k_2 y^*) \frac{\partial k_2}{\partial \gamma} + \frac{\partial k_1}{\partial \beta} - \frac{\partial k_1}{\partial \gamma} \right] \\ &= \frac{-\phi(k_2 y^*) \frac{\sqrt{q} \frac{1}{(1+\rho)^2}}{\sqrt{\frac{1-\rho}{1+\rho}}} \left( \frac{q^2}{\beta^2} \left( \frac{1}{q} - \frac{1}{\beta} \right) + \frac{q^2}{\gamma^2} \frac{1}{\beta} \right) + \left( \phi(k_2 y^*) \sqrt{\frac{1-\rho}{1+\rho}} \frac{1}{q} \frac{1}{2} - \frac{1}{\alpha} \right) \left( \frac{q^2}{\beta^2} - \frac{q^2}{\gamma^2} \right)}{k_1 - k_2 \phi(k_2 y^*)}, \end{aligned} \quad (58)$$

thus  $\frac{\partial y^*}{\partial \beta} < \frac{\partial y^*}{\partial \gamma}$  if and only if

$$-\phi(k_2 y^*) \frac{\sqrt{q} \frac{1}{(1+\rho)^2}}{\sqrt{\frac{1-\rho}{1+\rho}}} \left( \frac{q^2}{\beta^2} \left( \frac{1}{q} - \frac{1}{\beta} \right) + \frac{q^2}{\gamma^2} \frac{1}{\beta} \right) + \left( \phi(k_2 y^*) \sqrt{\frac{1-\rho}{1+\rho}} \frac{1}{q} \frac{1}{2} - \frac{1}{\alpha} \right) \left( \frac{q^2}{\beta^2} - \frac{q^2}{\gamma^2} \right) < 0, \quad (59)$$

where the first term is always negative. If  $\beta \leq \gamma$ ,  $\frac{q^2}{\beta^2} - \frac{q^2}{\gamma^2} \geq 0$ , and the second term is also negative. As a result, for  $\beta \leq \gamma$ ,  $\frac{\partial y^*}{\partial \beta} < \frac{\partial y^*}{\partial \gamma}$ . For  $\beta > \gamma$ ,  $\frac{\partial y^*}{\partial \beta} < \frac{\partial y^*}{\partial \gamma}$  if and only if

$$\left( \frac{\beta}{\gamma} \right)^2 - 1 < \frac{\phi(k_2 y^*) \frac{\sqrt{q} \frac{1}{(1+\rho)^2}}{\sqrt{\frac{1-\rho}{1+\rho}}}}{\frac{1}{q} - \frac{1}{\beta} + \left( \frac{\beta}{\gamma} \right)^2} < \frac{\frac{1}{\alpha} - \phi(k_2 y^*) \sqrt{\frac{1-\rho}{1+\rho}} \frac{1}{q} \frac{1}{2}}{\frac{1}{\alpha} - \phi(k_2 y^*) \sqrt{\frac{1-\rho}{1+\rho}} \frac{1}{q} \frac{1}{2}}, \quad (60)$$

where the LHS is strictly increasing in  $\frac{\beta}{\gamma}$ . At  $\frac{\beta}{\gamma} = 1$ , the LHS is zero while the RHS is positive. At  $\frac{\beta}{\gamma} = \infty$ , the LHS is 1. If RHS is always larger than 1, then for any  $\beta$  and  $\gamma$ , we have the LHS smaller than the RHS, i.e., the threshold  $\Delta = \infty$  such that for  $\frac{\beta}{\gamma} < \Delta$ ,  $\frac{\partial y^*}{\partial \beta} < \frac{\partial y^*}{\partial \gamma}$ . If the RHS can

be smaller than 1, then by monotonicity of  $\frac{\left(\frac{\beta}{\gamma}\right)^2 - 1}{\frac{1}{4} - \frac{1}{\beta} + \left(\frac{\beta}{\gamma}\right)^2}$ , for  $\frac{\beta}{\gamma}$  sufficiently close to 1, we have the LHS smaller than the RHS, i.e., there exists a  $\Delta > 1$ , such that for  $\frac{\beta}{\gamma} < \Delta$ ,  $\frac{\partial y^*}{\partial \beta} < \frac{\partial y^*}{\partial \gamma}$ . ■

### Proof of Proposition 5

**Proof.** In the proof of Proposition 3, we have shown  $\frac{\partial y^*}{\partial \beta} < 0$  and for  $\alpha < \alpha_L$ ,  $\frac{\partial y^*}{\partial \gamma} < 0$ . It thus remains to show that for  $\alpha_L < \alpha \leq \alpha_H$  and  $\bar{r}$  sufficiently close to  $\frac{1}{2}$ ,  $\frac{\partial y^*}{\partial \gamma} > 0$ . Notice first that when  $\bar{r}$  is sufficiently close to  $\frac{1}{2}$ ,  $y^*$  approaches 0 and  $\phi(k_2 y^*)$  approaches  $\sqrt{\frac{1}{2\pi}}$ . Also as shown in the proof of Proposition 3, for  $\alpha \in (\alpha_L, \alpha_H)$ ,

$$g(\alpha) > g(\alpha_L) = \sqrt{2\pi}, \quad (61)$$

therefore, when  $\bar{r}$  is sufficiently close to  $\frac{1}{2}$ ,  $\phi(k_2 y^*)$  approaches  $\sqrt{\frac{1}{2\pi}}$ , and  $g(\alpha) > \frac{1}{\phi(k_2 y^*)}$  for  $\alpha \in (\alpha_L, \alpha_H)$ . Hence we have  $\frac{\partial y^*}{\partial \gamma} > 0$ . ■

### Proof of Corollary 2

**Proof.** We first derive the equilibrium amount of withdrawals  $l$ , which depends on the fundamentals  $\tilde{r}$ . Specifically, given  $\tilde{r}$ , investor  $i$ 's signal  $\tilde{y}_i$  is normally distributed with a mean  $\tilde{r} - \bar{r}$  and a variance  $\frac{1}{\gamma} + \frac{1}{\beta}$ . Thus given the withdrawal threshold  $y^*$ , the portion of the investors who withdraw is

$$l(\tilde{r}) = \Pr(\tilde{y}_i \leq y^*) = \Phi \left( \sqrt{\frac{\beta\gamma}{\beta + \gamma}} [y^* - (\tilde{r} - \bar{r})] \right). \quad (62)$$

Substituting the expression of  $l(\tilde{r})$  into the conditional social welfare  $W(\tilde{r})$  gives,

$$W(\tilde{r}) = \left[ 1 - \Phi \left( \sqrt{\frac{\beta\gamma}{\beta + \gamma}} [y^* - (\tilde{r} - \bar{r})] \right) \right] \left[ \tilde{r} - \Phi \left( \sqrt{\frac{\beta\gamma}{\beta + \gamma}} [y^* - (\tilde{r} - \bar{r})] \right) \right], \quad (63)$$

and the ex-ante social welfare is

$$W = E_{\tilde{r}}[W(\tilde{r})]. \quad (64)$$

Recall that the prior of  $\tilde{r}$  is normally distributed with a mean  $\bar{r}$  and a variance  $\frac{1}{\alpha}$ . Changing  $\tilde{r}$  with  $\tilde{s} = \sqrt{\alpha}(\tilde{r} - \bar{r})$  yields,

$$W = E_{\tilde{s}} \left[ \left[ 1 - \Phi \left( \sqrt{\frac{\beta\gamma}{\beta + \gamma}} \left( y^* - \frac{\tilde{s}}{\sqrt{\alpha}} \right) \right) \right] \left[ \bar{r} + \frac{\tilde{s}}{\sqrt{\alpha}} - \Phi \left( \sqrt{\frac{\beta\gamma}{\beta + \gamma}} \left( y^* - \frac{\tilde{s}}{\sqrt{\alpha}} \right) \right) \right] \right], \quad (65)$$

where  $\tilde{s} \sim N(0, 1)$ . We now compare the effects of improving the accuracy and objectivity on the social welfare. To level the playing field, we focus on the case  $\beta = \gamma$ . Taking the derivative of  $W$  with respect to the accuracy and objectivity gives:

$$\begin{aligned}\frac{\partial W}{\partial \gamma} &= T_1 \frac{\partial y^*}{\partial \gamma} + \frac{1}{2} \sqrt{\frac{1}{\gamma}} \left( \frac{\beta}{\beta + \gamma} \right)^{\frac{3}{2}} T_2, \\ \frac{\partial W}{\partial \beta} &= T_1 \frac{\partial y^*}{\partial \beta} + \frac{1}{2} \sqrt{\frac{1}{\beta}} \left( \frac{\gamma}{\beta + \gamma} \right)^{\frac{3}{2}} T_2.\end{aligned}\tag{66}$$

where

$$\begin{aligned}T_1 &= E_{\tilde{s}} \left[ \left( 2 \Phi \left( \sqrt{\frac{\beta\gamma}{\beta + \gamma}} \left( y^* - \frac{\tilde{s}}{\sqrt{\alpha}} \right) \right) - 1 - \bar{r} - \frac{\tilde{s}}{\sqrt{\alpha}} \right) \phi \left( \sqrt{\frac{\beta\gamma}{\beta + \gamma}} \left( y^* - \frac{\tilde{s}}{\sqrt{\alpha}} \right) \right) \right], \\ T_2 &= E_{\tilde{s}} \left[ \left( 2 \Phi \left( \sqrt{\frac{\beta\gamma}{\beta + \gamma}} \left( y^* - \frac{\tilde{s}}{\sqrt{\alpha}} \right) \right) - 1 - \bar{r} - \frac{\tilde{s}}{\sqrt{\alpha}} \right) \phi \left( \sqrt{\frac{\beta\gamma}{\beta + \gamma}} \left( y^* - \frac{\tilde{s}}{\sqrt{\alpha}} \right) \right) \left( y^* - \frac{\tilde{s}}{\sqrt{\alpha}} \right) \right].\end{aligned}\tag{67}$$

In the symmetric case  $\beta = \gamma$ , we have

$$\frac{\partial W}{\partial \beta} - \frac{\partial W}{\partial \gamma} = T_1 \left( \frac{\partial y^*}{\partial \beta} - \frac{\partial y^*}{\partial \gamma} \right).\tag{68}$$

Proposition 4 shows that  $\frac{\partial y^*}{\partial \beta} < \frac{\partial y^*}{\partial \gamma}$ . Therefore,  $\frac{\partial W}{\partial \beta} > \frac{\partial W}{\partial \gamma}$  if and only if  $T_1 < 0$ . We have

$$T_1 = E_{\tilde{s}} \left[ \left( 2 \Phi \left( \sqrt{\frac{\beta\gamma}{\beta + \gamma}} \left( y^* - \frac{\tilde{s}}{\sqrt{\alpha}} \right) \right) - 1 - \bar{r} - \frac{\tilde{s}}{\sqrt{\alpha}} \right) \phi \left( \sqrt{\frac{\beta\gamma}{\beta + \gamma}} \left( y^* - \frac{\tilde{s}}{\sqrt{\alpha}} \right) \right) \right].\tag{69}$$

Let  $\tau = \sqrt{\frac{\beta\gamma}{\alpha(\beta + \gamma)}}$  and  $Y = \sqrt{\frac{\beta\gamma}{\beta + \gamma}} y^*$ , we have

$$\begin{aligned}T_1 &= \int_{-\infty}^{+\infty} \left[ 2 \Phi(Y - \tau \tilde{s}) - \frac{\tilde{s}}{\sqrt{\alpha}} - \bar{r} - 1 \right] \phi(Y - \tau \tilde{s}) \phi(\tilde{s}) d\tilde{s} \\ &= \int_{-\infty}^{+\infty} \left[ 2 \Phi(Y - \tau \tilde{s}) - \frac{\tilde{s}}{\sqrt{\alpha}} - \bar{r} - 1 \right] \frac{1}{2\pi} e^{-\frac{\tau^2 + 1}{2} \left( \tilde{s} - \frac{\tau Y}{\tau^2 + 1} \right)^2 - \frac{Y^2}{2} \left( \frac{1}{\tau^2 + 1} \right)} d\tilde{s},\end{aligned}\tag{70}$$

and changing  $\tilde{s} = \frac{\tilde{t}}{\sqrt{\tau^2+1}} + \frac{\tau Y}{\tau^2+1}$  gives

$$\begin{aligned}
& T_1 \tag{71} \\
&= \frac{e^{-\frac{Y^2}{2}\left(\frac{1}{\tau^2+1}\right)}}{\sqrt{2\pi(\tau^2+1)}} \int_{-\infty}^{+\infty} \left[ 2\Phi\left(\frac{Y}{\tau^2+1} - \frac{\tau\tilde{t}}{\sqrt{\tau^2+1}}\right) - \frac{\frac{\tilde{t}}{\sqrt{\tau^2+1}} + \frac{\tau Y}{\tau^2+1}}{\sqrt{\alpha}} - \bar{r} - 1 \right] \frac{1}{\sqrt{2\pi}} e^{-\frac{\tilde{t}^2}{2}} d\tilde{t} \\
&= \frac{e^{-\frac{Y^2}{2}\left(\frac{1}{\tau^2+1}\right)}}{\sqrt{2\pi(\tau^2+1)}} E_{\tilde{t}} \left[ 2\Phi\left(\frac{Y}{\tau^2+1} - \frac{\tau\tilde{t}}{\sqrt{\tau^2+1}}\right) - \frac{\frac{\tilde{t}}{\sqrt{\tau^2+1}} + \frac{\tau Y}{\tau^2+1}}{\sqrt{\alpha}} - \bar{r} - 1 \right] \\
&= \frac{e^{-\frac{Y^2}{2}\left(\frac{1}{\tau^2+1}\right)}}{\sqrt{2\pi(\tau^2+1)}} \left[ 2\Phi\left(\frac{Y}{\sqrt{(\tau^2+1)(2\tau^2+1)}}\right) - \frac{\tau Y}{\sqrt{\alpha}(\tau^2+1)} - \bar{r} - 1 \right],
\end{aligned}$$

which suggests that  $T_1 < 0$  if and only if

$$\bar{r} > 2\Phi\left(\frac{Y}{\sqrt{(\tau^2+1)(2\tau^2+1)}}\right) - \frac{\tau Y}{\sqrt{\alpha}(\tau^2+1)} - 1. \tag{72}$$

Given  $\beta = \gamma$ , the term  $2\Phi\left(\frac{Y}{\sqrt{(\tau^2+1)(2\tau^2+1)}}\right) - \frac{\tau Y}{\sqrt{\alpha}(\tau^2+1)} - \bar{r} - 1$  becomes

$$2\Phi\left(\sqrt{\frac{\alpha^2\gamma}{(2\alpha+\gamma)(\alpha+\gamma)}}y^*\right) - \frac{\gamma}{\gamma+2\alpha}y^* - \bar{r} - 1, \tag{73}$$

In addition, we have

$$\bar{r} + k_1 y^* = \Phi(k_2 y^*), \tag{74}$$

where at  $\beta = \gamma$ ,  $k_1 = \frac{\gamma}{\gamma+2\alpha}$ , and  $k_2 = \sqrt{\frac{\alpha^2\gamma}{(2\alpha+\gamma)(3\alpha+\gamma)}}$ . Thus

$$\begin{aligned}
& 2\Phi\left(\sqrt{\frac{\alpha^2\gamma}{(2\alpha+\gamma)(\alpha+\gamma)}}y^*\right) - \frac{\gamma}{\gamma+2\alpha}y^* - \bar{r} - 1 \tag{75} \\
&= 2\Phi\left(\sqrt{\frac{\alpha^2\gamma}{(2\alpha+\gamma)(\alpha+\gamma)}}y^*\right) - \Phi(k_2 y^*) - 1,
\end{aligned}$$

and  $T_1 < 0$  if and only if

$$\Phi\left(\sqrt{\frac{\alpha^2\gamma}{(2\alpha+\gamma)(\alpha+\gamma)}}y^*\right) - \Phi\left(\sqrt{\frac{\alpha^2\gamma}{(2\alpha+\gamma)(3\alpha+\gamma)}}y^*\right) < 1 - \Phi\left(\sqrt{\frac{\alpha^2\gamma}{(2\alpha+\gamma)(\alpha+\gamma)}}y^*\right). \tag{76}$$

Now consider two special cases. When  $\bar{r}$  is sufficiently close to  $\frac{1}{2}$ ,  $y^*$  approaches 0. Thus the LHS of the inequality (76) approaches 0, while the RHS approaches  $\frac{1}{2}$ . Thus the inequality (76) holds and



$T_1 < 0$ . On the other hand, when  $\alpha$  is close to 0,  $k_1$  approaches 1 and  $k_2$  approaches 0, which gives  $y^* = \frac{1}{2} - \bar{r} > 0$ . Therefore, the LHS of the inequality (76) approaches 0, while the RHS approaches  $\frac{1}{2}$ . Thus the inequality (76) holds and  $T_1 < 0$ . ■

### Proof of Corollary 3

**Proof.** Note first that following the analysis in our main model, it is straightforward to verify that if the regulator always discloses, investors withdraw if and only if  $y_i \leq y^*$ . We thus focus on verifying that given the investors' strategies, the regulator always discloses. From equation (62), conditional on  $\tilde{r}$ , the portion of investors who withdraw upon disclosure is

$$l(1, \tilde{r}) = \Pr(\tilde{y}_i \leq y^*) = \Phi \left( \sqrt{\frac{\beta\gamma}{\beta + \gamma}} [y^* - (\tilde{r} - \bar{r})] \right). \quad (77)$$

$l(1, r)$  is strictly decreasing in  $r$  and thus  $V(1, r) = -l(1, r)$  is strictly increasing in  $r$ .

We show that the regulator's equilibrium no-disclosure set  $ND$  must take the form of  $\{r | r \leq \hat{r}\}$ . To see this, suppose at some  $r = r'$ , the regulator chooses not to disclose. It must be the case that  $V(1, r') = -l(1, r') < V(0, r') = -l(0, r')$ . Now consider whether the regulator discloses for  $r < r'$ . Note that if the regulator chooses not to disclose, each investor's information regarding  $\tilde{r}$  must be the same and as a result, each investor makes the same decision. That is,  $l$  is either 0 or 1 and thus independent of  $\tilde{r}$ . Therefore

$$V(0, r) = V(0, r') > V(1, r') > V(1, r). \quad (78)$$

The first equality follows because  $l(0, r)$  is independent of  $r$  and the last inequality follows because  $V(1, r)$  is strictly increasing in  $r$ . That is, the regulator does not disclose for  $r < r'$ , which implies that  $ND = \{r | r \leq \hat{r}\}$ .

Next, we show the disclosure cutoff  $\hat{r} = -\infty$  such that the regulator always discloses. If the regulator discloses, her payoff is  $V(1, r) = -l(1, r) = -\Phi \left( \sqrt{\frac{\beta\gamma}{\beta + \gamma}} [y^* - (r - \bar{r})] \right) \geq -1$ . If the regulator chooses not to disclose, investors receive no information but understand that  $r \leq \hat{r}$ . As a result, investors hold an expectation of  $r$  as  $E[r | r \leq \hat{r}]$ . In this situation, there could be two equilibria. If all investors choose to withdraw, i.e.,  $l = 1$ , then the expected payoff of staying  $E[r | r \leq \hat{r}] - 1$  is lower than that of withdrawing 0. As a result,  $l = 1$  is an equilibrium. On the other hand, if all investors choose to stay, i.e.,  $l = 0$ , then the expected payoff of staying  $E[r | r \leq \hat{r}]$  is greater than that of withdrawing 0. Therefore,  $l = 0$  is also an equilibrium. However, once we apply the global game technique and assume that investors' belief differs from others' by an

infinitesimal amount of noise, the unique equilibrium is that  $l = 1$ . More specifically, standard results in global games (e.g., Morris and Shin, 2001b) show that  $l$  follows a uniform distribution in  $[0, 1]$  and thus the expected payoff for an investor to stay is

$$E[r - l|r \leq \hat{r}] = E[r|r \leq \hat{r}] - \frac{1}{2} < 0.$$

The last inequality follows because  $E[r|r \leq \hat{r}] < \bar{r} \leq \frac{1}{2}$ . That is, if the regulator does not disclose, the unique equilibrium is  $l(0, r) = 1$ . Under  $l(0, r) = 1$ , the regulator's payoff is  $V(0, r) = -1 \leq V(1, r)$ , where the inequality is strict if  $r > -\infty$ . The regulator thus always discloses for  $r \geq -\infty$ , i.e.,  $\hat{r} = -\infty$ . ■

### Proof of Corollary 4

**Proof.** When the disclosure cost  $c$  is close to 0, the regulator discloses for almost all  $r$ . Therefore, the regulator's disclosure decision conveys almost no information about  $r$  and investors still believe that  $r \sim N(\bar{r}, \frac{1}{\alpha})$  upon observing disclosure. Investors' equilibrium withdrawal decisions upon disclosure can be approximated by those in the costless-disclosure case. That is, investors withdraw if and only if  $y_i \leq y^*$ . From the proof of Corollary 3, the regulator's payoff when she discloses is given by

$$V(1, r) = -l(1, r) - c = -\Phi\left(\sqrt{\frac{\beta\gamma}{\beta + \gamma}}[y^* - (r - \bar{r})]\right) - c. \quad (79)$$

If the regulator does not disclose, we can follow the analysis in the costly-disclosure case and show that the unique equilibrium is that all investors withdraw and thus  $V(0, r) = -1$ . The regulator discloses if and only if  $V(1, r) \geq V(0, r)$ . Given that  $V(1, r)$  is increasing in  $r$ , we obtain that the regulator discloses if and only if  $r \geq \hat{r}$ , where  $\hat{r}$  solves

$$\Phi\left(\sqrt{\frac{\beta\gamma}{\beta + \gamma}}[y^* - (\hat{r} - \bar{r})]\right) = 1 - c. \quad (80)$$

Applying the implicit function theorem on equation (80) gives:

$$\begin{aligned} \frac{\partial \hat{r}}{\partial \beta} &= \frac{\partial y^*}{\partial \beta} + \frac{1}{2} \frac{\frac{1}{\beta^2}}{\sqrt{\frac{1}{\beta} + \frac{1}{\gamma}}} \Phi^{-1}(1 - c), \\ \frac{\partial \hat{r}}{\partial \gamma} &= \frac{\partial y^*}{\partial \gamma} + \frac{1}{2} \frac{\frac{1}{\gamma^2}}{\sqrt{\frac{1}{\beta} + \frac{1}{\gamma}}} \Phi^{-1}(1 - c). \end{aligned} \quad (81)$$

In a symmetric case  $\beta = \gamma$ ,

$$\frac{\partial \hat{r}}{\partial \beta} - \frac{\partial \hat{r}}{\partial \gamma} = \frac{\partial y^*}{\partial \beta} - \frac{\partial y^*}{\partial \gamma} < 0. \quad (82)$$

The last inequality follows from  $\frac{\partial y^*}{\partial \beta} < \frac{\partial y^*}{\partial \gamma}$  in Proposition 4. ■

### **Proof of Proposition 6**

**Proof.** The results are straightforward by observing the expressions of  $\beta = \frac{1}{\lambda^2 \delta}$  and  $\gamma = \frac{1}{\mu^2 \phi}$ . ■