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The role of information disclosure in financial intermediation with investment risk☆

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ABSTRACT

We study how information disclosure affects financial intermediation when the payoff to the long-term investment is risky. The analysis is based on a business-cycle version of the bank run model wherein a bank provides risk sharing to demand depositors who experience unobservable shocks to their liquidity preferences. The bank pre-commits to the precision of an interim signal regarding the payoff to the long-term investment. We examine the impact of bank disclosure on optimal risk sharing achieved by run-proof, signal-contingent demand-deposit contracts. We show that for utility functions that display non-increasing absolute risk aversion, more informative disclosure improves the ex ante risk sharing provided by financial intermediation.

1. Introduction

More stringent disclosure requirements for financial institutions have long been advocated by regulators (e.g., Board of Governors of the Federal Reserve System, 2000), academic researchers (French et al., 2010), and private-sector organizations.[1] Mandatory disclosure rules pervade both Basel II and Basel III (BCBS, 2006, 2017). In particular, by presenting an enhanced set of public disclosure requirements, Pillar 3 (the market discipline) of Basel II complements the other two Pillars (minimum capital requirements and supervisory review) (Lopez, 2003). As a general trend, banks are on track to expand the scope of their disclosures (e.g., BCBS, 2003).

We shed light on the efficacy of these disclosure regulations by examining the role of information disclosure in financial intermediation. Our model builds on the business-cycle version of the bank run model with aggregate risk (e.g., Allen and Gale, 1998). Demand depositors face idiosyncratic liquidity shocks, and they may value consumptions at different dates. Competitive banks raise funds from their depositors, offer them demand-deposit contracts, and invest in risky long-term assets or loans. Banks design demand-deposit contracts such that patient depositors will not mimic impatient depositors (or make any “runs” on their bank).

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[1] For example, the Working Group on Public Disclosure, a private-sector working group established by the Board of Governors of the Federal Reserve System, recommended enhanced and more frequent public disclosure of financial information by both banking and securities organizations. See: https://www.federalreserve.gov/boarddocs/press/general/2001/20010111/default.htm.

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By pooling deposits and investing in risky long-term assets (loans), banks thus provide insurance against liquidity shocks and risky returns. The novelty of our model rests in an interim signal (bank disclosure), the precision of which can be stipulated ex ante by the regulatory environment. The interim signal is released after the banks' asset portfolios are chosen, but before the long-term loans mature.

We prove that when agents have utility functions with non-increasing absolute risk aversion, more informative interim disclosure improves the risk sharing provided by the bank. To prove this result requires finding the conditions under which the following two optimization problems are equivalent: (i) the unconstrained optimization problem by the bank when agents' liquidity shocks are observable; and (ii) the constrained optimization problem by the bank when agents' types are unobservable and the contracts are incentive compatible for late consumers. We find that the equivalence holds when agents have a utility function with non-increasing absolute risk aversion, and offer intuitions based on the "prudence" property of the utility function. Once we have established the equivalence, it is straightforward to show that a more informative signal is always welfare-enhancing because the bank's optimization problem becomes a statistical decision problem (Blackwell, 1951).

In addition to their disciplinary role, bank disclosures have been used as the basis for macroprudential regulations that respond to changing economic conditions. In the context of our model, these regulatory interventions change the upper limit on how much impatient depositors can withdraw in aggregate from the bank conditional on specific realizations of the signal. With regulatory interventions, we show, through numerical analysis, that the relationship between informativeness of signal and risk-sharing may be non-monotonic and depend on additional factors, including whether the interventions are procyclical or countercyclical with respect to the signal, the strength of those interventions, and the magnitudes of credit risk and liquidity risk.

This paper is related to three strands of literature: (i) studies of how information affects risk sharing; (ii) models of financial intermediation with aggregate risk to long-term investment; and (iii) recent research on the informational and regulatory roles of supervisory actions or signals.

A considerable body of literature starting with Hirshleifer (1971) demonstrates that more information may be detrimental to risk sharing in a variety of settings (e.g., Schlee, 2001). Disclosure requirements and the disclosure of supervisory signals can have significant welfare implications for the banking industry. A recent study by Goldstein and Leitner (2018) examines the optimal disclosure policy of a bank regulator to show that disclosing too much information destroys risk-sharing opportunities. Goldstein and Sapra (2013) provide a conceptual framework for understanding the costs of disclosing supervisory signals. Our paper contributes to such studies by incorporating public disclosure and regulatory interventions into a model of financial intermediation. Departing from a standard banking model by assuming risk neutrality of late-consumers and a different asset structure, Parlatore (2015) finds that more precise information increases the economy's vulnerability to bank runs.

By incorporating aggregate risk into long-term asset payoff, this paper shares the "business cycle" view of financial intermediation adopted in prior studies.[2] Jacklin and Bhattacharya (1988) study informational runs, wherein agents receive an interim signal about fundamental risk, and compare the efficiency of a demand-deposit economy to that of an equity economy. Alonso (1996) explicitly computes the ex ante utility when there is a bank run to show that there are conditions under which bank runs are preferred to no runs at all. Allen and Gale (1998) show that bank runs may be a desirable contingency that helps achieve first-best risk sharing, a contingency absent from real-world deposit contracts.

Two recent studies are also relevant. Ahnert and Georg (2018) study a banking model of systemic risk with information contagion. Also allowing for fully contingent deposit contracts, Kučinskas (2019) studies the welfare properties of mutual funds in a Diamond-Dybvig economy with aggregate long-term investment risk and aggregate liquidity risk.

Even though prior literature has separately examined the effects of disclosure requirements (e.g., Chen and Hasan, 2006) and prudential regulation (e.g., Repullo, 2013), few studies have discussed the interactive effects of the two factors on the key function of banks: providing risk sharing.[3] In the extension of our baseline model, we evaluate the impact of bank disclosure on risk sharing in the presence of macroprudential interventions and emphasize that having more precise information may critically depend on the nature of the bank regulations. In this regard, our study is related to the emerging literature on how regulatory policies may play an informational role in various economic settings (e.g., Zwart, 2007; Baeriswyl and Cornand, 2010; James and Lawler, 2011). In these studies, governmental or regulatory interventions—such as a central bank's stabilization policy, bailouts of financial institutions, and IMF support—not only influence the payoffs of economic agents (e.g., households, financial firms, and countries), but also provide the public with incremental information regarding the underlying economic fundamentals.

Section 2 presents the basic model with interim disclosure. Section 3 studies the impact of interim disclosure. Section 4 presents an extension of the model that incorporates regulatory interventions and discusses the policy and empirical implications. Section 5 concludes.

2. The basic model

2.1. Agents and technology

We study a variant of the financial intermediation model first proposed by Diamond and Dybvig (1983) and found also in Jacklin (1987), Jacklin and Bhattacharya (1988), Allen and Gale (1998), and Farhi et al. (2009). In this model, financial intermediation or banking provides insurance against unobservable liquidity shocks faced by demand depositors. Our version of the model includes two important features. First, as with Jacklin and Bhattacharya (1988) and Allen and Gale (1998), the payoff to the long-term investment technology is uncertain (the "business cycle" view of bank runs). Second, as introduced in Section 3, a noisy signal on the future payoff of the long-term asset is disclosed to the public at the interim date. Unlike in Jacklin and Bhattacharya (1988) and Alonso (1996), the interim signal in our model is used as the basis for contracting between the bank and demand depositors as well as used for regulatory interventions.

Financial intermediation. There are three dates $t = 0, 1, 2$ and a single, all-purpose commodity that can either be invested or consumed. There are two types of investment technologies: short-term and long-term. The short-term investment is a storage technology that returns one unit of consumption good at $t+1$ for each unit invested at t; long-term investment (which can be interpreted as

[2] The business cycle view contrasts with the sunspot view of bank runs. Studies that adopt this view include Bryant (1980), Calomiris and Gorton (1991), Chari and Jagannathan (1988), and especially, Jacklin and Bhattacharya (1988), Alonso (1996), and Allen and Gale (1998). See Allen and Gale (2007) for a literature review.

[3] Ratnovski (2013) studied the interaction between liquidity buffer and transparency; however, his focus was on bank risk management.

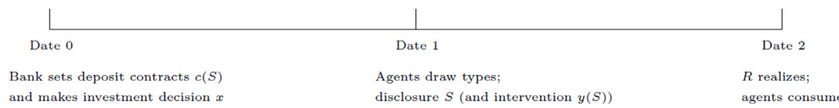

Fig. 1. Timeline of the model.

a risky "loan") pays off at date 2 for each unit invested at date 0. The return to the long-term investment, R, is a discrete random variable. The probability measure of R is $p(\cdot)$.

The long-term investment is entirely irreversible. If liquidated at the intermediate date (date 1), it yields 0. Banks have access to both short-term and long-term investment technologies, but agents only have access to the short-term technology. Banks collect deposits from agents and make investment decisions.

We assume that competition among banks drives bank profit to zero, so that banks will offer deposit contracts that maximize the expected utility of depositors. Therefore, the optimization problem of a representative bank is an optimal risk sharing problem as would be faced by a benevolent social planner. This assumption, also adopted by Allen and Gale (1998) and Fahri et al. (2009) among others, isolates the risk-sharing role of financial intermediation from other frictions that impact banks' efficiency such as agency issues. In the following we study the portfolio choice and the design of optimal demand-deposit contracts by a representative bank.

Depositors and liquidity shocks. There are a continuum of agents (or interchangeably, depositors). Each agent has an initial endowment of one unit of the consumption good at date 0 and none at subsequent dates. Ex ante, agents are identical and uncertain about their types, which will be privately observed at date 1 as idiosyncratic liquidity shocks: with probability π an agent is hit by a liquidity shock, and only values consumption at date 1 (or interchangeably, type-1 agent, "impatient" consumer, or "early" consumer); with probability $1-\pi$ an agent only values consumption at date 2 (type-2 agent, "patient" consumer, or "late" consumer). In summary, with consumption c_t at date t, $t = 1, 2$:

$$U(c_1, c_2) = \begin{cases} u(c_1) & \text{with probability} \quad \pi \\ u(c_2) & \text{with probability} \quad 1-\pi \end{cases} \tag{1}$$

where $u(\cdot)$ satisfies $u'(\cdot) > 0$ and $u''(\cdot) < 0$. Liquidity shocks are i.i.d. across agents. Given the continuum of agents, the Law of Large Numbers dictates that the fraction of type-j agents is deterministic. The lack of aggregate uncertainty over the composition of consumers makes risk sharing possible. The bank is modeled as an ex ante optimal mechanism allowing depositors to insure against the liquidity shock. Note that because preference types are only privately observed by agents, type-2 agents may claim to be type-1, obtain type-1 consumption at date 1, and use the storage technology to save it for date 2. It is assumed that $\sum_R u(R)p(R) > u(1)$, i.e., an agent who knows for sure that she is patient would want to invest in the long-term investment.[4]

"Depositors" in the model should not be narrowly interpreted as depositors of a traditional commercial bank. Rather, they may be any suppliers of short-term capital. For example, money market funds perform maturity transformation by investing in long-term assets while offering investors the ability to withdraw funds on demand. Such examples are abundant, as the intermediation functions traditionally associated with commercial banks are increasingly performed by non-bank institutions.

Contingency of demand-deposit contracts. A demand deposit is a contract that requires a depositor to deposit one unit of her endowment at date 0 in exchange for the right to withdraw a prespecified amount at a later date, conditional on the self-reported type and other information. As Jacklin (1987) argues, this contract optimally combines the two types of deposits that real-world depositors may hold: a long-term (two-period) savings deposit and a short-term (one-period) checking account, similar to the demand-deposit contract in Diamond and Dybvig (1983).

Demand-deposit contracts are written at date 0, in anticipation of all contractible contingencies at dates 1 and 2. At date 1, the uncertainty about depositors' liquidity preferences is resolved and agents types are privately revealed, but the uncertainty about returns to the risky project remains; this uncertainty is only partially resolved by a signal to be introduced in Section 3. Therefore, when there is an interim signal, date 1 consumptions will depend on reported types and the supervisory signal, while date 2 consumptions will depend on reported types, the signal, and the actual payoff to the risky long-term asset (loan). The timeline of the model is illustrated by Fig. 1.

2.2. *Financial intermediation without disclosure*

We first consider the benchmark case wherein there is no interim disclosure. The contracted consumption will only be contingent on reported types and realized loan payoffs: $c \equiv (c_1, c_2(R))$, where c_1 is the consumption (withdrawal) of agents who claim to be type 1 at date 1, and $c_2(R)$ is the date-2 consumption of agents who claim to be type-2, conditional on the risky loan payoff turning out to be R. The bank chooses deposit contract c and makes investment decision x to solve the following constrained efficiency problem P^1:

$$\max_{c_1, c_2(\cdot), x} \quad \pi u(c_1) + (1-\pi)\sum_R u(c_2(R))p(R) \tag{2}$$

$$\text{s.t.} \quad \pi c_1 \leqslant x, \tag{3}$$

$$\pi c_1 + (1-\pi)c_2(R) = x + R(1-x), \ \forall \ R, \tag{4}$$

$$\sum_R u(c_2(R))p(R) \geqslant u(c_1). \tag{5}$$

$x \in [0, 1]$ denotes the short-term investment in the storage technology and $1-x$ denotes the long-term investment. Eq. (3) states that the aggregate withdrawal (consumption) by type-1 agents has to be less than or equal to the investment in storage technology, which will be referred to as liquidity constraint. Eq. (4) is the resource constraint contingent on risky loan payoff, stating that the total consumption by all agents shall not exceed the total return obtained from the two investment technologies. Because agent types are unobservable, late consumers can potentially pretend to be early consumers, obtain consumption at date 1, and store it for consumption at date 2. Eq. (5) is the incentive-compatibility (IC) constraint that precludes misrepresentation by type-2 agents. Note that it is never optimal for a type-1 agent to mimic a type-2 agent because the former does not value consumption at date 2.

With financial intermediation, agents can pool individual liquidity risk and make more efficient aggregate investment decisions. How well the bank provides risk sharing can thus be quantified by a representative consumer's expected utility achieved through the bank's optimization program.

[4] Our main results do not rely on this assumption.

Now consider the first-best risk sharing problem, termed P^0, in which agents' liquidity shocks are observable by the bank. In other words, P^0 is defined as P^1 without the IC constraint. By definition, the value achieved by P^1 is bounded above by the first-best benchmark, P^0. However, the following proposition shows that for a broad category of utility functions, P^1 reaches the upper bound of P^0.

Proposition 1 (equivalence). *The solution to the problem is identical to the solution without constraint (5) if the utility function $u(c)$ displays non-increasing absolute risk aversion, i.e., $-u''(c)/u'(c)$ is non-increasing in c.*

The proof of Proposition 1 is provided in the Appendix. Proposition 1 establishes the conditions for equivalence between unconstrained efficiency and constrained efficiency. This result is the "business-cycle" counterpart (i.e., where the payoff to the long-term asset is uncertain) to the equivalence result obtained when the payoff to the long-term asset is deterministic, as seen in Diamond and Dybvig (1983) and Farhi et al. (2009).

Example 1 *(Exponential utility and binary payoff).* To illustrate the equivalence result, assume that agents' utility function takes exponential form, $u(c) = -\frac{1}{\gamma}\exp(-\gamma c)$, where $\gamma > 0$ is the risk-aversion coefficient. Although the exponential utility function has the drawback of allowing the possibility of negative consumption,[5] it is extremely tractable. The risky payoff follows a binary distribution: $R = R_L$ with probability θ and $R = R_H$ with probability $1 - \theta$. The contracted consumption is: $c \equiv (c_1, c_{2H}, c_{2L})$, where c_1 is the consumption (withdrawal) of agents who claim to be type 1 at date 1, and c_{2H} (c_{2L}) is the date-2 consumption of agents who claim to be type-2, conditional on the risky loan payoff R_H (R_L). The bank chooses deposit contract c and makes portfolio decision x to maximize $\pi u(c_1) + (1-\pi)\left[\theta u(c_{2L}) + (1-\theta)u(c_{2H})\right]$.

Consider the bank's optimization problem without the IC constraint. The Kuhn–Tucker conditions imply that

$$u'(c_1) \geqslant (1-\theta)u'(c_{2H}) + \theta u'(c_{2L}), \tag{6}$$

which, with exponential utility functions, is equivalent to

$$u(c_1) \leqslant (1-\theta)u(c_{2H}) + \theta u(c_{2L}). \tag{7}$$

Therefore, the IC constraint is automatically satisfied.

3. Financial intermediation with disclosure

3.1. Interim disclosure

We now augment the model with bank disclosure (an interim signal) and a regulatory intervention based on the signal. We abstract from institutional details, and assume that the regulatory and information environments permit pre-commitment to the precision (informativeness) of bank disclosure.

At date 1, all agents and banks observe a public signal S, which is informative of the quality of bank's long-term asset, R. Let the Markov matrix η denote the disclosure technology characterizing the random mapping from R to S. We define the informativeness of the disclosure technology η according to the Blackwell (1951) informativeness criterion.[6] Note that when the signal is perfectly informative about R, the model becomes similar to the information environment of the baseline settings of Allen and Gale (1998) and Chari and Jagannathan (1988), who assume that a perfectly accurate leading economic indicator is observed by all or a random fraction of late consumers at the interim date.

Consistent with the model assumption, real-world regulatory disclosure and accounting disclosure of credit losses contain a substantive forward-looking component. Bank regulators have long required expected losses as the basis for regulatory capital, and have blamed the incurred loss model, an alternative to expected loss model, for amplifying the financial downturn spiral (e.g., Dugan, 2009). In response to pressure from regulators, the Financial Accounting Standards Board (FASB) issued the final current expected credit loss (CECL) standard in 2016. Under the new accounting rules, financial institutions will be required to use historical information, current conditions, and reasonable forecasts to estimate the expected loss over the life of the loan.[7] Even though there still exist fundamental differences between expected credit losses for regulatory capital purpose and for financial reporting purpose, BCBS (2015) states that the regulatory measure may be a starting point for estimating expected credit loss for accounting purposes.

3.2. Optimal risk sharing

Consumptions are now contingent on the realization of the interim signal S. Anticipating that depositors' incentives would be affected by the interim signal, the bank designs ex ante scenario-specific, incentive-compatible contracts that preclude runs for different realizations of the signal. The constrained problem becomes P^{1S}:

$$\max_{c_1(\cdot), c_2(\cdot,\cdot), x} \quad \pi \mathbb{E}u(c_1(S)) + (1-\pi)\mathbb{E}u(c_2(S,R)) \tag{8}$$

$$\text{s.t.} \quad \pi c_1(S) \leqslant x, \quad \forall \ S, \tag{9}$$

$$\pi c_1(S) + (1-\pi)c_2(S,R) = x + R(1-x), \quad \forall \ S, R, \tag{10}$$

$$\mathbb{E}\left[u(c_2(S,R))|S\right] \geqslant u(c_1(S)), \quad \forall S. \tag{11}$$

Now let P^{0S} denote the first-best risk sharing problem, where the incentive constraint Eq. (11) is absent.

Proposition 2. *If the utility function $u(c)$ displays non-increasing absolute risk aversion, then the maximized value of the expected utility in P^{1S} is equal to that in P^{0S}.*

The formal proof of Proposition 2 is relegated to the Appendix. The key step in the proof is to understand why non-increasing absolute risk aversion (of which constant absolute risk aversion (CARA) and decreasing absolute risk aversion (DARA) are both special cases) plays a role in the constrained optimization problem. In the absence of the incentive constraint, the competitive bank's optimization leads to an Euler equation:

$$\mathbb{E}[u'(c_2(S,R))|S] \leqslant u'(c_1(S)), \tag{12}$$

where the inequality is strict only if the reserve x in the first period is exactly adequate. With $u' > 0$, $u'' < 0$ and $-u''/u'$ weakly decreasing, the above inequality implies a relationship between the expected utilities (instead of the marginal utilities):

$$\mathbb{E}\left[u(c_2(S,R))|S\right] \geqslant u(c_1(S)), \tag{13}$$

which is exactly the IC constraint.

Another way of interpreting the result is through prudence. When the absolute risk aversion is decreasing, the consumer is prudent (e.g., Liu and Meyer, 2012). The uncertainty in period 2 leads to

[5] We do not impose non-negativity constraints, which would otherwise complicate the analysis without gaining much insight.

[6] Blackwell (1951) proves that η is more informative than η' in a single-person decision problem if and only if $\eta' = M\eta$, where M is a Markov matrix.

[7] See "Financial Instruments: Credit Losses (Topic 326): Measurement of Credit Losses on Financial Instruments," 2016, FASB Accounting Standards Update No. 2016-13. Available at: http://www.fasb.org/jsp/FASB/Document_C/DocumentPage?cid=1176168232528.

precautionary savings of the bank on behalf of the consumer. Therefore, the optimization results in higher expected utility in period 2, automatically satisfying the incentive constraint.

With the equivalence result, it is straightforward to study the role of the interim public signal in the risk sharing problem. Corollary 1 goes a step beyond Proposition 2 to conclude that more information disclosure in the interim stage is always beneficial to risk sharing.

Corollary 1. *When the utility function displays non-increasing absolute risk aversion, complete information disclosure about the interim signal maximizes the consumers' ex ante welfare.*

Proof. Since P^{0S} is a single-agent decision problem, more informative disclosure about the interim signal S always weakly improves the maximized value of the problem, according to Blackwell (1951). Then, Proposition 2 establishes the equivalence of P^{1S} and P^{0S}. Therefore, optimal risk sharing is achieved in the original problem P^{1S} when the interim signal is perfectly informative of the risky payoff. □

4. Extension and discussion

4.1. Extension: regulatory interventions

Section 3 only models the informational role of the interim signal. In the real world, however, bank disclosure can also be used as a basis for regulatory intervention. In the following extension, we introduce the regulatory role of bank disclosure to the special case with an exponential utility function and a binary long-term asset payoff.

Assume $S \in \{S_H, S_L\}$ and $\Pr(S_H|R_H) = \Pr(S_L|R_L) = q$. In this binary case, the informativeness of the signal can be summarized by a scalar q. When $q = 0.5$, the signal is entirely uninformative; when $q = 1$, the signal completely reveals the date-2 payoff to the long-term investment. $p(S_H) \equiv \theta(1-q) + (1-\theta)q$ and $p(S_L) \equiv \theta q + (1-\theta)(1-q)$ are the unconditional probabilities of the realization of the signal. Let $\hat{\theta}(S_H) \equiv \Pr(R_L|S_H) = \theta(1-q)/p(S_H)$, $\hat{\theta}(S_L) \equiv \Pr(R_L|S_L) = \theta q/p(S_L)$.

The regulator imposes a macroprudential intervention contingent on the realization of bank disclosure.[8] For concreteness, consider an additional amount $y(S)$ of liquidity reserve that can be used to cover early withdrawals. The cyclical nature of $y(S)$ is defined below, in the spirit of Chetty (2001).

Definition 1. A capital reserve requirement $y(S)$ conditional on disclosure S is countercyclical if $y(S_H) > 0$ and $y(S_L) < 0$, i.e., if the required reserve is negative when anticipating low payoff and positive when anticipating high payoff to the risky asset. On the contrary, a capital reserve requirement $y(S)$ is procyclical if $y(S_H) < 0$ and $y(S_L) > 0$.

For simplicity, we focus on regulatory measures that linearly depend on the extent to which the disclosure revises the expectation of risky loan payoff. Given signal S, a regulatory intervention $y(S)$ takes the following form[9]:

$$y(S) \equiv \beta \cdot \left[E[\tilde{R}|S] - E[\tilde{R}]\right] = \beta(\theta - \hat{\theta}(S))(R_H - R_L). \quad (14)$$

A countercyclical intervention is one with $\beta > 0$, and a procyclical intervention is one with $\beta < 0$. When $\beta = 0$, there is no intervention, but the disclosure still plays a role in contracting. It is easy to show that $y(S_H) = \beta\theta(1-\theta)(2q-1)(R_H - R_L)/p(S_H)$ and $y(S_L) = -\beta\theta(1-\theta)(2q-1)(R_H - R_L)/p(S_L)$.

The demand-deposit contract takes the form of $c(S) \equiv (c_1(S), c_{2H}(S), c_{2L}(S))$. Bank's optimization problem is the following problem P_2^{1S},

$$\max_{c(S),x} \quad \pi \sum_S p(S) u(c_1(S))$$
$$+(1-\pi)\sum_S p(S)\left[(1-\hat{\theta}(S))u(c_{2H}(S)) + \hat{\theta}(S)u(c_{2L}(S))\right] \quad (15)$$

$$\text{s.t.} \quad \pi c_1(S) \le x + y(S), \quad \forall \ S, \quad (16)$$

$$\pi c_1(S) + (1-\pi)c_{2j}(S) = x + R_j(1-x), \quad j \in \{L, H\}, \quad (17)$$

$$(1-\hat{\theta}(S))u(c_{2H}(S)) + \hat{\theta}(S)u(c_{2L}(S)) \ge u(c_1(S)), \ \forall \ S. \quad (18)$$

The optimal risk sharing problem does not in general lend itself to an analytical solution. In the online appendix, we characterize the solutions to the optimal risk sharing problem. Through numerical analysis, we find that regulatory intervention, whether countercyclical or procyclical, leads to suboptimal risk sharing. The role of disclosure also varies with the cyclicality of the intervention. For instance, under many numerical examples of countercyclical interventions, a more informative interim signal leads to a lower level of risk sharing. The role of disclosure is also shown to be contingent on the magnitude of the inventions, the magnitude of credit risk, and the level of risk aversion.

The intuition behind the multi-faceted role of bank disclosure lies in the contingency of the demand-deposit contracts on the interim disclosure. Ex ante, banks pre-commit to a certain precision of disclosure as well as demand-deposit contracts that are conditioned on the interim signal. When the disclosure is projected to contain more precise forward-looking information about long-term risky assets, banks may have to offer demand-deposit contracts that are more "run-proof," thereby leading to greater constraints on any risk sharing. Such distortions to demand-deposit contracts has different ramifications for overall welfare under different directions of the intervening force.

4.2. Implications for disclosure regulations in the banking industry

Bank disclosure in the model may be regarded as any type of information on the underlying quality of bank assets that can be used as the basis for allocational regulations. For example, U.S. banks' quarterly Consolidated Reports of Condition and Income (call reports) are used by various regulatory agencies in capital regulations and risk control. Banks with publicly traded equity must also submit various filings to the Securities and Exchange Commission (SEC), in accordance with rules promulgated by the SEC and the FASB. The interpretation of bank disclosure in the model is not limited to information disclosed by the bank. It may also refer to supervisory information such as the 2009 Supervisory Capital

[8] Macroprudential instruments include caps on loan-to-value ratios, debt-to-income ratios, ceilings on credit or credit growth, reserve requirements, capital requirements, time-varying dynamic provisioning, and restrictions on profit distribution and others (Lim et al., 2011). A commonality of many macroprudential measures is that they impose intertemporal shifts of contractible payouts to bank stakeholders over different horizons. In our study, bank profit and equity are not modeled. Therefore, regulatory interventions only apply to the relative distributions of the investment returns to different types of agents.

[9] To allow negative reserves, we assume that the bank has access to zero-interest credit that is repaid at date 2.

Assessment Program (SCAP). The SCAP results and subsequent evaluations are publicized and used to guide government interventions such as bailouts. In addition, bank disclosure in the model may also take the form of objective, market-based information (Aiyar et al., 2015).

Increasing the transparency in financial institutions has been one of the central elements of regulators' responses to bank failures and financial instability. Regulators have called for more detailed as well as more frequent and timely disclosures (e.g., BCBS, 2017). Academics have generally shared the same view. For example, Barth et al. (2004) argue that policies forcing accurate information disclosure are effective in promoting bank development, performance, and stability. French et al. (2010) call for a new information infrastructure that promotes the gathering and dissemination of information, in addition to reforming bank regulations.

This study suggests that in the absence of regulatory interventions, better disclosure improves risk sharing. There may also be unintended negative consequences of increasing disclosure, however, especially in the presence of countercyclical regulations. The intuition is that the pre-committed precision of forward-looking disclosure affects the structure of demand-deposit contracts, which are designed to be more "run-proof," potentially leading to greater constraints on risk sharing. This observation is related to a long line of arguments regarding the negative role of public information in general (e.g., Hirshleifer, 1971) and the unintended negative consequences of disclosure in the bank setting (Goldstein and Sapra, 2013).[10] Our study thus suggests that the efficacy of disclosure requirements should be considered along with any macroprudential interventions, instead of simply as an isolated policy instrument.

Our study sheds light on the recent controversy surrounding an important type of credit loss disclosure—the allowance for loan losses. Loan loss provision plays a dual role that is both informational and regulatory. On the one hand, loan loss provision is indicative of the quality of loans (e.g., Wahlen, 1994); on the other hand, loan loss reserve changes the level of regulatory capital (e.g., Acharya and Ryan, 2016). How to provision for loan losses has been a subject of debate for regulators and accountants (e.g., Laeven and Majnoni, 2003). Bank regulators have blamed the incurred loss model for amplifying the financial downturn spiral (e.g., Dugan, 2009). Accounting standard setters and academics have maintained that financial reporting has a different objective from bank regulation and that tying loan loss accounting to regulatory purposes would give rise to more opportunism.[11] Nevertheless, FASB subsequently issued the CECL standard that partially addresses the regulatory push toward the expected-loss model. Our study identifies a potential welfare cost of credit loss disclosure if such disclosure is forward-looking, thus providing a cautionary note on the recently proposed accounting rules regarding credit losses.

4.3. Empirical predictions

Risk sharing is not directly observable and may take different forms in different strands of bank theories. In our setting with liquidity shocks, it is natural to interpret risk sharing provided by financial intermediation as liquidity creation. In this vein, our study provides testable predictions for the relationship between information quality and liquidity creation, as quantified by Berger and Bouwman (2009). Our study also speaks to the joint impact of disclosure and macroprudential regulations on bank liquidity creation. The joint impact could be examined to the extent that cross-country differences exist regarding disclosure requirements as well as the adoption of countercyclical instruments (e.g., the Spanish dynamic provisioning practice).

5. Concluding remarks

We study a business-cycle version of the bank run model augmented by an interim disclosure. We show that increasing the informativeness of the disclosure improves the risk sharing provided by the bank. With regulatory interventions, however, the relationship between the informativeness of bank disclosure and risk sharing becomes multi-faceted, depending on factors including the cyclicality and magnitude of regulatory interventions, credit risk, and liquidity risk.

There are two limitations of the study that may be addressed by future research. First, we do not study a mechanism design problem that selects the optimal form of regulatory interventions. Second, by focusing on optimal risk sharing as achieved through incentive-compatible demand-deposit contracts, we do not explicitly model the bank-run outcome. Future research, however, could extend this study in these directions.

Appendix A. Proofs

Proof of Proposition 1. Suppose $-\frac{u''(c)}{u'(c)}$ is non-increasing in c. We want to show that the solution to the problem without Eq. (5) indeed satisfies the Eq. (5). The Lagrangian reads

$$\begin{aligned}\mathcal{L} \equiv\ & \pi u(c_1)+(1-\pi)\sum_R u(c_2(R))p(R)\\ & +\mu(x-\pi c_1)+\gamma_0 x+\gamma_1(1-x)\\ & +\sum_R \lambda(R)(\pi c_1+(1-\pi)c_2(R)-x-R(1-x))\end{aligned}$$

Taking FOC, we have

$$\frac{\partial L}{\partial c_1}=\pi u'(c_1)-\mu\pi+\pi\sum_R\lambda(R)=0, \quad (19)$$

$$\frac{\partial \mathcal{L}}{\partial c_2(R)}=(1-\pi)u'(c_2(R))p(R)+(1-\pi)\lambda(R)=0, \quad (20)$$

$$\frac{\partial \mathcal{L}}{\partial x}=\mu+\gamma_0-\gamma_1+\sum_R(R-1)\lambda(R)=0. \quad (21)$$

The solution to the problem without Eq. (5) satisfies all these conditions. Combining (19) and (20),

$$u'(c_1)\geqslant\sum_R u'(c_2(R))p(R). \quad (22)$$

If $x=1$, then $c_2(R)=\frac{1-\pi c_1}{1-\pi}=c_2$ is a constant, so Eq. (22) implies $u'(c_1)\geqslant u'(c_2)$, and thus $c_1\leqslant c_2$ and $u(c_1)\leqslant\sum_R u(c_2(R))p(R)$. The last inequality is exactly the IC constraint.

If $x<1$, define $R^*\equiv\frac{c_1-x}{1-x}$, which is the unique R such that $c_1=c_2$ given $\pi c_1+(1-\pi)c_2=x+R(1-x)$. Now we study two functions: $f(R)\equiv u(c_2(R))-u(c_1)$ and $g(R)\equiv(u'(c_2(R))-u'(c_1))\frac{u'(c_1)}{u''(c_1)}$, where

[10] Opacity may be inherent to these banks' business. For example, Morgan (2002) states that "The push for increased market discipline of banks and self-disclosure may shed light. But reformers should remember what they are dealing with: banks may be the black holes at the center of the financial universe, powerful and influential, but are to some degree, unfathomable" (p. 888).

[11] See, for example, the discussion of the controversy in the article "Calculation Conundrum" in the March 2010 issue of *Risk* Magazine. A recent study by Jayaraman et al. (2017) suggests there is a tradeoff between bank stability and transparency inherent in preemptive provisioning. Acharya and Ryan (2016) offer a review of the literature on the relationship between bank financial reporting and financial stability.

$c_2(R) = \frac{x-\pi c_1+R(1-x)}{1-\pi}$ by the resource constraint in period 2. Note that f and g are both strictly increasing in R, and crossing zero at the same location R^*. Moreover, they are tangent at R^*:

$$g'(R^*) = u''(c_2(R^*))\frac{u'(c_1)}{u''(c_1)} = u'(c_1) = u'(c_2(R^*)) = f'(R^*).$$

For $R > R^*$, we have $f'(R) \geqslant g'(R)$ because $-\frac{u''(c)}{u'(c)}$ is positive and non-increasing by assumption. Similarly, $f'(R) \leqslant g'(R)$ for $R < R^*$. That is, $f(R) \geqslant g(R)$ for all R. Therefore,

$$\mathbb{E}[u(c_2(R)) - u(c_1)] \geqslant \mathbb{E}\left[(u'(c_2(R)) - u'(c_1))\frac{u'(c_1)}{u''(c_1)}\right]$$

$$= \frac{u'(c_1)}{u''(c_1)}(E[u'(c_2(R))] - u'(c_1)) \geqslant 0,$$

which is indeed the IC constraint. □

Proof of Proposition 2. Suppose $-\frac{u''(c)}{u'(c)}$ is non-increasing in c. We want to show that the solution to the problem without Eq. (11) indeed satisfies the Eq. (11). The Lagrangian reads

$$\begin{aligned}\mathcal{L} \equiv\ & \pi\mathbb{E}u(c_1(S)) + (1-\pi)\mathbb{E}u(c_2(S,R)) \\ & +\mathbb{E}\mu(S)(x - \pi c_1(S)) + \gamma_0 x + \gamma_1(1-x) \\ & +\mathbb{E}\lambda(S,R)(\pi c_1(S) + (1-\pi)c_2(S,R) - x - R(1-x))\end{aligned}.$$

Taking FOC, we have

$$\frac{1}{p(S)}\frac{\partial\mathcal{L}}{\partial c_1(S)} = \pi u'(c_1(S)) - \pi\mu(S) + \pi\mathbb{E}[\lambda(S,R)|S] = 0, \quad (23)$$

$$\frac{1}{p(S,R)}\frac{\partial\mathcal{L}}{\partial c_2(S,R)} = (1-\pi)u'(c_2(S,R)) + (1-\pi)\lambda(S,R) = 0, \quad (24)$$

$$\frac{\partial\mathcal{L}}{\partial x} = \mathbb{E}\mu(S) + \gamma_0 - \gamma_1 + \mathbb{E}(R-1)\lambda(S,R) = 0. \quad (25)$$

The solution to the problem without Eq. (11) satisfies all conditions. Combining (23) and (24),

$$u'(c_1(S)) - \mathbb{E}[u'(c_2(S,R))|S] = \mu(S) \geqslant 0. \quad (26)$$

If $x = 1$, then $c_2(S,R) = \frac{1-\pi c_1(S)}{1-\pi} \equiv c_2(S)$ is independent of R, so (26) implies $u'(c_1(S)) \geqslant u'(c_2(S))$, and thus $c_1(S) \leqslant c_2(S)$ and $u(c_1(S)) \leqslant \mathbb{E}[u(c_2(S))|S]$, for all S. The last inequality is exactly the IC constraint Eq. (11).

If $x < 1$, define $R^*(S) \equiv \frac{c_1(S)-x}{1-x}$, which is the unique R such that $c_1(S) = c_2(S,R)$ given Eq. (10). Fix a signal S, we study two functions: $f_S(R) \equiv u(c_2(S,R)) - u(c_1(S))$ and $g_S(R) \equiv (u'(c_2(S,R)) - u'(c_1(S)))\frac{u'(c_1(S))}{u''(c_1(S))}$, where $c_2(S,R) = \frac{x-\pi c_1(S)+R(1-x)}{1-\pi}$ by Eq. (10). Note that f_S and g_S are both strictly increasing in R, and crossing zero at the same location $R^*(S)$. Moreover, they are tangent at $R^*(S)$:

$$g_S'(R^*(S)) = u''(c_2(S,R^*(S)))\frac{u'(c_1(S))}{u''(c_1(S))} = u'(c_1(S))$$

$$= u'(c_2(S,R^*(S))) = f_S'(R^*(S)).$$

For $R > R^*(S)$, we have $f_S'(R) \geqslant g_S'(R)$ because $-\frac{u''(c)}{u'(c)}$ is positive and non-increasing by assumption. Similarly, for $R < R^*(S)$ we have $f_S'(R) \leqslant g_S'(R)$. That is, $f_S(R) \geqslant g_S(R)$ for all R. Therefore,

$$\mathbb{E}[u(c_2(S,R)) - u(c_1(S))|S] \geqslant \mathbb{E}\left[(u'(c_2(S,R)) - u'(c_1(S)))\ \frac{u'(c_1(S))}{u''(c_1(S))}\middle| S\right]$$

$$= \frac{u'(c_1(S))}{u''(c_1(S))}\left(E\left[u'\ (c_2(S,R))\middle| S\right] - u'(c_1(S))\right) \geqslant 0,$$

which is indeed the IC constraint. □

Appendix B. Supplementary data

Supplementary data associated with this article can be found, in the online version, at https://doi.org/10.1016/j.jfs.2019.100720.

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