

Liquidity and Transparency in Bank Risk Management

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Abstract

Liquidity risk is associated with solvency uncertainty at the refinancing stage. To insure, banks can accumulate liquid assets, or enhance transparency to facilitate refinancing. A liquidity buffer provides complete insurance against small liquidity shocks, while transparency offers partial insurance against large ones as well. We show that, due to leverage, banks can under-invest in both liquidity and transparency, and within that have a bias towards liquidity as it preserves internal control. While liquidity can be imposed, transparency is not verifiable. This multi-tasking problem complicates liquidity regulation. Reserve requirements may compromise banks' endogenous transparency choices, and may therefore need to be complemented by an emphasis on transparency.

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1 Introduction

Banks perform maturity transformation and insure public's liquidity needs, but in process become exposed to liquidity risk (Diamond and Dybvig, 1983). When refinancing frictions prevent a solvent bank from covering a liquidity shortage, it may go bankrupt despite having valuable long-term assets.

Most recent bank liquidity events in developed countries were associated with increased solvency concerns. Some prominent examples are:

- 1991, Citibank and Standard Chartered (Hong Kong): rumors of technical insolvency caused runs on insured and uninsured deposits of both banks;
- 1998, Lehman Brothers (US): rumors of severe losses on emerging markets prompted suspension of credit lines, margin calls, and refusal to trade with the bank;
- 2002, Commerzbank (Germany and UK): rumors of insolvency due to trading losses lead to trimmed credit lines and illiquidity of the bank's CDs.

Even when rumors turn out to be unsubstantiated, cash withdrawals and restricted access to new funding impose significant strain. To survive, a bank must be able to support itself with own funds for the duration of liquidity stress, and/or alleviate the market's concerns over its solvency to regain access to funds as soon as possible.

This paper studies the options for bank's liquidity risk management. We suggest that there are two distinct ways in which a solvent bank can insure against default due to liquidity shocks. One is to accumulate *liquidity* – form a precautionary buffer of short-term assets to cover possible outflows internally. Another is to adopt *transparency* – establish a set of mechanisms that facilitate solvency information transmission to the market and help access new external finance. Both investments – in liquidity and in transparency – are strategic ex-ante decisions. We derive socially optimal and private liquidity risk management choices, explore the interaction between liquidity and transparency, and formulate empirical and policy implications.

The intuition of our results is as follows. A bank has a valuable project that with a small probability can turn out to be of zero value, creating some long-term solvency risk. At the intermediate date, a bank faces an exogenous random withdrawal. In most states of the world, the bank is known to be highly solvent, and investors are willing to extend new financing in place of withdrawals. However with some probability, investors receive a negative intermediate signal that the likelihood of insolvency is high, and become unwilling to refinance the bank.

In such an event, a precautionary buffer of liquid assets can allow a solvent bank to cover outflows internally. Transparency – established mechanisms that facilitate information transmission to the market – can help resolve solvency uncertainty and enable external refinancing.

Yet precise effects of liquidity and transparency are different. A precautionary buffer allows to cover internally all liquidity shortages within its size, providing complete insurance against smaller shocks. However holding large buffers is prohibitively costly, so liquidity cannot be used to insure against large shocks. Transparency helps resolve solvency uncertainty and enables external refinancing. That can cover any liquidity shocks – small or large. Yet, since it relies on effective ex-post communication, transparency is effective only with some probability, and therefore provides incomplete insurance. We show that banks may optimally combine liquidity and transparency in their risk management, using liquidity to fully insure against small shocks, and transparency to partially cover large shocks as well.

Liquidity and transparency have costs. Firstly, a bank has limited borrowing capacity, so that ex-ante investments in liquidity or transparency crowd out profitable long-term investment. Secondly, there are direct costs. For liquidity, we consider those stemming from increased moral hazard (Myers and Rajan, 1998), when bankers can use liquid assets to fund private benefits projects in insolvent banks. The costs of transparency include the expenses of establishing credible disclosure mechanisms.

Due to risk-shifting incentives (Jensen and Meckling, 1976), bankers may underinvest in liquidity, or transparency, or both. This justifies policy intervention to reinstate optimal liquidity risk management. However, while liquidity is verifiable and can be imposed (for example by reserve requirements), regulatory lever on transparency choices is small. This makes liquidity regulation a multi-tasking problem, and complicates optimal policy design. There are two problems:

Firstly, liquidity requirements can compromise banks' endogenous transparency choices. This is especially likely when transparency is by itself an effective risk management mechanism, and market access is important in mitigating liquidity shocks. There is a danger that financial stability and social welfare may deteriorate as a result of ill-designed liquidity requirements.

Secondly, when liquidity is associated with significant private benefits of control (as in Myers and Rajan), banks may have a private bias towards liquidity, at the expense of transparency. In that case, reserve requirements target the lesser distortion. Under some conditions, policies aiming to improve transparency may be equally or even more important.

This paper contributes to the literature on liquidity crises. Our modelling of liquidity

events differs from the mainstream Holmstrom and Tirole (1998) approach in several aspects. Firstly, in our model, liquidity needs originate on the liabilities side of the balance sheet and are clearly related to refinancing events. Secondly, the refinancing problem is driven by asymmetric information, not moral hazard or aggregate liquidity shortages. Such specification reflects the "flight to quality" phenomenon (Bernanke et al., 1996), and has strong empirical foundations. Lastly, in relationship to earlier models of solvency uncertainty (such as Chari and Jagannathan, 1988), we are able to better capture the properties of contemporary wholesale finance markets.

The concerns about suboptimal bank liquidity and transparency have received significant yet separate attention in the literature. While a degree of liquidity risk is essential for bank operations (Diamond and Rajan, 2001), their private liquidity choices may be compromised by opportunistic incentives (Bhattacharya and Gale, 1987). Empirical evidence confirms episodes of seemingly insufficient bank liquidity (Gatev et al., 2004, Gonzalez-Eiras, 2003). Transparency enables market access and facilitates the management of liquidity shocks (Goodfriend and King, 1998). Larger and publicly and publicly held banks (with better market access) were found to be less reactive to monetary policy tightening (Kashyap and Stein, 1990, Holod and Peek, 2004). Yet, again, there is evidence of banks' likely relative opaqueness (Morgan, 2002).

Our contribution is to analyze liquidity and transparency jointly, and emphasize the complex interaction between the two. We suggest that, beyond substitute effects evident at the first brush, liquidity and transparency can be complements. Liquidity is effective in covering small (or routine) shocks, while transparency enables dealing with large (or exceptional) events.

The literature has yet devoted little attention to the choice between cash in hand and borrowing capacity. In a recent paper, Acharya et al. (2006) relate it to long-term hedging choices when future access to external finance is uncertain. We offer an additional, contemporaneous, perspective, where liquidity has certain but limited hedging capacity, while transparency can potentially insure against larger shocks as well.

The interactions identified in this model offers avenues for empirical research. Our analysis suggests that it may be not fully precise to measure bank financial constraints only by institutional liquidity (or factual cash flows, see Paravisini, 2006). Market access and borrowing opportunities may be important as well. We predict that more liquid banks will be resilient to small shocks, while more transparent banks able to withstand large shocks as well. As a response, banks will use transparency to manage larger shocks, and precautionary buffers to manage everyday or other more routine liquidity needs. Larger banks may rely less on liquidity buffers if their size enables easier market access. Lastly, we relate positive effects of transparency to financial market development.

The rest of the paper proceeds as follow. Section 2 sets up the model. Section 3 solves for the social optimum. Section 4 explores distortions created by leverage and shows that banks may under-invest in liquidity and transparency. Section 5 discusses regulatory intervention and possible effects of reserve requirements on bank's transparency choices. Section 6 extends the basic model and shows a possible bias towards liquidity at the expense of transparency. Section 7 concludes.

2 Setup

2.1 Economy and Agents

Consider a risk-neutral economy with three dates: 0, 1, 2. The economy is populated by multiple small investors (depositors) and a single bank. Small investors are endowed with money. They have access to a safe storage technology (cash), or can lend to the bank, charging the gross interest rate of 1.

The bank has no initial capital, but has access to a profitable investment project. For each unit of financing at date 0, the project returns at date 2 a high return X with probability $1 - s$, but 0 with a small probability s (s for the probability of a solvency problem). A bank maximizes date 2 profit, and operates under a leverage constraint (representing capital requirements) and cannot borrow more than 1 at date 0. All financing takes the form of simple debt.

2.2 Solvency Uncertainty and Liquidity Risk

Two events happen at date 1. One is a random withdrawal of initial financing. Another is a signal on the bank's solvency. The two events are independent – withdrawals are made by uninformed depositors or represent maturing term funding, and are not influenced by the solvency signal.

Withdrawals and liquidity need. While the project is long-term, some debt matures earlier and must be refinanced. In reality there may be multiple refinancing events through the course of the project, but for the analysis we collapse them into a single "intermediate" date 1. The amount of funds maturing at date 1 – liquidity need – is random. With probability $1/2$, the liquidity need is low – the bank has to repay some $L < 1$. With additional probability $1/2$, the liquidity need is high – the bank has to repay 1. If the bank cannot repay, it fails and goes bankrupt with no liquidation value.

Information and liquidity risk. Because investors always offer an elastic supply of funds, a bank known to be solvent is able to refinance itself by new borrowing and thus substitute any withdrawals at date 1. However this may be prevented by possible

asymmetric information effects, namely increased solvency concerns. This is the origin of liquidity risk in this model.

Recall that a bank is solvent with probability $1 - s$ and insolvent with probability s . Assume that the bankers receive complete information on the bank's solvency before date 1, while the public's information is noisy. With probability $1 - (s + q)$ the public receives a correct signal that a bank is solvent and will yield X with certainty. Solvent banks are able to obtain refinancing at the risk-free rate.

With the residual probability $s + q$, the signal indicates that the bank is likely to be insolvent. This represents a probability q that a solvent bank is pooled with insolvent banks. The posterior probability of insolvency in such a case, $s/(s + q)$, is higher than the ex-ante probability of insolvency, s . This higher uncertainty over bank's value may prevent external refinancing. We therefore call such event a "liquidity shock".

We impose the following restrictions on parameter values:

1. A bank has a positive NPV, even if it always failed in a liquidity shock.

$$X > \frac{1}{1 - (s + q)} \quad (\text{A1})$$

This assures that a bank is always financed at date 0.

2. A bank in a liquidity shock has a negative posterior expected NPV at date 1.

$$X < \frac{s + q}{q} \quad (\text{A2})$$

Observe that (A1) and (A2) imply that transparency (knowledge of terminal payoff) becomes critical for obtaining external finance at the intermediate date (due to possible informational effects), but has lower importance at the initial date.

We make two additional assumptions for expositional simplicity – to focus on the most relevant cases.

1. The charter value of the bank is sufficiently large, so that public and private risk management choices under leverage are not too divergent.

$$X > 2 \quad (\text{A3})$$

2. Investments at date 0 are covered by deposit insurance. However, refinancing at date 1 is not covered by it. (For instance the date 0 investments can be deposits, while date 1 refinancing market-based – corresponding to the banks' usual practice of using wholesale funds to manage liquidity needs).

These moderately restrictive assumptions do not affect qualitative properties of the model. Both higher charter value and deposit insurance reduce leverage – the main distortion. Therefore they can only weaken our results.

2.3 Liquidity Risk Management

We consider two distinct ways in which a bank can hedge its liquidity risk.

1. **Accumulate liquidity.** A bank can invest L units in the short-term asset (cash). This allows to fully cover small withdrawals at date 1, and therefore insure against small liquidity shocks that happen with probability $1/2$.
2. **Adopt transparency.** A bank can invest T to establish transparency. We think of transparency as a strategic ex-ante investment, such as credible disclosure, that allows a bank to better communicate solvency information to the market. In particular, this may enable the bank to publicly confirm its solvency in the event of liquidity shock. We assume that, since transparency relies on ex-post information communication, it is effective (enables a bank to prove its solvency) with a probability $t < 1$. The effectiveness of transparency may be determined by factors outside a single bank's control, such as the level of financial market development in a country. Notice that transparency allows to insure against both small and large liquidity shocks.

Both liquidity and transparency have costs. We consider two sources of liquidity costs. Firstly, given maximum date 0 leverage, liquidity crowds out investment in a profitable project. This reduces the return to a successful liquid bank from X to $X(1 - L) + L$, a loss of $-(X - 1)L$.

Secondly, we assume that when a liquid bank fails (e.g., due to inability to refinance a large liquidity shock or insolvency), the value of its liquidity buffer is lost. It may be spent in costly bankruptcy proceedings, or appropriated by the bankers and transformed into marginal private benefits (as in Myers and Rajan; we model such moral hazard in more detail in Section 6). This makes the return to a failing liquid bank 0.

The cost of transparency is the value of associated investment, T , which is, firstly, a direct expense and, secondly, crowds out investment in a profitable project. Transparency reduces return to a successful bank from X to $X(1 - T)$, a loss of $-TX$.

To focus this analysis on different effects rather than costs of liquidity and transparency (costs would have a symmetric impact), we normalize their costs to be equal:

$$(X - 1)L = TX = C$$

where C is a generic cost of hedging, either with liquidity or with transparency. Notice that should a bank choose to invest in both liquidity and transparency, a return in the successful state would be $X(1 - L - T) + L = X - 2C$. The costs simply double.

Liquidity and transparency are therefore costly hedges against liquidity risk. The decisions on whether and how to hedge are made by the bankers, and, we assume here, are not contractible. In the presence of leverage, this gives rise to a risk-shifting problem (Jensen and Meckling, 1976) that may lead to insufficient hedging. This basic conflict of interest is the principal distortion of our model.

The timeline of the game is as follows.

Date 0. Banks attract deposits. They divide assets between the profitable project, the precautionary liquidity buffer, and the investment in transparency;

Date 1. A bank may be hit by a liquidity shock and require refinancing. A bank that is unable to cover withdrawals from the precautionary buffer or by borrowing from the market, is liquidated;

Date 2. Project returns realize; successful banks repay debts and consume profits.

The game tree is shown on Figure 1.

<<Figure 1 goes here>>

3 First Best

We first consider socially optimal levels of bank's liquidity and transparency, and show that, when costs of hedging are not too high, it is optimal for the bank to combine liquidity and transparency in its risk management. Then, precautionary buffer completely insures a solvent bank against small shocks, while transparency partially against large ones by enabling external refinancing.

3.1 Risk Management Options

We first derive the social payoffs depending on the bank's liquidity management choices. They are:

For a strategy "N" when a bank is not liquid and not transparent:

$$\Pi_N^S = (1 - s - q) \cdot X - 1$$

Here, $1 - s - q$ is the probability that a bank is not hit by a solvency or liquidity shock, X is the return in that case, and 1 is the initial investment.

For a strategy "L" when a bank is liquid but not transparent:

$$\Pi_L^S = (1 - s - q/2) \cdot (X - C) - 1$$

A solvent bank is able to survive a small liquidity shock by covering it from the precautionary buffer (probability $q/2$), but fails in a large liquidity shock that is above the buffer size. The probability of a solvency shock is s , and of a large liquidity shock $q/2$. Therefore the probability of survival is $1 - s - q/2$; the return in that case is $X - C$ (C is the hedging cost), and the initial investment is 1.

For a strategy "T" when a bank is transparent but not liquid:

$$\Pi_T^S = (1 - s - q(1 - t)) \cdot (X - C) - 1$$

A solvent bank is able to survive a liquidity shock (either small or large) when it is successful in communicating solvency information to the market, with probability t . The probability of a solvency shock is s , and that of a solvent bank being unable to prove its solvency to the market $q(1 - t)$. Therefore the probability of survival is $1 - s - q(1 - t)$; the return in that case is $X - C$, and the initial investment is 1.

Lastly, for a strategy "LT", when a bank is both liquid and transparent:

$$\Pi_{LT}^S = (1 - s - q(1 - t)/2) \cdot (X - 2C) - 1$$

A solvent bank is able to survive a small liquidity shock always by covering it from a precautionary buffer, and a large liquidity shock with probability t when it is successful in communicating solvency information. The probability of a solvency shock is s , and of a large liquidity shock when a bank is unable to prove its solvency to the market $q/2 \cdot (1 - t)$. Therefore the probability of survival is $1 - s - q(1 - t)/2$, the return in that case is $X - 2C$ (note double hedging cost), and the initial investment 1.

3.2 Optimal Risk Management

We use these four payoffs to compare social welfare and derive bank's optimal risk management choices.

Consider first the choice between liquidity and transparency. Liquidity insures against half of the shocks – small ones only. Transparency insures against a share t of the shocks – only when ex-post information communication is successful. Thus for $t < 1/2$ liquidity is more effective: $\Pi_L^S > \Pi_T^S$, and for $t > 1/2$ transparency is more effective: $\Pi_T^S > \Pi_L^S$.

Another dimension is the depth of hedging – whether to hedge at all, adopt a single

hedge (liquidity or transparency – whichever more effective), or have both hedges. Note that the marginal benefit of the second hedge is lower than that of the first hedge. This is because the first hedge is a more effective one (liquidity for $t < 1/2$ and transparency for $t > 1/2$), and moreover already protects a bank from a range of liquidity shocks. We analyze the optimal depth of hedging, as a function of the cost of hedging C , in two cases:

Case 1: Liquidity more effective, $t < 1/2$. It is optimal that a bank:

– Has no hedge, "N", for $\Pi_N^S > \Pi_L^S$, corresponding to high costs of hedging:

$$C > \frac{q/2}{1-s-q/2} \cdot X$$

– Is only liquid, "L", for $\Pi_L^S > \Pi_N^S$ and $\Pi_L^S > \Pi_{LT}^S$, corresponding to intermediate costs of hedging:

$$\frac{qt/2}{1-s-q(1/2-t)} \cdot X < C < \frac{q/2}{1-s-q/2} \cdot X$$

– Is both liquid and transparent, "LT", for $\Pi_{LT}^S > \Pi_L^S$, corresponding to low costs of hedging:

$$C < \frac{qt/2}{1-s-q(1/2-t)} \cdot X \tag{1}$$

Case 2: Transparency more effective, $t > 1/2$. Analogously, it is optimal that a bank:

– Has no hedge, "N", for $\Pi_N^S > \Pi_T^S$, corresponding to:

$$C > \frac{qt}{1-s-q(1-t)} \cdot X$$

– Is only transparent, "T", for $\Pi_T^S > \Pi_N^S$ and $\Pi_T^S > \Pi_{LT}^S$, corresponding to:

$$\frac{q(1-t)/2}{1-s} \cdot X < C < \frac{qt}{1-s-q(1-t)} \cdot X$$

– Is both liquid and transparent, "LT", for $\Pi_{LT}^S > \Pi_T^S$, corresponding to:

$$C < \frac{q(1-t)/2}{1-s} \cdot X \tag{2}$$

Now observe that for any t , and any q and s , there exists C low enough, such that

having both hedges is socially optimal:

We can formulate the first main result.

Proposition 1 *Banks can combine liquidity and transparency in their risk management. There exist parameter values (1) or (2), such that it is optimal that a bank is both liquid and transparent.*

This demonstrates that both holding precautionary buffers (liquidity) and enhancing ability to borrow (transparency) are important dimensions of liquidity risk management. They may need to be combined to achieve a socially optimal outcome. In the following analysis we will focus on the case when conditions (1) or (2) are satisfied.

4 Suboptimal Liquidity Risk Management

We now turn to bank's private liquidity and transparency choices. They may deviate from the social optimum due to leverage. The presence of debt creates risk-shifting incentives, revealed as lower private incentives to hedge. The reason is that the bankers incur the costs of hedging as a reduced payoff in the good state, but do not carry the burden of failure in the bad state thanks to limited liability. The losses in case of default are born by debtholders.

We study how leverage can distort hedging incentives and bias bank's liquidity risk management choices away from the socially optimal ones. We analyze liquidity and transparency choices as not contractible – for example because depositors are small – but return to the possibility of their regulation in the next section.

4.1 Private Payoffs

Consider the amount of debt the bank has to repay in the case of success. At date 0, it borrowed 1 unit of money, with a nominal repayment amount 1 thanks to deposit insurance. When the bank refinances some debt at date 1 with new borrowing, this has zero net effect on debt outstanding (intermediate refinancing is also risk-free because it is provided only to banks known to be solvent). If a solvent bank repays L from the precautionary buffer at date 1, this reduces the debt outstanding to $1 - L$. In any case, the bank's total net debt repayment in case of success is always 1.

We can now derive the private payoffs. They are similar to the social payoffs, with the difference that the bankers repay initial investment only if the project succeeds. The payoffs are:

For a strategy "N" when a bank is not liquid and not transparent:

$$\Pi_N = (1 - s - q) \cdot (X - 1)$$

For a strategy "L" when a bank is liquid but not transparent:

$$\Pi_L = (1 - s - q/2) \cdot (X - C - 1)$$

For a strategy "T" when a bank is transparent but not liquid:

$$\Pi_T = (1 - s - q(1 - t)) \cdot (X - C - 1)$$

Lastly, for a strategy "LT", when a bank is both liquid and transparent:

$$\Pi_{LT} = (1 - s - q(1 - t)/2) \cdot (X - 2C - 1)$$

4.2 Risk Management Choices

Since liquidity and transparency have the same costs, and the bankers benefit from the effectiveness of hedge they adopt, the private choice between liquidity and transparency is not distorted by leverage. As in the social optimum, liquidity is preferred $\Pi_L > \Pi_T$ for $t < 1/2$, and transparency is preferred $\Pi_T > \Pi_L$ for $t > 1/2$.

However, leverage affects the choice of the depth of hedging. Since the incentives to hedge are lower, the same depth is chosen only for lower costs of hedging. As before, we distinguish two cases:

Case 1: Liquidity more effective, $t < 1/2$. The bank:

– Chooses not to hedge, "N", for $\Pi_N > \Pi_L$, corresponding to high costs of hedging:

$$C > \frac{q/2}{1 - s - q/2} \cdot (X - 1)$$

– Chooses to be liquid, "L", for $\Pi_L > \Pi_N$ and $\Pi_L > \Pi_{LT}$, corresponding to intermediate costs of hedging:

$$\frac{qt/2}{1 - s - q(1/2 - t)} \cdot (X - 1) < C < \frac{q/2}{1 - s - q/2} \cdot (X - 1)$$

– Chooses to be both liquid and transparent, "LT", for $\Pi_{LT} > \Pi_L$, corresponding to low costs of hedging:

$$C < \frac{qt/2}{1-s-q(1/2-t)} \cdot (X-1) \quad (3)$$

Case 2: Transparency more effective, $t > 1/2$. The bank:

– Chooses not to hedge, "**N**", for $\Pi_N > \Pi_T$, corresponding to:

$$C > \frac{qt}{1-s-q(1-t)} \cdot (X-1)$$

– Chooses to be transparent, "**T**", for $\Pi_T > \Pi_N$ and $\Pi_T > \Pi_{LT}$, corresponding to:

$$\frac{q(1-t)/2}{1-s} \cdot (X-1) < C < \frac{qt}{1-s-q(1-t)} \cdot (X-1) \quad (4)$$

– Chooses to be both liquid and transparent, "**LT**", for $\Pi_{LT} > \Pi_T$, corresponding to:

$$C < \frac{q(1-t)/2}{1-s} \cdot (X-1) \quad (5)$$

Note the difference with threshold points in the social optimum. The cost of hedging is now traded-off not with the social return X but with the private return $X-1$. This biases all threshold points towards lower values of C .

We can now derive private risk management choices. We start by ruling out extreme cases:

Lemma 1 *When combining liquidity and transparency is socially optimal ((1) or (2)), and private and public incentives are not too divergent (A3), banks choose to have at least some liquidity risk hedge (liquidity, or transparency, or both)*

Proof. See Appendix. ■

Lemma 1 rules out the possibility of a bank choosing not to hedge at all. We must now only consider the choice between having a single hedge or both hedges. When the cost of hedging is very low, such that conditions (3) or (5) are satisfied, the bankers will choose to be both liquid and transparent, in line with the social optimum. However, when the cost of hedging is not as low, bankers may choose to have only one hedge, despite the fact that a combination of liquidity and transparency is socially optimal. In particular, for any t , q and s , there exists C such that:

For $t < 1/2$, a bank chooses to be only liquid while it is socially optimal that it is both liquid and transparent:

$$\frac{qt/2}{1-s-q(1/2-t)} \cdot (X-1) < C < \frac{qt/2}{1-s-q(1/2-t)} \cdot X \quad (6)$$

For $t > 1/2$, a bank chooses to be only transparent while it is socially optimal that it is both liquid and transparent:

$$\frac{q(1-t)/2}{1-s} \cdot (X-1) < C < \frac{q(1-t)/2}{1-s} \cdot X \quad (7)$$

The scope for divergence is determined in particular by X – returns in the good state (related to the charter value) that reduce effective leverage. We can now formulate the following result:

Proposition 2 *A bank may under-invest in liquidity and transparency due to risk-shifting incentives associated with leverage. There exist parameter values (6) or (7) such that a bank chooses only liquidity or only transparency, whereas a combination of liquidity and transparency is socially optimal.*

5 Reserve Requirements and Transparency

The previous section established that banks' private liquidity risk management choices can be suboptimal, as they under-invest in liquidity or transparency due to leverage. This creates scope for regulatory intervention. It is relatively easy to influence a bank's liquidity, because it is normally verifiable and can be imposed by reserve requirements. The regulatory lever on transparency is weaker. Mandatory disclosure is ineffective when it is difficult to define relevant quantifiable parameters. Also, without proper private incentives, disclosure can be not credible – perfunctory or "creative". A suggestion by Calomiris (1999) to mandate regular issuance of short-term subordinated debt so as to strengthen market discipline is intriguing, but has not yet been fully tested in practice.

This implementation issue (cf. Glaeser and Shleifer, 2001) may explain why financial regulation typically puts emphasis on ensuring prudential liquidity rather than transparency and market access. However, when transparency is an important component of risk management, the optimal design of liquidity regulation becomes a multi-tasking problem, and reserve requirements may affect bank's endogenous transparency choices.

Consider a bank with suboptimal liquidity, in a setting where a combination of liquidity and transparency is socially optimal. Note that, by Lemma 1, a bank must be transparent. The fact that banks choose transparency over liquidity implies that transparency is more effective: $t > 1/2$. From (2) and (4), the range of relevant costs of hedging, such that $\Pi_{LT}^S > \Pi_T^S$ but $\Pi_{LT} < \Pi_T$, is:

$$\frac{q(1-t)/2}{1-s} \cdot (X-1) < C < \frac{q(1-t)/2}{1-s} \cdot X \quad (8)$$

Suppose that the authorities respond to suboptimal liquidity by imposing reserve requirements. The aim is to restore socially optimal liquidity risk management, which combines liquidity and transparency. The problem is that, due to multitasking, this cannot always be achieved. In particular, there is a danger that, in response to liquidity requirements, a bank may stop investing in transparency.

Under reserve requirements, the transparency decision depends on its effectiveness as a second hedge. When transparency is very effective compared to the cost of hedging, the bank is more likely to preserve it on top of mandated liquidity. The bank would retain transparency for $\Pi_{LT} > \Pi_L$ (3) as determined by low C and high t :

$$C < \frac{qt/2}{1-s-q(1/2-t)} \cdot (X-1)$$

However when transparency is less effective, the bank may choose to drop transparency and remain with mandated liquidity only. This would happen for $\Pi_{LT} < \Pi_L$ and

$$C > \frac{qt/2}{1-s-q(1/2-t)} \cdot (X-1) \quad (9)$$

Observe that there exist parameters such that this interval is nonempty:

$$\frac{qt/2}{1-s-q(1/2-t)} \cdot (X-1) < \frac{q(1-t)/2}{1-s} \cdot X \quad (10)$$

at least for t close to but above $1/2$ (the two fractions become identical, while $X-1 < X$).

Proposition 3 *Liquidity requirements may compromise banks' endogenous transparency choices. There exist parameters (4) and (9) such that a bank stops investing in transparency in response to reserve requirements.*

This shift from transparency to liquidity would be detrimental for financial stability and social welfare. Recall that a bank originally chose transparency over liquidity because it was a more effective method of hedging liquidity risk ($t > 1/2$). Under liquidity, the probability of solvent bank failures (and associated welfare losses) increases from $q(1-t)$ to $q/2$.

Observe that transparency is likely to be effective ($t > 1/2$) in countries with developed financial markets, where banks can better rely on external refinancing. There,

ill-designed liquidity requirements may have adverse effects. Developing countries are likely to gain less from transparency ($t < 1/2$), and may have to rely on liquidity instead. (This corresponds to the evidence that banks in developed countries are typically highly liquid, and face more binding reserve requirements.) Therefore, there may be heterogeneity in optimal liquidity-transparency outcomes across countries of different financial development, and this has to be borne in mind during possible international convergence of liquidity regulation.

6 Liquidity Bias

This section extends the basic model to study the private benefits of liquidity. Myers and Rajan (1998) pointed that, while offering protection against liquidity shocks, short-term asset holdings also give managers (bankers) private benefits of control. The reason is that, compared to encumbered long-term assets, it is relatively easy to direct liquid funds in privately beneficial ways – invest in pet projects, spent on perks, or just tunnel away.

So far in the model, leverage has only affected the private choice of hedging depth, but not the choice between liquidity and transparency. Here we show that, under private benefits of liquidity, that latter choice can also become distorted. Banks may choose liquidity when transparency is preferred from a social welfare standpoint.

Liquidity-driven moral hazard is associated with non-viable banks – insolvent, or those under a large liquidity shock but with no market access. In these cases, a bank fails, leaving no equity value to the bankers. We assume that, in response, they are able to transform the remaining liquidity into private benefits β .

Expected private benefits of liquidity, β times the probability of failure, add to the social and private payoffs to liquid banks:

$$\begin{aligned}\Pi_{L,\beta}^S &= (1 - s - q/2) \cdot (X - C) - 1 + \beta(s + q/2) \\ \Pi_{L,\beta} &= (1 - s - q/2) \cdot (X - C - 1) + \beta(s + q/2) \\ \Pi_{LT,\beta}^S &= (1 - s - q(1 - t)/2) \cdot (X - 2C) - 1 + \beta(s + q(1 - t)/2) \\ \Pi_{LT,\beta} &= (1 - s - q(1 - t)/2) \cdot (X - 2C - 1) + \beta(s + q(1 - t)/2)\end{aligned}$$

Observe that private benefits distort the private choice between liquidity and transparency. In particular, there exist parameter values such that transparency achieves higher social welfare than liquidity $\Pi_T^S > \Pi_{L,\beta}^S$, yet bankers prefer liquidity that gives

them private benefits of control $\Pi_T > \Pi_{L,\beta}$:

$$1/2 + \beta \frac{(s + q/2)}{q(X - C)} < t < 1/2 + \beta \frac{(s + q/2)}{q(X - C - 1)} \quad (11)$$

This may lead to the situation when banks choose both suboptimal depth *and* type of hedging – are liquid only when a combination of liquidity and transparency is welfare optimal and transparency only is a second best.

To verify this, consider the intersection of suboptimal type of hedging (11) with suboptimal depth of hedging $\Pi_{LT,\beta}^S > \Pi_T^S$ while $\Pi_{LT,\beta} < \Pi_T$:

$$\frac{q(1-t)/2}{1-s} \cdot (X-1) + \beta \frac{s + q(1-t)/2}{1-s} < C < \frac{q(1-t)/2}{1-s} \cdot X + \beta \frac{s + q(1-t)/2}{1-s} \quad (12)$$

Proposition 4 *When liquidity gives private benefits of control, in addition to suboptimal depth, bankers may use suboptimal type of hedging – use prudential buffers instead of investing in transparency. There exist parameter values such that the intersection of (11) and (12) is not empty.*

Proof. see Appendix ■

The fact that banks may have an intrinsic bias towards liquidity, at the expense of transparency, cautions against sole reliance on liquidity requirements. Liquidity requirements may need to be complemented by an emphasis on transparency.

7 Conclusion

This paper studied the roles of liquidity and transparency in bank risk management. Liquidity risk was modelled as solvency uncertainty at the refinancing stage. We showed that both liquidity and transparency are important hedges, and moreover can be combined in risk management. However, banks' private choices can be distorted by leverage, and policy response is complicated by multi-tasking. Reserve requirements may compromise banks' transparency incentives. Liquidity requirements may need to be complemented by an emphasis on transparency. The paper has identified a number of empirical implications.

A Proofs

Lemma 1 Proof. For $t < 1/2$ we have to show that

$$\frac{q/2}{1-s-q/2} \cdot (X-1) > \frac{qt/2}{1-s-q(1/2-t)} \cdot X$$

Indeed, in the numerator, $X-1 > tX$ since $X > 2$ and $t < 1/2$; and in the denominator, $1-s-q/2 < 1-s-q(1/2-t)$.

For $t > 1/2$ we have to show that

$$\frac{qt}{1-s-q(1-t)} \cdot (X-1) > \frac{q(1-t)/2}{1-s} \cdot X$$

Indeed, in the nominator, $X-1 < (1-t)X$ since $X > 2$ and $(1-t) > 1/2$; and in the denominator, $1-s-q(1-t) < 1-s$. ■

Proposition 4 Proof. Rewrite (11) as

$$X-1 - \frac{s+q/2}{q(1/2-t)} < C < X - \frac{s+q/2}{q(1/2-t)}$$

We have to show that there exist parameter values such that

$$\frac{q(1-t)/2}{1-s} \cdot (X-1) + \beta \frac{s+q(1-t)/2}{1-s} < X - \frac{s+q/2}{q(1/2-t)}$$

and

$$X-1 - \frac{s+q/2}{q(1/2-t)} < \frac{q(1-t)/2}{1-s} \cdot X + \beta \frac{s+q(1-t)/2}{1-s}$$

Consider, for example, parameter values such that the first expression holds with near equality:

$$\frac{q(1-t)/2}{1-s} \cdot (X-1) + \beta \frac{s+q(1-t)/2}{1-s} \approx X - \frac{s+q/2}{q(1/2-t)} = A$$

Then in the second expression, the left-hand side is $A-1$ while the right hand side $A + \frac{q(1-t)/2}{1-s} > A-1$ ■

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Figure 1: Game tree

