A walk down Lombard Street : essays on banking

Ratnovski, L.

Publication date
2008

Chapter 3

Liquidity and Transparency in Bank Risk Management

Banks are exposed to liquidity risk when solvency concerns arise at the refinancing stage. To manage that risk, banks can accumulate liquid assets, or enhance transparency to facilitate refinancing. A liquidity buffer provides complete insurance against small liquidity needs, while transparency offers partial insurance against large ones as well. Without regulatory incentives, banks can under-invest in both liquidity and transparency. While liquidity can be imposed, transparency is not verifiable. This multi-tasking problem complicates liquidity regulation. Liquidity requirements can compromise banks' endogenous transparency choices, leaving them exposed to large shocks.[1]

3.1 Introduction

Banks perform maturity transformation: their liabilities (demandable and term) usually have a shorter contractual maturity than their assets. A bank therefore needs to routinely roll over debt and refinance withdrawals. Liquidity events, when a solvent bank cannot refinance despite having valuable long-term assets, can lead to costly bank failures.

[1] I thank for useful comments Viral Acharya, Arnoud Boot, Charles Goodhart, Mark Flannery, Charles Kahn, Erlend Nier, Daniel Paravisini, Enrico Perotti, Rafael Repullo, Jean-Charles Rochet, Javier Suarez, Ernst-Ludwig von Thadden, Tanju Yorulmazer, and participants of the WFA meetings (2006, Denver), EFA meetings (2006, Zurich), BCBS/FDIC workshop on "Banking, Risk, and Regulation", CEPR conference on "Corporate Finance and Risk Management", and LSE conference on "Cycles, Contagion, and Crises". All errors are mine.

The literature has traditionally linked liquidity risk to uninformed depositor runs (Diamond and Dybvig, 1983). Yet recent evidence suggests that the origin of liquidity risk has shifted to wholesale funding markets. Most recent liquidity events in developed countries were caused by bank solvency concerns that were widely spread among "informed" market participants:

- Citibank and Standard Chartered (HK), 1991: rumors of technical insolvency;
- Lehman Brothers, 1998: rumors of severe losses in emerging markets;
- Commerzbank, 2002: rumors of insolvency due to trading losses;
- The interbank market meltdown of August-September 2007 was also in large part attributed to banks' uncertain exposures to subprime mortgage-backed securities and troubled investment vehicles.

In each instance, a bank with uncertain solvency typically had to cover all maturing wholesale outflows with minimal access to new funds. In contrast, retail outflows have been relatively modest, e.g. only 5% of the deposit base for BAWAG in 2006 and 8% for Northern Rock in 2007. To survive a liquidity shock, a bank needed to support itself with own funds for the duration of stress, and alleviate market's concerns over its solvency to regain access to external funds as soon as possible.

This paper offers a novel model of bank liquidity risk aligned with recent evidence that refinancing frictions in solvent banks are driven by asymmetric information in wholesale funding markets, and considers risk management and regulatory implications.

In the model, we consider a bank with a valuable long-term project that normally produces a high return, but with a small probability can turn out to be of zero value. Because solvency risk is small, it does not prevent initial funding. At the intermediate date, the bank needs to refinance an exogenous random withdrawal. Yet its ability to do so can be compromised by informational frictions. In most states of the world, the bank is confirmed to be solvent, and investors are willing to refinance it. Yet with some probability investors can receive a negative signal that the likelihood of insolvency is high. In that case, investors will become unwilling to refinance, creating liquidity risk – and a possibility of failure, even for a solvent bank. The effect where the lemon premium can suddenly increase during the refinancing stage is the key feature of this model. It allows explaining why, with no changes in fundamental value, banks that could easily obtain initial funding remain exposed to refinancing frictions later.

When external refinancing is not available, a precautionary *liquidity buffer* of easily tradeable short-term assets allows to cover possible withdrawals internally. An alternative hedging strategy is for a bank to adopt *transparency*. We understand transparency as a set of mechanisms that facilitate the communication of solvency information to the market. Transparency reduces asymmetric information, improves access to external funds, and lowers the probability that refinancing will be unavailable in the first place. Both liquidity and transparency are ex-ante investments that need to be undertaken before possible liquidity shocks occur.

While liquidity and transparency are strategic substitutes, their precise effects are different. A precautionary liquidity buffer allows the bank to cover any outflows within its size, providing complete insurance against small liquidity needs. Transparency, on the other hand, helps resolve solvency concerns and obtain external refinancing for liquidity needs of any size. Yet it is effective only with probability (ex-post communication is imperfect) and provides incomplete insurance. This leads to the result that liquidity and transparency can complement each other. Banks can combine them in risk management, using liquidity buffers to fully insure against small shocks, and transparency (enhanced ability to borrow) to partially cover large shocks as well.

Banks' incentives to invest in liquidity and transparency can be distorted by leverage (Jensen and Meckling, 1976). Suboptimal hedging justifies policy intervention. However, while liquidity is verifiable and can be imposed (for example, through explicit ratios), transparency is not easily verifiable and is more difficult to regulate. A resultant multi-tasking problem complicates optimal policy design. The most surprising result is that liquidity requirements can compromise banks' transparency choices. The reason is that more liquid banks are insured against a wider range of shocks and have lower marginal benefits of investing in transparency. When transparency is crowded out, overall bank risks can increase and social welfare – deteriorate, because market access is important for covering large liquidity needs.

This paper contributes to the literature on liquidity crises. A close model of liquidity events based on asymmetric information, Chari and Jagannathan (1987), considers consumer-based panics. When uninformed depositors observe withdrawals and make solvency inferences, but are unable to distinguish between information and liquidity reasons for withdrawals, they can run on fundamentally solvent banks. In contrast, this paper adopts a wholesale finance perspective. It downplays the determinants of withdrawals, because banks known to be solvent should be able to refinance (Goodfriend and King, 1988)[2]. Instead we focus on the refinancing problem, where a bank may need to prove its

[2] Chari and Jagannathan themselves state that "the most serious problem" with their approach is that it assumes "the absence of markets for trading is asset claims" (*p.722, remark 2*).

solvency on order to access funding markets.

Another closely related model is Freixas et al. (2004). They model wholesale refinancing frictions under asymmetric information by assuming that a solvent bank that requires refinancing is indistinguishable from an insolvent bank that attracts additional funds to gamble for resurrection. We offer a more streamlined approach, where both solvent and insolvent banks face a fundamentally identical liquidity need – to refinance withdrawals, while refinancing frictions relate exclusively to asymmetric information on solvency.

Empirical literature has demonstrated that both stock liquidity (Paravisini, 2007) and transparency (better access to external financing, Kashyap and Stein, 1990, Holod and Peek, 2004) determine bank financial constraints. There is evidence that banks may be insufficiently liquid (Gatev et al., 2004, Gonzalez-Eiras, 2003) and transparent (Morgan, 2002). Yet the literature has mostly considered liquidity and market access separately[3]. Our paper articulates a descriptive joint framework, emphasizing a certain but limited in size hedging effect of cash holdings, and a more flexible in size but uncertain hedging effect of transparency and market access. This offers a number of novel empirical predictions for bank liquidity risk and its management.

Firstly, the model indicates that the correct measurement of bank financial constraints should include both its liquidity position and ability to borrow. Secondly, the mix of bank's liquidity insurance choices affects its resilience to shocks of different magnitude. More liquid banks have higher resilience to small shocks, while more transparent banks can better withstand large shocks. Lastly, the model has predictions for banks' choice between liquidity and transparency. Other else equal, more liquid banks will choose to be less transparent, while more transparent banks (for example, listed ones) – less liquid. Also, banks will rely on liquidity to manage routine cash flows, but emphasize transparency (borrowing capacity) in the anticipation of large liquidity needs.

Our analysis yields a number of topical policy implications. Firstly, we caution on the consequences of wrongly designed liquidity requirements, which can have unwanted effects, such as reduced transparency and market access. The considerations of asymmetric information should feature prominently in the design of liquidity regulation.

Secondly, the model demonstrates that solvency regulation alone cannot fully address liquidity risk. The reason is that refinancing frictions are driven by *asymmetric information* on solvency. Unless asymmetric information is reduced, higher solvency would not

[3]A rare exception is Acharya et al. (2006) who show that debt capacity is a more effective way of boosting investment in high cash flow states, while retained earnings – in low cash flow states.

necessarily lead to a reduction in liquidity risk. And even when it does, using liquidity regulation (rather than excessively stringent solvency requirements) can be more efficient.

Finally, the model sheds light on the relationship between the move to market-based financing of banks (and the proliferation of non-bank financial intermediaries) and liquidity risks in the financial system. If liquidity risk was primarily driven by demandable deposits, then lower reliance on retail funding would imply reduced risks. Yet, our model shows that liquidity risk is present also without demandable deposits and classic bank runs. In fact, extrapolating from recent events, retail liabilities are a relatively more stable source of bank financing (cf. Gatev and Strahan, 2006). Consequently, liquidity risks are likely to remain, if not increase, as financial intermediaries move to market-based funding. Indeed, during August-September 2007, banks that most heavily relied on wholesale funding (such as Countrywide in the US or Northern Rock in the UK) appeared particularly vulnerable.

The paper proceeds as follows. Section 2 discusses the notion of bank transparency. Section 3 sets up the model of liquidity risk driven by asymmetric information. Section 4 introduces hedging choices and shows that banks can optimally combine liquidity and transparency in risk management. Section 5 observes that banks can under-invest in hedging due to leverage. Section 6 analyses whether regulation can improve banks' hedging choices, and identifies the multi-tasking problem. Section 7 discusses robustness. Section 8 concludes.

3.2 What is Bank Transparency?

A better understanding of determinants and effects of bank transparency is important in the context of recent debates on Pillar 3 (market discipline) of Basel II. The issue is also relevant for the analysis of the interbank market meltdown of August-September 2007 when access to funding was restricted in part because banks could not verify that they were sufficiently solvent. This section provides examples of strategic actions by which banks can enhance their transparency. We clarify that achieving transparency requires more than mechanical disclosure, and that transparent assets are not necessarily liquid (so that there is scope for a liquidity-transparency trade-off).

Banks are inherently opaque, because through lending relationships they obtain non-verifiable information on borrowers. One way by which they can reduce asymmetric information is to offer less information-sensitive loans (Boot and Thakor, 2000), for example standardized mortgages. Yet our focus is different. We suggest that, in addition, banks can make a specific investment in *transparency* that reduces asymmetric information for any given asset mix.

Transparency is different from mechanical disclosure. We interpret it as an ex-ante investment to allow reliable disclosure ex-post (Perotti and Von Thadden, 2003). Otherwise, disclosure – ex-post information release – can be not credible or ineffective (Boot and Thakor, 2001).

There are a number of actions that banks can take to enhance transparency. Banks can issue subordinated debt (Calomiris, 1999) even when cheaper funding is possible, in order to have market participants who specialize on assessing them available should a genuine need for funds arise. Banks can invest in risk management and accounting systems that produce better (and externally verifiable) information on the effects of possible shocks. Transparency can be improved by streamlining "large and complex financial institutions" (LCFIs) so as to make their individual businesses more comparable with specialized counterparts. Banks can also build reputation for credible future disclosure[4].

Observe from these examples that enhancing transparency may require complex actions. This makes transparency not easily contractible, and even more difficult to regulate when required actions differ across banks. Also neither of the mechanisms can guarantee perfect transparency. For example, while the suggestion of Calomiris (1999) to mandate regular issuance of subordinated debt is intriguing, it has not yet been fully tested in practice. Moreover, the events of August-September 2007 demonstrated how debt valuations can deviate from fundamentals (a large part of debt in question was secured as ABCP, but unsecured debt can be not immune to similar distortions either)[5].

Assets traded on liquid markets can typically be regarded as transparent when their price provides relatively precise information on fundamental value. In contrast, not all transparent assets are liquid. For example, outsiders may have good information on assets' fundamental value, but if collecting repayment requires bank-specific skills such assets

[4]The actions of Citicorp following the Latin American debt crisis (Griffin and Wallach, 1991) are illustrative. In late 1980-es, many U.S. banks experienced large and uncertain losses on defaulted Latin American debts, which hampered their access to money markets. In May 2007, Citicorp became the first large bank to make substantial provisions ($3 billion). That served as a signal of commitment to draw a line under prior losses – credible due to the risk of a negative market reaction if realized losses ended up being higher. The provisioning led to a *positive* market reaction and improved access to funds. Similar effects were observed following the events of August-September 2007.

[5]The effectiveness of bank's investment in transparency can also be affected by country-specific (more developed and liquid financial markets) or industry-specific (transparent peer banks or location in the financial centre when there are positive informational externalities, Admati and Pfleiderer, 2000) factors that are outside a single bank's control.

cannot be simply sold to raise cash. Instead, a bank may be able to raise cash by borrowing against their future value. In the paper we explore this dichotomy between holding liquid assets that can be simply converted into cash and having transparency over the value of illiquid assets that enables borrowing.

The last remark is that while bank transparency has numerous effects[6], this paper focuses on the effects of transparency during the time of sudden shocks. The reason, as we show, is that when shocks are associated with increased asymmetric information, the effects of transparency are particularly pronounced.

3.3 A Model of Liquidity Risk

3.3.1 Economy and Agents

Consider a risk-neutral economy with three dates $(0, 1, 2)$ and no discounting. The economy is populated by multiple competitive investors and a single bank. The investors are endowed with money that they can lend to the bank against expected rate of return 1.

The bank has no initial capital, but enjoys exclusive 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). The bank operates under a leverage constraint and cannot borrow more than 1 at date 0. It is financed by debt (some of it is short-term and needs to be refinanced at date 1, as detailed below) and maximizes date 2 profit. The timeline is given in Figure 1.

<< *Figure 1* >>

3.3.2 Solvency Concerns and Liquidity Risk

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

[6] For example, beneficial when it increases fundamental value and reduces overall funding costs by facilitating screening and monitoring (Boot and Schmeits, 2000, Flannery 2001), or negative such as when information is passed to competitors.

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 l, the liquidity need is low – the bank has to repay some $L < 1$. With additional probability $1-l$, the liquidity need is high – the bank has to repay 1. If a 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 (there is no aggregate liquidity shortage), a bank known to be solvent is able to refinance any date 1 withdrawals by new borrowing. Yet smooth refinancing can be impeded by the effects of asymmetric information, namely – increased solvency concerns. That is the origin of liquidity risk, and the key ingredient of this model.

Recall that a bank is fundamentally solvent with probability $1-s$ and insolvent with probability s. Assume that, at date 1, investors receive a *noisy* signal of bank solvency. Concretely, with probability $1-(s+q)$ there is a correct "positive" signal that a bank is solvent and will yield X with certainty. Solvent banks are able to refinance themselves at a risk-free rate.

However, with a residual probability $s+q$, there is a "negative" signal that a bank is likely to be insolvent. That signal is received by a mass s of genuinely insolvent banks, but also by a mass q of solvent banks that are wrongly pooled together with insolvent ones. The posterior probability of insolvency under a "negative" signal, $s/(s+q)$, is higher then the ex-ante probability of insolvency, s. Higher solvency risk can prevent external refinancing, creating liquidity risk. The informational structure determining liquidity risk in this model is illustrated in Figure 2.

<< *Figure 2* >>

The fact that the lemon premium for a bank affected by solvency concerns at date 1 is higher than the original lemon premium at date 0 is the key to our modelling of liquidity risk. It implies that a sudden increase in asymmetric information can prevent refinancing even though a bank has been able to attract initial funding.

Formally, we impose two restrictions. Firstly:

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

This assures that a bank can always obtain initial financing at date 0. Even if it always failed in a liquidity shock (upon a "negative" signal at date 1, which happens with probability $1-(s+q)$), it could borrow by offering repayment $1/[1-(s+q)]$ in case of success. Secondly:

$$X < (1-L) + L \cdot \frac{s+q}{q} \tag{A2}$$

This is a sufficient condition under which a bank with a "negative" signal at date 1 cannot obtain refinancing. The condition addresses the most mild scenario of a small withdrawal of size L, to refinance which the bank has to offer repayment $L \cdot [s+q]/q$, and the lowest possible interest rate 1 on initial funding (of which $(1-L)$ does not need to be refinanced). A bank faced with a more severe scenario of a large withdrawal of size 1 would also be unable to refinance since, by (A2), $X < [s+q]/q$.

Observe that there exist parameter values such that (A1) and (A2) are satisfied simultaneously (take $s+q << 1$ and $q << s$). We can now summarize the main property of this model:

Proposition 4 *Under (A1) and (A2) a bank can attract initial funding at date* 0*, but if faced with solvency concerns (in a mass q of solvent banks pooled together with a mass s of insolvent banks) cannot obtain intermediate refinancing at date* 1*. This is the source of liquidity risk in the model.*

The corollary from Proposition 1 is that the ability to separate from insolvent banks (which we will further interpret as transparency) is less important at date 0 but may become critical in case of a "negative" intermediate signal at date 1.

Before proceeding to the analysis of risk management options, we make a simplifying assumption that initial financing at date 0 is covered by deposit insurance. This makes the repayment the bank has to promise original investors 1. To preserve refinancing frictions at the intermediate stage, we maintain that date 1 refinancing is *not* covered by deposit insurance. (This is plausible when date 0 investments are deposits, while date 1 refinancing is market-based, corresponding to the practice of using wholesale funds to manage liquidity needs.) The deposit insurance assumption does not affect qualitative properties of the model; it reduces leverage (which is the main distortion) and can only weaken our results. We discuss robustness in Section 7.

3.4 Liquidity Risk Management

In this section, we introduce the instruments of bank liquidity risk management – liquidity buffers and transparency – and analyze socially optimal hedging choices. We show that liquidity and transparency are only partial substitutes, and for low enough costs of hedging can be optimally combined in risk management. Then, a precautionary liquidity buffer fully insures a solvent bank against small withdrawals, which happen with probability l. At the same time, transparency partially insures against large withdrawals as well, by allowing to confirm bank solvency and enabling external refinancing with probability t.

3.4.1 Instruments

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

Firstly, a bank can *accumulate a liquidity buffer*. A bank can invest L into short-term assets (storage: cash or easily tradeable securities that at any date produce a safe but minimal return of 1). This allows to fully cover possible small withdrawals at date 1, which happen with probability l. Note that, by construction, a bank cannot use liquidity to insure against large withdrawals (of size 1) because that would require allocating all initial financing to storage, leaving nothing for the profitable investment.

Secondly, a bank can *adopt transparency*. A bank needs to spend T to establish it. We think of transparency as a strategic ex-ante investment that facilitates future information communication. Transparency can help the bank publicly confirm its solvency and refinance both small and large liquidity needs. Yet, transparency is imperfect due to unavoidable frictions in ex-post communication; we assume that it is effective only with probability $t < 1$.

Both liquidity and transparency have costs. They crowd out profitable investment. Investing L in liquidity reduces return to a successful bank by $L(X-1)$, investing T in transparency – by TX, and having both liquidity and transparency together – by $L(X-1)+TX$. Since we are primarily interested in different hedging effects of liquidity and transparency, we take their costs to be equal: $L(X-1) = TX = C$ (for both hedges $L(X-1) + TX = 2C$), where C is the generic cost of hedging. We also assume that when a liquid bank fails at date 1 its liquidity buffer is lost (liquidity is allocated to costly bankruptcy proceedings or converted into marginal bankers' private benefits, Myers and Rajan, 1998); this makes return to a failing bank always 0.

For definitiveness, when indifferent, banks prefer to be hedged, and prefer liquidity over transparency. Bank returns, depending on its ex-ante hedging choice and the shock realized at date 1, are summarized in Figure 3.

<< *Figure 3* >>

3.4.2 Hedging Strategies

We first derive the levels of social welfare corresponding to different bank hedging choices.

When a bank is neither liquid nor transparent (strategy "N"):

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

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.

When a bank is liquid but not transparent (strategy "L"):

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

A solvent bank survives a small liquidity shock (probability ql) by covering it from the precautionary buffer. It fails in a solvency shock (probability s) or in a large liquidity shock when withdrawals exceed the size of the buffer (probability $q(1-l)$). Therefore the probability of survival is $1 - s - q(1 - l)$, the return in that case is $X - C$ (C is the cost of hedging), and the initial investment is 1.

When a bank is transparent but not liquid (strategy "T"):

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

A solvent bank survives a liquidity shock (either small or large) when it is successful in communicating solvency information to the market, with probability t. It fails in a solvency shock (probability s) or in a liquidity shock when transparency is ineffective (probability $q(1 - t)$). 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, when a bank is both liquid and transparent (strategy "LT"):

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

A solvent bank survives a small liquidity shock (probability ql) by covering it from a precautionary buffer, and a large liquidity shock when successful in communicating solvency information, with probability t. It fails in a solvency shock (probability s) or in a large liquidity shock when transparency is ineffective (probability $q(1-l)(1-t)$). Therefore, the probability of survival is $1 - s - q(1-l)(1-t)$, the return in that case is $X - 2C$ (note double hedging cost), and the initial investment is 1.

3.4.3 Optimal Risk Management

We use these four payoffs to compare social welfare and derive bank's socially optimal hedging strategy.

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

Another dimension is the depth of hedging – whether to hedge at all, adopt a single hedge, or have both hedges. Note that the marginal benefit of having a second hedge is lower than that of the first hedge. This is because the first hedge adopted is a more effective one (liquidity for $l \geq t$ and transparency for $l < t$), and already protects a bank from a range of liquidity shocks. Optimal depth of hedging depends on its cost C. It is optimal that a bank has no hedge for high costs of hedging, a single hedge (liquidity or transparency, whichever more effective) for intermediate costs of hedging, and both hedges (liquidity *and* transparency) for low costs of hedging. We consider two cases:

Case 1: Liquidity is more effective, $l \geq t$. It is optimal that a bank:

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

$$C > \frac{ql}{1 - s - q(1-l)} \cdot X$$

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

$$\frac{q(1-l)t}{1 - s - q(1-l)(1-2t)} \cdot X < C \leq \frac{ql}{1 - s - q(1-l)} \cdot X$$

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

$$C \leq \frac{q(1-l)t}{1-s-q(1-l)(1-2t)} \cdot X \tag{3.1}$$

Case 2: Transparency is more effective, $l < t$. Analogously, it is optimal that a bank:

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

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

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

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

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

$$C \leq \frac{ql(1-t)}{1-s-q(1-2l)(1-t)} \cdot X \tag{3.2}$$

Now consider conditions (3.1) and (3.2). Observe that they have strictly positive right sides. Therefore, for any l, t, q, s, there exists a cost of hedging C low enough, such that any of them holds, and it is socially optimal for a bank to be both liquid and transparent. This leads to the following main result:

Proposition 5 *When costs of hedging are low enough, it is optimal that banks combine liquidity and transparency in their risk management. For any l, t, q, s, there exists C low enough, such that conditions (3.1) for $l \geq t$ or (3.2) for $l < t$ are satisfied.*

Proposition 2 establishes that there exist conditions when it is optimal for the bank to be both liquid (to fully hedge small withdrawals) and transparent (to partially hedge large withdrawals), in order to mitigate liquidity risk to the maximum extent possible in the model. It shows that both liquidity and transparency are important dimensions of liquidity risk management, and may need to be combined to achieve a socially optimal outcome.

If the cost of hedging were higher, a bank could improve by foregoing the less efficient hedging mechanism, or avoiding hedging altogether. Yet, without loss of generality, we focus further analysis on possible distortions from optimal full hedging, and consider the case when conditions (3.1) or (3.2) are satisfied.

3.5 Suboptimal Risk Management

We now turn to bank's private liquidity and transparency choices. They can be distorted by leverage. The cost of hedging reduces bankers' payoff in the good state. At the same time, bankers do not fully internalize the benefits of lower probability of failure due to limited liability, sharing them with debtholders (or the deposit insurance fund). Consequently, when hedging choices are not contractible, banks can under-invest in hedging. (We introduce the possibility of contracting on hedging choices in the next section, in the context of regulation.) Such risk-shifting is a standard agency problem in corporate finance (Jensen and Meckling, 1976). For banks, similar distortions can also be derived from systemic externalities of bank failure (Acharya and Yorulmazer, 2007A and -B) or gambling for LOLR rents (Mailath and Mester, 1994, Ratnovski, 2007).

3.5.1 Private Payoffs

Consider the amount of debt the bank has to repay in case of success. At date 0, it borrowed 1 unit of money, with a nominal repayment 1 thanks to deposit insurance. When the bank refinances some debt at the intermediate date with new borrowing, that has zero net effect on debt outstanding (intermediate refinancing also has a 1 nominal interest rate – it is risk-free since 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 $1-L$ that will have to be repaid at date 2. As a result, the bank's total debt repayment in case of success is always 1. (Debt repayment in case of failure is 0.)

We can now derive the private payoffs. They are similar to the social ones, with the difference that the bank does not internalize the debt repayment of 1 that it makes in case of success. The payoffs for strategies "N", "L", "T" and "NT" are:

$$
\begin{aligned}
\Pi_N &= (1-s-q)\cdot(X-1) \\
\Pi_L &= (1-s-q(1-l))\cdot(X-C-1) \\
\Pi_T &= (1-s-q(1-t))\cdot(X-C-1) \\
\Pi_{LT} &= (1-s-q(1-l)(1-t))\cdot(X-2C-1)
\end{aligned}
$$

3.5.2 Risk Management Choices

Observe that leverage does not affect the choice between liquidity and transparency: as in the social optimum, banks prefer liquidity for $l \geq t$ ($\Pi_L \geq \Pi_T$) and transparency for $l < t$ ($\Pi_L < \Pi_T$). The reason is that liquidity and transparency have the same cost, and bankers benefit from the effectiveness of the hedge they adopt.

We can now derive banks' private hedging choices. Recall that we focus on sufficiently low values of C ((3.1) for $l \geq t$ or (3.2) for $l < t$), such that it is socially optimal for banks to combine liquidity and transparency in risk management. As before, we distinguish two cases:

Case 1: Liquidity is more effective, $l \geq t$. The bank:

– Chooses to be only liquid ("L") or unhedged ("N") – deviating from the social optimum – for intermediate costs of hedging $\Pi_{LT} < \Pi_L$ (but restricted to $\Pi^S_{LT} \geq \Pi^S_L$):

$$\frac{q(1-l)t}{1-s-q(1-l)(1-2t)} \cdot (X-1) < C \leq \frac{q(1-l)t}{1-s-q(1-l)(1-2t)} \cdot X \tag{3.3}$$

– Chooses to be both liquid and transparent ("LT") – in line withy the social optimum – for low costs of hedging $\Pi_{LT} \geq \Pi_L$:

$$C \leq \frac{q(1-l)t}{1-s-q(1-l)(1-2t)} \cdot (X-1) \tag{3.4}$$

Case 2: Transparency is more effective, $l < t$. The bank:

– Chooses to be only transparent ("T") or unhedged ("N") for $\Pi_{LT} < \Pi_T$ (but restricted to $\Pi^S_{LT} \geq \Pi^S_T$):

$$\frac{ql(1-t)}{1-s-q(1-2l)(1-t)} \cdot (X-1) < C \leq \frac{ql(1-t)}{1-s-q(1-2l)(1-t)} \cdot X \tag{3.5}$$

– Chooses to be both liquid and transparent ("LT") for $\Pi_{LT} \geq \Pi_T$:

$$C \leq \frac{ql(1-t)}{1-s-q(1-2l)(1-t)} \cdot (X-1)$$

Note that the bank is more likely to deviate from the social optimum for higher cost of hedging C and lower return in case of success (related to charter value) X. For any

X there exist values of C such that public and private hedging incentives diverge, which leads to our next result:

Proposition 6 *A bank can under-invest in liquidity and transparency when its incentives are distorted by leverage. For any l, t, q, s, there exist values of C such that conditions (3.3) for $l \geq t$ or (3.5) for $l < t$ are satisfied.*

3.6 Multitasking in Liquidity Regulation

Banks' suboptimal hedging choices can justify regulatory intervention. Observe that influencing the size of the bank's liquidity buffer is relatively easy, because the holdings of liquid assets are (to a large extent) verifiable and can be imposed, for example, by explicit ratios. However, the regulatory lever on transparency is weaker and at best indirect. Mandatory disclosure is ineffective when it is difficult to define relevant quantifiable parameters, or when banks can engage in "creative" reporting. Further, Section 2 listed examples of other actions that banks may need to undertake to enhance transparency, and explained why it can be difficult to contract on them in advance, especially in the context of regulation.

This implementation issue (cf. Glaeser and Shleifer, 2001) can help explain why financial regulation typically puts emphasis on ensuring prudential liquidity buffers rather than transparency and market access. However, when transparency is an important yet not verifiable component of risk management, the optimal design of liquidity regulation becomes a multi-tasking problem. The challenge is that liquidity requirements can affect bank's endogenous incentives to adopt transparency.

To see this analytically, consider the setting where:

- It is socially optimal that a bank is both liquid and transparent, $\Pi^S_{TL} \geq \Pi^S_T$ (3.2);
- Without regulation, the bank chooses to be transparent only: this implies $t > l$, and $\Pi_T > \Pi_{TL}$ and $\Pi_T \geq \Pi_N$:

$$\frac{ql(1-t)}{1-s-q(1-2l)(1-t)} \cdot (X-1) < C \leq \frac{qt}{1-s-q(1-t)} \cdot (X-1) \tag{3.6}$$

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

Under liquidity requirements, the decision to retain transparency depends on its effectiveness as a second hedge. When transparency is very effective, compared to the effectiveness of liquidity and the cost of hedging, the bank is likely to preserve it on top of mandated liquidity. The bank would retain transparency for $\Pi_{LT} \geq \Pi_L$ (3.4) as determined by low C, low l, and high t. However when transparency is less effective, the bank can choose to drop transparency. This happens for $\Pi_{LT} < \Pi_L$:

$$C > \frac{q(1-l)t}{1-s-q(1-l)(1-2t)} \cdot (X-1) \tag{3.7}$$

We show in the Appendix that there exist parameters value of X, l, t, q, s and C, such that the intersection of (3.2), (3.6) and (3.7) is nonempty:

$$\begin{aligned} C &\leq \min\left\{\frac{ql(1-t)}{1-s-q(1-2l)(1-t)} \cdot X \; ; \; \frac{qt}{1-s-q(1-t)} \cdot (X-1)\right\} \\ C &> \max\left\{\frac{ql(1-t)}{1-s-q(1-2l)(1-t)} \cdot (X-1) \; ; \; \frac{q(1-l)t}{1-s-q(1-l)(1-2t)} \cdot (X-1)\right\} \end{aligned} \tag{3.8}$$

Then, under liquidity requirements, previously transparent banks lose incentives to invest in transparency and remain with mandated liquidity only. Recall that in this setup transparency was a more effective method of hedging liquidity risk ($t > l$). Therefore when liquidity is substituted for transparency the probability of solvent bank failures increases from $q(1-t)$ to $q(1-l)$, representing higher risks and lower social welfare.

Proposition 7 *Liquidity requirements reduce banks' incentives to invest in transparency. There exist parameters l, t, q, s and C, which satisfy $t > l$ and (3.8), so that a bank stops investing in transparency in response to liquidity requirements, leading to higher risks and lower social welfare.*

Observe that transparency is likely to be effective ($t > l$) in countries with more developed financial markets, and there the adverse effects of incorrect liquidity requirements are most likely. In contrast, banks in developing countries have relatively limited market access ($t < l$) and can more safely emphasize stock liquidity. This is consistent with the evidence that liquidity regulation is not binding in advanced banking systems, such as those of US or UK (Bennet and Peristiani, 2002, Chaplin et al., 2000), while banks in developing countries often face stringent liquidity requirements (Freedman and Click, 2006). These cross-country differences in optimal liquidity-transparency outcomes may need to be born in mind during possible international convergence of liquidity regulation.

3.7 Robustness

Withdrawals and information The model assumed that the size of withdrawals (L with probability l and 1 with probability $1 - l$) is independent of the concurrent informational signal. This reflects the behavior of uninformed depositors (who do not receive or cannot interpret the solvency signal) or term funding with pre-defined volumes of liabilities maturing at any point in time. Still, our model is robust to the possibility of high withdrawals being correlated with a signal of possible insolvency. Indeed, in the model the size of withdrawals does not matter under a "positive" signal (a bank known to be solvent can refinance any withdrawals). Therefore, l and $1 - l$ can be interpreted as the probability of low and high withdrawals contingent on the "negative" signal. All results remain.

Deposit insurance For modelling convenience, we assumed that initial (date 0) funding is covered by non-contributory deposit insurance. This assured that the repayment bank had to promise initial investors and the bank's total net repayment over dates 1 and 2 were both always 1. Note that the deposit insurance assumption lowers the amount a bank has to repay in case of success, reducing risk-shifting and *increasing* hedging incentives. This works against our result on under-investment in hedging.

The results are therefore robust to altering the deposit insurance set-up, for example by considering no deposit insurance or fairly priced deposit insurance. Then the ultimate cost of under-hedging would be born by bankers themselves, not the public deposit insurance fund. Yet when liquidity and transparency choices are not contractible banks can still under-hedge in equilibrium, distorting social welfare. The multi-tasking problem in liquidity regulation will also remain.

Other effects of liquidity Some features of bank liquidity were left outside this model. Banks can be biased towards liquidity instead of transparency if liquidity gives private benefits of control (Myers and Rajan, 1998) or allows to conceal losses (Rajan, 1994). Similarly, when some liquidity is preserved in failing banks and distributed back to depositors (as opposed to being lost as assumed for simplicity in the model), that would reduce the social costs of bank liquidity. Among other possible effects, anecdotal evidence (e.g. on Barclays in 1987 and Lehman Brothers in 1998) suggests that banks in crises can try to boost liquidity, apparently using it to signal solvency. During August-September 2007, banks were observed to "hoard" liquidity, possibly in anticipation of potential future losses. Lastly, while we assumed elastic liquidity supply, episodes of its aggregate shortage remain a possibility, e.g. during flight to quality episodes or in severe operational disruptions (as on September 11, 2001).

3.8 Conclusions

This paper modelled liquidity risk driven by asymmetric information in wholesale funding markets, associating it with solvency concerns that can arise at the refinancing stage. The setting gave rise to a number of risk management and regulatory implications. We showed that banks can optimally combine liquidity buffers and transparency (enhanced ability to borrow) in risk management. Yet their private choices can be distorted by leverage, while regulation complicated by multi-tasking. In particular, liquidity requirements can reduce incentives to invest in transparency and leave banks exposed to large shocks. Among other policy implications, we showed that high bank solvency cannot fully alleviate liquidity risks due to remaining asymmetric information, and that liquidity risks are likely to persist as banks shift from retail deposits to wholesale funding.

3.9 Proofs

Proof that condition (3.8) is nonempty Recall (3.8):

$$\begin{aligned} C &< \min\left\{\frac{ql(1-t)}{1-s-q(1-2l)(1-t)}\cdot X\ ;\ \frac{qt}{1-s-q(1-t)}\cdot(X-1)\right\} \\ C &> \max\left\{\frac{ql(1-t)}{1-s-q(1-2l)(1-t)}\cdot(X-1)\ ;\ \frac{q(1-l)t}{1-s-q(1-l)(1-2t)}\cdot(X-1)\right\} \end{aligned}$$

Consider the fist inequality. Observe that for $X > 2$

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

because in the nominator, $ql(1-t)X < qt(X-1)$ ($X > 2$ and $t > l > l(1-t)$), and in the denominator, $q(1-t) > q(1-2l)(1-t)$.

Therefore for $X > 2$ (3.8) transforms into

$$\begin{aligned} C &< \frac{ql(1-t)}{1-s-q(1-2l)(1-t)} \cdot X \\ C &> \max\left\{\frac{ql(1-t)}{1-s-q(1-2l)(1-t)} \cdot (X-1)\ ;\ \frac{q(1-l)t}{1-s-q(1-l)(1-2t)} \cdot (X-1)\right\} \end{aligned}$$

Observe that there always exist C such that

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

and there exist C such that

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

at least for t close to but above l since the two fractions become identical and $X - 1 < X$. *QED.*

FIGURE 1

The timeline

Date 0

* Banks attract initial funds

* Banks divide funds between investment in the profitable project, the precautionary liquidity buffer, and the investment in transparency;

Date 1

* A bank faces a random withdrawal of a part of initial funding

* There is a noisy public signal on bank's solvency

* A bank attempts refinancing (or can use a liquidity buffer)

* Insolvent banks, or those unable to serve withdrawals, fail at 0 liquidation value.

Date 2

* Project returns realize

* Successful banks repay debts and consume profits.

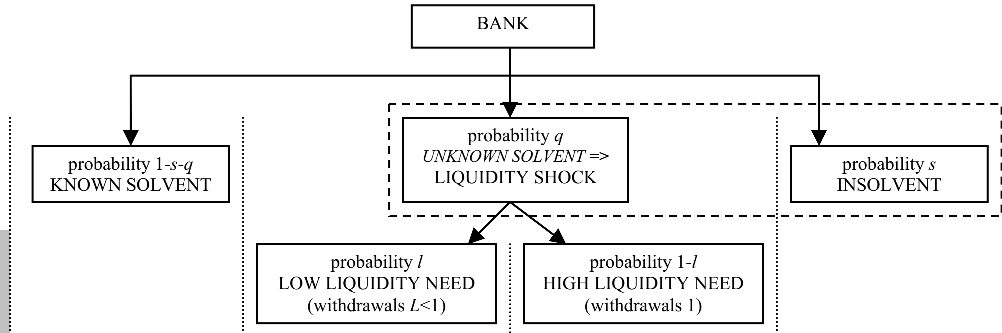
FIGURE 2

<u>Information structure at the Intermediate date</u>

Fundamentals	**Solvent, 1–*s***		**Insolvent, *s***
Information at date 1	**Positive signal, known solvent**	**Negative signal, pooled together**	
Outcome	**1–*s*–*q*** **Able to refinance**	***q*** **Solvent, but unable to refinance**	***s*** **Insolvent**

FIGURE 3

Bank returns, for states at date 1, depending on ex-ante hedging decisions



EX-ANTE HEDGING DECISIONS	probability 1-*s*-*q* KNOWN SOLVENT	probability *l* LOW LIQUIDITY NEED (withdrawals *L*<1)	probability 1-*l* HIGH LIQUIDITY NEED (withdrawals 1)	probability *s* INSOLVENT
NO HEDGE	Survives, returns *X*	Fails, returns *0*	Fails, returns *0*	Fails, returns *0*
LIQUID (can refinance small shocks)	Survives, returns *X-C*	Survives, returns *X-C*	Fails, returns *0*	Fails, returns *0*
TRANSPARENT (can refinance any shoks w.p. *t*)	Survives, returns *X-C*	Survives w/p *t*, returns *X-C* Fails w/p *1-t*, returns *0*	Survives w/p *t*, returns *X-C* Fails w/p *1-t*, returns *0*	Fails, returns *0*
BOTH	Survives, returns *X-2C*	Survives, returns *X-2C*	Survives w/p *t*, returns *X-2C* Fails w/p *1-t*, returns *0*	Fails, returns *0*