A walk down Lombard Street : essays on banking

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The thesis consists of three essays in banking. The first two deal with bank liquidity risk. The third addresses the issue of bank credit standards. The first essay, "Bank Liquidity Regulation and the Lender of Last Resort", studies banks' incentives to make suboptimal liquidity risk management choices under the distortive influence of rents associated with the lender of last resort intervention in a possible systemic crisis. The second essay, "Liquidity and Transparency in Bank Risk Management", analyses the interaction between two principal ways in which a bank can hedge the risk of liquidity shortfalls: accumulating liquidity buffers vs. enhancing transparency -- ability to communicate with the market, which allows better access to external refinancing. The third essay, "Credits Standards, Information, and Competition" (joint work with Enrico Perotti), suggests a novel rationale for banks' occasional use of lax credit standards.

Lev Ratnovski (1980) received his bachelor's from the Higher School of Economics in Moscow before proceeding to a doctorate at the University of Amsterdam. During graduate studies, he has visited University of Toulouse, University of Mannheim, and CEMFI in Madrid. Lev has interned at the Bank of England and IMF, and spent the last year of his studies as a full-time research economist at the Bank of England's financial stability area.

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A Walk Down Lombard Street
Lev Ratnovski

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Essays on Banking

Lev Ratnovski

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A Walk Down Lombard Street:
Essays on Banking

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I would like to dedicate this thesis to my parents and to my dear friend Marina, a source of my strength and inspiration.

February 2008, London

Contents

Chapter 1

Introduction

The banking industry undergoes dramatic change. The change is driven by increased competition (both within the industry and from non-banks) and by financial innovation. As a result, banks increasingly depart from the traditional model of conservative retail business, and adopt innovative funding and lending strategies. While some of those strategies undoubtedly increase efficiency and contribute to social welfare, others (or even the same ones!) also expose the banking system to new types of risks. The dangers associated with novel and often complex banking activities were abundantly illustrated during the recent credit market turmoil.

Two lessons from the recent events stand out. The first is the complexity of banks' funding strategies. Traditionally, banks financed themselves though fixed capital and (usually passive) deposits. Most strategic choices were taken on the asset side of the balance sheet. Not anymore. As competition for demandable deposits increases, banks increasingly use elaborate wholesale market funding tools (such as repos, commercial paper, etc.). The new structure of funding creates new types of risks. Should wholesale markets be disrupted (as during the recent events), banks can experience an effective creditor "run". Liquidity risks, which were considered mitigated under robust deposit insurance systems, re-emerge as a new and material threat.

The second lesson is that competition and innovation affect banks' prudence on the asset side of balance sheet. There, competition increases incentives to seek yield, while financial innovation provides instruments by which increased risks can be managed or, if desired, – concealed. This highlights the importance of understanding incentive structures behind banks' lending standards.

Although the current challenges in the banking system are time-specific, broadly they are not new. A large number of concerns – optimal ex-ante regulation, central bank credibility, ex-post resolution – were articulated as early as 150 years ago, in Walther Bagehot's "*Lombard Street: A Description of the Money Market*". The questions raised by Bagehot are as topical today as they were in 1873. The title of this thesis – "*A Walk Down Lombard Street*" – is a tribute to the originator of contemporary banking literature.

This thesis consists of three essays in banking. The first two deal with bank liquidity risk. The third addresses the issue of bank credit standards.

The first essay, "*Bank Liquidity Regulation and the Lender of Last Resort*", studies banks' incentives to take suboptimal liquidity risk management choices (e.g. hold insufficient liquidity buffers) and derives policy implications. The principal distortion I explore is the effect of rents associated with the lender of last resort (LOLR) intervention in a possible systemic crisis. The paper shows that such rents can reduce banks' incentives to accumulate sufficient liquidity ex-ante and make them gamble for ex-post LOLR support instead. Interestingly, this behavior can have self-fulfilling characteristics: due to inter-bank complementarity of payoffs, a bank can change its behavior (and start gambling) simply in response to gambling by another bank.

I argue that there are two ways in which the regulator can intervene to assure socially optimal bank liquidity. The first, mechanical, is to impose quantitative requirements. The second is to structure LOLR process so as to minimize its distortions. In designing the LOLR intervention, the regulator faces the conflict between maximizing ex-post repayment (to reduce rents) and preserving the bank's charter value (to keep bankers' incentives aligned). I show that, within that trade-off, the regulator can "price" LOLR loan more accurately when it has more precise information about banks' asset values. This is normally possible in more advanced, transparent banking systems. The country cross-sectional implication – that emerging economies have to rely on explicit liquidity regulation, while advanced countries can have less binding regulation compensated by effective ex-post corrective action – is consistent with existing evidence.

In the second essay, "*Liquidity and Transparency in Bank Risk Management*", I study the interaction between two principal ways in which a bank can hedge the risk of liquidity shortfalls. One, traditional, is to accumulate highly liquid assets, in order to finance possible shortfalls internally. Another, less conventional, is to enhance transparency – ability to communicate with the market that allows better access to external refinancing. The paper argues that, although 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 internally, offering 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. Hence, liquidity and transparency can complement each other, and banks can optimally combine them in risk management.

Banks' incentives to invest in liquidity and transparency can be distorted by leverage, and 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. This would leave the bank exposed to large liquidity needs, increasing overall risks and reducing social welfare. The paper shows how imposing liquidity buffers on banks may in fact increase liquidity risks they face.

The third essay, "*Credits Standards, Information, and Competition*" (joint work with Enrico Perotti), suggests a novel rationale for banks' occasional use of lax credit standards. We show that extending credit to "bad" firms increases information asymmetry between the informed incumbent bank and possible external competitors at the refinancing stage. This limits credit market competition and allows the inside bank to collect high relationship rents on good firms, more than compensating for losses on bad credit.

The paper shows that the capacity of the incumbent bank to distort competition through lax credit standards depends on entrants' ability to screen firms. This gives an interesting insight into the effects on increased inter-bank competition on credit quality: credit standards can either deteriorate or improve, depending on the qualities of new entrants. These effects can help better understand the prudential impact of banking deregulation and foreign entry.

Chapter 2

Bank Liquidity Regulation and the Lender of Last Resort

Banks can make suboptimal liquidity choices and gamble for lender of last resort (LOLR) support. Endogenous bailout rents are driven by the need to preserve bankers' incentives under uncertain net worth. In equilibrium, banks can herd in risk management, choosing suboptimal liquidity when they expect others to do so. Optimal liquidity can be restored by quantitative requirements, but such regulation is costly. An LOLR policy incorporating bank capital information can reduce distorting rents and allow for a more efficient solution, but may only be possible in transparent economies.[1]

2.1 Introduction

Banks provide liquidity insurance by offering demandable deposits and underwriting credit lines to firms (Diamond and Dybvig, 1983, Kashyap et al., 2002). In doing so, they become exposed to liquidity risk. The concern is that a bank with positive capital may fail due to a liquidity shortage. To insure, banks maintain precautionary "liquidity buffers" of tradeable short-term assets, which can be converted into cash without loss at a short notice.

[1] Journal of Financial Intermediation, forthcoming. I am grateful for helpful comments to Enrico Perotti (my advisor), George Pennacchi (the Editor), two anonymous referees, Viral Acharya, Arnoud Boot, Erlend Nier, Rafael Repullo, Javier Suarez, Ernst-Ludwig von Thadden, Tanju Yorulmazer, and seminar participants at University of Amsterdam, CEMFI, and Bank of England for helpful comments. The hospitality of University of Mannheim and financial support from the European Corporate Governance Training Network are gratefully acknowledged. All errors are mine.

A bank unable to cover a liquidity shortage fails unless it is bailed out. Its central bank may be averse to providing a bailout in the form of Lender of Last Resort (LOLR) support due to monetary and incentive costs (Rochet and Tirole, 1996). Yet the intervention is unavoidable in a systemic crisis, when the survival of at least some banks is essential for real economic activity[2]. The possibility of LOLR support creates rents for banks. Rents can distort banks' incentives to accumulate sufficient liquidity ex-ante and make them gamble for LOLR support instead.

The purpose of this paper is to analyze the sources of bail out rents and examine the possibilities for policy response. In particular, we ask whether quantitative liquidity requirements are necessary, or whether under some conditions there may be other ways of reinstating optimal bank liquidity.

Liquidity Regulation There are two principal ways in which the regulator can intervene to assure socially optimal bank liquidity. The first, mechanical, is to impose quantitative requirements. However quantitative regulation of liquidity is costly (cf. Glaeser and Shleifer, 2001) because it may be difficult to define precisely the set of appropriate liquid assets.

As an alternative to quantitative regulation, a central bank may attempt to improve the LOLR process in order to reduce bailout rents and eliminate the fundamental distortion. There are two possibilities. The first is to prioritize LOLR support to banks that have made an ex-ante socially optimal choice – were liquid. A credible *ex-ante* commitment to support liquid banks would increase liquidity incentives. However this policy suffers from time inconsistency. Failures of liquid banks occur when their net worth becomes negative, leaving managers no incentives to operate the bank prudently. Therefore, *ex-post*, offering LOLR support to illiquid but potentially positively capitalized banks (with a higher asset value) increases social welfare. Consequently, the policy of conditioning LOLR policy on banks' liquidity is likely unsustainable.

The second possibility is to reduce the *value* of LOLR rents. We show that rents are driven by uncertainty over bank's net worth[3]. If a central bank could use information on bank asset value in setting LOLR repayment terms and charge more to banks with high net worth, that would reduce the distorting rents and bring banks' liquidity choices

[2] Otherwise, severe negative effects may include a payments gridlock or a credit crunch (Freixas et al., 2000, Bernanke and Gertler, 1989).

[3] In this paper, we use the terms "net worth" and "bank capital" interchangeably, referring to the economic value of bank capital. In financial regulation, banks with positive capital are often referred to as "solvent", and those with negative capital – as "insolvent".

close to the social optimum. However such policy is only feasible when a central bank has rather precise information on banks' capitalization, even in times of crisis. Arguably, this is only possible in sufficiently *transparent* financial systems.

We conjecture that regulators in financially developed countries are able to rely less on quantitative liquidity requirements, thanks to the possibility of less distortive LOLR interventions. This is consistent with the observation that liquidity requirements have generally become non-binding in advanced economies, such as the UK or US (Chaplin et al., 2000, Bennett and Peristiani, 2002). In contrast, developing countries, where information on banks' net worth is less readily available, have to (and in practice do) rely on quantitative liquidity regulation (Freedman and Click, 2006).

Modelling In the center of this paper is a model of bank liquidity choices and systemic stability. We consider two banks that face a liquidity risk and choose whether to hold a precautionary buffer against it. Holding liquidity is costly, because a liquidity buffer facilitates managerial moral hazard if a bank becomes insolvent (cf. Myers and Rajan, 1998). Yet in the first best banks decide to be liquid in order to insure long-term charter value.

The distortion we consider is that in a systemic crisis, when both banks fail, the central bank has to bail out one of them to preserve systemic stability. Such intervention is associated with rents, which are driven by the need to preserve bankers' incentives under uncertain net worth. Banks may have assets of high or low value, and can switch to a moral hazard project if the value of bankers' equity stake is too low. If the central bank lacks individual asset value information, it has to set repayment so as to preserve incentives even for a low asset value bank. Generous repayment terms benefit high asset value banks. Banks therefore face a trade-off between a higher probability of preserving charter value (if liquid) and a higher probability of failing and receiving bailout rents (if illiquid). In equilibrium, possible bailout rents may distort incentives to accumulate liquidity ex-ante.

We identify an inter-bank strategic complementarity in liquidity choices, which may lead to self-fulfilling risk management equilibria. A bank has higher incentives to be liquid when it expects another bank to be liquid, because another bank is more likely to weather a possible liquidity shock, reducing the probability of a bailout. A bank has higher incentives to be illiquid when another bank is illiquid, because a systemic liquidity crisis and bailout are more likely. In comparative statics, suboptimal liquidity is more likely when banks have low charter value, or expect severe shocks that reduce the charter value.

Note that banks therefore have incentives to relax risk management in the anticipation of particularly adverse circumstances (such as economic or financial market downturns).

Related literature The paper relates to three strands of literature and policy debate – on suboptimal liquidity, LOLR, and bank herding. It is understood that some liquidity risk may be essential for bank operations (Diamond and Rajan, 2001). However banks' private liquidity choices (investments in cash or easily tradeable assets, Goodfriend and King, 1998) can be compromised by opportunistic incentives (Bhattacharya and Gale, 1987, Allen and Gale, 2004). Empirical evidence demonstrates instances of seemingly lacking bank liquidity. For instance, Gatev et al. (2004) find that not all US banks had sufficient liquidity to be resilient to the 1998 crisis, and Gonzalez-Eiras (2003) shows that Argentinian banks reduced liquidity holdings before the 2001 crisis in the anticipation of LOLR involvement with no apparent fundamental reason. Regulatory concerns are reflected in discussions on whether capital requirements are a sufficient lever for liquidity regulation (Berger and Bouwman, 2006), and the 2006 formation of the Basel Committee's Liquidity working group.

The doctrine of the central bank as the Lender of Last Resort responsible for systemic stability was first articulated by Bagehot (1873). The caveats were that the "last resort" funds should be provided only to institutions with positive capital, and at penalty rates. However these restrictions are not easily implemented in practice. Firstly, there is likely to be uncertainty over the net worth of banks affected by liquidity shortages: it is hard or impossible to distinguish pure liquidity events from deeper capitalization crises (Goodhart, 1999). Secondly, contractual imperfections and the need to preserve bankers' incentives (see Acharya and Yorulmazer, 2007A) can render the central bank unable to secure full repayment of the LOLR loan, let alone impose penalties.

In this paper, the LOLR distortion stems from the need to preserve bankers' incentives under uncertain net worth, and has the impact of banks under-investing in liquidity ex-ante. The literature has suggested other plausible LOLR costs, which we see as complementary. Rochet and Tirole (1996) showed that the expectation of LOLR may reduce incentives for peer monitoring among banks. Also, large banks benefit disproportionately from LOLR due to the "too-big-to-fail" guarantee (O'Hara and Shaw, 1990), while smaller banks may get incentives to herd due to a "too-many-to-fail" effect (Acharya and Yorulmazer, 2007A).

While agents' beliefs about a central bank's behavior were long established as an important determinant of financial stability (e.g. Freixas, 1999), the emphasis on beliefs about peer behavior is less conventional (rare exceptions are Mitchell, 1998, and Perotti, 1998). Our herding result is related to similar findings in the other contexts of banking behavior, such as lending standards (Rajan, 1994) or assets choice (Acharya and Yorulmazer, 2007C). Herding in risk management practices, emphasized here, is a topical concern in the current regulatory debate. For example, there are reservations that when banks are allowed discretion in the choice of risk management models, they seem to converge on similar techniques, as driven not by model superiority, but by the search for regulatory arbitrage.

The rest of the paper is structured as follows. Section 2 sets up the model. Section 3 solves for banks' optimal liquidity in the first best. Section 4 analyzes the general case, identifies the source of LOLR rents, and derives equilibrium bank behavior. Section 5 examines possible policy responses. Section 6 discusses the robustness of assumptions and results. Section 7 concludes.

2.2 The Model

Economy Consider a risk-neutral economy with three dates: 0, 1, 2, and no discounting. The economy is populated by multiple small depositors, two banks, and a central bank.

At date 0, banks borrow from small depositors to invest in a long-term project and a liquidity buffer. At date 1, banks may experience a liquidity shock, which can in turn trigger a central bank intervention. Final returns of successful banks are realized at date 2. The detailed sequence of events is shown on Figure 1.

<<FIGURE 1 HERE>>

Depositors Depositors are endowed with wealth, which they can lend to banks against an expected return of 1 (that is, a zero expected rate of return). We denote the corresponding return that the bank has to promise depositors by R. All financing takes the form of straight debt. Since depositors are small, the debt is non-renegotiable. We treat deposits as uninsured; the effects of deposit insurance are discussed in Section 6.

Banks Banks have no initial capital, but enjoy exclusive access to a fixed-size long-term investment technology. The technology is modelled in the spirit of Holmstrom and Tirole

(1998)[4]. It requires initial financing of 1 at date 0, and produces a risky return X_H or X_L at date 2, each with probability 1/2. Return realizations are independent across banks[5]. Bankers learn future return before date 1, but it remains their private information until date 2.

At date 1 a bank may be hit by a "liquidity shock". We consider an asset-side shock, which relates to adverse conditions when the project is in distress and requires additional investment L to materialize. If the bank injects L, it proceeds to realize X_H or X_L (there is no additional return on L). Yet if the bank is unable to inject L, the investment collapses with 0 liquidation value. The probability of a shock is a. We consider the shocks as systemic (occurring to both banks simultaneously; introducing an idiosyncratic component would not alter results) and binary (either no shock, or a shock of fixed magnitude; Section 6 discusses continuous shocks).

Note that this model focuses on asset-side shocks. They can be interpreted as a borrower drawing on a line of credit, or requesting an additional cash injection within some sort of loan restructuring. Asset-side events have been shown to be a significant determinant of bank liquidity needs (Kashyap et al., 2002, Gatev and Strahan, 2006, Pennacchi, 2006). A close setting with demand-side shocks (depositors withdrawing prematurely) is possible when such shocks impact bank's net worth. This can be due to costly emergency refinancing, or commitment problems when depositor financing is substituted by the market (as in Diamond and Rajan, 2001).

A bank can hedge against a possible liquidity shock by becoming *liquid*. To become liquid, a bank has to attract in advance (at date 0) additional financing L and invest it into a precautionary buffer of tradeable short term assets[6]. It can then use this buffer to cover a possible funding need at date 1.

The last technology feature we consider is that at the end of date 1 (after a possible shock) bankers can opportunistically switch to an inferior moral hazard project. Such a project brings them marginal private benefits $\beta < L$, but leaves nothing to depositors.

[4] Banks in this paper are analogous to firms in Holmstrom and Tirole (1998). We have the similar setup with asset-side liquidity shocks, the need to hedge them in advance due to financial market frictions, and ex-post moral hazard that makes banks with negative net worth not viable. As Holmstrom and Tirole, we find that government liquidity provision ex-post may result in private under-investment in liquidity ex-ante.

[5] We assume that individual bank asset returns do not depend on another bank's performance or survival. Perotti and Suarez (2002) show that expected "last-bank standing" rents due to lower competition post crisis can improve ex-ante prudence incentives.

[6] Observe that, since the bank forms a liquidity buffer in advance, it cannot use liquidity holdings to signal asset value (which it learns as private information only at date 1).

This moral hazard risk will be shown to determine both liquidity costs and LOLR rents.

Banks maximize profit, including possible private benefits. For definitiveness, when indifferent, banks prefer to be liquid, and do not switch to moral hazard. Banks' liquidity decisions are observable.

Parameters We set up model parameters to reflect the following properties. Firstly, from the perspective of date 0, the bank's investment has a positive ex-ante net present value (NPV), and banks are always safe (have positive capital) *unless* there is a liquidity shock:

$$X_H > X_L > 1/(1-a) + \beta \tag{2.1}$$

In the right part, $1-a$ is the minimal probability of bank survival (if it always failed in a liquidity shock), therefore $1/(1-a)$ is the maximum return the bank may need to offer depositors to compensate for the probability of failure. The condition shows that, in the absence of a liquidity shock, even a bank with low asset value X_L has sufficient worth to compensate depositors and not engage in moral hazard: its equity value exceeds β. Note that (2.1) is a sufficient condition for financing at date 0: a bank can always be financed if illiquid. A liquid bank with an additional investment L can also be financed if liquidity increases its profit by reducing risk.

Secondly, as a result of a liquidity shock, the net worth of a bank with low asset value becomes negative:

$$X_L < 1 + L \tag{2.2}$$

Here, X_L is asset value, 1 is the minimal repayment to initial depositors, and L the amount of necessary additional financing. Observe that continuing the project is socially optimal as long as $X_L > L$ (because the cost of initial investment is sunk), but prevented by debt overhang (deposits are non-renegotiable, while bankers need minimal equity value to preserve their incentives). Due to negative net worth, the managers get incentives to engage in moral hazard, making a bank with low asset value not viable after a shock even if it was liquid.

Lastly, banks (including liquid ones) with high asset value X_H, retain positive net worth in a liquidity shock:

$$X_H > (1+L)/(1-a) + \beta \tag{2.3}$$

The term X_H is the asset value, and $(1 + L)/(1 - a)$ is the maximum possible debt repayment: $(1 + L)$ is the originally borrowed amount for a liquid bank, and $1/(1 - a)$ is the maximum possible interest rate. Banks with high asset value do not have incentives to switch to a moral hazard project, because their equity value exceeds β.

Central Bank An illiquid bank hit by a liquidity shock, as well as a bank that has switched to a moral hazard project, fail at date 1 unless bailed out. We consider the Central Bank as a lender of last resort (LOLR), entrusted with the responsibility for financial stability. We interpret financial stability as a need to assure that at least one bank is present at date 2 – survives a liquidity shock and does not engage in moral hazard. The Central Bank intervenes when a bank is in the process of failing. A bailout, firstly, helps a bank cover a liquidity shortage and, secondly, serves to increase bank's equity value when that is necessary to preserve bankers' incentives[7].

The Central Bank is averse to extending LOLR support. It never bails out a bank if another one is stable. In a systemic crisis, when both banks are failing, it bails out *one* of them *randomly* (we alter the assumption of random intervention in further analysis). The reason is that bailouts are associated with a substantial deadweight cost of public funds (e.g. due to the disincentive effects of taxation). While the bankers obtain a perfect signal of asset value before the refinancing stage, it remains their private knowledge and is not available to the Central Bank (we alter the assumption of private asset value information in further analysis).

Lastly, we assume that when a failing bank receives LOLR support, its depositors still lose their investment. In the sense, bankers are bailed out in order to preserve financial stability, but depositors still bear the costs of failure. Such effects are relatively common in developing countries, which do not have a strong enough fiscal position to fully compensate depositors of failing institutions (cf. Demirguc-Kunt and Detragiache, 2002). Even when depositors are repaid, they often receive money with significant delays or in fixed nominal terms that do not account for inflation or currency depreciation that may have occurred in the meanwhile. This assumption allows us to simplify the exposition by abstracting from a marginal effect of possible bailouts on deposit rates, but it does not influence the qualitative results.

The game tree summarizing strategies and payoffs for liquid and illiquid banks in the case of a liquidity shock, depending on central bank actions, is shown on Figure 2.

[7]In some cases, beyond the scope of this model, the Central Bank may also resolve crises by playing a coordinating role (see Freixas et al, 2000), as was in the LTCM case.

Depositors are repaid when there is no liquidity shock, or when a bank is able to weather a liquidity shock on its own.

<<FIGURE 2 HERE>>

2.3 First Best

We first consider a setting with a single bank and no Central Bank intervention, to study liquidity choices in a world without LOLR distortions. Note that while we consider this a first best benchmark to our setting, it still contains imperfections such as the bankers' moral hazard.

Consider first the payoff to an *illiquid* bank. With probability $1-a$ it avoids a shock and receives average return $(X_H + X_L)/2$. With probability a it is hit by a shock, unable to cover it, and goes bankrupt. Anticipating this, investors require the promised return $R = 1/(1-a)$. The payoff is:

$$\begin{aligned} \Pi_{FB}^{ILL} &= (1-a)\left(\frac{X_H + X_L}{2} - \frac{1}{1-a}\right) \\ &= (1-a)\frac{X_H + X_L}{2} - 1 \end{aligned} \tag{2.4}$$

Before deriving the payoff to a liquid bank, we establish the *endogenous cost of holding liquidity*. Recall that there are no exogenous frictions in liquidity provision in our model, as depositors can elastically supply funds at a required expected return of 1. The liquidity buffer of size L allows a bank with high asset value to cover a possible liquidity shortage, survive a shock, and realize returns. However, the net worth of a bank with low asset value becomes negative in a liquidity shock. Such a bank has two prudent alternatives: either let its long-term assets collapse and distribute the buffer L back to depositors, or use the buffer to cover the liquidity shortage and obtain and pay out X_L at date 2. While both resolutions could be beneficial to depositors, they leave no equity value to the bankers. Therefore, in the spirit of Myers and Rajan (1998), banks that are liquid but have negative capital will exercise moral hazard: use the buffer to cover the liquidity shortage and then switch to a lemon project. In doing so they destroy $L - \beta$ of value. This opportunistic behavior drives the endogenous cost of liquidity: depositors anticipate possible losses on a liquidity buffer, and price them in the nominal interest rate. If the bankers were able to commit to return the liquidity buffer to depositors in the case of negative net worth, holding liquidity on books would have been costless. Therefore, *an endogenous cost of liquidity originates from moral hazard in banks that are liquid but have negative capital.*

Note that a bank's liquidity buffer choice is binary. A smaller buffer $\check{L} < L$ has no benefits (it cannot help a bank with positive capital overcome a liquidity shock), but leads to a loss of value $\check{L} - \beta$ in a bank that is about to fail. A larger buffer $\hat{L} > L$ has no additional benefits compared to a buffer of size L, but a higher cost $\hat{L} - \beta > L - \beta$.

Consider now the payoff to a *liquid* bank. With probability $1 - a$ it avoids a shock and receives average return $(X_H + X_L)/2 + L$ including preserved liquid assets. With probability $a/2$ it is hit by a shock and has assets of high value: it covers the liquidity shortage with buffer L and receives return X_H. With probability $a/2$ it is hit by a shock and has assets of low value: bankers cover the liquidity shortage and then switch to a moral hazard project, retaining private benefits β. The bank fails with probability $a/2$ and investors require the promised return $R = 1/(1-a/2)$ on the borrowed amount $1+L$. The payoff is:

$$\begin{aligned}\Pi_{FB}^{LIQ} &= (1-a)\left(\frac{X_H + X_L}{2} + L - \frac{1+L}{1-a/2}\right) + \frac{a}{2}\left(X_H - \frac{1+L}{1-a/2}\right) + \frac{a}{2}\beta \quad (2.5)\\ &= (1-a)\frac{X_H + X_L}{2} + \frac{a}{2}(X_H - L) - \frac{a}{2}(L-\beta) - 1\end{aligned}$$

Note that $a/2 \cdot (\beta - L)$ are the costs of liquidity: value $(L - \beta)$ is lost with probability $a/2$ in a bank that is liquid but has negative net worth.

We can now find the bank's first best liquidity choice. A bank prefers to be liquid for

$$\Pi_{FB}^{LIQ} \geq \Pi_{FB}^{ILL}$$

Substituting from (2.5) and (2.4) gives:

$$L \leq L_{FB} = \frac{X_H + \beta}{2}$$

In comparative statics, a bank chooses to be liquid when X_H (a measure of charter value) and β (private benefits of liquidity) are high enough, while L (the size of a possible liquidity shock, which decreases survival value) is low enough. In the following analysis, we will study how a bank's liquidity choice can deviate from the L_{FB} benchmark when the Central Bank provides LOLR support.

2.4 Suboptimal Liquidity

We now return to the general model with two banks and a Central Bank offering LOLR support in the case of a systemic crisis. We first articulate the main distortion of the model: rents associated with a LOLR intervention.

Consider a Central Bank bailing out a failing illiquid bank. Such a bank has an unknown (high or low) asset value. When setting repayment on the LOLR loan, the Central Bank must assure that bankers do not get incentives to switch to a moral hazard project. Therefore, the terms of LOLR support must leave equity value of at least β even for a low asset value bank. Because asset value information is private, the Central Bank cannot discriminate repayment terms against high asset value banks, leaving them with even higher rent $\beta + (X_H - X_L)$. This makes average bailout rents for an illiquid bank $\beta + (X_H - X_L)/2$.[8]

A failing liquid bank has low asset value, so the possible bailout needs to leave the bankers rents β to compensate for what they would receive if switched to moral hazard. Liquid high asset value banks weather a possible liquidity crisis by themselves, and receive no rents at all. Therefore, *endogenous LOLR rents are determined by the need to preserve bankers' incentives under uncertain asset value of illiquid banks. As a result, illiquid banks receive higher average LOLR rents.*

The trade-off The anticipation of rents may distort banks' ex-ante liquidity decisions. Banks make liquidity decisions in the trade-off between preserving charter value (a liquid bank has a higher probability of surviving a shock and realizing long-term returns) and obtaining bail out rents (an illiquid bank has a higher probability of failing and receiving rents, which will also be of higher value due to its uncertain asset value).

The bank's bailout probability, and hence the expected value of rents, depends on the liquidity choice of *another* bank. Consider the consequences of a liquidity shock from the perspective of an illiquid bank. The Central Bank intervenes only if both banks fail. If

[8] While this result hinges on the assumption that LOLR funds are provided under a debt contract, in Section 6 we show that the results are robust to recapitalization when a central bank obtains an equity stake in a bank, and also discuss scope for more complex LOLR contracts.

another bank is liquid, it will survive a liquidity shock by covering it with precautionary buffer if it has high asset value – with probability 1/2. Joint failure occurs only if another bank has low asset value (and chooses to switch to a moral hazard project) – with probability 1/2. The bailout accrues to a given bank randomly, making the ultimate probability of a bank receiving rents 1/4. However if another bank is illiquid as well, it will always fail in a liquidity shock, triggering a systemic crisis. A given bank is bailed out with probability 1/2. Due to a higher probability of obtaining LOLR rents, a bank has higher incentives to be illiquid when it expects the same from another bank.

To see this analytically, consider a bank's payoffs to liquidity and illiquidity under different liquidity choices of another bank.

Consider the payoff to a *liquid* bank. With probability $1-a$ there is no shock and it receives average return $(X_H + X_L)/2 + L$ including preserved liquid assets. With probability $a/2$ it is hit by a shock and has assets of high value: it covers the liquidity shortage and receives X_H. With probability $a/2$ it is hit by a shock and has assets of low value. The bank would switch to moral hazard and receive rents β unless bailed out.

The Central Bank intervenes if another bank also fails. Another bank fails with probability 1/2 if liquid (only when it has low asset value), and always if illiquid. The probability of a bank receiving LOLR support is therefore 1/8 and 1/4, for a liquid and illiquid other bank respectively. Observe that LOLR support does not alter rents obtained by a liquid bank with negative capital – the Central Bank only needs to compensate it for the private benefits of moral hazard β. Nor does LOLR intervention impact the deposit rate – depositors by assumption lose money anyway. In either case, the bank does not repay depositors with a probability $1-a/2$, and the promised return is $R = 1/(1-a/2)$. As a result, the payoff of the liquid bank is independent of LOLR actions and, consequently, from another bank's liquidity. The payoff, identical to (2.5), is:

$$\begin{aligned}
\Pi^{LIQ} &= (1-a)\left(\frac{X_H + X_L}{2} + L - \frac{1+L}{1-a/2}\right) + \frac{a}{2}\left(X_H - \frac{1+L}{1-a/2}\right) + \frac{a}{2}\beta \\
&= (1-a)\frac{X_H + X_L}{2} + \frac{a}{2}(X_H - L) - \frac{a}{2}(L-\beta) - 1 \qquad (2.6)
\end{aligned}$$

Consider now the payoff to an *illiquid* bank. With probability $1-a$ there is no shock and it receives average return $(X_H + X_L)/2$. With probability a there is a shock, and the bank fails. The Central Bank intervenes only if another bank fails as well, which depends on its liquidity choice. If liquid, another bank fails only if it has low asset value

– with probability 1/2, making the bail out probability 1/4. If illiquid, it fails always, doubling the bail out probability to 1/2. This is the source of strategic complementarity: an illiquid bank has higher expected bail out rents when it expects another bank to be illiquid as well.

LOLR support of an illiquid bank leaves a low asset value bank with rents β, but a high asset value bank with $\beta + (X_H - X_L)$, making average rents $\beta + (X_H - X_L)/2$. Investors are not repaid with probability a and require the promised return $R = 1/(1-a)$. The payoffs to an illiquid bank, depending on another bank's liquidity or illiquidity, are:

$$\begin{aligned}\Pi^{ILL}_{LIQ} &= (1-a)\left(\frac{X_H + X_L}{2} - \frac{1}{1-a}\right) + \frac{a}{4}\left(\beta + \frac{X_H - X_L}{2}\right) \\ &= (1-a)\frac{X_H + X_L}{2} + \frac{a}{4}\left(\beta + \frac{X_H - X_L}{2}\right) - 1\end{aligned} \tag{2.7}$$

$$\begin{aligned}\Pi^{ILL}_{ILL} &= (1-a)\left(\frac{X_H + X_L}{2} - \frac{1}{1-a}\right) + \frac{a}{2}\left(\beta + \frac{X_H - X_L}{2}\right) \\ &= (1-a)\frac{X_H + X_L}{2} + \frac{a}{2}\left(\beta + \frac{X_H - X_L}{2}\right) - 1\end{aligned} \tag{2.8}$$

We can now derive the bank's optimal liquidity choices. Due to strategic complementarity, they will depend on liquidity choices of another bank.

A bank will choose to be liquid in response to a liquid other bank for:

$$\begin{aligned}\Pi^{LIQ} &\geq \Pi^{ILL}_{LIQ} \\ L &\leq L_{HIGH} = \frac{3X_H + X_L + 2\beta}{8}\end{aligned}$$

A bank will choose to be liquid in response to an illiquid other bank only for:

$$\begin{aligned}\Pi^{LIQ} &\geq \Pi^{ILL}_{ILL} \\ L &\leq L_{LOW} = \frac{X_H + X_L}{4}\end{aligned}$$

It is easy to verify that $L_{LOW} < L_{HIGH}$. For $L \leq L_{LOW}$, a bank will always choose to be liquid. For $L > L_{HIGH}$, a bank will always choose to be illiquid. In the intermediate range $L_{LOW} < L \leq L_{HIGH}$ there is a strategic complementarity: a bank will choose to be liquid when expects another bank to liquid, but illiquid when expects the other bank to be illiquid. This can be interpreted either as inter-bank herding in liquidity risk management choices, or as the impact of a self-fulfilling "climate" of prudence in the banking system.

It is also easy to verify that $L_{HIGH} < L_{FB}$. This means that banks choose liquidity for a narrower range of parameter values than socially optimal: never for $L_{HIGH} < L \leq L_{FB}$ and only in some equilibria for $L_{LOW} < L \leq L_{HIGH}$. We can now state the main result of this section.

Proposition 1 *Banks' equilibrium liquidity choices are characterized by two thresholds* $L_{LOW} < L_{HIGH}$*, such that:*

1. *For* $L \leq L_{LOW}$*, banks choose to be liquid, in a unique equilibrium in dominating strategies;*
2. *For* $L_{LOW} < L \leq L_{HIGH}$*, the game has multiple Nash equilibria, with a bank choosing to be liquid when it expects another bank to be liquid, and illiquid when it expects another bank to be illiquid. There also exists an equilibrium in mixed strategies;*
3. *For* $L > L_{HIGH}$*, banks choose to be illiquid, in a unique equilibrium in dominating strategies.*

Banks' choices can be socially suboptimal: there exist parameter values where banks choose illiquidity, while liquidity is the first best.

The equilibrium threshold values of L and corresponding banks' strategies are depicted on Figure 3.

<<FIGURE 3 HERE>>

In comparative statics, threshold values L_{LOW} and L_{HIGH} depend positively on the proxies of bank charter value X_H and X_L and private benefits β: a bank is more likely to be illiquid when its charter value is low or the expected shock severe. This can be related to the times of recession or the end of expansion with downside expectations, and indicate conditions when regulators should be particularly concerned about suboptimal liquidity risk management.

2.5 Policy Response

The previous section identified that bank liquidity choices can be socially suboptimal due to distortions associated with a possible LOLR intervention. There are a number of measures that authorities can undertake to try and correct banks' liquidity choices.

The direct mechanical solution is to impose quantitative liquidity requirements. However quantitative regulation of liquidity is costly (cf. Glaeser and Shleifer, 2001), because it is difficult to define precisely the set of appropriate liquid assets. For example, assets unconditionally eligible for central bank repo operations have guaranteed liquidity, but are typically restricted to select government bonds and therefore particularly expensive to hold[9]. Banks could ideally use cheaper (but still sufficiently liquid) assets, such as high-grade corporate bonds. Yet their liquidity may change over time, being especially unpredictable in times of crises. Since it is difficult or impossible to define in advance which assets will be liquid in relevant future contingencies (and can be allowed in the prudential buffer), these non-central bank eligible assets are unsuitable for effective quantitative liquidity requirements. Put differently, when asset liquidity changes unpredictably over time, it may be observable ex post, but cannot be well contracted upon ex-ante.

There are two additional concerns which also determine the costs of liquidity requirements. Firstly, due to changing assets' liquidity, quantitative liquidity requirements often become outdated with time, especially when there is no institutional flexibility to change them frequently. Secondly, within broader risk management agenda, banks may over-rely on mandatory ratios and avoid evaluating liquidity needs by themselves, softening internal risk management frameworks. Due to all these limitations, regulators prefer to rely on less distortive mechanisms of restoring optimal liquidity when possible.

As an alternative, the authorities may attempt to redesign LOLR procedures to make them targeted and informed (as opposed to random and uninformed in the basic model). There are two sources of information that may be used in LOLR decisions: banks' liquidity and banks' capitalization (net worth); the latter – only if such information is available to the Central Bank). We will now analyze the possibility of conditioning LOLR on that information.

[9] Central banks typically maintain conservative collateral lists, in order to avoid credit risks that could compromise their balance sheets. Eurosystem central banks accept some lower quality assets (such as MBS), yet only with high haircuts, which makes liquidity generated by them costly as well. The discount window of the Federal Reserve System also employs haircuts, as well as penalty rates.

2.5.1 LOLR and Liquidity

The first option is to redirect LOLR rents by offering priority support to liquid banks. If a liquid bank is more likely to be bailed out, that would reduce expected rents accruing to an illiquid bank.

Consider the case when, if faced with two failing banks, of which one is liquid and another illiquid, the Central Bank bails out a liquid bank. Such policy would remove any bailout rents from the payoff to an illiquid bank when another bank is liquid, making it

$$\tilde{\Pi}^{ILL}_{LIQ} = (1-a)\frac{X_H + X_L}{2} - 1 \tag{2.9}$$

and changing the L_{HIGH} threshold to

$$\begin{aligned} \Pi^{LIQ} &\geq \tilde{\Pi}^{ILL}_{LIQ} \\ L &\leq \tilde{L}_{HIGH} = \frac{X_H + \beta}{2} = L_{FB} \end{aligned}$$

Therefore, credible conditioning of LOLR support on ex-ante liquidity can reduce distortions and improve incentives, allowing multiple equilibria in the range $L_{HIGH} < L < L_{FB}$, where banks used to unambiguously choose illiquidity under a random bail out.

The problem however is that such policy is time inconsistent. Ex-post, failing liquid banks have low asset value with certainty, while failing illiquid banks can have high asset value with probability 1/2. Saving an illiquid bank with potentially high asset value instead of a liquid one with low asset value increases ex-post social welfare. If a Central Bank was conditioning on liquidity, but unable to commit to an ex-ante optimal policy, it would end up offering priority support to illiquid banks instead. That would increase (rather than decrease) the payoff to an illiquid bank when a peer is liquid:

$$\tilde{\Pi}^{ILL}_{LIQ} = (1-a)\frac{X_H + X_L}{2} + \frac{a}{2}\left(\beta + \frac{X_H - X_L}{2}\right) - 1 \tag{2.10}$$

and reduce L_{HIGH} to

$$\begin{aligned} \Pi^{LIQ} &\geq \tilde{\Pi}^{ILL}_{LIQ} \\ L &\leq \tilde{L}_{HIGH} = \frac{3X_H + X_L + 2\beta}{8} = L_{LOW} \end{aligned}$$

This is a distortion further from social optimum: in the range $L_{LOW} \leq L < L_{HIGH}$ banks would always choose illiquidity, instead of multiple equilibria under a random bailout. When liquidity-conditional bailout is likely to be unsustainable, it is inferior to the random one.

Proposition 2 *The policy of conditioning LOLR support on prudent liquidity risk management is time inconsistent. Ex-ante it is optimal to bail out liquid banks; ex-post – illiquid banks since they may have positive net worth. If banks anticipate ex-post policy, they never choose liquidity for $L > L_{LOW}$.*

2.5.2 LOLR and Capitalization

Another option is to try and reduce the value of LOLR rents. Remember that their principal component stemmed from uncertain capital (asset value) of illiquid banks. The Central Bank could not distinguish between pure liquidity shortages (in banks with high asset value) from deeper capitalization problems (in banks with low asset value). If the Central Bank had such information, it could demand higher repayment from high asset value banks, reducing the expected value of bail out rents.

We call conditions where bank asset value information is readily available *transparency*. We do not distinguish between the availability of information to the central bank or to the markets. The reason is that there will unlikely be any divergence in the case of an unexpected significant shock. There is little evidence that central banks have superior information on an individual bank's conditions (except for short periods after extensive regulatory assessments, see Berger et al., 2000, Flannery, 1997). Nor is there a reason to believe that a well-functioning central bank is unable to collect information available to market participants.

Assume that the Central Bank has information on banks' net worth. When faced with two failing banks, one with positive capital and another with negative capital, it can bail out the one with positive capital (high asset value) and charge it an appropriate repayment that leaves bankers only minimal incentive compatible rents β. When faced with two negatively capitalized banks, liquid and illiquid, the Central Bank can now also credibly commit to bail out the liquid bank, because there is no asset value difference between the two.

Consider the probability of a bailout of an illiquid bank when a peer bank is liquid. With probability 1/2 another bank has negative capital and there is a joint failure. With further probability 1/2 the illiquid bank has positive capital and is bailed out; otherwise both banks have negative capital and a liquid bank is bailed out. Another parameter that changes is the value of bailout rents. Because the Central Bank is able to charge a higher repayment to a high asset value bank, removing excess component $(X_H - X_L)$, the expected value of rents for an illiquid bank decreases from $\beta + (X_H - X_L)/2$ to β. The new payoffs are:

$$\hat{\Pi}_{LIQ}^{ILL} = (1-a)\frac{X_H + X_L}{2} + \frac{a}{4}\beta - 1 \tag{2.11}$$

$$\hat{\Pi}_{ILL}^{ILL} = (1-a)\frac{X_H + X_L}{2} + \frac{a}{2}\beta - 1 \tag{2.12}$$

The threshold points are:

$$\begin{aligned} \hat{\Pi}^{LIQ} &\geq \hat{\Pi}_{LIQ}^{ILL} \\ L &\leq \hat{L}_{HIGH} = \frac{X_H + \beta/2}{2} \end{aligned}$$

and

$$\begin{aligned} \Pi^{LIQ} &\geq \Pi_{ILL}^{ILL} \\ L &\leq \hat{L}_{LOW} = \frac{X_H}{2} \end{aligned}$$

Both $\hat{L}_{LOW}$ and $\hat{L}_{HIGH}$ are within $\beta/2$ of L_{FB}: the solution approaches the social optimum, and the divergence between the socially optimal and private banks' liquidity choices is possible only on a small interval of length $\beta/2$. The size of possible private benefits β that determine the length of that interval can be related to the bankers' ability to create and retain moral hazard benefits, as driven in particular by financial development (legal environment, supervision, enforcement, etc.).

Proposition 3 *When bank capital information is available and private benefits of moral hazard are low, a capital-based LOLR policy can bring banks' liquidity choices close to the social optimum. Under a capital-based LOLR policy, banks always choose liquidity for* $L \leq L_{FB} - \beta/2$.

Observe that both the availability of capital (asset value) information and low private benefits of moral hazard are likely to be found in more advanced financial systems. They may be lacking in developing countries, making capital-based LOLR policies less feasible there.

2.6 Discussion

This paper showed that expected ex-post LOLR action can affect banks' ex-ante liquidity choices, and analyzed how the authorities can respond to such a distortion. The modelling relied on a number of mildly restrictive simplifying assumptions. In this section, we recall those modelling features and analyze their robustness to possible generalizations.

Bailouts The model posits that the Central Bank will always have to intervene in a systemic crisis: to preserve systemic stability, at least some banks will have to be bailed out. Therefore, importantly, any claim that no assistance will be offered to banks in a systemic crisis is not credible.

We also assume that the Central Bank would never bail out a bank when another one is stable, and bail out only a single bank in a systemic crisis when both fail. For this we offer an intuitive explanation through the costs of extra taxation, which if sufficiently high and convex, would prevent any unnecessary bailouts. This effect is likely to be amplified by unnecessary bailouts reducing banks' incentives to hold liquidity, making systemic crises and consequent LOLR interventions more frequent in the first place.

Indeed, in the extreme when the Central Bank always bails out all failing banks, the payoff to an illiquid bank increases from (2.7) and (2.8) to:

$$\Pi^{ILL} = (1-a)\frac{X_H + X_L}{2} + a\left(\beta + \frac{X_H - X_L}{2}\right) - 1 \tag{2.13}$$

It is clear that $\Pi^{ILL} > \Pi^{ILL}_{ILL}$, so under blanket bail-outs banks would have lower incentives to be liquid. Banks would choose to hold buffers only for $\Pi^{LIQ} \geq \Pi^{ILL}$ or $L \leq (X_L - \beta)/2 < L_{LOW}$, which is a very limited range of parameter values.

Equity financing The model focused on debt as initial financing vehicle. Debt is, indeed, the major source of finance used by banks, perhaps as it alleviates the costly state verification problem (Townsend, 1979), strengthens monitoring mechanisms (Calomiris and Kahn, 1991), and helps commit to a degree of prudence (Diamond and Rajan, 2001). Nevertheless, banks do use *some* equity financing. In particular, the lower bound on equity – capital requirements – is one of the cornerstones of contemporary banking regulation.

We can introduce some initial equity financing into the model without affecting the results, because the underlying conflict of interest is not between bankers and depositors, but between bankers and the LOLR. Yet, it is essential for our exposition (and factual) that banks are not default-free and can become under-capitalized and fail as a result of *some* adverse shocks. This limits the amount of equity that can be tractably considered[10]. Indeed, in the extreme, when the bank is fully equity financed, it cannot have negative net worth by definition.

To verify this formally, consider a bank endowed with A units of initial capital. However $A < 1$, so that additional external financing of at least $1 - A$ is always necessary, and

$$X_L < 1 - A - L \tag{2.14}$$

so that a low asset value bank has negative capital following a liquidity shock.

Under these conditions, the introduction of equity financing into the set-up does not affect the bank's decisions (in particular, the decision to switch to the moral hazard project when its future asset value is low). Nor does it therefore affect the costs of liquidity. Consequently, the reduction of leverage affects the payoffs (4-8) in the same way: the volume of deposits to be repaid falls by A (the last term -1 transforms into $-(1 - A)$). The threshold points L_{FB}, L_{LOW} and L_{HIGH} do not change.

If some equity within A was external (not belonging to the bankers), that would not change the qualitative results either. In fact, compared to inside equity, external equity makes bankers more likely to switch to suboptimal projects, because they claim only a share of monetary profit, but retain full private benefits. A higher bailout grant would be necessary to keep them from switching to a moral hazard project. If the stake of insiders was i and that of outsiders $1 - i$, the bailout must leave the bank profits of at least β/i to keep insiders from switching to an inferior project. This relative ineffectiveness of external equity in disciplining banks may be related to the fact that banks indeed often have relatively concentrated ownership (see Caprio et al., 2005).

[10] Banking regulation recognizes that the extent to which banks can rely on equity financing, and the degree of safety that it provides, are limited. Indeed, capital requirements are only one of the three pillars of the Basel II accord (the other two being supervisory review and market discipline).

Recapitalization We also focused on debt in the LOLR mechanism. Based on this, we derived the bailout rents: if a low asset value bank needed rents β, the high asset value bank charged the same debt repayment ended up with rents $\beta + (X_H - X_L)$. An alternative LOLR arrangement could be recapitalization, when, in return for the bailout, the central bank obtains an equity stake the bank.

Our model is robust to the possibility of recapitalization. Assume that, instead of debt, the Central Bank retains an equity stake in the saved illiquid bank. The bankers' remaining equity stake α must leave the low asset value bank rents of at least β: $\alpha\,(X_L - D) > \beta$ where D is some nominal repayment to depositors. The same equity stake α would leave a high asset value bank with excess rents $\alpha\,(X_H - D) = \beta + \alpha(X_H - X_L)$, comparable to those in the case of debt refinancing.

In some circumstances, more complex contracts may be used. In particular, a constrained optimal contract, under which a high asset value bank repays $X_H - X_L$ more than a low asset value bank, would reduce rents to an incentive-compatible minimum of β and result in an equilibrium equivalent to that of Proposition 3. Regulators may also have other powers, such as to replace bank managers. For example, in the case of the largest US bank failure Continental Illinois, the government (FDIC) injected new capital in return for hiring new management and obtaining junior preferred stock convertible into common stock, as well as (non-convertible) adjustable rate rate preferred stock in the restructured bank.

All these regulatory powers and capabilities strengthen banks' ex-ante incentives to be prudent. However, the scope for such arrangements (even that of simple equity recapitalization) may be constrained in countries with less advanced financial system or less developed regulatory practices and crisis resolution capabilities. There, central banks may have limited experience and may be reluctant to get involved in managing commercial banks, as well as be less able to implement complex financial solutions under the time pressures involved in financial crisis management.

Refinancing This model did not consider the possibility of external refinancing in a liquidity shock. The breakdown of access to wholesale money markets, that in normal times can provide necessary liquidity at a short notice, is indeed a distinguishing feature of most recent bank liquidity crises in industrial economies (Citibank and Standard Chartered in Hong Kong in 1991, Lehman Brothers in 1998, and Commerzbank in 2002). There may be a number of reasons involved: aggregate liquidity shocks (Holmstrom and Tirole, 1998), some type of flight to quality (Bernanke et al., 1996), or strategic counterparty behavior

(Brunnermeier and Pedersen, 2005). These frictions can prevent refinancing even when the bank's capitalization is publicly known (as in Section 5.2).

Another fundamental constraint on external refinancing, which may be most naturally introduced into our setting, is asymmetric information on a bank's capital. In the event of a liquidity shock, the probability of under-capitalization rises, and financiers would only be prepared to lend at high interest rates. In our model, the probability of negative capital in a liquidity shock is 1/2 and the corresponding promised loan return $R_{refin} = 2$. Unless X_H is very high, such a loan return may be prohibitive and lead to negative net worth even for a bank with a high asset value:

$$X_H < 1 + 2L + \beta$$

Here 1 is the minimal repayment to initial depositors (for $R = 1$) and $2L$ the repayment on the refinancing loan (for $R_{refin} = 2$). Note that, in contrast to ex-post refinancing, by attracting a liquidity buffer ex-ante, the bank effectively spreads its cost between good and bad states (Acharya et al., 2007).

Observe also that when a failing bank is liquid, this contains a negative signal on its capitalization and the possibility of refinancing. Therefore if for any reason the bank's ex-ante liquidity position was not fully observable, that would make it more difficult for outsiders to distinguish between illiquidity and low capital. Interest rates would increase as a result, making refinancing even more problematic.

Deposit insurance Deposit insurance reduces interest rates that the bank must pay depositors, however its overall effects on the cost of funds depends on deposit insurance premia. If deposit insurance was fairly priced such that an ex-post premium of $R - 1$ was paid to the insurer whenever the bank had positive net worth, no change in the previous analysis would occur. If premia were set unfairly, various additional distortions could occur. How these distortions affect liquidity decisions depends on a particular structure of subsidies. Yet we have verified that even under a fully publicly funded deposit insurance, banks could still choose to be illiquid and gamble for a bailout when associated rents exceed the benefit of preserving long term charter value[11].

[11] Consider a simple quantitative example. Assume $X_H = 2$, $X_L = 1.2$, $\beta = .2$, $L = .6$. Then $L_{FB} = 1.1$, so in the first best the bank should be liquid. Assume that the other bank is illiquid, so that a bailout happens with probability 1/2 in joint failure. The bank's payoff to being liquid is

$$a(\frac{2+1.2}{2} - 1) + a/2(2 - .6 - 1) + a/2 \cdot .2 = .6a + .3a = .9a$$

Another alternative is an ex-post funded deposit insurance, where surviving banks are taxed to repay depositors and possibly even boost the equity value of failing counterparts. Such equalizing taxation has indeed sometimes been used in practice, for example during the Japanese banking crisis (Hoshi, 2002). Yet such arrangements carry the risks of increased moral hazard ex-ante (banks have less incentives to survive a crisis) and undermining financial stability ex-post (risks are transferred to stable banks). Moreover, ex-post deposit insurance may be not functional in a wide systemic crisis, when no banks can be feasibly taxed.

Continuous liquidity shocks The model considered binary liquidity events – either no shock, or a shock of fixed magnitude. This can be extended to account for liquidity shocks of varying sizes. The main intuition would persist: banks would hedge against smaller shocks and leave the larger shocks that deplete charter value unhedged. The depth of hedging depends negatively on the probability of a bailout.

To see this formally, consider the following extension. Assume that liquidity shocks occur with probability a and are uniformly distributed on $[L_1; L_2]$. As in the main model, assume that X_L banks have negative capital as a result of any liquidity shock, while X_H banks remain positively capitalized in any liquidity shock:

$$\begin{aligned} X_L &< 1 + L_1 \\ X_H &> (1 + L_2)/(1 - a) + \beta \end{aligned}$$

Consider a single bank that is bailed out with an exogenous probability p, and observe its payoff from having a liquidity buffer $L : L_1 \leq L \leq L_2$. In the case of a liquidity shock, with probability $\frac{1}{2}\frac{L-L_1}{L_2-L_1}$ the bank is positively capitalized and liquid. It invests additional funds as required (average liquidity shock in that interval $\frac{L_1+L}{2}$) and obtains return X_H. With probability $\frac{1}{2}\frac{L-L_1}{L_2-L_1}$ the bank is liquid but has negative capital. It covers the liquidity shock and switches to the inferior project, destroying long-term value but obtaining private benefits β (the part of the liquidity buffer not used to cover the shock is returned to depositors). With probability $\frac{1}{2}\frac{L-L_1}{L_2-L_1}$ the bank is illiquid. It receives 0 return if liquidated (an insufficiently liquid bank fails immediately and the liquidity buffer is

The bank's payoff to being illiquid is

$$a(\frac{2+1.2}{2} - 1) + a/2(.2 + \frac{2-1}{2}) = .6a + .35a = .95a$$

Therefore, the bank would choose to be illiquid.

transferred to depositors), β if bailed out but has a low asset value, and $\beta + (X_H - X_L)$ if it has a high asset value.

This makes the overall payoff for a bank with liquidity buffer L

$$\begin{aligned} \Pi &= (1-a)\frac{X_H + X_L}{2} + \frac{a}{2}\frac{L - L_1}{L_2 - L_1}\left(X_H - \frac{L + L_1}{2}\right) - \frac{a}{2}\frac{L - L_1}{L_2 - L_1}\left(\frac{L + L_1}{2} - \beta\right) \\ &+ \frac{a}{2}p\frac{L_2 - L}{L_2 - L_1}\left(\beta + \frac{X_H - X_L}{2}\right) - 1 \end{aligned} \tag{2.15}$$

The payoff is maximized for

$$L^* = \frac{X_H + \beta}{2} - p\frac{\beta + (X_H - X_L)/2}{2}$$

Observe that in the first best with no LOLR intervention, $p = 0$: $L^* = L_{FB}$. A higher probability of bailout p distorts the bank's choice of liquidity buffer below that of the social optimum.

2.7 Conclusions

This paper demonstrated that banks may make suboptimal liquidity choices due to distortions associated with a LOLR intervention that is unavoidable in a systemic crisis. Endogenous bailout rents are driven by the need to preserve bankers' incentives under uncertain net worth. Banks may herd and are more likely to choose suboptimal liquidity when they expect other banks in the system to do so. We showed that a LOLR policy based on bank's capital information can reduce the distortion, but such information may be available only for more transparent economies. Other jurisdictions, such as developing countries, may need to rely on costly quantitative liquidity regulation. This may explain observed global divergence in approaches to liquidity regulation: liquidity requirements become increasingly marginal in advanced economies, but are substantially relied upon in the developing world.

Figure 1.

The time line

Date 0

* Banks make liquidity decisions

* Banks attract initial financing (1 unit to invest in a long-term project; liquid banks also L units for a buffer)

Date 1

* Bankers receive a perfect signal of their date 2 asset value

* Banks may be hit by a shock, and can use a precautionary buffer to cover resulting liquidity shortage

* Banks that covered the shortage can switch to a moral hazard project

* Banks that did not cover the shortage or switched to moral hazard start failing

* If both banks are failing, the Central Bank bails out one of them randomly. This reverses imminent failure and can restore bankers' incentives

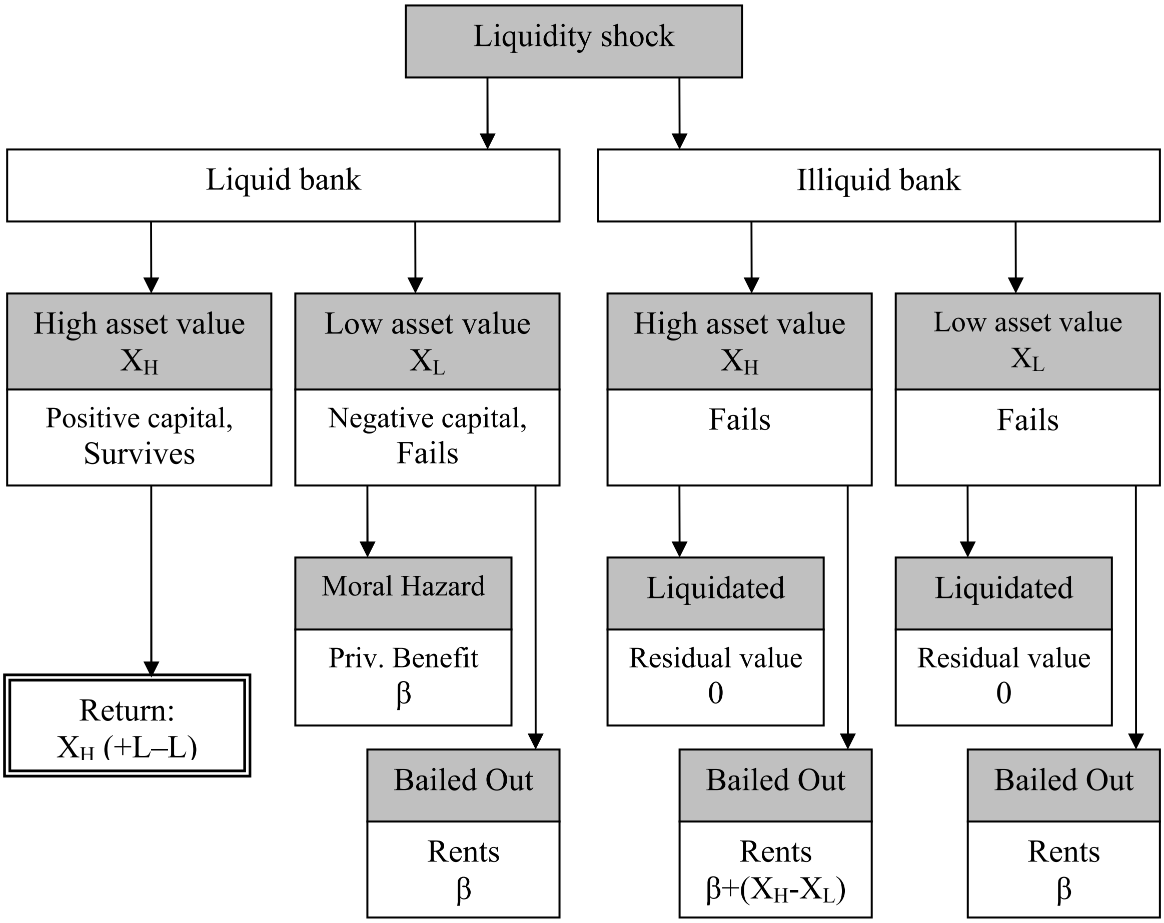
* Banks that did not refinance fail with 0 liquidation value. Banks that switched to moral hazard fail with bankers obtaining private benefits β

Date 2

* Surviving banks realize returns X_H or X_L, repay depositors and the Central Bank, and consume profit

Figure 2.

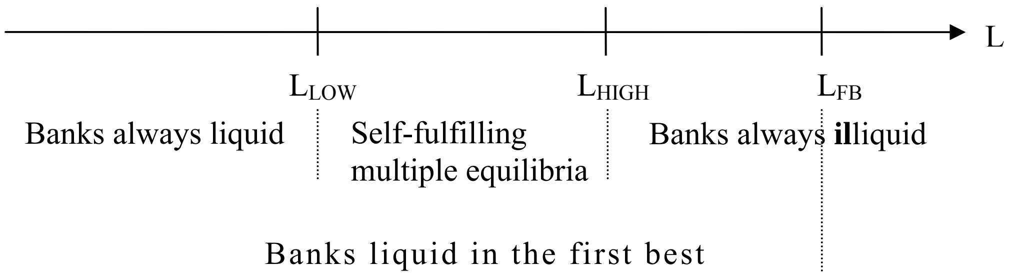
The game tree



Note: Bail out happens when another bank fails as well.
It accrues to a given bank randomly with probability ½

Figure 3.

Threshold values of banks' liquidity choices



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:

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

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 $\Pi_T^S \ge \Pi_N^S$ and $\Pi_T^S > \Pi_{LT}^S$:

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

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

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

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 $l \ge t$ 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 $\Pi_{LT}^S \geq \Pi_L^S$):

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

– 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 $\Pi_{LT}^S \geq \Pi_T^S$):

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

– 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	Date 1	Date 2
* Banks attract initial funds * Banks divide funds between investment in the profitable project, the precautionary liquidity buffer, and the investment in transparency;	* 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.	* Project returns realize * Successful banks repay debts and consume profits.

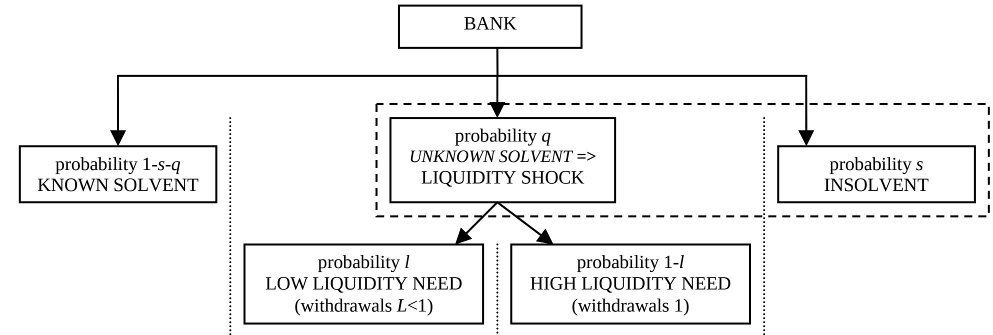
FIGURE 2

<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	KNOWN SOLVENT	LOW LIQUIDITY NEED	HIGH LIQUIDITY NEED	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*

Chapter 4

Credit Standards, Information, and Competition

Banks are often criticized for overly lax credit standards. It appears that banks are sometimes aware of the low quality of individual borrowers but choose to extend credit anyway. This paper suggests a novel rationale for banks' lax credit standards. Typical firm projects are long-term, while financing is short-term, so intermediate refinancing is required. Initial credit standards determine the degree of asymmetric information at the refinancing stage. Stringent standards lead to low asymmetric information and intense price competition ("poaching" of good borrowers). Lax standards lead to high asymmetric information, and allow informed banks to collect higher relationship rents. Such banks may moreover "unload" bad credit onto competitors, minimizing its cost.[1]

4.1 Introduction

Banks are known to on occasions employ lax credit standards – extend credit to low quality borrowers. The literature has highlighted a number of possible explanations, such as reputation concerns that create incentives for evergreening (Rajan, 1994), or low benefits of screening when average firm quality is high (Ruckes, 2004). Yet there is evidence of lax credit standards even when screening costs seem much lower than ultimate default losses. Moreover, banks sometimes appear to initiate lending even when they are fully aware of borrowers' low quality. For example, in the case of Parmalat, it has been

[1] Joint work with Enrico Perotti.

claimed that many "insider" banks were aware of the irregularities for a long time, but continued to lend anyway.

This paper suggests a novel rationale for lax bank credit standards. We suggest that extending some credit to "bad" firms increases asymmetric information between the informed bank and possible competitors at the refinancing stage. This limits credit market competition and allows the inside bank to collect higher relationship rents on good firms.

The intuition is that, when a bank is known to employ most stringent credit standards, competitors infer that firms in the bank's portfolio are mostly high-quality, and can easily "poach" them next time firms require refinancing. Relaxing credit standards and adding some bad firms to the portfolio exposes competitors to the winner's curse. Lower competition and higher return on good firms can more than compensate the informed bank for some bad credit. Moreover, under certain conditions (modelled as the possibility of liquidity shocks), the informed bank can unload bad credit onto competitors, escaping its costs.

We capture these effects with a simple model. Penniless firms can be of two types – creditworthy or not. They require financing for a long-term project, while the only available source of funding is short-term debt. This creates the need for intermediate refinancing. Banks are also of two types. A single "inside" bank has information on firms' quality (e.g. due to prior business). It competes with multiple uninformed "outside" banks at two dates – initial funding and refinancing. Outside banks can reveal the firms' type by screening at a cost, or can lend without screening if they believe that average firm quality is high.

Outsiders can assess the average quality of firms financed by the inside bank by observing the volume of lending (the mass of good firms in public knowledge). When the inside bank provides initial financing only to good firms, outsiders infer the high quality of its credit portfolio, and there is intense price competition ("poaching") that eats away insider's relationship rents. Yet if the insider finances also some bad firms, this exposes outside banks to the winner's curse. At first, the effect of reduced competition is strong enough for extra relationship rents on good credit to compensate the inside bank for losses on bad credit. However when credit standards become very lax, outsiders may start screening at the refinancing stage. This reduces the informational advantage of the inside bank, and limits the degree to which bad credit can increase relationship rents. The possibility of screening assures an internal optimum of the inside bank's credit standards decision.

In an extension, we consider the case where the inside bank is subject to liquidity shocks at the refinancing stage. A liquidity shock prevents any lending – to a good firm or to a bad one. When some good firms are rejected by the inside bank at the refinancing stage, outsiders can choose to offer them credit. If they do so without screening (when proportion of good firms among rejected is high) they also take on bad credit issued initially by the inside bank. This passes onto them the costs associated with bad credit ("unloading"), creating additional incentives for the inside bank to adopt lax credit standards.

Our analysis relates to several strands of the literature. In the heart of the paper is a model of credit market competition under asymmetric information. That was first analyzed by Sharpe (1990) and refined by von Thadden (2004). We construct a simplified version of their approach, and extend it in two ways. Firstly, we take a step back and analyze how credit market competition at the refinancing stage influences initial banks' credit standards decisions. Secondly, we study the novel effect of the possibility of unloading bad credit.

Close effects of insider manipulation in credit markets were identified in the literatures on conflict of interests in universal banking (e.g. Rajan, 1995, Puri, 1996) and loan securitization (Gorton and Pennacchi, 1995). The impact on bank liquidity shortages on lending practices was studied by Detragiache et al. (2000) among others.

The paper sheds new light on the controversial relationship between bank competition and the quality of lending. The traditional view is that high competition reduces banks' charter values and increases risk-taking incentives. Yet that line of reasoning is being challenged on theoretical (e.g. Boyd and De Nicolo, 2005) and, more importantly, empirical grounds. In particular, foreign bank entry is commonly associated with improved financial sector performance. This paper offers a possible explanation for the latter effect, suggesting that banking performance improves when new entrants bring about efficiency improvements. In particular, when outsiders can screen more effectively, that reduces the extent to which established banks can generate relationship rents through lax credit standards. As a result, credit quality in the economy increases.

The paper proceeds as follows. Section 2 sets up the model. Section 3 shows that stringent credit standards are the equilibrium in the first best. Section 4 solves the main case and shows that banks can relax credit standards in order to maximize relationship rents. Section 5 introduces liquidity shocks and the possibility of unloading bad credit. Section 6 concludes.

4.2 Setup

Projects and financing Consider a risk-neutral economy with three dates 0, 1, 2 and no discounting. There is a mass 1 of small penniless firms, each with a single investment project. Each project requires an initial investment 1 at date 0. For a mass $g < 1$ of firms, the project is good and returns $X > 1$ at date 2. For an additional mass $1 - g$ of firms, the project is bad and returns 0. Any project can be liquidated at the intermediate date 1, at residual value $L : 0 < L < 1$. A firm does not know its type.

Firms seek external financing from banks. We consider the setting where the only available type of external finance is *short-term debt*. This reflects the fact that, in practice, short-term debt is indeed the predominant source of finance used by all but the largest firms. The reasons for relying on short-term debt have been widely explored in the literature (see e.g. von Thadden, 1995). The need of intermediate refinancing is a convenient modelling feature that allows to study repeated credit market interaction without complex effects associated with retained earnings. Under short term debt, firms borrow 1 from date 0 to date 1 against promised return R_1, and then refinance R_1 by borrowing from date 1 to date 2 against promised return R_2. A firm that cannot refinance at date 1 is automatically liquidated, and proceeds L go to the original lender.

Information We consider the interaction between an informed and multiple uninformed banks in an competitive banking sector. We assume that a single "inside" bank is endowed with information on firms' types (for example, due to prior business). Multiple "outside" banks initially do not have information on individual firms' types, but can reveal it by screening before granting credit. We model screening is a binary decision (screen or not screen), which has a unit cost C, is possible at both dates 0 and 1, and for simplicity always produces a correct signal of firm quality.

We impose a number of restrictions on the cost of screening C. They assure that C is not too high, and allow to focus on the most relevant cases. We assume that:

- $C < 1 - g$: at date 0, outsiders prefer screening to uninformed finance, because its cost is lower than possible loss on lending to bad firms;
- $C < 1 - L$: at date 1, the informational advantage of insiders (when it is related to the cost of screening by outsiders) is lower than the cost of extending credit to bad firms.

Banks do not screen when indifferent.

Credit market competition Banks compete for granting credit to firms at both dates 0 and 1. We model each round of credit market competition as follows:

1. The inside bank posts an interest rate, and commits to it;
2. Outside banks post interest rates, and commit to them;
3. Firms approach the winning bank;
4. The winning bank can screen;
5. The winning bank offers or denies credit at the pre-specified interest rate;
6. If rejected, a firm can seek credit from other banks.

Assuming consequential bids allows to derive an easily tractable equilibrium in pure strategies (simultaneous-move credit market competition under asymmetric information only has a complex equilibrium in mixed strategies, see Von Thadden, 2004). Commitment to pre-specified interest rates allows to avoid undercutting after another bank has incurred the cost of screening. In a benchmark equilibrium, outsiders never undercut nor lend, but their presence caps interest rates the inside bank can offer.

Note that although the inside bank is the first to post an interest rate, that does not necessarily reveal information to outsiders (as would have been if it had to charge a higher rate to bad firms), because the insider can always reject a bad firm later. Instead, it is the credit offer/rejection decision at date 0 that provides information that outsiders can use at date 1. From the volume of lending of the inside bank, d, and the known share of good firms in the economy, g, outsiders can infer the proportion of good and bad firms in the pool financed at date 0. This knowledge reduces asymmetric information at date 1. For example, when the insider bank lends only to good firms at date 0, outside banks observe $d = g$ and there is symmetric information at date 1.

For simplicity, we assume that $R_1 \geq 1$. This can be rationalized by that, otherwise, heavily subsidized date 0 lending would affect "fly-by-night operators". We also impose that X is high enough so that lending is always possible: $X > (1 + C/g)/g$ (the latter term will be shown to be a feasible lending rate). Banks' cost of funds is 1, they maximize total profit. Other else equal, firms prefer to borrow from the inside bank.

4.3 The First Best

We start with a first best benchmark. The main friction in the model is asymmetric information over firms' types during credit market competition at date 1. Here we consider a hypothetical scenario when firm quality information is symmetric at the refinancing stage. We assume that, for some exogenous reason, all inside bank's information becomes public knowledge before date 1. We verify that in this case the inside bank chooses stringent initial credit standards.

We solve backwards. Assume that at date 0, along with a mass g of good firms, the inside bank financed a mass b of bad firms, making total lending $d = g + b$. Since firm quality is public information, no outside bank will extend credit to bad firms at date 1. The inside bank also prefers to liquidate them to recover L instead of 0 if they are allowed to continue.

Since good firms are also known, lending to them is risk-free. They can receive credit from any bank at $R_2 = R_1$. The inside bank makes no relationship rents on date 1 lending, because it does not possess private information.

The inside bank therefore makes a profit $(R_1 - 1)\, g$ on lending to good firms, and loses $(L - 1)\, b$ on lending to bad firms. The loss is minimized for $b = 0$. The inside bank therefore has no incentive to lend to bad firms at date 0. This gives the benchmark result:

Proposition 8 *When information on firm type is symmetric at the refinancing stage, initial credit standards are stringent: the inside bank lends only to good firms at date* 0.

To close the solution, we derive initial interest rate R_1 and the inside bank's profit. The maximal repayment the insider can offer without being undercut is the minimal repayment an outsider can offer without making a loss. If an outsider wins credit market competition at date 0, it has to incur the cost of screening C (this is preferred to uninformed lending since $C < 1 - g$). The cost of screening cannot be recouped later because there are no relationship rents at date 1. (For this, there are two reasons. Firstly, information at date 1 is assumed symmetric in this section. Secondly, even if it was not, the information on firms' types is shared by the inside bank, leading to Bertrand competition.) The minimal repayment the outsider can offer must cover the cost of screening all firms C by repayment from a mass g of good firms. Such repayment is $R_1 = 1 + C/g$. As explained, R_1 will remain the same also in the presence of asymmetric information, analyzed in the following sections of the paper.

The insider's profit is $\Pi_{FB} = g(R_1 - 1) = C$. This reflects the value of the insider's initial informational advantage: it does not need to screen at date 0 to establish firms' types.

4.4 Credit Standards and "Poaching"

We now solve for the main case with asymmetric information at date 1. We show that more stringent insider's credit standards at date 0 reveal more private information on firm quality that outsiders can use at date 1. This increases competition at the refinancing stage and reduces relationship rents the insider can collect. Consequently, the inside bank has incentives to adopt less than fully stringent credit standards.

We again solve backwards. We start with date 1 credit market competition, taking date 0 credit standards as given. We then return to date 0 and derive inside bank's profit-maximizing credit standards.

Refinancing stage Consider date 1. Assume that at date 0 the inside bank extended credit to a mass g of good firms and a mass b of bad firms, making total lending $d = g + b$. At date 1, those firms seek refinancing of the earlier promised repayment R_1. The maximal repayment the insider can offer without being undercut is the minimal repayment an outsider can offer without making a loss. Observe that an outsider who wins credit market competition at date 1 has two options:

1. *Finance all firms without screening.* This leads to a loss on lending to bad firms $(d - g) \cdot R_1$, which must be covered from return on loans to a mass g of good firms. (Put differently, the bank extends credit to a mass d of firms, but only a mass $g < d$ repays). The minimal possible repayment is therefore:

$$R_2^{NoScr} = \frac{d}{g} R_1$$

We verify in the end of this section that return X is high enough for good firms to be able to repay this amount.

2. *Screen and finance good firms only.* The cost of screening $d \cdot C$ must be covered from return on loans to good firms. This makes the minimal possible repayment

$$R_2^{Scr} = R_1 + \frac{d}{g} C$$

A winning outsider would prefer to finance *without screening* for $(d - g) \cdot R_1 \leq d \cdot C$, equivalent to

$$d \leq d^* = g \frac{R_1}{R_1 - C} \tag{4.1}$$

and to finance *only after screening* for $d > d^*$. Note that $d^* > g$.

The intuition is that when initial credit standards are relatively stringent and few bad firms are financed ($g < d \leq d^*$), average quality of firms that require refinancing is high. Then an outsider can refinance all of them without screening, only incurring a loss on a few bad firms. However when initial credit standards are very lax ($d > d^*$), average quality of firms that require refinancing is low. Then an outsider would only extend credit to good firms after screening all the firms.

The repayment $R_2 = R_2^{NoScr}$ for $d \leq d^*$ or $R_2 = R_2^{Scr}$ for $d > d^*$ is the maximal the inside bank can offer at date 1 without being undercut. They are the inside bank's best date 2 response to its own previous lending decision d. Overall, the inside bank makes profit $(R_2 - 1)\, g$ on lending to good firms. It liquidates bad firms by denying them credit at date 1. (Outsiders infer that those firms are bad, and do not finance them either.) The insider ends up with a loss $(L - 1)\, b$ on lending to bad firms. Its total profit as a function of earlier credit standards d is therefore $g\,(R_2 - 1) + (d - g)(L - 1)$.

Initial lending Consider now date 0. We derive the inside bank's profit depending on its credit standards decision d.

For $d \leq d^*$, the inside bank's profit is:

$$\begin{aligned} \Pi &= g\left(R_2^{NoScr} - 1\right) + (d - g)(L - 1) \\ &= g\left(\frac{d}{g}R_1 - 1\right) + (d - g)(L - 1) \end{aligned}$$

Observe that the first derivative is positive:

$$\frac{\partial \Pi}{\partial d} = R_1 + (L - 1) > 0$$

because $R_1 \geq 1$ while $(1 - L) < 1$. The inside bank has incentives to relax credit standards in order to increase relationship rents.

For $d > d^*$, the inside bank's profit is:

$$\begin{aligned} \Pi &= g\left(R_2^{Scr} - 1\right) + (d - g)(L - 1) \\ &= g\left(R_1 + \frac{d}{g}C - 1\right) + (d - g)(L - 1) \end{aligned}$$

Observe that the first derivative is now negative:

$$\frac{\partial \Pi}{\partial d} = C + (L - 1) < 0$$

because the costs of screening is assumed low enough $C < 1 - L$. (Note also that the inside banks's profit is continuous at d^* because $R_2^{NoScr}(d^*) = R_2^{Scr}(d^*)$.)

The profit is therefore non-monotonous in credit standards. It increases in d while $d \leq d^*$, but falls in d for $d > d^*$. The intuition is that when credit standards are relatively stringent, outsiders do not screen at the refinancing stage, and a marginal reduction in credit standards significantly increases the winner's curse. However when standards become too lax, outsiders choose screening as their optimal response at date 1. The possibility of screening by outsiders reduces the marginal informational advantage the inside bank gains from extending more bad credit. The inside bank's profit as a function of d is shown in Figure 1.

Therefore, the profit of the inside bank is maximized at d^* and is

$$\begin{aligned} \Pi &= \left(g\frac{R_1}{R_1 - C}R_1 - g\right) + \left(g\frac{R_1}{R_1 - C} - g\right)(L-1) \\ &= g\frac{R_1}{R_1 - C}(R_1 + L - 1) - gL \end{aligned} \tag{4.2}$$

We can now formulate the first main result:

Proposition 9 *Bad credit allows the inside bank to maintain relationship rents on good credit.*

1. *Fully stringent credit standards are never optimal:* $\partial\Pi/\partial d_{d=0} > 0$.
2. *The opportunity to collect rents is limited by the screening capacity of outside banks. Inside bank's credit standards have an internal optimum d^*, corresponding to the point where outside banks start screening at the refinancing stage in response to deteriorating credit quality.*

Proposition 2 identifies the source of banks' incentives to adopt lax credit standards. Lax credit standards preserve asymmetric information at the refinancing stage and allow the inside bank to collect relationship rents. However the scope for doing so is limited by outsiders' opportunity to screen when credit standards become too lax. Therefore, credit standards have an internal optimum, d^*.

To close the solution we derive R_1 and the profit of the inside bank. The maximal repayment the insider can demand at date 0 without being undercut is the minimal repayment a winning outside bank can offer at date 0 without making a loss. An outside bank that wins credit market competition at date 0 has to cover the costs of screening (there are no relationship rent at date 1 because firm type information is shared by the inside bank). The minimal repayment that covers the costs of screening is $R_1 = 1 + C/g$. Note that

$$R_2^{NoScr} = \frac{d}{g}(1 + C/g) \leq \frac{1}{g}(1 + C/g) < X$$

so that the return of good firms is sufficient to repay R_2^{NoScr} charged on lending at date 1 (and sufficient to repay R_2^{Scr} when $R_2^{Scr} < R_2^{NoScr}$).

We substitute R_1 in (4.1) to obtain

$$d^* = g\frac{1 + C/g}{1 + C/g - C}$$

and in profit (4.2) to obtain

$$\begin{aligned} \Pi &= g\frac{1 + C/g}{1 + C/g - C}(C/g + L) - gL \\ &= \frac{1 + C/g}{1 + C/g - C}C \end{aligned}$$

Observe that

$$\Pi = \frac{1 + C/g}{1 + C/g - C}C > C = \Pi_{FB}$$

The profit of the inside bank is higher when it can collect relationship rents thanks to asymmetric information, compared to the "first best" case when information was symmetric and relationship rents were impossible.

4.5 Liquidity Shocks and "Unloading"

Here we extend the analysis to study how the inside bank can unload bad credit onto uninformed competitors at the refinancing stage. This allows the inside bank to avoid the costs of bad credit, in addition to enjoying the relationship rents on good credit that it generates. To study unloading, we make one extension. We assume that the inside bank is subject to possible liquidity shocks at date 1. When the inside bank is hit by a liquidity shock, it cannot lend to any firm – good or bad.

We model liquidity shocks as firm-specific events. We assume that firms arrive for refinancing at date 1 sequentially. At the time of the arrival of each firm, a bank may be hit with a liquidity shock, each time with probability λ. In that case the bank is unable to extend credit to that particular firm. This leads to the inside bank rejecting a mass λg of good firms along with all bad firms[2].

Since the inside bank also rejects some good firms, outsiders can decide to extend credit to firms not refinanced by the inside bank. When outsiders offer refinancing without screening, they also take on the inside banks' rejected bad credit. In that case, the inside bank avoids liquidating bad credit at a cost.

A liquidity shocks can be interpreted as a genuine liquidity shortage, a need to diversify from a particular sector, or the emergence of more profitable investments opportunities. Occurrence of a shock is private information to the bank.

The last simplifying assumption we make is that the inside bank is subject to liquidity shocks only when it lends at date 0. In the out-of-equilibrium case when it is an outside bank that lends at date 0, the inside bank is able to compete fully at date 1. This simplifies the derivation of R_1 (making it the same as in the previous section), and does not affect qualitative results.

We modify restriction on X to ensure it is high enough to make lending to rejected firms always possible: $X > (\lambda g + (1-g))(1+C/g)/\lambda g$ (this will be shown to above a feasible repayment demanded from rejected firms) As before, we solve the model backwards.

Refinancing stage Assume that at date 0 the inside bank extended credit to a mass g of good firms and a mass b of bad firms, making total lending $d = g + b$. At date 1, those firms seek refinancing of the earlier promised repayment R_1. As in the previous section, the inside bank offers the maximum repayment R_2 that cannot be undercut by outsiders immediately ($R_2 = R_2^{NoScr}$ for $d \leq d^*$ or $R_2 = R_2^{Scr}$ for $d > d^*$). After that, the inside bank rejects all bad firms and also a share λ of good firms to which it cannot offer credit due to liquidity problems.

[2]The same effects can be modelled as an aggregate (not firm-specific) liquidity shock, where a bank is only able to extend volume $(1-\lambda)gR_1$ of new credit, also having to deny credit to a mass λg of good firms as a result.

As a result, outside banks are faced with a pool of rejected firms that contains a mass $g\lambda$ of good ones and $d-g$ of bad ones. There are two options in which a winning outside banks can finance these firms.

1. *Finance all remaining firms without screening.* This leads to a loss on lending to bad firms $(d-g)\cdot R_1$, which must be covered from return on loans to a mass λg of good firms. The minimal possible competitive repayment is therefore:

$$R_2^{NoScr2} = \frac{\lambda g + (d-g)}{\lambda g} R_1$$

We verify in the end of this section that return X is high enough for good firms to be able to repay this amount.

2. *Screen and finance good firms only.* The cost of screening $(\lambda g + (d-g)) \cdot C$ must be covered from return on loans to good firms. This makes the minimal possible repayment

$$R_2^{Scr2} = R_1 + \frac{d-(1-\lambda)g}{\lambda g} C$$

A winning outside bank would therefore finance the remaining firms without screening for $(d-g)\cdot R_1 \leq (d-(1-\lambda)g)\cdot C$, equivalent to

$$d \leq d^{**} = g\frac{R_1 - (1-\lambda)C}{R_1 - C} \tag{4.3}$$

and finance only good ones after screening for $d > d^*$. Note that $g < d^{**} < d^*$ and $\partial d^{**}/\partial\lambda > 0$.

The intuition is that when initial credit standards are relatively stringent (low d) and the probability of liquidity shocks is high (high λ), the share of good firms among those rejected at date 1 is high. In this case, outsiders prefer to refinance the rejected firms without screening. However as liquidity standards become more lax, or if the probability of liquidity shocks is low, the share of good firms among those rejected at date 1 becomes low. In this case, outsiders would only extend refinancing to good firms after screening all the firms.

When outsiders screen the remaining firms, they reject bad ones. Such firms are liquidated at a cost $b(L-1)$ to the inside bank. However when outside banks refinance rejected firms without screening, they take on bad firms as well. Then the inside bank effectively "unloads" bad credit on outside competitors, enjoying profit $b(R_1-1)$ on lending to bad firms.

Initial lending We can now derive the inside bank's profit depending on its credit standards decision d.

For $d \leq d^{**}$, the inside bank's profit is:

$$\begin{aligned} \Pi &= g(1-\lambda)(R_2^{NoScr}-1)+g\lambda(R_1-1)+(d-g)(R_1-1) \\ &= g(1-\lambda)\left(\frac{d}{g}R_1-1\right)+g\lambda(R_1-1)+(d-g)(R_1-1) \end{aligned} \tag{4.4}$$

Observe that on this interval the presence of bad credit both increases relationship rents *and* has no costs to the inside bank because it is unloaded to uninformed competitors at the refinancing stage. The first derivative is therefore positive:

$$\frac{\partial \Pi}{\partial d} = (1-\lambda)R_1 + (R_1-1) > 0$$

For $d^{**} < d \leq d^{*}$, the inside bank's profit is:

$$\begin{aligned} \Pi &= g(1-\lambda)(R_2^{NoScr}-1)+g\lambda(R_1-1)+(d-g)(L-1) \\ &= g(1-\lambda)\left(\frac{d}{g}R_1-1\right)+g\lambda(R_1-1)+(d-g)(L-1) \end{aligned} \tag{4.5}$$

On this interval, bad credit increases relationship rents, but is associated with a unit cost $(L-1)$ to the inside bank, because outsiders screen and refuse refinancing to bad firms. There is a discreet fall in profits by $(d-g)(R_1-L)$ at d^{**}, as outside firms start screening and rejecting bad credit. The first derivative is:

$$\frac{\partial \Pi}{\partial d} = (1-\lambda)R_1 + (L-1)$$

The first derivative is positive for low λ (converges to $R_1 + (L-1) > 0$ for $\lambda \to 0$), as a bank is able to collect higher relationships rents on good credit. However it becomes negative for high λ (converges to $L-1$ for $\lambda \to 1$), since relationship rents fall as liquidity shocks become more frequent.

For $d > d^*$, the inside bank's profit is:

$$\begin{aligned}
\Pi &= g(1-\lambda)(R_2^{Scr}-1) + g\lambda(R_1-1) + (d-g)(L-1) \\
&= g(1-\lambda)\left(R_1 + \frac{d-(1-\lambda)g}{g}C - 1\right) + g\lambda(R_1-1) + (d-g)(L-1)
\end{aligned}$$

The first derivative is negative:

$$\frac{\partial \Pi}{\partial d} = (1-\lambda)C + (L-1) < 0$$

Note that the profit-maximizing credit standards d depend therefore on the probability of liquidity crises λ. On the one hand, when λ is high and liquidity shocks are likely, the profit of the inside bank is maximized at d^{**}. More lax credit standards ($d > d^{**}$) result in a loss of possibility to unload bad credit, while relationship rents are reduced by possible liquidity shocks. Yet on the other hand, when λ is low and liquidity shocks are less likely, profits are maximized in d^*, because higher relationship rents outweigh the benefits of unloading bad credit. The inside bank's profit as a function of d is shown in Figure 2.

Formally, from (4.4) and (4.5), $\Pi(d^{**}) \geq \Pi(d^*)$ when

$$\lambda \geq 1 - \frac{(d^{**}-g)(R_1-1) - (d^*-g)(L-1)}{R_1\,(d^*-d^{**})}$$

Substituting from (4.1) and (4.3)

$$\begin{aligned}
d^{**} - g &= g\frac{\lambda C}{R_1 - C} \\
d^* - g &= g\frac{C}{R_1 - C} \\
d^* - d^{**} &= g\frac{(1-\lambda)C}{R_1 - C}
\end{aligned}$$

We obtain:

$$\lambda \geq 1 - \frac{\lambda(R_1-1) - (L-1)}{R_1(1-\lambda)}$$

Observe that the latter inequality is always satisfied for $\lambda = 1$ (the right part tends to $-\infty$), and is never satisfied for $\lambda = 0$ $(1-(1-L)/R_1 > 0)$. The threshold point is:

$$\lambda^* = \frac{3R_1 - 1 + \sqrt{5R_1^2 - 2R_1 - 4LR_1 + 1}}{2R_1} \tag{4.6}$$

The bank's optimal credit standards can be summarized in the following Lemma:

Lemma 10 *There exists a threshold value λ^* (4.6) such that $\Pi(d^{**}) = \Pi(d^*)$.*

- *For $\lambda \geq \lambda^*$ the inside bank's profit is maximized in credit standards at $d = d^{**}$: the bank foregoes additional relationship rents for the possibility of unloading bad credit.*
- *For $\lambda < \lambda^*$ the profit is maximized at $d = d^*$: the bank prefers higher rents to the possibility of unloading.*

We can now formulate the final main result:

Proposition 11 *When the inside bank is subject to liquidity shocks (and their occurrence is private information), the bank can unload bad credit onto outside competitors.*

1. *Fully stringent credit standards are never optimal: $\partial\Pi/\partial d_{d=0} > 0$.*
2. *There is a trade-off between the possibility to unload bad credit (d^{**} preferred when the probability of liquidity shocks λ is high) and higher relationship rents (d^* preferred when λ is low).*

To close solution, we derive d^*, d^{**}, and λ^*. Recall that $R_1 = 1 + C/g$ (it is the same as in the previous analysis, due to the simplifying assumption that the inside bank does not have liquidity shocks when it did not lend at date 0). Note that

$$R_2^{NoScr2} = \frac{\lambda g + (d-g)}{\lambda g}(1 + C/g) \leq \frac{\lambda g + (1-g)}{\lambda g}(1 + C/g) < X$$

so that the return of good firms is sufficient to repay R_2^{NoScr2} charged by outsiders on lending to firms rejected at date 1 (and sufficient to repay R_2^{Scr2} when $R_2^{Scr2} < R_2^{NoScr2}$).

Substituting into (4.1), (4.3) and (4.6) gives:

$$\begin{aligned}
d^* &= g\frac{1 + C/g}{1 + C/g - C} \\
d^{**} &= g\frac{1 + C/g - (1-\lambda)C}{1 + C/g - C} \\
\lambda^* &= \frac{3(1 + C/g) - 1 + \sqrt{5(1 + C/g)^2 - (2 + 4L)(1 + C/g) + 1}}{2(1 + C/g)}
\end{aligned}$$

Expressions for the inside bank's profit can be obtained by substituting d^*, d^{**}, R_1 and R_2^{NoScr} into (4.4) and (4.5).

4.6 Conclusions

This paper suggests a novel rationale for suboptimal lax bank credit standards. We show that an informed bank can extend some "bad" credit, to increase relationship rents on good credit. Moreover, the bank may be able to avoid the costs of bad credit by "unloading" it to competitors at the refinancing stage.

The results also shed light on the relationship between competition and credit standards. While the traditional view holds that competition is detrimental for the quality of lending, we demonstrate that if new competition brings about efficiency improvements (e.g. in screening technology) that can lead to improved credit standards.

Figure 1

Profit as a function of credit standards

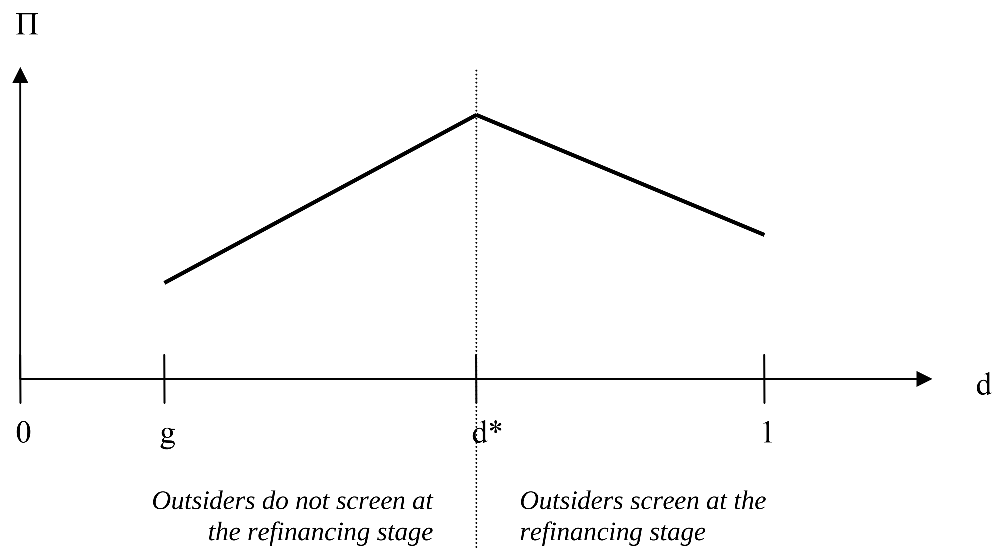
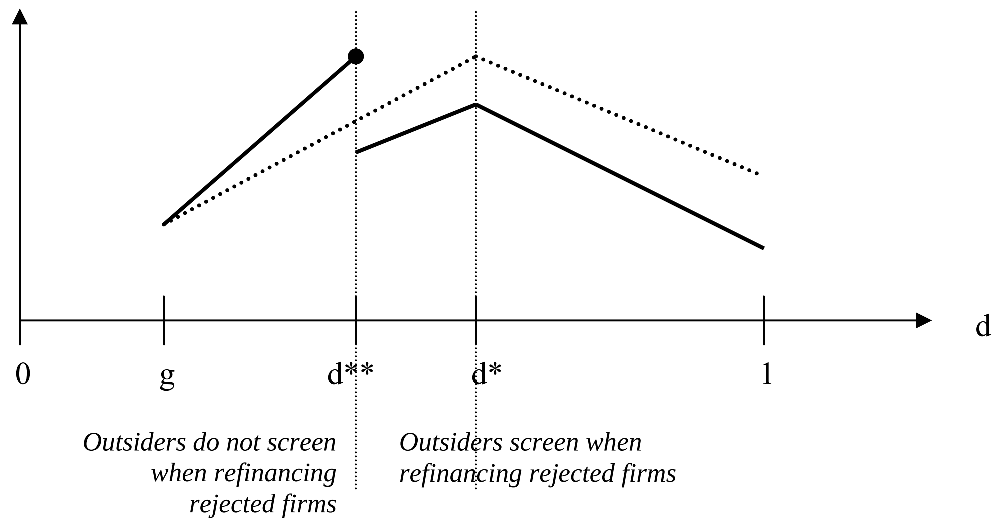


Figure 2

Profit as a function of credit standards, in the presence of liquidity shocks



Chapter 5

Nederlandse Samenvatting (Summary in Dutch)

Deze thesis bestaat uit drie papers over het bankwezen.

In de eerste paper, Bank Liquidity Regulation and the Lender of Last Resort, worden de incentives van banken bestudeerd om niet-optimale liquiditeitskeuzes te maken. De hoofdzakelijke vertekening is het gevolg van de toeslagen gekoppeld aan de lender of last resort (LOLR, geldschieter in laatste instantie)-interventie in een systemische crisis. Ik toon aan dat deze de incentives van banken kunnen verlagen om liquiditeit te accumuleren en ervoor kunnen zorgen dat banken daarentegen op LOLR-steun gokken. Ik toon verder ook aan dat regelende instanties tussenbeide komen door dure, expliciete vereisten op te stellen of door de LOLR-vertekening te minimaliseren. Dat laatste is echter alleen mogelijk als regelende instanties over voldoende accurate informatie over de vermogenswaarde van de bank beschikken.

In de tweede paper, Liquidity and Transparency in Bank Risk Management, worden twee manieren bestudeerd waarop banken zich tegen het risico op liquiditeitstekorten kunnen indekken. De eerste manier is door uiterst liquide middelen te accumuleren. De tweede manier is door de transparantie te verbeteren om zo voor betere toegang tot externe financiering te zorgen. Ik toon aan dat een liquiditeitsbuffer een bank volledig beschermt tegen kleine liquiditeitsbehoeften, terwijl transparantie de bank beschermt tegen alle behoeften, zij het slechts gedeeltelijk. Hoewel liquiditeit eenvoudig te reguleren is, is transparantie niet verifieerbaar. Dit bemoeilijkt dan ook het opstellen van een beleid. Het verrassendste resultaat is dat de liquiditeitsvereisten de keuzes op het gebied van transparantie kunnen compromitteren en banken kwetsbaar kunnen maken in het geval van grote liquiditeitsbehoeften.

In de derde paper, Credits Standards, Information, and Competition (in samenwerking met Enrico Perotti), wordt een nieuwe rationale voorgesteld voor het gebruik van lakse kredietnormen door banken. Het verlenen van krediet aan 'slechte' ondernemingen verhoogt de informatie-asymmetrie tussen de uitvoerende bank en de concurrenten in het herfinancieringsstadium. Dit beperkt de concurrentie op de kredietmarkt en maakt hogere relatietoeslagen op leningen aan goede ondernemingen mogelijk, die op hun beurt de verliezen op slecht krediet meer dan goed maken. Dit effect leidt tot een beter inzicht in de financiële effecten van het dereguleren van het bankwezen en de toetreding van buitenlandse spelers.

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