American Economic Journal: Macroeconomics 2012 4(2): 184–217
http://dx.doi.org/10.1257/mac.4.2.184

Imperfect Competition in the Interbank Market for Liquidity as a Rationale for Central Banking[†]

By Viral V. Acharya, Denis Gromb, and Tanju Yorulmazer*

We study interbank lending and asset sales markets in which banks with surplus liquidity have market power vis-à-vis banks needing liquidity, frictions arise in lending due to moral hazard, and assets are bank-specific. Surplus banks ration lending and instead purchase assets from needy banks, an inefficiency more acute during financial crises. A central bank acting as a lender-of-last-resort can ameliorate this inefficiency provided it is prepared to extend potentially loss-making loans or is better informed than outside markets, as might be the case if it also performs a supervisory role. This rationale for central banking finds support in historical episodes. (JEL E58, G01, G21, G28, L13, N21)

The liquidity squeeze during the ongoing financial crisis has been likened by some, including the International Monetary Fund (IMF), to the Depression-era turmoil. Early in the crisis, central banks faced difficulties channeling liquidity to the neediest parts of the financial system via open market operations, the discount window, or securities lending. Some lending facilities, such as the discount window, were not availed by players, and others resulted in liquidity hoarding by banks and other institutions.[1] In response, central banks around the world, most notably the

*Acharya: New York University, Department of Finance, Stern School of Business, New York University, 44 West Fourth Street, Room 9-84, New York, NY 10012 and Centre for Economic Policy Research (CEPR) and National Bureau of Economic Research (NBER) (e-mail: vacharya@stern.nyu.edu); Gromb: INSEAD, Boulevard de Constance, Fontainebleau 77305, France and CEPR (e-mail: denis.gromb@insead.edu); Yorulmazer: Federal Reserve Bank of New York, 33 Liberty Street, New York, NY 10045 (e-mail: tanju.yorulmazer@ny.frb.org). The views expressed here are those of the authors and do not necessarily represent the views of the Federal Reserve Bank of New York or the Federal Reserve System. We are grateful to Franklin Allen, Arnoud Boot, Enrica Detragiache, Darrell Duffie, Douglas Gale, Jacob Goldfield, Charles Goodhart, Enisse Kharroubi, Alan Morrison, Leonard Nakamura, Henri Pagès, Loriana Pelizzon, Raghuram Rajan, Adriano Rampini, Stacey Schreft, Peter Sinclair, Hyun Shin, Ellis Tallman, Anjan Thakor, Vikrant Vig, Goetz von Peter, Lucy White, Matthew Willison, and seminar participants at Bank of France; Bank of England; Bank of Portugal; the BCBS-CEPR-JFI "Risk Transfer Mechanisms and Financial Stability" Workshop; the CEPR conference on Banking and the Macroeconomy at ETH Zurich; CREST; University of Chicago; ESSEC; Essex University; ESSFM Gerzensee 2008; FIRS Alaska 2008; IFN Stockholm; INSEAD; Lancaster; London Business School; London School of Economics; Queen's University; the Second New York Fed-Princeton Liquidity Conference; the Federal Reserve Banks of Cleveland, New York and Philadelphia; the Swiss Winter Finance Conference in Champery; and the Université Paris Dauphine for helpful suggestions. A grant from the Fondation Banque de France is gratefully acknowledged. Part of this project was completed while Viral Acharya was visiting Stanford-GSB. All errors remain our own.

[†] To comment on this article in the online discussion forum, or to view additional materials, visit the article page at http://dx.doi.org/10.1257/mac.4.2.184.

[1] Acharya and Merrouche (2009) report that UK banks' liquidity buffers experienced an almost permanent 30 percent rise in August 2007, resulting in higher borrowing costs between banks and an almost complete drying up of liquidity in interbank markets but for very short maturities. See also "Hoarding by banks stokes fears over crisis: Borrowing costs rise between institutions; (Central Bank) Efforts on lending fail to bear fruit," *Financial Times*, March 26, 2008.

Federal Reserve (Fed), undertook significant changes to their lender-of-last-resort (LOLR) facilities, in particular, by extending maturities of discount window and open market operations, extending eligible collateral to include investment-grade debt securities, and making such adjustments for lending to primary dealers.

We propose that during crises, efficient liquidity transfers may not occur from banks with excess liquidity (surplus banks) to liquidity stricken ones (needy banks). We analyze one source of inefficiency arising when surplus banks use their market power in interbank lending to purchase assets from needy banks at fire sale prices, thus gaining market share at their expense. We determine conditions under which a central bank can mitigate this inefficiency by standing ready to lend to needy banks. We report historical episodes in support of this role and discuss the implications of recent debates on the central banks' supervisory and LOLR functions.

We consider liquidity transfers between a surplus bank and a needy bank through two markets: the interbank lending market and the asset sales market. Our model has three main ingredients. First, we assume that some assets are bank-specific. They are worth more under current than alternative owners, e.g., as these may lack the current owners' expertise. As a result, asset sales are less efficient than borrowing. Second, we assume frictions in the interbank lending market, which we model as due to moral hazard. Specifically, we assume that banks can, at a cost, monitor their assets to improve their performance. A bank borrowing in the interbank market must retain a large enough claim on its own assets to have incentives to monitor them. This limits banks' borrowing capacity. Third, we assume liquidity to be concentrated within a few banks, giving them market power.

We show that the surplus bank's market power can lead to more inefficient asset sales by the needy bank. The intuition is that the surplus bank can exploit its market power to capture a larger part of the surplus a liquidity transfer creates. To do so, it first increases the cost of borrowing it charges the needy bank. Eventually, however, that cost is so high that it discourages the needy bank from monitoring its assets. At that point, asset sales become more attractive. The higher the surplus bank's market power, the greater the inefficiency from excessive asset sales. This inefficiency also increases with the needy bank's demand for liquidity as larger needs are more likely to exhaust the bank's borrowing capacity and thus forces asset sales. The surplus bank's ability to exploit its market power is limited by the needy bank's outside option e.g., raising liquidity from outside (nonbank) markets through commercial paper or public debt. Therefore, the problem of inefficient asset sales is more acute when the outside market is weaker, e.g., when assets are more opaque or information sensitive or consist of bank-specific loans made to small borrowers.

Overall, due to market power, even states with an aggregate liquidity surplus can exhibit effective liquidity shortage. While this effect may arise in normal times, it is likely to be more acute during financial crises as they combine a number of amplifying factors. First, the surplus banks' position vis-à-vis needy banks may be particularly strong during crises. Indeed, many banks may be sidelined by insolvency or the fear thereof, leaving few surplus banks with bargaining power in liquidity supply. The illiquid banks' need for liquidity may also be urgent, weakening their bargaining position. Second, the demand for liquidity may be especially large. Third, outside options may also favor surplus banks given that many players may be seeking

liquidity. At the same time, outside markets may be weak as nonbank's disadvantage in valuing and arguably managing bank assets may be particularly high. In our analysis, all these conditions lead to more severe inefficiency in the allocation of liquidity. Finally, in the run-up to a crisis, banks may find it difficult to prearrange sufficient insurance through lines of credit, as each seeks to preserve liquidity for its own purpose, given that aggregate liquidity shortages are more likely. Thus, banks may enter a crisis with uninsured liquidity needs even if an aggregate liquidity shortage does not materialize.

Next, we argue that this inefficiency creates a rationale for the LOLR role of a central bank. A central bank that is credible in providing liquidity to needy banks curbs the market power of surplus banks in the interbank lending market and thus improves the efficiency of liquidity transfers. In particular, the central bank can play a "virtual and virtuous" role. In our model, it never actually lends to needy banks, but improves their bargaining position vis-à-vis surplus banks. We show, however, that such a role requires the central bank to either be better than outside markets at extending loans to needy banks or be ready to incur losses. The former situation is more likely if the central bank also has a supervisory role allowing it to improve its ability to monitor its loans to needy banks. In particular, supervision ex ante does not reduce the incidence of the central bank making loans ex post, but makes such intervention credible, thereby improving the allocation of liquidity

We also report historical and current evidence supporting the notion of market power of liquid banks during crises. We describe failures of private coinsurance arrangements, such as the Clearinghouse System established by the New York City banks in 1853; liquid players exploiting their market power over illiquid ones during crises, such as J.P. Morgan and National City Bank in the 1907 crisis; the conversion of central banks from business rivals of other banks to their modern form of public institutions concerned with financial stability; the establishment of the Federal Reserve as LOLR preventing surplus banks from exerting market power; and market power between banks and nonbank financial institutions (without access to central bank lending) during the crisis of 2007–2010 and the previous decade.

In summary, our model illustrates that when strategic issues can hinder the private provision of liquidity, the (mere credibility of) public provision of liquidity can improve the private provision of liquidity, even in times of aggregate liquidity surplus. This rationale for the LOLR role of central banks complements the traditional one, which is to deal with aggregate liquidity shortages and contagious failures (Allen and Gale 1998; Holmström and Tirole 1998; Diamond and Rajan 2005; and Gorton and Huang 2006). In the traditional rationale, central banks generate information about banks through supervision or other interactions, e.g., open market operations (OMO), emergency lending facilities, resolution authority where it is combined with the central bank, etc. Our analysis suggests that central banks should assume the roles of both supervisor and LOLR to mitigate market-power-induced inefficiencies in interbank lending. Of course, there may be other reasons for central banks to combine those roles, in which case our model helps highlight another benefit of doing so. Nonetheless, historical evidence suggests that market power issues were an important factor in the creation of the Federal Reserve System and, more broadly, of modern central banking.

Our paper is related to the literature on the failure of interbank markets that justifies the LOLR role of central banks.[2] Goodfriend and King (1988) argue that with efficient interbank markets, central banks should not lend to individual banks, but instead provide liquidity via OMOs, which the interbank market would then allocate among banks. Others, however, argue that interbank markets may fail to allocate liquidity efficiently due to frictions, such as asymmetric information about banks' assets (Flannery 1996; Freixas and Jorge 2007), banks' free-riding on each other's liquidity (Bhattacharya and Gale 1987), or on the central bank's liquidity (Repullo 2005). Instead, our paper focuses on the (additional) frictions brought about by market power.[3]

Donaldson (1992) is, to our knowledge, the only paper with a similar focus. It shows that even if aggregate liquidity is in surplus, if some surplus banks have a significant proportion of the excess cash, such that other cash-rich banks cannot satisfy the total liquidity demand, the surplus banks can charge higher-than-competitive rates.

While some papers study the allocation of funds (Holmström and Tirole 1998) and others that of assets (Shleifer and Vishny 1992; Gorton and Huang 2004), our paper studies both and illustrates the trade-offs involved. We believe the banks' dual role as each other's financiers and business rivals to be an important and specific aspect of their relationships. For instance, the sale of Bear Stearns to JPMorgan Chase (JPMC) in March 2008 illustrates well the confluence of the roles of lender and asset purchaser (by JPMC). During the liquidity crisis at Bear Stearns and its subsequent resolution, JPMC explicitly stated its interest in Bear Stearns' prime brokerage business. While there were systemic-risk concerns about Bear Stearns' possible collapse, JPMC seems to have made the acquisition at a fire-sale price. In early March 2008, Bear Stearns started experiencing a run on overnight repurchase agreements against mortgage-backed securities. On March 13, Bear Stearns' stock price was $57. JPMC agreed to acquire Bear Stearns on March 17 at $6 a share with a guarantee of $30 billion from the Fed to fund Bear Stearns' less liquid assets, such as mortgage-backed securities. JPMC's stock increased 10 percent on March 17, whereas most other financial stocks lost value. Finally, JPMC agreed to raise the purchase price to $10 a share and to bear the first $1 billion of loss that may arise from the loan provided by the Fed.

Our paper is also related to studies of the relationship between competition and stability in banking (Vives 2011) and of predation i.e., rivals taking actions to impede a firm's access to funds (Bolton and Scharfstein 1990; Cestone 1999). Here, however, the dual relationship between banks means that the predator is also the prey's financier.

[2] Indirectly, therefore, it is also related to the literature justifying the existence of interbank markets in the first place, specifically their role in allowing banks to insure each other against liquidity shocks through borrowing and lending facilities (e.g., Rochet and Tirole 1996; Allen and Gale 2000).

[3] Under asymmetric information, a central bank unwilling to extend loss-making loans can help ex post only if it is a better monitor of needy banks relative to surplus banks. Instead, in our model, the central bank can help even if it is worse than surplus banks in monitoring needy banks as long as it is better than outsiders. Further, with asymmetric information, the central bank will lend to needy banks to improve outcomes, unless it can credibly convey its information to surplus banks. In our model, the central bank need not lend in equilibrium; its mere credibility as a LOLR curbs surplus banks' bargaining power.

The paper proceeds as follows. Section I presents the model. Section II presents its analysis. Section III presents the rationale for central banking. Section IV provides empirical support for assumptions and results. Section V presents policy implications. Section VI concludes. An online Appendix contains proofs and addresses the issue of ex ante liquidity insurance.

I. The Model

Consider a model with three dates, $t = 0, 1, 2$; two banks, Bank A and Bank B; universal risk neutrality; and no discounting.[4]

At $t = 0$, Bank A has a continuum of measure 1 of risky assets, e.g., corporate loans. At $t = 2$, the portfolio of risky assets yields a random return $\tilde{R} \in \{0, R\}$.

At $t = 1$, Bank A needs some refinancing of ρ units of cash per unit of asset, e.g., rolling over of an existing mortgage or corporate loan, or a drawdown on a line of credit.[5] If assets are not refinanced, $\tilde{R} = 0$. If they are refinanced, the return is $\tilde{R} = R$ with probability p, and $\tilde{R} = 0$ otherwise. Bank A can affect the probability p by monitoring its assets at $t = 1$: $p = p_H$ if it monitors, and $p = p_L = p_H - \Delta p$ otherwise, with $\Delta p > 0$. Monitoring is nonverifiable, and if it does not monitor, the bank enjoys a private benefit b per unit of asset. If the assets are not refinanced, the bank does not derive a private benefit either. We assume that it is efficient to refinance assets only if they are monitored, i.e.,

$$p_H R > \rho > p_L R + b. \tag{1}$$

We assume that Bank B has enough excess liquidity to fund Bank A's assets.[6] Liquidity can be transferred in two ways: Bank A can borrow from Bank B or sell Bank B some of its assets.

Borrowing.—Due to limited liability, moral hazard in monitoring limits Bank A's borrowing capacity. Indeed, an interbank loan is a transfer L from Bank B to Bank A against a repayment r if $\tilde{R} = R$ and 0 if $\tilde{R} = 0$.[7] Bank A chooses to monitor its assets only if

$$\Delta p(R - r) \geq b. \tag{2}$$

This incentive compatibility constraint requires the repayment r to be small enough, i.e.,

$$r \leq R - R_b \text{ with } R_b \equiv b/\Delta p. \tag{3}$$

[4] The model builds on Holmström and Tirole (1998).

[5] Alternatively, in a model with liability structure of banks, the liquidity need could stem from depositor withdrawals or the bank's inability to roll over unsecured funding, such as short-term commercial paper.

[6] This assumes implicitly that banks that form interbank lending relationships have imperfectly correlated liquidity shocks. Cocco, Gomes, and Martins (2009) report evidence that Portuguese banks with more volatile shocks rely more on lending relationships and borrow from banks with less volatile and less correlated shocks.

[7] Note that with two cash flows, one being zero, the distinction between debt and equity is immaterial.

Bank A's borrowing capacity conditional on monitoring, i.e., the maximum funding it can raise against each unit of asset while retaining monitoring incentives is therefore

$$p_H(R - R_b). \tag{4}$$

Asset Sales.—Each unit of asset can be sold to Bank B for P. Yet Bank A is the most efficient user of its assets, i.e., they are Bank A-specific. This may stem from expertise or learning-by-doing in making and administering loans or from customer relationships, expertise relevant for renewal, renegotiation, or termination decisions.[8] Moreover, Bank A's advantage over Bank B may vary across assets. For instance, small loans or loans relying on Bank A's relationship with the borrower may be difficult for Bank B to take over. The relevant characteristic is captured by a variable θ distributed over $[0, 1]$ according to the cumulative distribution function (CDF) F. Assets with smaller values of θ are less redeployable to Bank B. Nevertheless, we assume that it is efficient to refinance assets even if they are owned by Bank B. If Bank B owns an asset with characteristic θ, then $p = p_B(\theta)$ with

$$p_H > p_B(\theta) > \rho/R \quad \text{and} \quad \frac{dp_B(\theta)}{d\theta} > 0. \tag{5}$$

With bank-specific assets, asset sales are less efficient than borrowing (conditional on monitoring).[9] However, more funds can be raised from asset sales than from borrowing. In particular, we assume that moral hazard in monitoring is severe (i.e., b large) enough so that Bank A can raise more funds by selling an asset than by pledging some of its return.[10]

ASSUMPTION 1: *For all* $\theta \in [0, 1]$, $p_B(\theta)R > p_H(R - R_b)$.

We model the banks' interaction in the interbank lending and asset markets as a two-stage bargaining game of alternating offers with a risk of breakdown (Figure 1). First, Bank B makes Bank A an offer with three components: a subset of measure α of Bank A's assets to be acquired by Bank B, a repayment $r \leq (1 - \alpha) R$ from Bank A to Bank B per unit of assets when $\tilde{R} = R$, and a transfer T from Bank B to Bank A. This transfer corresponds to a price P per unit of asset sold and a loan L per unit of asset retained, i.e., $T = \alpha P + (1 - \alpha) L$. Note that the split between P and L is generally indeterminate. A transfer T corresponds to various combinations of asset-sale price and amount lent.

If Bank A accepts the offer, it is implemented and bargaining is over. If Bank A rejects the offer, then, with probability β, bargaining breaks down and each bank

[8] This assumption is natural if banks forming interbank lending relationships are in different businesses or have relationship-specific, information-sensitive loans. For instance, a commercial bank focused primarily on prime mortgage lending may not be able to take efficient renegotiation decisions if it were to acquire a portfolio of subprime mortgages.

[9] Implicitly, we are assuming that acquiring a bank affects its operations, i.e., ownership has real effects. For brevity, we use this reduced form rather than providing a foundation for the effect of ownership.

[10] Our results would be largely unchanged if $p_B(\theta) R > \rho$ and $p_B(\theta) R > p_H(R - R_b)$ both held only for some assets.

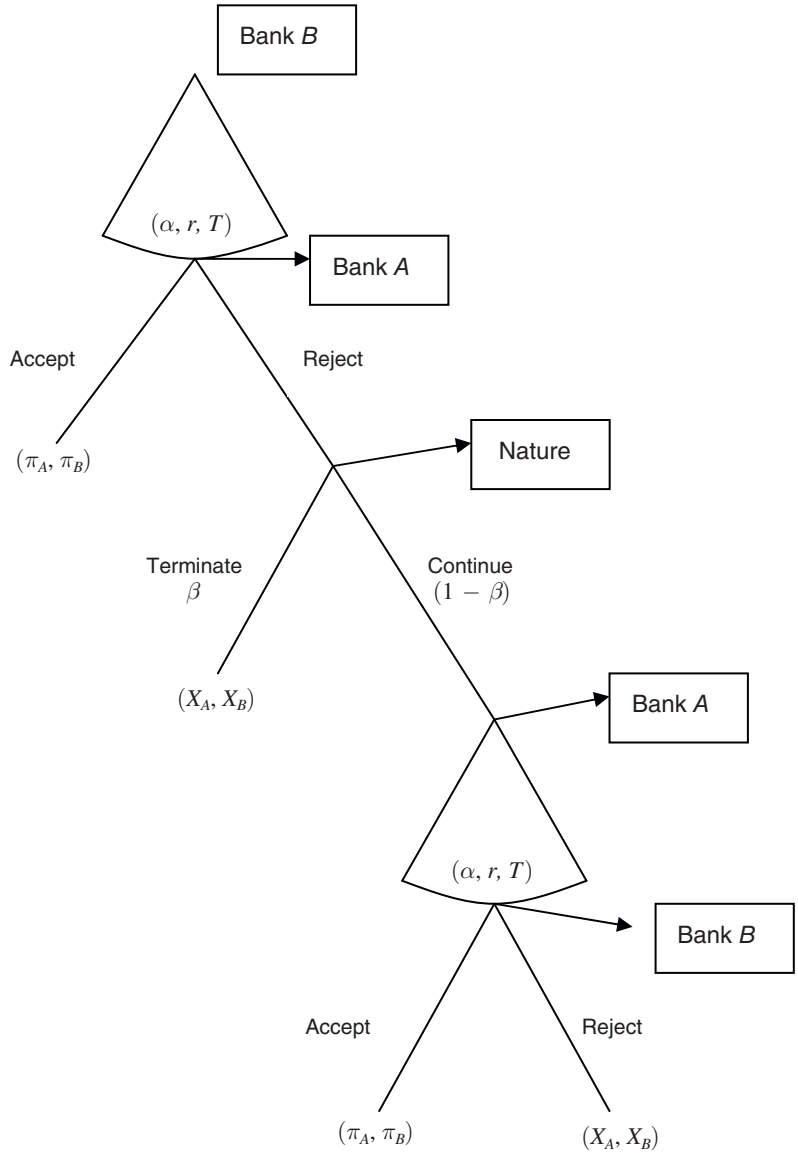

FIGURE 1. THE BARGAINING GAME

receives its outside option, $X_i \geq 0$, for $i = A, B$ (Section IID discusses possible determinants of these). With probability $(1 - \beta)$, however, bargaining continues and Bank A gets to make Bank B an offer. If Bank B accepts the offer, it is implemented. Otherwise, bargaining breaks down and each bank receives its outside option.

Some observations are in order. First, the model nests the case of perfect competition, i.e., $\beta = 0$. Second, considering $\beta < 1$ allows us to study the effect of Bank B's outside option. Third, the bargaining surplus is affected by how it is shared due to specificity of Bank A's assets and moral hazard in monitoring.

Finally, we assume that X_A and X_B are small enough, i.e., there are always gains from trade between the banks. Since Bank B's ability to make transfers to Bank A is limited, we assume that trade is beneficial even if Bank A has to sell all of its assets to Bank B, i.e.,

$$\int_0^1 p_B(\theta) R dF(\theta) > X_A + X_B + \rho. \tag{6}$$

II. The Interbank Market for Liquidity

We begin with the case $\beta = 0$, where Bank A can always make the final offer, and thus pin down Bank B to its outside option. This corresponds to the case of perfect competition in the supply of liquidity in the interbank market in the sense that Bank B makes zero profit. Then, we turn to the case in which Bank B has market power ($\beta > 0$). While this situation may arise in normal times, it is likely to be more pertinent during financial crises. Indeed, during crises, many banks are sidelined by insolvency or the fear thereof, leaving only a few surplus banks with bargaining power in liquidity supply. At the same time, the illiquid banks' need for liquidity may be especially urgent, which also weakens their bargaining position.

A. *Perfect Competition*

Bank A's optimal offer maximizes its payoff subject to Bank B's payoff meeting its outside option. It is easily seen that the optimal offer will satisfy three further properties. First, it must satisfy the incentive compatibility constraint (3), $r \leq (R - R_b)$. Otherwise, Bank A would not monitor its remaining assets, so that selling them to Bank B would be more efficient. Second, Bank B's transfer to Bank A must be sufficient to refinance Bank A's remaining assets. Otherwise, these assets would be worthless, and selling them to Bank B would, again, be more efficient. Last, Bank A will sell its most redeployable assets (if any), i.e., all loans with θ above a threshold $\hat{\theta}$. Hence, Bank A's problem is

$$\begin{aligned} \max_{\hat{\theta}, r, T} \quad & \int_0^{\hat{\theta}} [p_H(R - r) - \rho] \, dF(\theta) + T \\ s.t. \quad & r \leq (R - R_b) \\ & T \geq F(\hat{\theta})\rho \\ & \int_0^{\hat{\theta}} p_H r dF(\theta) + \int_{\hat{\theta}}^1 [p_B(\theta)R - \rho] \, dF(\theta) - T \geq X_B. \end{aligned} \tag{7}$$

Under the optimal offer $(\theta_A^*, r_A^*, T_A^*)$, Bank A sells a fraction $\alpha_A^* = 1 - F(\theta_A^*)$ of its assets.

PROPOSITION 1: *Under perfect competition* $(\beta = 0)$, *the outcome is as follows:*

(*i*) *If* $p_H(R - R_b) - \rho \geq X_B$, *the outcome is efficient. Bank A funds all of its assets by borrowing from Bank B and sells no assets* $(\alpha_A^* = 0)$. Its payoff is

$$\pi_A = p_H R - (X_B + \rho). \tag{8}$$

(*ii*) *Otherwise, the outcome is inefficient. Bank A sells a fraction* $\alpha_A^* = 1 - F(\theta_A^*)$ *of its assets to Bank B with* θ_A^* *defined by*

$$\int_{\theta_A^*}^{1} [p_B(\theta)R - p_H(R - R_b)]\, dF(\theta) = (X_B + \rho) - p_H(R - R_b), \tag{9}$$

and funds its other assets with the sale's proceeds and a loan from Bank B. Its payoff is

$$\pi_A = p_H R - (X_B + \rho) - \int_{\theta_A^*}^{1} [p_H - p_B(\theta)]\, R dF(\theta). \tag{10}$$

In equilibrium, Bank B must contribute ρ to fund all of Bank A's assets and enjoy an expected payoff X_B. Hence, Bank A must pledge $(X_B + \rho)$ to Bank B, which it can do by borrowing from Bank B or selling its assets. Since the assets are Bank A-specific, borrowing is Bank A's preferred source of funds. Hence, if Bank A's pledgeable income $p_H(R - R_b)$ exceeds $(X_B + \rho)$, Bank A will meet its entire funding needs by borrowing. In that case, it captures the full value of its assets, net of Bank B's outside option (expression (8)). Otherwise, it must sell some assets to Bank B to fund the shortfall, i.e., the right-hand side of (9). Indeed, owning an asset is more valuable to Bank B than holding a debt claim against it (Assumption 1). Asset sales being inefficient, Bank A will sell as few assets as needed for the shortfall to be covered by the increased funding capacity these sales allow, i.e., the left-hand side of (9). In that case, Bank A's payoff is curtailed by the inefficiency associated with asset sales, i.e., the last term of (10). The larger the shortfall, the more assets that must be sold, and the more inefficient is the outcome.

B. *Imperfect Competition*

Now consider imperfect competition in the supply of liquidity $(\beta > 0)$. In that case, Bank B's market power allows it to extract a payoff exceeding its outside option, i.e., the zero profit condition no longer holds. We solve the model by backward induction. If Bank A gets to make the final offer, the outcome is as in Proposition 1. In the previous stage, Bank B makes the first offer. When deciding whether to accept it, Bank A must consider the possibility that bargaining will break

down, which happens with probability β. Hence, Bank A will accept an offer only if its expected payoff is at least

$$E(\pi_A) = \beta X_A + (1 - \beta)\pi_A. \tag{11}$$

As before, the optimal offer satisfies three further properties. Bank A will sell its most redeployable assets, i.e., with θ above some threshold $\hat{\theta}$, and set $r \leq (R - R_b)$ and $T \geq F(\hat{\theta})\rho$. Hence, Bank B's problem is

$$\begin{aligned} \max_{\hat{\theta}, r, T} \quad & \int_0^{\hat{\theta}} p_H r dF(\theta) + \int_{\hat{\theta}}^1 [p_B(\theta)R - \rho]\, dF(\theta) - T \\ s.t. \quad & r \leq (R - R_b) \\ & T \geq F(\hat{\theta})\rho \\ & \int_0^{\hat{\theta}} [p_H(R - r) - \rho]\, dF(\theta) + T \geq E(\pi_A). \end{aligned} \tag{12}$$

Under the optimal offer (θ^*, r^*, T^*), Bank A sells a fraction $\alpha^* = 1 - F(\theta^*)$ of its assets.

PROPOSITION 2: *The negotiation's outcome is as follows:*

(*i*) *If* $E(\pi_A) \geq p_H R_b$, *the outcome is efficient. Bank A funds all its assets by borrowing from Bank B and sells no assets* $(\alpha^* = 0)$.

(*ii*) *Otherwise, the outcome is inefficient. Bank A sells a fraction* $\alpha^* = (1 - E(\pi_A)/p_H R_b)$ *of its assets to Bank B* $\left(\text{all loans with } \theta > \theta^* = F^{-1}(E(\pi_A)/p_H R_b)\right)$, *and funds its other assets with the sale's proceeds and a loan from Bank B.*

Bank B aims to acquire as many of Bank A's assets as possible, subject to Bank A getting its reservation payoff. Indeed, under Assumption 1, a sale is the most effective way to transfer value from Bank A to Bank B. For instance, for $E(\pi_A) = 0$, Bank B acquires all of Bank A's assets for free, i.e., sets $\alpha^* = \theta^* = 1$ and $T^* = 0$. As $E(\pi_A)$ increases, Bank B must ensure that Bank A accepts its offer. The most efficient way to increase Bank A's payoff is for Bank B to leave it some assets and fund them, i.e., $T = F(\hat{\theta})\rho$. Since the assets are Bank A-specific, this is preferred to Bank B making a cash transfer to Bank A above its funding needs. In that case, Bank A should obviously keep its least redeployable assets. For the same reason, maximizing r is always weakly optimal, i.e., $r^* = (R - R_b)$. Indeed, leaving Bank A with a stake exceeding R_b on an asset is akin to a cash transfer. In turn, α^* is determined by Bank A's participation constraint. When $E(\pi_A) = 0$, Bank B acquires all of Bank A's assets $(\alpha^* = 1)$. As $E(\pi_A)$ increases, Bank B must leave Bank A some assets financed with borrowing with $r = R - R_b$. Hence, for each asset left with Bank A, Bank A's expected payoff is $p_H R_b$. Hence, α^* is determined by $(1 - \alpha^*)\, p_H R_b = E(\pi_A)$.

C. *Properties*

Bank A selling all assets with $\theta > \theta^*$ involves a deadweight loss,

$$K^* \equiv \int_{\theta^*}^{1} (p_H - p_B(\theta))\, RdF(\theta).$$

We begin with the effect of Bank B's market power on the equilibrium liquidity transfer.

COROLLARY 1: *Efficiency* (*weakly*) *decreases with Bank B's market power. More precisely*:

(*i*) *A threshold* $\beta^* \in [0,1]$ *exists such that the outcome is efficient if and only if* $\beta < \beta^*$.
(*ii*) *For* $\beta > \beta^*$, *asset sales and the associated inefficiency increase strictly with* β.
(*iii*) *In some cases, the outcome is efficient only if competition is intense enough*: $\beta^* \in (0,1)$.

The intuition for the existence of a threshold β^* is as follows. Bank B does not acquire assets when $E(\pi_A) \geq p_H R_b$. Since $E(\pi_A)$ decreases with β, a threshold β^* exists such that asset sales occur only if $\beta > \beta^*$. If $p_H R_b > X_A$, there will be asset sales if Bank B is certain to make the final offer ($\beta = 1$), and hence $\beta^* < 1$. If $p_H(R - R_b) - \rho > X_B$, no assets are sold if Bank A always has the option to make an offer ($\beta = 0$), and hence $\beta^* > 0$.

The intuition for the fraction of Bank A's assets sold increasing with β (for $\beta > \beta^*$) is as follows. When β increases, Banks A's reservation payoff $E(\pi_A)$ decreases. Therefore, Bank B must transfer less value to Bank A. Once Bank A has exhausted its borrowing capacity, it must start selling assets to Bank B, even though doing so is inefficient, as this is the most effective means of transferring value to Bank B (Assumption 1).

Intuitively, the incentive problem can require that Bank A sell some assets. However, with perfect competition in liquidity supply, asset sales would be at the constrained efficient level. It is imperfect competition among surplus banks that leads to constrained inefficiency by inducing more asset sales than necessary, given the incentive problem.[11]

Confirming this intuition, Corollary 1 shows that the market power of liquid banks can lead to an inefficient allocation of liquidity, even in situations where the allocation would be efficient if those same banks were perfectly competitive. This scenario corresponds to $\beta > \beta^* > 0$. There are also situations in which frictions in the interbank market (here, moral hazard in monitoring) would lead to an inefficient allocation of liquidity even if liquid banks were perfectly competitive. This corresponds to $\beta^* = 0$. In those situations, liquid banks' market power increases

[11] This could also lead to other costs, such as spillover to other needy banks, for example, through fire-sale externalities (Cifuentes, Ferucci, and Shin 2005).

the inefficiency of the allocation of aggregate liquidity. It must be stressed that market power alone would not lead to an inefficient outcome. Indeed, absent moral hazard in monitoring, Bank *B* would be able to increase its interest rate without affecting the value of Bank *A*'s asset. It would find it optimal to do so since Bank *A*'s assets are bank-specific. The reason why Bank *B*'s market power would not lead to an inefficient allocation is that we allow its offer to Bank *A* to specify *both* price and quantity.

COROLLARY 2: *Efficiency* (*weakly*) *decreases with the liquidity need* ρ *and with Bank B's outside option* X_B, *and increases with Bank A's outside option* X_A. *Formally*, *an increase in* ρ, *an increase in* X_B, *and a decrease in* X_A *all have the following effect:*

(*i*) β^* *decreases weakly for* $\beta^* = 1$ *and strictly for* $\beta^* \in (0,1)$.
(*ii*) *For* $\beta > \beta^*$, *asset sales and the associated inefficiency increase*.

By reducing Bank *A*'s reservation payoff $E(\pi_A)$, an increase in X_B or a decrease in X_A tilts the bargaining outcome toward Bank *B*'s interest, which is to acquire more of Bank *A*'s assets. If $\beta > \beta^*$, Bank *A* has exhausted its borrowing capacity and an increase in ρ forces it to sell more assets to Bank *B*. The properties of α^* imply those of β^*.

Again, a financial crisis may combine several factors leading to more severe inefficiency in the allocation of liquidity. First, needy banks' demand for liquidity (ρ) may be especially large. Surplus banks' outside options (X_B) may also be favorable given that many players may be seeking liquidity from them. Finally, needy banks' outside options (X_A), in particular outside (nonbank) markets, may be especially weak, an issue we elaborate upon next.

D. *Asset Characteristics*

We now focus on how the specificity of Bank *A*'s assets affects the outcome. We model explicitly the fact that Bank *A* has access to competitive outside markets for borrowing and asset sales. We assume that Bank *B* is better than outsiders both for using Bank *A*'s assets and for lending against them, which we model as follows.

Asset Sales.—If an outsider owns an asset of Bank *A* with characteristic θ, then $p = p_o(\theta)$. We assume Bank *B* to be better than outsiders at managing Bank *A*'s assets. That is, banks are special relative to outsiders, i.e., they are better monitors of small, relationship-specific loans. Moreover, we assume that those assets for which Bank *A*'s advantage over Bank *B* is the greatest are also those for which Bank *B*'s advantage over outsiders is the greatest, i.e., assets' Bank *A*-specificity and their bank-specificity relative to outsiders are correlated:

$$p_o(\theta) < p_B(\theta) \qquad \text{and} \qquad \frac{dp_o(\theta)}{d\theta} > \frac{dp_B(\theta)}{d\theta}. \tag{13}$$

Nevertheless, we assume that funding Bank A's assets is efficient even if owned by an outsider:

$$p_o(\theta) > \rho/R. \tag{14}$$

Borrowing.—We assume that Bank B is more effective than outsiders at lending to Bank A.[12] This advantage may be due to a past lending relationship or expertise in assessing Bank A's business. Specifically, we assume that when borrowing from outsiders, Bank A's benefit from not monitoring is $b_o \geq b$, so that it must retain a larger exposure to its assets to have an incentive to monitor, i.e., $R_b^o \equiv b_o/\Delta p \geq R_b$.

To simplify, we assume, again, that Bank A can raise more funds by selling outsiders an asset than by pledging some of its return to them, i.e.,

$$\forall \theta \in [0, 1], p_o(\theta) R > p_H(R - R_b^o). \tag{15}$$

The outcome is obtained from Proposition 1 by replacing Bank B's characteristics with those of outsiders, i.e., by setting $X_B = 0$, $b = b_o$, and $p_B = p_o$. The intuition is similar. If Bank A's borrowing capacity $p_H(R - R_b^o)$ exceeds its funding need ρ, Bank A should only borrow from outsiders as this is more efficient. Otherwise, it must sell them some assets.

LEMMA 1: *If bargaining between Bank A and Bank B breaks down, the outcome is as follows:*

(*i*) *If* $p_H(R - R_b^o) - \rho \geq 0$, *the outcome is efficient. Bank A funds all of its assets by borrowing from outsiders and sells no assets* $(\alpha_o^* = 0)$. *Its payoff is*

$$X_A = p_H R - \rho. \tag{16}$$

(*ii*) *Otherwise, the outcome is inefficient. Bank A sells a fraction* $\alpha_o^* = 1 - F(\theta_o^*)$ *of its assets to outsiders with* θ_o^* *defined by*

$$\int_{\theta_o^*}^1 [p_o(\theta)R - p_H(R - R_b^o)]\, dF(\theta) = \rho - p_H(R - R_b^o), \tag{17}$$

and funds its other assets with the sale's proceeds and loans from outsiders. Its payoff is

$$X_A = p_H R - \rho - \int_{\theta_o^*}^1 [p_H - p_o(\theta)]\, R dF(\theta). \tag{18}$$

We can now analyze bargaining between Bank A and Bank B. For now, we assume that Bank B's outside option X_B is independent of Bank A's distribution

[12] Section IV discusses the role of peer monitoring in interbank markets.

of loan characteristics F. Recall that Bank A sells all of its loans with θ above θ^*. This threshold does depend on the distribution of loan characteristics. Hence, the fraction α^* of its assets that Bank A sells to Bank B depends on F directly, but also through its effect on θ^*.

PROPOSITION 3: *Efficiency increases with the outsiders' ability to monitor loans to Bank A, with their ability to operate assets, and with the redeployability of Bank A's assets. Formally, for $\beta > \beta^*$, a decrease in b_o, an increase in the function $p_o(\cdot)$, or a shift of the distribution F towards higher values in the sense of FOSD results in fewer asset sales α^* and a lower inefficiency K^*.*

The effect of a decrease in b_o or an increase in $p_o(\cdot)$ is simple. Indeed, such changes increase X_A but keep all other variables constant. Therefore, this result is a simple implication of Corollary 2. The effect of a shift in F is more complex as it affects not only Bank A's outside option in its bargaining with Bank B, but also other variables relevant to that bargaining.

Our analysis implies that the market failure in the transfer of liquidity is more severe when banks needing liquidity have more small, relationship-specific loans, as this decreases their outside option and gives surplus banks a better opportunity to exert market power. Put differently, the outside option provided by outside (non-bank) markets may be particularly weak during financial crises because nonbank's disadvantage relative to banks in valuing and managing bank assets is also particularly high during crises.

III. Central Bank as Lender of Last Resort

We have shown how the market power of surplus banks can worsen or even create inefficiencies in the interbank market for liquidity. An important implication is that an aggregate liquidity surplus is no guarantee that liquidity will find its way to banks needing it most. In this context, we study how a central bank acting as a LOLR can mitigate inefficiencies by curbing surplus banks' ability to exploit their market power. We also determine the conditions under which such an improvement can occur.

Note that our analysis sidesteps the issue of the central bank's optimal policy. First, we focus only on the ex post effects of central bank intervention. However, central bank actions can affect bank behavior ex ante, e.g., lead to moral hazard and mismanagement of liquidity and credit risk (Repullo 2005 and Acharya, Shin, and Yorulmazer 2011). Also, we do not analyze the optimality of the intervention. Indeed, our model, as it stands is ill-suited for such an analysis as it does not specify explicitly the limits to central bank intervention. Hence, taking the model literally, the central bank could "force" the efficient allocation of liquidity by directly setting transfers between banks. For instance, it could set caps on interest rates and floors on asset prices. In practice, several problems might make such direct intervention less effective, and a meaningful analysis of optimal regulation should account for these.

In this section, we introduce a central bank. Say bargaining between banks A and B breaks down. Bank A can seek liquidity first from a central bank and then from competitive outside markets. For brevity, we assume the central bank to have full bargaining power vis-à-vis Bank A.

To simplify, the central bank cannot buy Bank A's assets, it can only lend to it. In that case, Bank A's benefit from not monitoring its assets is b_C, and we define $R_b^C \equiv b_C/\Delta p$. Importantly, the central bank is worse than Bank B at making loans to Bank A, i.e., $b_C \geq b$. Or else, it would be the efficient lender to Bank A even under perfect interbank competition.[13] The incentive problem created by private benefits limits the income Bank A can pledge to its lender. The larger the private benefit, the greater the imperfection in the lending relationship between Bank A and its lender. For instance, a smaller private benefit can reflect the lender's greater ability to monitor Bank A.

We model the central bank's objectives and constraints as follows. Ex post (i.e., after banks A and B bargain), the central bank seeks to minimize the inefficiency in the allocation of Bank A's assets subject to its own expected losses not exceeding some level $\Lambda \in [0, \overline{\Lambda}]$ chosen ex ante (i.e., before banks A and B bargain).[14] The upper limit $\overline{\Lambda}$ captures that losses may have to be met through government funds, adding to government debt and fiscal costs that need to be financed through distortionary taxes, and that the central bank itself might loathe to rely on government support to protect its independence. The ex ante choice of $\Lambda \in [0, \overline{\Lambda}]$ captures the central bank's ability to commit to limited intervention. (We discuss briefly the no commitment case in Section VI).

Finally, denote β_o^*, the value of β^* absent any intervention by the central bank. If $\beta < \beta_o^*$, the efficient outcome is reached, i.e., Bank A does not sell any of its loans and refinances them all. In that case, there is no role for the central bank. Instead, we now assume that $\beta > \beta_o^*$ and study the effect of central bank acting as LOLR.

A. *Central Bank Ex Post Intervention*

We discuss the form of the central bank's ex post optimal intervention. Since it is, up to a limit, willing to extend some potentially loss-making loans, it would be willing to make a transfer to Bank A of up to Λ, or a larger transfer against some claim on Bank A's assets. To clarify, we denote L_C the part of the transfer that corresponds to a fairly priced (i.e., zero profit) loan from the central bank to Bank A, and T_C the part of the transfer above that loan. The latter part of the transfer corresponds to a pure transfer, a subsidy from the central bank to Bank A. We discuss the possible forms it can take below.

PROPOSITION 4: *The central bank's optimal intervention is as follows:*

(*i*) *If the central bank is not better than outsiders at making loans to Bank A* ($b_C \geq b_o$), *its optimal intervention amounts to a pure transfer to Bank A.*

$$T_C = \min\{\Lambda, \rho - p_H(R - R_b^o)\}. \tag{19}$$

[13] Central banks have other features that we do not model, e.g., a longer horizon than private banks, especially in a crisis, or a lower cost of providing funds with immediacy, given its flexibility in creating reserves. These would only strengthen central banks' LOLR role.

[14] We also assume that all else equal, the central bank minimizes its expected losses.

Bank A should borrow $p_H(R - R_b^o)$ *from outsiders and sell them any remaining assets.*

(*ii*) *Otherwise* $(b_C < b_o)$, *its optimal intervention amounts to lending to Bank A and possibly making it a pure transfer.*

$$(20) \qquad L_C = p_H(R - R_b^C) \text{ and } T_C = \max\{\min\{\Lambda, \rho - p_H(R - R_b^C)\}, 0\}.$$

Bank A should not borrow from outsiders and should only sell them any remaining assets.

(*iii*) *In both cases, as the central bank's maximum expected loss* Λ *increases, asset sales decrease* (*until they reach zero*).

Consider first the case of a central bank that is not better than outsiders at monitoring loans to Bank *A*. In that case, loans should be made only by outsiders, i.e., the central bank should not use Bank *A*'s limited borrowing capacity. Moreover, being competitive, the outsiders make zero profits. Thus, there is no action by the central bank that can induce them to extend more loans. Hence, the central bank's actions do not affect Bank *A*'s borrowing capacity. The only action the central bank can take is to make (what amounts to) a pure transfer to Bank *A*. Such a transfer can be implemented in different ways: a pure transfer, or possibly a guarantee of Bank *A*'s debt toward outsiders. Importantly, however, the central bank should not receive claims on Bank *A*'s cash flows because outsiders value these more.

Consider now the case of a central bank that is better than outsiders at monitoring loans to Bank *A*. This advantage may, for instance, stem from the central bank's supervisory role.[15] In that case, it should substitute itself to outsiders, i.e., the outsiders should not use Bank *A*'s limited borrowing capacity. The central bank increases Bank *A*'s borrowing capacity, which eventually reduces the need for inefficient asset sales.[16]

There is no room for collateral or secured lending as such in our model. However, the central bank's liquidity transfer can be interpreted as a lowering of the quality of collateral against which the central bank extends liquidity support, e.g., by lending to needy banks against mortgages at a lower rate than the market does if these loans are likely to be terminated in the absence of liquidity support.

[15] Using US data, Berger, Davies, and Flannery (2000) show that shortly after supervisors have inspected a bank, supervisory assessment of the bank is more accurate than the market's. However, the reverse holds for periods where the supervisory information is stale. Hirtle and Lopez (1999) show that supervisory information gathered during examinations ceases to provide a useful picture of a bank's condition after 6–12 quarters. The decay rate is faster when the banking industry experiences financial difficulties, and for troubled banks.

[16] Note, however, that in our model, outsiders have incentives to supervise banks since they would gain from the improved ability to lend to needy banks. One reason they may not do so is that banks may be more forthcoming in disclosing information to a not-for-profit regulator than to outsiders who may be (or become) players in similar markets, and might be tempted to exploit such information for their own benefit.

B. *Impact on Interbank Market*

We now study how the possibility of central bank intervention ex post affects the bargaining between banks *A* and *B* ex ante. As a benchmark, consider a central bank that is neither better than outsiders at monitoring Bank *A* nor willing to accept losses.

PROPOSITION 5: *A central bank that is not better than outsiders at monitoring Bank A* ($b_C \geq b_o$) *and is not ready to accept losses* ($\overline{\Lambda} = 0$) *cannot ameliorate the inefficiency arising from Bank B's market power.*

The intuition is simple. Indeed, if the central bank is willing and able to take a given action, so are any of the outsiders. In effect, the central bank is like an outsider, possibly one that is less effective at extending loans. Hence, Bank *A*'s outside option is the same as it is absent the central bank, and the outcome of its negotiation with Bank *B* is unchanged.

Turning the result on its head, we can characterize situations in which central bank intervention can have a positive impact.

PROPOSITION 6: *The central bank can improve outcomes if it is better than outsiders at monitoring Bank A* ($b_C < b_o$) *or ready to accept losses* ($\overline{\Lambda} > 0$). *Moreover, asset sales and the associated inefficiency decrease with the central bank's willingness to make losses and with its ability to monitor Bank A* (*if* $b_C < b_o$), *i.e., for* $\alpha^* > 0$,

$$\frac{\partial \alpha^*}{\partial \Lambda} < 0 \qquad \text{and} \qquad b_C < b_o \Rightarrow \frac{\partial \alpha^*}{\partial b_C} > 0.$$

The central bank can improve outcomes without actually extending loans in equilibrium, i.e., it can play a "virtual and virtuous" role. It is sufficient that the central bank provides potential competition to Bank *B*. By acting as LOLR, the central bank can improve Bank *A*'s outside option in its negotiation with Bank *B*, provided that the central bank is either better than outsiders at monitoring Bank *A* or willing to extend loss-making loans. Of course, the central bank's impact would be greater if it were better than Bank *B* at monitoring Bank *A*, a case we assume away. Importantly, our analysis shows that this arguably unrealistic condition is not necessary for the central bank to be effective.

We find that the central bank's willingness to incur losses can be effective at curbing Bank *B*'s market power. Such willingness may however be limited and costly. The central bank's effectiveness at making loans to Bank *A* can reduce the losses it ought to be ready to incur. For a given b_C, define $\Lambda^*(K, b_C)$ as the expected loss Λ the central bank must be ready to incur ex post so that bargaining between banks *A* and *B* results in an efficiency loss no greater than *K*.

COROLLARY 3: *If the central bank is better than outsiders at monitoring Bank A* ($b_C < b_o$), *the expected loss it must incur to ensure a given level of efficiency decreases with its ability to monitor Bank A, i.e.,*

$$\frac{\partial \Lambda^*(K, b_C)}{\partial b_C} > 0. \tag{21}$$

The intuition is simply that as b_C decreases, Bank A can pledge a larger fraction of its return to the central bank so that loss-making loans are less costly to the central bank. Hence, if the central bank stands as a LOLR, it will have incentives to improve its ability to make loans, e.g., to assess and monitor borrowing banks. From a policy standpoint, it may also be optimal to assign other tasks (such as supervision) to the central bank if they increase its expertise in monitoring loans to banks.[17] In other words, through its supervisory role, the central bank can limit its commitment to losses. Note that this argument differs from the one that states that since the central bank is a LOLR, it ought to supervise banks to avoid being in a position to need the LOLR.

C. *Liquidity Insurance*

So far, we have considered liquidity transfers after a liquidity shock, ignoring the possibility for banks to insure against such shocks (Bhattacharya and Gale 1987; Allen and Gale 2000; Leitner 2005). In an online Appendix, we study this possibility, which reduces the inefficiency in interbank liquidity transfers. However, as long as banks can only get partial liquidity insurance, surplus banks' ex post market power increases (or creates) inefficiency in the allocation of liquidity. This yields further results. First, if banks likely to have excess liquidity and market power ex post are also the best liquidity insurers ex ante, their market power reduces the scope for liquidity insurance. Put simply, committing to provide liquidity conflicts with incentives to retain market power. Second, committing to provide liquidity is costly for banks that may need liquidity in the future too. Thus, if states of aggregate shortage of liquidity are more likely (as in a financial crisis), liquidity insurance is more costly, resulting in less insurance. This, in turn, increases the ex post market power of cash-rich banks even in states of aggregate liquidity surplus.

Other reasons that liquidity insurance is only partial include the impossibility to enter binding long-term contracts, the fragility of implicit contracts during crises, or the possibility of aggregate liquidity shortage combined with liquid banks' cost of capital being nonverifiable. For instance, banks could enter implicit contracts for liquidity provision, sustained through repeated interactions. This may, however, also be less relevant during crises. Indeed, Carlin, Lobo, and Viswanathan (2007) show that such contracts break down when the "prey" is large or close to default since the continuation of a relationship is less valuable. Again, crises may represent such situations.

This discussion and our results in the online Appendix imply that ex ante liquidity insurance is likely to be incomplete, as observed in practice, and market power considerations arise when liquidity distribution across banks is highly skewed. An

[17] The Bank of England recently getting some of its supervisory role back from the Financial Services Authority constitutes one such example. During the Northern Rock episode, the division of responsibilities between the UK Treasury, the Bank of England, and the FSA had been subject to criticism. In a Treasury Committee hearing, William Buiter argued that: "The notion that the institution that has the knowledge of the individual banks that may or may not be in trouble would be a different institution from the one that has the money, the resources, to act upon the observation that a particular bank needs lender of last resort support is risky. It is possible, if you are lucky, to manage it, but it is an invitation to disaster, to delay, and to wrong decisions." (Source: The Run on the Rock, report for the House of Commons Treasury Committee, page 105 http://www.publications.parliament.uk/pa/cm200708/cmselect/cmtreasy/9181918.pdf).

implication is that as long as only partial liquidity insurance occurs in equilibrium, the central bank can improve efficiency by committing to act as LOLR.

IV. Empirical Evidence

We report evidence supporting our main assumptions and discuss historical and current episodes suggesting market power of liquid banks, particularly during crises.

A. *Support for Assumptions*

Asset Specificity.—We have assumed that some assets are bank-specific, e.g., because banks are better monitors of small, relationship-specific loans (Fama 1985; James 1987; Houston and James 1996). This notion was introduced in Corporate Finance by Williamson (1988) and Shleifer and Vishny (1992). Firms whose assets cannot be readily redeployed by other firms are likely to experience lower liquidation values ("fire-sale" discounts), especially when industry peers are also in financial or economic distress.[18] For US data for 1985–1988, James (1991) reports that significant going-concern value is preserved if a failed bank is sold to another bank, but lost if it is liquidated by the Federal Deposit Insurance Corporation (FDIC). Furthermore, Dell'Ariccia, Detragiache, and Rajan (2008) and Kroszner, Laeven, and Klingebiel (2007) report that financially dependent sectors perform relatively worse during banking crises, which is consistent with the importance of bank relationships and information-sensitive loans.

Moral Hazard and Inside Ownership in Banking.—Our model relies on the feature that moral hazard is addressed by greater ownership of the bank by insiders. This assumption finds empirical support in cross-country bank ownership data. Caprio, Laeven, and Levine (2007) study the ownership patterns of 244 banks across 44 countries. They document that banks in general are not widely held (where a widely held bank is one in which no legal entity owns 10 percent or more of the voting rights), a finding similar to that of La Porta, Lopez de Silanes, and Shleifer (1999) for firms in general. In particular, they find that controlling ownership of banks by insiders, especially families, and by the state are much more common than dispersed ownership. This observation is stronger in countries with weaker shareholder protection laws.[19] Importantly, they also find that greater inside ownership of banks enhances bank valuation, especially in countries with weaker shareholder protection laws.

Overall, these findings are consistent with our model in that weaker shareholder protection laws should imply a greater risk of cash-flow appropriation by insiders,

[18] Also, see Allen and Gale (1994, 1998) for models of cash-in-the-market pricing and empirical support for this idea in, e.g., Pulvino (1998); Acharya, Bharath, and Srinivasan (2007); Berger, Ofek, and Swary (1996); and Stromberg (2000).

[19] For example, more than 90 percent of the banks in Canada, Ireland, and the United States are widely held, but not more than 50 percent in Italy, Spain, and Venezuela are widely held. A significant proportion of the remaining ones are controlled by families, whereas 21 out of 44 countries (e.g., Argentina, Brazil, Chile, Israel, Mexico, and Thailand) do not have a single widely held bank among their largest banks.

and, in turn, lead to greater inside ownership of banks in equilibrium. At the same time, however, this evidence makes it clear that our model may not be literally applicable to countries with strong shareholder protection since their banks are indeed widely held. In such countries, the relevant moral hazard is likely to be at the level of bank managers. There is evidence that such managerial moral hazard is an important determinant of bank performance and failures. The Office of the Comptroller of the Currency in the United States in 1988 completed a study based on 171 banks that failed, became distressed and recovered, or remained healthy during the 1979–1987 period, and identified characteristics and conditions present when the health of the banks deteriorated. The study found that "Management-driven weaknesses played a significant role in the decline of 90 percent of the failed and problem banks the OCC evaluated." The study also concluded that principal-agent problems within banks are a key reason for bank failures, in addition to the deteriorating quality of assets during business downturns. Our model does not explicitly consider incentive for managers of widely held banks, but the moral-hazard problem we study can be considered as a metaphor for a general class of principal-agent problems affecting banks.

Concentration and Market Power.—Our model of interbank markets aims at capturing market power issues. As we have argued, they are likely to be more acute during financial crises as these combine several amplifying factors, and absent a central bank acting as LOLR. We report some evidence of this in the next section. However, it is also plausible for market power issues to arise during normal times, a possibility we discuss here.

Market power can arise from "tiering," whereby some banks ("tier-1" banks) access central bank liquidity and act as clearing banks for other banks ("tier-2" banks). Even in large interbank markets, such tiering exists, and hence issues of market power remain important. For example, in the US Fed Funds market, JPMC and Bank of America are much bigger borrowers than others, and State Street and JPMC are much bigger lenders. Furthermore, many banks are connected with only one or two banks, the average number of connections being between three and four (Bech and Atalay 2010). The UK also has a tiered system, and the volatility induced in interbank lending rates due to the cornering of collateral and liquidity by some of the large settlement banks during 2001–2005 was one of the main rationales for the Sterling Money Market Reform in 2006. Post-reform, the Bank of England increased the number of banks allowed to participate in OMOs from 10 to over 35 (Bank of England 2005 and Tucker 2004).

Another important feature is that large and unsecured interbank loans make peer monitoring among banks important (see Rochet and Tirole 1996 and Freixas and Holthausen 2005 for theory). Such monitoring confers information monopolies to larger players in interbank markets. Cocco, Gomes, and Martins (2009) report evidence of strong relationships in the Portuguese interbank market, suggesting that some banks are more important lenders and pivotal, even in normal times. They document that large banks, in terms of size and participation in interbank lending, enjoy market power; they borrow and lend at more favorable terms (see also Furfine 2001). Often small banks, with limited access to foreign interbank markets, concentrate all their borrowing in the domestic interbank markets and with a few

large banks. They also highlight the essentially bilateral nature of interbank lending: most of the lending volume is accounted for by "direct" loans in which loan amount and interest rate are agreed to on a one-to-one basis between borrower and lender, other banks do not necessarily have access to the same terms and may not even observe the transaction, posted quotes are merely indicative, and the identity of lending banks affects the interest rate.

B. *Historical Evidence*

As we have argued, while market power effects can arise in normal times, they are likely to be more acute during financial crises as these combine a number of amplifying factors. Our analysis also suggests they are also more likely to arise in the absence of a central bank serving as LOLR. It is therefore natural to focus on the pre-central banking era and on institutions without access to central-bank lending. Hence, we provide historical evidence (see Freixas et al. 1999 for a survey) and then present some recent evidence.

The Failure of Private Coinsurance Arrangements.—Liquidity support operations occurred often in the past. In the United States, the Clearinghouse System assumed a crisis prevention and management role before the Federal Reserve System was established in December 1913 (Gorton 1985; Gorton and Mullineaux 1987; Calomiris and Kahn 1996; Gorton and Huang 2004, 2006). The first clearinghouse, set up by the New York City banks in 1853, created an organized interbank market. In normal times, clearinghouses performed their service of clearing payments; whereas during crises, they helped member banks sustain their solvency and liquidity positions. At such times, clearinghouses suspended payments of the distressed member banks. They equalized reserves, pooling all legal reserves of member banks and granting them equal access to that pool. In addition, clearinghouses issued loan certificates that banks acquired by depositing qualifying assets with the Clearing House Association to be used in interbank settlements. These certificates prevented costly asset liquidations. Since they were provided only when the Clearing House Association judged that the bank had enough assets to back them up, certificates also certified the bank as healthy (Park 1991).

These measures, aimed at easing liquidity constraints on banks experiencing runs, worked well at times. However, their effectiveness was hampered by competitive pressures in the banking industry. In particular, voluntary participation by healthy banks was difficult to elicit due to the short-term competitive advantage they enjoyed during crises. The Clearinghouse System was eventually brought down early in the twentieth century by the sharp increase in banking competition in New York.[20]

[20] Other historical episodes confirm the tension between the viability of private arrangements and competition. An example is the 1893 financial crisis in Australia. The Australian banking system was relatively unregulated during the second half of the nineteenth century with no central bank and no government-provided deposit insurance. In 1893, 11 commercial banks failed, and the rest experienced severe bank runs. At the time, the Associated Banks of Victoria was a coalition of private banks, just like the Clearing House Association in New York, and had been initially set up to coordinate and divide the finances of the colonial governments. Before the crisis, the Associated Banks announced that, if and when needed, they would provide financial assistance to each other (*The Economist*, March 25, 1893, 364). However, during the crisis, this arrangement proved ineffective when the Federal Bank was

J.P. Morgan and the 1907 *Panic in the US.*—Discussing the 1907 panic in New York, Sprague (1910) suggests that the banks were initially reluctant to rescue distressed trust companies[21] since they were not adversely affected by the distressed companies' problems and even benefited by attracting their depositors.

The immediate cause of the panic was the collapse of copper stocks. On October 17, depositors started a run on the Mercantile National Bank, whose president Heinze had tried to corner the stock of United Cooper. Runs spread to banks controlled by Morse and Thomas, two speculators financially affiliated with Heinze. The New York Clearing House Association granted assistance to those banks after examining their solvency and forcing Heinze, Morse, and Thomas to resign. This action subdued severe runs on banks.

Trust companies, however, were also experiencing difficulties. Depositors, fearing their involvement in speculation, started a run on the Knickerbocker Trust Company on October 21 and on the Trust Company of America on October 23.[22] The New York Clearing House, an organization of banks, did not assist these trusts. Knickerbocker had to suspend on October 22, and the Trust Company of America, a solvent institution, suffered runs for two weeks. Eventually, Treasury Secretary George B. Cortelyou earmarked $35 million of federal money to quell the storm. On November 6, New York trust companies, urged by J. P. Morgan, organized a team of bank and trust executives, raised a $25 million fund for distressed trust companies, redirected money between banks, secured further international lines of credit, and bought the plummeting stocks of healthy corporations.[23] Runs on the Trust Company of America and other small institutions subsided after the resolution.

While J. P. Morgan is credited as the coordinator and rescuer in this financial crisis, several aspects of his involvement suggest strategic behavior and market power. First, in 1906, Heinze had acquired Knickerbocker, and Morse gained control of the Bank of North America. Even prior to the 1907 crisis, banking industry leaders, including Morgan, staged a financial attack on Knickerbocker. They felt threatened by the developing trusts and wished to sway public and congressional opinion against them.

Second, the banks controlled by Morgan and his associates experienced only minor difficulties in 1907, thanks to their reputation for soundness. According to Sprague (1910), while five banks controlled by Heinze and Morse suffered severe deposit withdrawals, the six strongest clearinghouse banks showed slight gains in deposits. The delay in assisting the trust companies is thus often seen as a strategic move on the part of the clearinghouse banks.

allowed to fail without any assistance in January 1893. Pope (1989) suggests that competitive pressures played a major role in the failure of private arrangements as banks stood to gain market share from failed banks.

[21] These are effectively commercial banks, organized to perform the fiduciary role of trusts and agencies.

[22] Goodhart (1969) documents that on October 21, 1907, the National Bank of Commerce refused to act as clearing house for Knickerbocker, which had not yet experienced any significant problems, precipitating a run on Knickerbocker. He suggests that this move was part of severe competition—"internecine rivalry"—and a fight for market share between national banks and trust companies in New York, with the National Bank of Commerce taking the opportunity to eliminate a rival, indeed a set of rivals, since the Knickerbocker run spilled over to all other trust companies.

[23] Tallman and Moen (2006) confirm that the large New York banks acted as private liquidity providers using New York Clearing House loan certificates, and that this led to problems in the distribution of liquidity.

Most importantly, Chernow (1990) discusses how J. P. Morgan gained from the trust companies' problems in the 1907 crisis. On November 2, Morgan organized a rescue package for the distressed Trust Company of America, and Lincoln Trust, as well as Moore and Schley, a speculative brokerage house $25 million in debt. Moore and Schley held a majority stake in the Tennessee Coal and Iron Company as collateral against loans. Were they to liquidate that stake, they might collapse and pull down other institutions. To save Moore and Schley, Morgan wanted some benefit for himself and told friends he had done enough and wanted some *quid pro quo*. He arranged a deal in which US Steel, his favorite creation that could profit from Tennessee Coal's huge iron ore and coal holdings, would buy Tennessee Coal stock from Moore and Schley if the trust company presidents assembled a $25 million pool to protect weaker trusts. While the takeover would normally have been barred on antitrust grounds, US Steel secured President Roosevelt's approval, and the Sherman Antitrust Act was not used. Senator Robert M. La Follette said bankers had rigged up the panic for their own profit. Financial analyst John Moody said the Tennessee Coal and Iron's property had a potential value of about $1 billion, confirming the $45 million distressed price as a steal. Later on, Grant B. Schley, head of Moore and Schley, admitted that his firm could have been rescued by a cash infusion rather than by the sale of the Tennessee Coal stock.

The 1907 crisis paved the way for the establishment of the Federal Reserve System as Senator Nelson W. Aldrich declared: "Something has got to be done. We may not always have Pierpont Morgan with us to meet a banking crisis" (Sinclair 1981).[24] The Federal Reserve System was a natural response to the realization that control and leadership of the US financial system had effectively been outsourced to one private businessman.

The Emergence of Modern Central Banks.—One should distinguish two possible reasons for the failure of private coinsurance arrangements: lack of coordination among clearinghouse members (e.g., due to free-riding)[25] and strategic behavior. It appears that coordination was factored into the organization of clearinghouses, and that it was really market power that led to their failure.

Timberlake (1984) argues that in US clearinghouses, one bank usually assumed the central administration role for the clearing member banks' accounts. However, a temptation existed for the central commercial banks to exploit a crisis to force a rival out of business by not providing them with the assistance they could have expected in normal times. This concern accords well with J.P. Morgan's role in the 1907 crisis. Hence, such conflicts of interest create a natural need for a noncompetitive, nonprofit maximizing central bank.

[24] Strouse (1999) details how, during the crisis, panicked crowds on the streets of Manhattan would stop to cheer as Morgan walked past, puffing at a cigar. So powerful was the House of Morgan—more powerful in the financial world than the government—that nobody dared to say no to him. The 1907 crisis was played out in his library amid his collection of books and art. Dozens of financiers would be in the room as Morgan told them they had to work collectively. At one point he locked the doors, refusing to let anyone leave until he had the answer he wanted—at 4 AM.

[25] Kindleberger (1978), Corrigan (1990), and Goodhart and Schoenmaker (1995) allude to such a possibility.

Interestingly, early central banks did not take this noncompetitive form. In the first half of the nineteenth century, a central bank's key feature resided in its relationship with the government and its privileged role as a (monopolistic) note issuer. Importantly, a central bank was considered to be one of the competitive banks. True central banking did not develop until the need for central banks to be noncompetitive was realized and established. Bagehot (1873, chapter 7), Goodhart (1988), and Goodhart and Schoenmaker (1995) report episodes of commercial rivalry between central banks and needy (regular) banks.

Bagehot wrote his famous *Lombard Street* in 1873 in the aftermath of the Overend, Gurney & Company crash of 1866, when there was suspicion that the Bank of England, then a private commercial bank, was reluctant to support Overend Gurney due to commercial rivalry. Bagehot points out that while it was accepted that the central bank should only assist banks expected to be solvent or to regain solvency under normal conditions, it should seek to act for the public good, and not simply as a business competitor. In contrast, the Bank of England's coordination of the rescue of Baring Brothers in 1890, its organization of a "lifeboat" during the secondary banking crisis in the early 1970s, and its rescue of Johnson Matthey Bankers Ltd. in 1984 in response to heightened competition in the financial sector (Capie et al. 1994) are prominent examples of the Bank of England performing its role in a noncompetitive fashion.[26]

These episodes suggest that even if it is not their sole *raison d'être*, at least central banks' modern form as noncompetitive, nonprofit maximizing entities does find its roots in competition issues.

Interest Rate Behavior During Crises in the Pre- and Post-Fed Era.—Using US data from 1873–1933, Donaldson (1992) shows that during banking panics interest rates were substantially higher than they were pre-crisis (by as much as 500 percent at times), which he interprets as evidence of market power by surplus banks. He shows that in contrast to the pre-Fed era, interest rates during crises after the establishment of the Federal Reserve System were not significantly different from pre-crisis rates. He also documents a structural change in the pricing of cash between panic and nonpanic periods, consistent with surplus banks using their market power to exploit needy banks during crises. Cash was indeed priced higher during panics than they were during nonpanic times in the pre-Fed period, but not so in the post-Fed period.[27] He concludes that the Fed's establishment as LOLR during panics prevented surplus banks from exploiting needy banks. The fact that banks hoarded liquidity for such strategic purposes, which would contribute to liquidity shortages

[26] The relation between Banque de France and potential competitors in the mid-nineteenth century is another good example. In particular, Banque de France used its influence to restrict competition from chartered banks. Because of such strong influence, the Conseil d'Etat was reluctant to grant charters to banks. And in 1867, after being involved in unsuccessful real estate speculation, Credit Mobilier experienced difficulties, and its enemies at Banque de France took advantage of the situation and forced it into liquidation.

[27] The 1914 panic took place in August. The Federal Reserve System was created via the Federal Act of December 23, 1913, and the Reserve Banks opened for business on November 16, 1914. These dates imply that the 1914 panic took place before the Fed was open. Donaldson (1992, table 1) covers the behavior of interest rates between weeks 31–49 of 1914. A careful examination reveals that the interest rates for 1914 are (slightly) higher than the rates in 1933, which is still consistent with Donaldson's overall argument.

and rises in interbank rates, is confirmed in Cleveland and Huertas (1985)'s accounts of the 1893 and 1907 crises. They describe the strategy of the National City Bank (which was to become Citibank) to anticipate crises and to build up liquidity and capital beforehand to attract dealers away from its troubled rivals.[28]

C. *Recent Evidence*

We provide evidence of the market power of banks vis-à-vis hedge funds and an investment bank, none of which had direct access to central bank lending, during the crisis of 2007–2010 and in the preceding decade.

Hedge Fund Failures in the Crisis of 2007–2010.—Several large hedge funds that failed over that period claimed they were at the mercy of banks that could force them into liquidation at will. While lenders may force liquidations even absent market power, the discussions from press reports below suggest that market power played a role, especially due to the specificity and illiquidity of the asset-backed securities in hedge fund portfolios.[29]

Tequesta Capital Advisors: This hedge fund was asked by its banks to put up more money or risk losing its loans. It was unable to meet the margin call as the market for mortgage-backed debt seized up, which prevented it from selling securities to raise the cash, and ultimately led to the liquidation of the $150 million fund. Founder Ivan Ross claimed: "Because it's impossible in this environment to move among dealers, you're at the mercy of counterparties. To the extent they want to shut you down, they can."[30]

Peloton Partners: On February 24, 2008, this London-based hedge fund gave up efforts to stave off demands from banks, including UBS and Goldman Sachs for 25 percent collateral for securities that once required 10 percent. Peloton, run by former Goldman partners Ron Beller and Geoff Grant, liquidated the $1.8 billion ABS Fund, its largest. In a letter to clients, Beller and Grant said "Credit providers have been severely tightening terms without regard to the creditworthiness or track record of individual firms, which has compounded our difficulties and made it impossible to meet margin calls."[31]

[28] About the 1907 crisis, Cleveland and Huertas (1985, 52) write: National City Bank again emerged from the panic a larger and stronger institution. At the start, National City had higher reserve and capital ratios than its competitors, and during the panic it gained in deposits and loans relative to its competitors. Stillman (President) had anticipated and planned for this result. In response to Vanderlip's (Vice President) complaint in early 1907 that National City's low leverage and high reserve ratio was depressing profitability, Stillman replied: "I have felt for sometime that the next panic and low interest rates following would straighten out good many things that have of late years crept into banking. What impresses me as most important is to go into next Autumn (usually a time of financial stringency) ridiculously strong and liquid, and now is the time to begin and shape for it. If by able and judicious management we have money to help our dealers when trust companies have suspended, we will have all the business we want for many years."

[29] This discussion is based on various Bloomberg articles.

[30] Tom Cahill and Katherine Barton, "Hedge Funds Reel From Margin Calls Even on Treasuries. Bloomberg, March 10, 2008 (http://www.bloomberg.com/apps/news?pid=newsarchive&sid=agsXY9R7AbkY).

[31] Pierre Paulden and Caroline Salas, "Peloton Lays Blame on Wall Street Lending Crackdown," Bloomberg, February 29, 2008 (http://www.bloomberg.com/apps/news?pid=newsarchive&sid=aBxfX.kGYQ6s).

Thornburg Mortgage: This home lender had lost 93 percent of its market value and was near collapse on March 7, 2008, after it failed to meet $610 million of margin calls. CEO Larry Goldstone said the company fell victim to a "panic that has gripped the mortgage financing industry." Goldman Sachs was one of the 22 financial companies that had lent money to Thornburg. It was using about $200 million of a Goldman credit line backed by mortgage loans. In August 2007, Goldman was the first firm to begin aggressively marking down the assets that Thornburg had used as collateral for the loan, arguing they were not valuable enough to repay the loan if Thornburg defaulted. Goldman demanded more cash to shore up the account, arguing that the value of similar mortgages traded by third parties had been priced at lower levels. "When we tried to negotiate price, they argued that they were aware of transactions that were not broadly known on the Street," said a former Thornburg employee who was briefed on the talks with Goldman: "That was their justification for why they were marking us down as aggressively as they were—that they were aware of things that others were not." But Goldman, according to two people with knowledge of the situation, had not actually seen such trades. However, soon after Goldman demanded more funds from Thornburg, analysts began downgrading its shares on news of the collateral calls. Beaten down by the broader mortgage collapse, Thornburg filed for bankruptcy on May 1, 2009.[32]

Bear Stearns and J.P. Morgan.—Bear Stearns was one of the largest investment banks in the world until its sudden collapse and eventual purchase by J.P. Morgan in mid-March 2008. In the days leading up to its final demise, Bear Stearns was desperately seeking liquidity. Indeed, it had been relying heavily on overnight sale-and-repurchase ("repo") markets, but its credit downgrade induced a freeze from money market funds, its primary repo financiers. Importantly, Bear Stearns being a non-depository institution, it did not have direct access to Federal Reserve emergency lending facility for borrowing against illiquid mortgage-backed securities (MBS).[33] Instead, it was getting liquidity from J.P. Morgan against its MBS collateral, which in turn J.P. Morgan was using to get liquidity from the Fed, since it was eligible for the Fed's emergency lending against MBS. Thus, even though the Fed's intention was to transfer emergency liquidity indirectly to Bear Stearns, instead J.P. Morgan's role as an intermediary became potentially quite lucrative as J.P. Morgan controlled the terms of its lending to Bear. Indeed, Tom Flexner, the Bear Stearns vice chairman is quoted as saying: "From what I was told by our treasury department . . . we were posting collateral to JP and it was haircutting at 20 percent, and then taking the same stuff to the Fed and getting 98 cents on the dollar for it" and "This was a liquidity facility that was putting us out of business, and JP was making money off of it. [Bear Stearn's CFO] Sam Molinaro told me at one point that we had to post $25 billion of collateral to get $15 billion liquidity. That's game, set, match!"[34] Our counterfactual is that had Bear been eligible for

[32] Gretchen Morgenson and Louise Story. "Clients Worried About Goldman's Dueling Goals," *The New York Times*, May 18, 2010. (http://www.nytimes.com/2010/05/19/business/19client.html?pagewanted=all).

[33] Bear Stearns would have become eligible by end of March but was not in mid-March.

[34] See Cohan (2009, 79).

direct Fed borrowing against illiquid MBS, it would have not faced the incremental haircut from J.P. Morgan, its private lender.

While these allegations of market power are still being evaluated, the fact that they have been raised suggest that market power issues are important in the midst of a financial crisis.

Hedge Fund Failures before the Crisis.—In the decade before the crisis, two major hedge funds collapsed: Long Term Capital Management (LTCM) in 1998 and Amaranth Advisors LLC in 2006. In both cases, other players seem to have tried to exploit their difficulties.

After its remarkable success from 1994–1997, LTCM began to experience difficulties during the financial turmoil triggered by the Russian default in August 1998. LTCM had to buy large amounts of Treasury bond futures to unwind its short position. Anticipating the direction of LTCM's trades and with the advantage of observing customer order flow, market makers had incentives to engage in front running, i.e., trading in the same direction knowing that the order will be coming and unwinding the position afterwards to profit from the order's price impact.[35] For example, *BusinessWeek* wrote: ". . . if lenders know that a hedge fund needs to sell something quickly, they will sell the same asset, driving the price down even faster. Goldman Sachs & Co. and other counterparties to LTCM did exactly that in 1998."[36] Cai (2003) examines the trading behavior of market makers in the Treasury bond futures market when LTCM faced binding margin constraints in 1998 and finds that during the crisis market makers in the aggregate engaged in front running against customer orders from a particular clearing firm (coded PI7) that closely match features of LTCM's trades through Bear Stearns. Furthermore, many market makers made abnormal profits on most trading days during the crisis. Eventually, fearing that LTCM's fall might disrupt financial markets, the New York Fed hosted a meeting of 14 financial institutions that led to a private-sector recapitalization of LTCM, which helped avoid fire sales. This, in turn, reversed the profitability of speculative trading against LTCM.

Similarly, the *Wall Street Journal* reported Amaranth Advisors LLC's failure and the efforts of other energy market players to exploit its difficulties.[37] When Amaranth's bets in the energy market turned out to be unfavorable, it started to lose value and by the end of Friday, September 15, 2006, was down more than $2 billion from its August value. The losses prompted J.P. Morgan, Amaranth's natural-gas clearing broker, to raise margin calls to be paid by Monday, September 18. In the past, Amaranth had met such demands by selling nonenergy investments, but thinking that some of these could not be liquidated quickly, Amaranth started negotiations with Wall Street banks to raise cash, eventually securing a deal with Goldman Sachs. However, J.P. Morgan

[35] Some recent papers model such strategic behavior. In Brunnermeier and Pedersen (2005), traders exploit the difficulties of other traders facing forced liquidations. If a distressed large investor must unwind her position, other traders initially trade in the same direction, and, to benefit from the price impact, buy back the same asset. Hence, as in our model, market participants withdraw liquidity, instead of providing it when liquidity is most needed. See also Carlin, Lobo, and Vishwanathan (2007).

[36] Peter Lay, *BusinessWeek*, February 26, 2001, "The Wrong Way to Regulate Hedge Funds."

[37] Ann Davis, Gregory Zuckerman, and Harry Sender, *Wall Street Journal*, January 30, 2007, "Amid Amaranth's Crisis, Other Players Profited."

refused to release Amaranth's cash collateral claiming that the deal did not free it from the risk that Amaranth's trades may not get paid. This killed the deal. Later on, J.P. Morgan itself got into the game and agreed to jointly assume most of Amaranth's energy positions with a partner, Citadel Investment Group.[38] In a speech in November 2006, Jamie Dimon, J.P. Morgan's CEO, said the Amaranth deal produced a "very nice increment to fixed-income trading" and in January 2007, *RISK* magazine named J.P. Morgan "Energy Derivatives House of the Year."

These episodes illustrate that liquidity markets can be ridden by strategic behavior by counterparties and lenders, especially when they stand to gain from failure of needy firms.

V. Policy Implications

A. *The Discount Window*

The result that central banks change needy banks' outside option, forcing surplus banks to adjust their liquidity supply, has implications for central banks' LOLR facilities.

For example, the Federal Reserve's discount window offers banks a lending facility at a premium to the federal funds rate, i.e., the rate at which banks (depository institutions) lend their balances at the Fed to other banks, usually overnight. However, this discount window is seldom used. Some have argued that the stigma of being seen as having funding problems explains banks' reluctance to use it. Our analysis implies that this need not necessarily mean that the discount window is useless. The federal funds rate plus the premium sets an upper bound on the cost of borrowing when aggregate liquidity is in surplus. In particular, this limits the surplus banks can squeeze out of needy banks.

A second implication concerns the discount window premium. How high should the premium be? Could it be so high that it has little effect on borrowing outcomes?[39] Lack of borrowing at the discount window should not cause as much alarm as the lack of any effect of a change in the premium at the discount window on interbank borrowing rates—an issue that has received little attention. Within our model, the discount window has no effect on borrowing outcomes if the lending rate at the window exceeds that at which outside (nonbank) markets would lend against the same assets. Indeed, the central bank may find it desirable to commit to an effective lending rate below the outside market rate even if this means bearing some losses.

[38] The deal with Goldman Sachs would require Amaranth to pay nearly $1.85 billion to take toxic trades off its hands. Amaranth intended to use the $1 billion to $2 billion in cash J.P. Morgan held in a margin account to pay Goldman Sachs for the deal. In the final deal, Amaranth's total payments to Merrill Lynch, J.P. Morgan, and Citadel, plus the last few days' market losses, came to about $3.2 billion. While Amaranth suffered huge losses during the process, J.P. Morgan earned an estimated $725 million from the deal.

[39] For example, in August 2007, the Fed cut the discount rate to just a half percentage point above the federal funds rate, from the usual spread of a full point, hoping to encourage banks to seek funds from the window to help customers finance holdings of illiquid securities. Fed officials told banks at the time that any such borrowing would be seen as a sign of strength, not weakness. "This change did not lead to a big increase in borrowing … (because) even at a (half point) spread, the (discount) rate was higher than the rate on alternative sources of funds for most depository institutions," William Dudley (Executive Vice President), who managed open market operations at the New York Fed at that time, told an audience at the Philadelphia Fed in October 2007.

There is some historical evidence of such use of the discount window at a discount to the federal funds rate (rather than at a premium) having been effective during the 1970 Penn Central commercial paper crisis.[40]

An important question is whether central banks need to lend to individual institutions directly, or whether they should rely on OMOs (Goodfriend and King 1988). Our model implies that when there are market power issues, OMOs may not succeed unless the central bank pumps enough liquidity to break the market power of some banks. Consistent with this view, Governor of Bank of England Mervyn King and the Chancellor of the Exchequer Alistair Darling, during the hearings about the Northern Rock episode in Fall of 2007, pointed out the difficulties with OMOs in channeling liquidity to needy banks as the primary reason for lending directly to individual institutions. In particular, they pointed out that to channel the £14 billion that Northern Rock borrowed from the Bank of England to that institution would have required many more billions of pounds to be injected through the OMOs.

B. *New Forms of Central Bank Funding*

Our analysis also implies that unless outside markets are themselves strapped of liquidity, needy banks should have no trouble raising liquidity against collateral that requires little monitoring skills or expertise. Illiquidity issues arise for those loans over which other banks have an advantage in terms of monitoring and usage, conferring upon them market power. Indeed, collateral that is highly bank-specific may be inefficiently liquidated. Hence, a discount window or other LOLR facility that lends only against high-quality collateral may not improve much the allocation of liquidity.

This perspective is useful for understanding the new facilities set up by the Fed in 2007–2009 aimed at channeling liquidity to the neediest corners of the financial system. These new facilities have extended maturities to include up to 90-day loans, maturities at which money markets have dried up in the aftermath of sub-prime losses; extended eligible collateral to include investment-grade debt securities (including high-rated but illiquid mortgage-backed securities); and extended these privileges not only to banks but also to securities dealers since they are also affected by funding problems caused by the drying up of liquidity extension from banks.[41] These changes are more likely to be effective than are

[40] Calomiris (1994) describes the crisis, and the Fed's use of the discount window to combat it. The Fed lent to member banks through the discount window for purposes of making loans to commercial paper issuers. Importantly, funds were lent at a discount to the federal funds rate, rather than the normal premium, which succeeded in channeling liquidity to needy institutions reliant on commercial paper market during normal times. Firms likely to have had outstanding debt in the form of commercial paper suffered larger negative abnormal returns during the onset of the crisis, and larger positive ones after the Fed intervened to lower the cost of commercial paper rollover.

[41] In particular, in addition to the traditional tools the Fed uses to implement monetary policy (e.g., Open Market Operations, Discount Window, and Securities Lending program), new programs have been implemented since August 2007: 1) Term Discount Window Program (announced August 17, 2007) extended the length of discount window loans available to institutions eligible for primary credit from overnight to a maximum of 90 days; 2) Term Auction Facility (TAF) (announced December 12, 2007) provides funds to primary credit eligible institutions through an auction for a term of 28 days; 3) Single-Tranche OMO (Open Market Operations) Program (announced March 7, 2008) allows primary dealers to secure funds for a term of 28 days. These operations are intended to augment the single day repurchase agreements (repos) that are typically conducted; 4) Term Securities Lending Facility (TSLF) (announced March 11, 2008) allows primary dealers to pledge a broader

traditional facilities in restoring liquidity in the interbank markets, even if they are not directly tapped into, since they have created a direct option for raising funding against assets rendered illiquid.[42]

Early in the crisis of 2007–2009, the Federal Reserve used OMOs to ease the strain in money markets. While OMOs had some success in stabilizing the overnight rate, the rates on term loans continued to rise. On December 12, 2007, the Fed introduced the Term Auction Facility (TAF), which provides term funding to eligible depository institutions through auctions. McAndrews, Sarkar, and Wang (2008) study whether TAF succeeded in easing the strain in money markets, measured as downward shifts in LIBOR. They show that TAF was successful, where a cumulative reduction of 50 basis points in the LIBOR-OIS spread can be associated with the TAF announcements and its operations (see also Wu 2008).

Furthermore, during the crisis, many central banks extended maturities and accepted a broader range of collateral. William Buiter provides a rationale for this by criticizing the Bank of England's strict collateral requirements early in the crisis: "Basically, they would discount only stuff that is already liquid: UK government securities; European Economic Area government securities; a few international organizations' debt like the World Bank; and then under special circumstances, US Treasury bonds. All that stuff is liquid already."

C. *Coordination Role of Central Banks*

Outside the scope of our model, but relevant to its conclusions, is the role of central banks beyond that of LOLR. Much like the IMF's constraints in dealing with the 1980s' LDC debt crisis, central banks have insufficient resources and expertise to deal with the most serious financial crises out of their own funds or nationalize large parts of the financial sector. Hence, central bank funding in rescue packages is often tied with private sector funding and ownership of rescued institutions either by a single private player or a consortium. Such quasi-regulatory support operations are more likely to succeed if done under the leadership of a central bank that must impress upon profit-maximizing players the need to coordinate an outcome that balances their interest with broader welfare concerns. To perform this role, a central bank should be above the competitive battle, a noncompetitive, not-for-profit body. The success of the LTCM rescue in 1998 with a consortium of bankers, and the expedient resolution of Bear Stearns' distress through a sale to JPMC in March 2008, both at the initiative of the Fed, point to the importance of this coordination role of central banks.

---

range of collateral than is accepted with the Securities Lending program, and also to borrow for a longer term—28 days versus overnight; and, 5) Primary Dealer Credit Facility (PDCF) (announced March 16, 2008) is an overnight loan facility that provides funds directly to primary dealers in exchange for a range of eligible collateral; 6) Commercial Paper Funding Facility (CPFF) (announced November 7, 2008) is designed to provide a liquidity backstop to US issuers of commercial paper; 7) Money Market Investor Funding Facility (MMIFF) (announced November 21, 2008) is aimed to support a private-sector initiative designed to provide liquidity to US money market investors; 8) Term Asset-Backed Securities Loan Facility (TALF) (announced November 25, 2008) is designed to help market participants meet the credit needs of households and small businesses by supporting the issuance of asset-backed securities (ABS) collateralized by auto loans, student loans, credit card loans, etc.

[42] Acharya and Backus (2009) point out, however, that given potential solvency concerns about borrowing banks, such LOLR might need to be combined with solvency-linked covenants, as in the private lines of credit that banks write for their borrowers.

VI. Conclusion

We propose that when the distribution of liquidity among banks is highly skewed, surplus banks may strategically ration their liquidity provision to needy banks to gain from their closure or the liquidation of their assets. This problem is more acute when the surplus bank commands higher market power, and when needy banks' liquidity needs are high and their outside options are weak, all being common features of financial crises.

Such strategic behavior illustrates crises in the pre-Fed era and provides a rationale for the LOLR role of central banks. A central bank that is credible in providing liquidity to banks in need at competitive rates can curb the market power of surplus banks in the interbank market and improve the efficiency of liquidity transfers and asset sales. This LOLR rationale for the existence of a central bank complements the traditional one observed in times of aggregate liquidity shortages and contagious failures. Our model illustrates that the public provision of liquidity can improve its private provision even when aggregate liquidity is in surplus. More broadly, it also provides a rationale for central banks to play the role of coordinating liquidity injection to needy institutions.

Our analysis can be extended in several directions. It would be useful to endogenize the structure of liquidity shocks based on the optimal liability structure of banks (Diamond and Rajan 2001; Acharya and Viswanathan 2011). In particular, one might ask how issues of market power and the resulting under-provision of liquidity insurance affect the optimal asset-liability (mis)match and liquidity management by banks. Our model also takes the structure of interbank relationships and market power as given. Does market power arise from interbank relationships that are efficient from an ex ante perspective? What is the ex-ante optimal industrial organization of interbank markets? In particular, does it feature "tiering" in which some large banks hoard reserves and acquire rents during crises, and others remain smaller, less liquid players, borrowing from large banks, but get squeezed during crises? Similarly, the nature of the game between the surplus bank and the central bank raises important questions. We showed that the effectiveness of the central bank in curbing the market power of the surplus bank increases with the quality of its supervision. We have, however, ruled out direct bargaining between the surplus bank and the central bank. The former could try to extract concessions from the latter to rescue needy banks.[43] Finally, we have assumed that the central bank can commit to limited intervention. Absent this, Bank *A* could try to exploit the central bank's soft budget constraint. This well-known moral hazard problem, which our

[43] The financial crisis in the UK and the bailout and subsequent nationalization of Northern Rock in 2007 showed that surplus banks can exert power not only on needy banks but also on authorities (see "The Bank loses a game of chicken," *Financial Times*, September 20, 2007; "Lessons of the fall," *The Economist*, November 8, 2007). On August 13, 2007, Northern Rock informed regulatory authorities about its liquidity problems. By mid-September, the longer-term funding markets were closed for Northern Rock. While the possibility of Bank of England acting as a LOLR had been discussed among the authorities, the option of selling Northern Rock to another bank had been tried first. Even though Lloyds TSB emerged as a serious contender, the deal did not go through since Lloyds' demand for a loan of up to £30 billion from the Bank of England had been rejected on the grounds that it would not be appropriate to help finance a bid by one bank for another. The case of Bear Stearns' acquisition by J.P. Morgan Chase in March 2008 has been much the same, except that the Fed provided a loan of up to $30 billion for the acquisition (see the discussion in Introduction for details).

analysis leaves aside, ought to be balanced against the benefits of curbing liquid banks' market power. We leave these questions for future research.

REFERENCES

Acharya, Viral, and David Backus. 2009. "Private Lessons for Public Banking: The Case for Conditionality in LOLR Facilities." In *Restoring Financial Stability: How to Repair a Failed System*, edited by Viral Acharya and Matthew Richardson, 305–22. Hoboken: John Wiley & Sons.

Acharya, Viral V., Sreedhar T. Bharath, and Anand Srinivasan. 2007. "Does Industry-Wide Distress Affect Defaulted Firms? Evidence from Creditor Recoveries." *Journal of Financial Economics* 85 (3): 787–821.

Acharya, Viral V., and Ouarda Merrouche. 2009. "Precautionary Hoarding of Liquidity and Inter-Bank Markets: Evidence from the Sub-prime Crisis." New York University Stern School of Business Working Paper FIN-09-018.

Acharya, Viral V., Hyun Song Shin, and Tanju Yorulmazer. 2011. "Crisis Resolution and Bank Liquidity." *Review of Financial Studies* 24 (6): 2166–2205.

Acharya, Viral V., and S. Viswanathan. 2011. "Leverage, Moral Hazard, and Liquidity." *Journal of Finance* 66 (1): 99–138.

Allen, Franklin, and Douglas Gale. 1994. "Limited Market Participation and Volatility of Asset Prices." *American Economic Review* 84 (4): 933–55.

Allen, Franklin, and Douglas Gale. 1998. "Optimal Financial Crises." *Journal of Finance* 53 (4): 1245–84.

Allen, Franklin, and Douglas Gale. 2000. "Financial Contagion." *Journal of Political Economy* 108 (1): 1–33.

Bagehot, Walter. 1873. *Lombard Street: A Description of the Money Market*. London: H. S. King.

Bank of England. 2005. *Reform of the Bank of England's Operations in the Sterling Money Markets*. Money Market Publication. London, April.

Bech, Morten L., and Enghin Atalay. 2010. "The Topology of the Federal Funds Market." *Physica A: Statistical Mechanics and its Applications* 389 (22): 5223–46.

Berger, Allen N., Sally M. Davies, and Mark J. Flannery. 2000. "Comparing Market and Supervisory Assessments of Bank Performance: Who Knows What When?" *Journal of Money, Credit, and Banking* 32 (3): 641–67.

Berger, Philip G., Eli Ofek, and Itzhak Swary. 1996. "Investor Valuation of the Abandonment Option." *Journal of Financial Economics* 42 (2): 257–87.

Bhattacharya, Sudipto, and Douglas M. Gale. 1987. "Preference Shocks, Liquidity, and Central Bank Policy." In *New Approaches to Monetary Economics: Proceedings of the Second International Symposium in Economic Theory and Econometrics*, edited by William A. Barnett and Kenneth J. Singleton, 69–88. New York: Cambridge University Press.

Bolton, Patrick, and David S. Scharfstein. 1990. "A Theory of Predation Based on Agency Problems in Financial Contracting." *American Economic Review* 80 (1): 93–106.

Brunnermeier, Markus K., and Lasse Heje Pedersen. 2005. "Predatory Trading." *Journal of Finance* 60 (4): 1825–63.

Cai, Fang. 2003. "Was There Front Running During the LTCM Crisis?" Board of Governors of the Federal Reserve Board System, International Finance Discussion Paper 758.

Calomiris, Charles W. 1994. "Is the Discount Window Necessary? A Penn Central Perspective." *Federal Reserve Bank of St. Louis Review* 76 (3): 31–55.

Calomiris, Charles W., and Charles M. Kahn. 1996. "The Efficiency of Self-Regulated Payments Systems: Learning from the Suffolk System." *Journal of Money, Credit, and Banking* 28 (4): 766–97.

Capie, Forrest, Charles Goodhart, Stanley Fischer, and Norbert Schnadt. 1994. *The Future of Central Banking: The Tercentenary Symposium of the Bank of England*. Cambridge, UK: Cambridge University Press.

Caprio, Gerard, Luc Laeven, and Ross Levine. 2007. "Governance and Bank Valuation." *Journal of Financial Intermediation* 16 (4): 584–617.

Carlin, Bruce Ian, Miguel Sousa Lobo, and S. Viswanathan. 2007. "Episodic Liquidity Crises: Cooperative and Predatory Trading." *Journal of Finance* 62 (5): 2235–74.

Cestone, Giacinta. 1999. "Corporate Financing and Product Market Competition: An Overview." *Giornale degli Economisti e Annali di Economia* 58 (2): 269–300.

Chernow, Ron. 1990. *The House of Morgan: The Secret History of Money and Power*. Sydney: Simon & Schuster.

Cifuentes, Rodrigo, Gianluigi Ferrucci, and Hyun Song Shin. 2005. "Liquidity Risk and Contagion." *Journal of the European Economic Association* 3 (2–3): 556–66.

Cleveland, Harold van B., and Thomas F. Huertas. 1985. *Citibank, 1812–1970.* Cambridge, MA: Harvard University Press.

Cocco, Joao F., Francisco J. Gomes, and Nuno C. Martins. 2009. "Lending Relationships in the Interbank Market." *Journal of Financial Intermediation* 18 (1): 24–48.

Cohan, William. 2009. *House of Cards: A Tale of Hubris and Wretched Excess on Wall Street*. New York: Doubleday.

Corrigan, E. G. 1990. Statement Before US Senate Committee on Banking, Housing and Urban Affairs, Washington DC.

Dell'Ariccia, Giovanni, Enrica Detragiache, and Raghuram Rajan. 2008. "The Real Effect of Banking Crises." *Journal of Financial Intermediation* 17 (1): 89–112.

Diamond, Douglas, and Raghuram Rajan. 2001. "Liquidity Risk, Liquidity Creation, and Financial Fragility: A Theory of Banking." *Journal of Political Economy* 109 (2): 287–327.

Diamond, Douglas W., and Raghuram G. Rajan. 2005. "Liquidity Shortages and Banking Crises." *Journal of Finance* 60 (2): 615–47.

Donaldson, R. Glen. 1992. "Costly Liquidity, Interbank Trade, Bank Runs and Panics." *Journal of Financial Intermediation*, 2(1): 59–82.

Dunn, Kenneth B., and Chester S. Spatt. 1984. "A Strategic Analysis of Sinking Fund Bonds." *Journal of Financial Economics* 13 (3): 399–423.

Fama, Eugene F. 1985. "What's Different about Banks?" *Journal of Monetary Economics* 15 (1): 29–39.

Flannery, Mark J. 1996. "Financial Crises, Payment System Problems, and Discount Window Lending." *Journal of Money, Credit, and Banking*, 28(4): 804–24.

Freixas, Xavier, Curzio Giannini, Glenn Hoggarth, and Farouk Soussa. 1999. "Lender of Last Resort: A Review of the Literature." *Bank of England Financial Stability Review* 151–67.

Freixas, Xavier, and Cornelia Holthausen. 2005. "Interbank Market Integration under Asymmetric Information." *Review of Financial Studies* 18 (2): 459–90.

Freixas, Xavier, and Jose Jorge. 2007. "The Role of Interbank Markets in Monetary Policy: A Model with Rationing." Department of Economics and Business, Universitat Pompeu Fabra, Working Paper 1027.

Furfine, Craig H. 2001. "Banks as Monitors of Other Banks: Evidence from the Overnight Federal Funds Market." *Journal of Business*, 74(1): 33–57.

Goodfriend, Marvin, and Robert G. King. 1988. "Financial Deregulation, Monetary Policy, and Central Banking." *Federal Reserve Bank of Richmond Economic Review* 74 (3): 3–22.

Goodhart, C. A. E. 1969. *The New York Money Market and the Finance of Trade, 1900–1913*. Cambridge, MA: Harvard University Press.

Goodhart, Charles. 1988. *The Evolution of Central Banks*. Cambridge, MA: MIT Press.

Goodhart, Charles, and Dirk Schoenmaker. 1995. "Should the Functions of Monetary Policy and Banking Supervision Be Separated?" *Oxford Economic Papers* 47 (4): 539–60.

Gorton, Gary. 1985. "Clearinghouses and the Origin of Central Banking in the United States." *Journal of Economic History* 45 (2): 277–83.

Gorton, Gary, and Lixin Huang. 2004. "Liquidity, Efficiency, and Bank Bailouts." *American Economic Review* 94 (3): 455–83.

Gorton, Gary, and Lixin Huang. 2006. "Bank Panics and the Endogeneity of Central Banking." *Journal of Monetary Economics* 53 (7): 1613–29.

Gorton, Gary, and Donald J. Mullineaux. 1987. "The Joint Production of Confidence: Endogenous Regulation and Nineteenth Century Commercial-Bank Clearinghouses." *Journal of Money, Credit, and Banking* 19 (4): 457–68.

Hirtle, Beverly J., and Jose A. Lopez. 1999. "Supervisory Information and the Frequency of Bank Examinations." *Federal Reserve Bank of New York Economic Policy Review* 5 (1): 1–19.

Holmström, Bengt, and Jean Tirole. 1998. "Private and Public Supply of Liquidity." *Journal of Political Economy* 106 (1): 1–40.

Houston, Joel, and Christopher James. 1996. "Bank Information Monopolies and the Mix of Private and Public Debt Claims." *Journal of Finance* 51 (5): 1863–89.

James, Christopher. 1987. "Some Evidence on the Uniqueness of Bank Loans." *Journal of Financial Economics* 19 (2): 217–35.

James, Christopher. 1991. "The Losses Realized in Bank Failures." *Journal of Finance* 46 (4): 1223–42.

Kindleberger, Charles P. 1978. *Manias, Panics, and Crashes: A History of Financial Crises*. New York: Basic Books.

Kroszner, Randall S., Luc Laeven, and Daniela Klingebiel. 2007. "Banking Crises, Financial Dependence, and Growth." *Journal of Financial Economics* 84 (1): 187–228.

La Porta, Rafael, Florencio Lopez-de-Silanes, and Andrei Shleifer. 1999. "Corporate Ownership around the World." *Journal of Finance* 54 (2): 471–517.

Leitner, Yaron. 2005. "Financial Networks: Contagion, Commitment, and Private Sector Bailouts." *Journal of Finance* 60 (6): 2925–53.

McAndrews, James, Asani Sarkar, and Zhenyu Wang. 2008. "The Effect of the Term Auction Facility on the London Inter-Bank Offered Rate." Federal Reserve Bank of New York Staff Reports 335.

Park, Sangkyun. 1991. "Bank Failure Contagion in Historical Perspective." *Journal of Monetary Economics* 28 (2): 271–86.

Pope, David. 1989. "Free Banking in Australia before World War I." Australian National University, Economic History Working Paper 129.

Pulvino, Todd C. 1998. "Do Asset Fire Sales Exist? An Empirical Investigation of Commercial Aircraft Transactions." *Journal of Finance* 53 (3): 939–78.

Repullo, Rafael. 2005. "Liquidity, Risk Taking, and the Lender of Last Resort." *International Journal of Central Banking* 1 (2): 47–80.

Rochet, Jean-Charles, and Jean Tirole. 1996. "Interbank Lending and Systemic Risk." *Journal of Money, Credit, and Banking* 28 (4): 733–62.

Shleifer, Andrei, and Robert W. Vishny. 1992. "Liquidation Values and Debt Capacity: A Market Equilibrium Approach." *Journal of Finance* 47 (4): 1343–66.

Sinclair, Andrew. 1981. *Corsair: The Life of J. Pierpont Morgan*. Boston: Little Brown.

Sprague, Oliver. 1910. *History of Crises under the National Banking System*. Washington DC: US Government Printing Office.

Stromberg, Per. 2000. "Conflicts of Interest and Market Illiquidity in Bankruptcy Auctions: Theory and Tests." *Journal of Finance* 55 (6): 2641–92.

Strouse, Jean. 1999. *Morgan: American Financier*. New York: Random House.

Tallman, Ellis W., and Jon R. Moen. 2006. "Liquidity Creation without a Lender of Last Resort: Clearinghouse Loan Certificates in the Banking Panic of 1907." Federal Reserve Bank of Atlanta Working Paper 2006-23.

Timberlake, Richard H., Jr. 1984. "The Central Banking Role of Clearinghouse Associations." *Journal of Money, Credit, and Banking* 16 (1): 1–15.

Tucker, Paul. 2004. "Managing the Central Bank's Balance Sheet: Where Monetary Policy Meets Financial Stability." Lecture to mark the 15th anniversary of the founding of Lombard Street Research, July 28.

Vives, Xavier. 2011. "Competition and Stability in Banking." In *Monetary Policy under Financial Turbulence*, Vol. 16, edited by Luis Felipe Céspedes, Roberto Chang, and Diego Saravia, 455–502. Santiago, Chile: Central Bank of Chile.

Williamson, Oliver E. 1988. "Corporate Finance and Corporate Governance." *Journal of Finance* 43 (3): 567–91.

Wu, Tao. 2008. "On the Effectiveness of the Federal Reserve's New Liquidity Facilities." Federal Reserve Bank of Dallas Working Paper 0808.