Imperfect Competition in the Inter-Bank Market for Liquidity as a Rationale for Central Banking*

Viral V. Acharya
London Business School and CEPR

Denis Gromb
London Business School and CEPR

Tanju Yorulmazer
Federal Reserve Bank of New York

October 15, 2007

Abstract

We consider liquidity transfers between banks through the inter-bank borrowing and asset sale markets when banks providing liquidity may have market power and assets may be bank-specific. We show that when the outside options of liquidity-affected banks are weak, surplus banks may strategically underprovide lending. thereby inducing excessive and inefficient sales of bank-specific assets. A regulator such as a Central Bank can ameliorate this inefficiency by standing to lend to affected banks, provided it has greater information about banks (for example, through supervision) compared to the outside markets, or absent such information access, it is prepared to make some loss-making loans. The public provision of liquidity to banks, or its mere credibility, can thus improve the private allocation of liquidity among banks. This rationale for the existence of a Central Bank finds support in historical episodes preceding the modern era of Central Banking and has implications for recent debates concerning the supervisory and lender-of-last-resort roles of Central Banks.

*Contact: Viral Acharya, Department of Finance, London Business School, Regent's Park, London – NW1 4SA, England. Tel: +44 (0)20 7000 8255 Fax: +44 (0)20 7000 8201 e–mail: vacharya@london.edu. We are grateful to Franklin Allen, Darrell Duffie, Douglas Gale, Alan Morrison, Raghuram Rajan, Peter Sinclair (discussant), Hyun Shin, Anjan Thakor (discussant), Lucy White and seminar participants at Bank of England, Bank of Portugal and London Business School for helpful suggestions. All errors remain our own. A part of this paper was completed while Viral Acharya was visiting Stanford-GSB. Opinions expressed here do not necessarily reflect the views of the Federal Reserve Bank of New York or the Federal Reserve System.

JEL classification: G21, G28, G38, E58, D62.

Keywords: Competition, Inter-bank lending, Market power, Asset specificity, Lender of last resort.

1 Introduction

In this paper, we propose that during crises episodes, efficient transfers of liquidity may not take place between surplus and needy banks. We attribute the source of this inefficiency to the market power of liquidity-rich banks in the market for liquidity transfers between banks and the strategic gains accruing to liquidity-rich banks upon the liquidation of assets of cash-stricken ones. We argue that a Central Bank by standing ready to lend to needy banks can ameliorate this inefficiency. We present conditions under which the Central Bank can improve upon the market outcomes. We provide some anecdotal support for our rationale for Central Banking based on historical episodes and discuss implications of our results for recent debates concerning the supervisory and lender-of-last-resort (LOLR) activities.

We build a model of liquidity transfers through two markets: inter-bank lending market and asset sales. Our model has three main ingredients.

- First, we assume that some assets are bank-specific, i.e., they are worth more under current than under alternative ownership. For instance, alternative users may lack the current user's expertise. For this reason, asset sales may be less efficient than borrowing.
- Second, we assume frictions in the interbank lending market, which we model as a moral hazard problem. These frictions limit banks' borrowing capacity, leading to inefficient asset sales.
- Third, we assume that during crises episodes, identified as situations when total surplus liquidity is small relative to the liquidity demand, liquidity is concentrated with a few players who enjoy market power.

In this context, we show that the market power of surplus banks leads to more asset sales, and importantly, more *inefficient* asset sales by needy banks. This problem is more acute the weaker is the market for assets outside of the banking sector, a scenario that would arise, for instance, in liquidation of information-sensitive and specific loans made to small borrowers.

Such strategic behavior by surplus banks describes well the crises episodes in the pre-Federal Reserve era. In direct evidence for such behavior, Donaldson (1992), using US data for the period 1873-1993, reports the stylized fact that interest rates increase and stock prices plunge during banking panics. He shows that the interest rates during panics

before the establishment of the Federal Reserve System were higher than the competitive rates, which he interprets as evidence of market power for banks with excess liquidity. Furthermore, he shows that after the establishment of the Federal Reserve System, interest rates were not different from competitive rates.

Our analysis also provides a rationale for the existence of a Central Bank to address this market failure. A Central Bank that is credible in providing liquidity to banks in need curbs the market power of surplus banks in the inter-bank market and can potentially improve the efficiency of liquidity transfers and asset sales. In particular, the Central Bank can play a "virtual and virtuous" role in our model since it never actually lends in equilibrium to the needy banks, but merely improves their outside options. We show that for such an improvement to occur, the Central Bank must either be better-informed than outside markets about banks (for example, through its supervisory role), or absent such superior information, it should be prepared to lend ex post even if it ends up making losses on some assets against which it lends (for example, by lending against some lower quality assets as collateral).

To summarize, our model illustrates that the public provision of liquidity (in fact, its mere credibility) can improve the private provision of liquidity even in times when there is no aggregate shortage of liquidity. This lender-of-last-resort rationale for the existence of a Central Bank is complementary to the traditional one which pertains to times when there is in fact an aggregate shortage of liquidity. Our model also clarifies why the supervisory and LOLR roles of a Central Bank are naturally linked to each other.

Our model is related to the literature on the failure of inter-bank markets that justifies the lender-of-last-resort role of Central Banks in lending to individual banks.[2] Goodfriend and King (1988), one of the early papers in this strand of literature, argues that with efficient interbank markets, solvent banks that need liquidity can always borrow in the interbank market. Hence, as per their argument, Central Banks should provide sufficient liquidity via open market operations and the interbank market would allocate the liquidity among banks. In particular, Central Banks should not lend to banks on an individual basis.

However, others have argued that interbank markets may fail to ensure efficient liquidity transfers due to frictions such as asymmetric information about the quality of banks' assets (Flannery, 1996), banks' free-riding on other banks' liquidity (Bhattacharya and

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

Gale, 1987), or on the Central Bank's liquidity (Repullo, 2005). Bhattacharya and Gale (1987), for example, build a model of the interbank market where banks are subject to liquidity shocks with random sizes, and where the composition of liquid and illiquid assets in each bank's portfolio as well as the size of the liquidity shock affecting each bank is private information. Since the liquid asset has a lower return and given that bank portfolios and liquidity shocks are private information, banks have an incentive to under-invest in liquid assets and free-ride on the common pool of liquidity. Hence, even in the presence of an inter-bank market, there can be liquidity shortages at the aggregate level and a Central Bank that can monitor banks' asset choices may alleviate the free-rider problem.

Our paper is in the spirit of this second set of papers, but the failure in the inter-bank market arises in our model due to the strategic benefit accruing to potential lenders once liquidity shocks have affected some banks. This failure arises even in the presence of complete information about liquidity shocks. In essence, pumping liquidity into the banking sector at large does not guarantee that liquidity will end up at needy institutions. Surplus institutions may have incentives to hoard their liquidity, acquire additional liquidity in open-market operations, and channel it to needy institutions only at exorbitant rates.

The paper proceeds as follows. Section 2 provides further historical evidence supporting our thesis. Section 3 presents the model. Section 4 provides the analysis. Section 5 discusses factors affecting the banks' outside options. Section 6 presents the rationale for Central Banking in our setup. Section 7 discusses robustness of our results to allowing for ex-ante contracting on liquidity shocks and broader implications for failures in liquidity transfers among financial institutions of modern-day capital markets (other than banks). Section 8 concludes. Proofs are in the Appendix.

2 Historical evidence

In this section, we first discuss some of the private arrangements amongst banks to manage liquidity shocks prior to the modern Central Banking era, and next discuss the role of private benefits and strategic behavior in the failure of such arrangements, as witnessed during some significant historical episodes.[3]

Orchestrated liquidity support operations occurred often in the past. The Bank of England's coordination of the rescue of Baring Brothers in 1890 and its organization of a "life-boat" during the secondary banking crisis in the early 1970s are prominent examples. Similarly, the Clearinghouse System in the United States assumed the crisis prevention

[3]See Freixas, Giannini, Hoggarth and Sousa (1999) for an excellent survey.

and management role before the establishment of the Federal Reserve System.[4] The first clearinghouse, established by the New York City banks in 1853, created an organized market for exchange between banks. During normal times, clearinghouses performed their service of clearing payments, whereas during crisis periods, they evolved into an organization that managed the crisis by helping member banks sustain their solvency and liquidity positions. During such periods, clearinghouses used several methods such as suspension of payments, equalization of reserves and issuance of clearing house loan certificates to ease the suffering of the member banks in distress. The equalization of reserves, which is essentially the pooling of all legal reserves of clearing house member banks in an emergency and granting member banks equal access to the pooled resources, eased the liquidity constraint on banks that experienced runs. Also, clearing houses issued loan certificates which were acquired by banks by depositing qualifying assets with the Clearing House Association to be used in interbank settlements. These loan certificates prevented costly asset liquidations and improved affected banks' liquidity position. Since they were provided only when the Clearing House Association decided that the bank had enough assets to back them up, loan certificates also served the purpose of providing information that the bank was healthy.[5]

Such private arrangements and voluntary participation into rescue efforts to help distressed banks worked well at times in the past. However, their effectiveness was hampered by the competitive pressures in the banking industry. In particular, voluntary participation in rescue efforts was often difficult to elicit because of the short-term competitive advantage healthy banks could experience during crises. As a result, private-sector solutions became less feasible as the degree of competition in the market increased.

The Clearinghouse System was eventually brought down at the beginning of the 20th century by the marked increase in competition in the banking industry in New York. Similarly, these arrangements became more difficult to organize in the UK during the 1980s and serious difficulties were encountered in the rescue of Johnson Matthey Bankers Ltd. due to heightened competition in the financial industry.[6] Historical evidence and accounts seem to confirm the existence of this tension between the effectiveness of private arrangements and the degree of competition in the financial system.

Kindleberger (1978), for example, highlights the tension between voluntary rescue efforts and competitive behavior very nicely:

[4]For a discussion of the clearing house arrangements, see Gorton (1985), Gorton and Mullineaux (1987), Calomiris and Kahn (1996), and Gorton and Huang (2002a, 2002b).

[5]See Park (1991) for a detailed discussion.

[6]See Capie et al (1994) for a discussion.

"... the optimum may be a small number of actors, closely attuned to one another in an oligarchic relation, like-minded, applying strong pressure to keep down the chiselers and free-riders, prepared ultimately to accept responsibility."

Referring to recent episodes such as the John Matthey Bankers Ltd. failure in the UK, Goodhart and Shoenmaker (1995) highlight the challenges ahead for the sustainability of private rescue packages: "Although rescues financed on an implicit central bank-commercial banks basis may seem desirable, it is doubtful how far it will be sustainable much longer. These rescues depend on the cohesion of a well-defined group of banks, which are prepared to finance a self-supporting regime under the leadership, usually, of a central bank. ... Greater competition has made commercial banks less willing to participate (in such cartels and coalitions), and reduced the clout of the central bank in dragooning unwilling volunteers. Growing fuzziness of dividing line between banks and non-banks, and the problems raised by foreign banks, would allow for endless discussion and recrimination over the question of what share of the rescue each volunteer should take."

In countries where competition in the financial system had until recently been somewhat limited, such as France, Italy, or Germany, the notion that liquidity support should be seen primarily as the responsibility of the institutions operating in the market had however survived.[7] In contrast, the U.S. authorities at the beginning of the 1990s were concerned that the high level of competition, a characteristic of the US financial markets, prevented this feature of continental European banking. As Corrigan (1990) puts it:

"Private institutions either are more willing, or feel more compelled, to participate in stabilization or rescue efforts in foreign countries than they are in the United States. ... Where a handful of banks dominate national banking systems, that handful of banks feels more directly threatened by potential dangers of a systemic nature than do banks here in the United States".

Focusing on the US, where data and evidence on these private arrangements have been most widely available, Donaldson (1992) provides several important insights. Using US data for the period 1873-1933, he shows that a stylized fact, during banking panics, was increased interest rates and plunging stock prices. He shows that the interest rates during panics were larger than the competitive rates, which he interprets as evidence for the strategic behavior of banks with excess liquidity. Using the strategic pricing model of Dunn and Spatt (1984), he shows that even if there is enough liquidity to satisfy all banks' liquidity demands, if some banks have a significant proportion of the excess cash

[7] In Germany, LikoBank was created in the 1970s to deal with liquidity problems at smaller banks.

so that the other cash rich banks' resources are not enough to satisfy the total liquidity demand, banks can exploit this captive demand and charge higher than competitive rates. He investigates the behavior of interest rates before and after the establishment of the Federal Reserve System and shows that the interest rates after the establishment of the Federal Reserve System were not different from the competitive rates while the rates were higher than the competitive rates during the pre-Fed period (see Table 1).

Donaldson also tests whether interest rates were determined by the same economic structure during panic and non-panic periods, which would support the view that cash was priced competitively even during panic periods, or whether there was a structural change between the panic and non-panic periods, which would suggest that interest rates were determined by a different mechanism during panic periods, and that cash-rich banks may have used their market power to exploit the difficulties of cash-stricken banks. He divides the sample into two, namely, the pre-Fed (1867-1913) and post-Fed (1914-1933) periods, and confirms through this econometric test that cash was indeed priced at higher than competitive rates during panics in the pre-Fed period whereas rates were not different from the competitive rates during panics in the post-Fed period (see Table 2 for results). This suggests that the establishment of the Federal Reserve System to act as a lender-of-last-resort during panic periods prevented cash-rich banks from exerting market power and exploiting cash-stricken banks.

Given this overall background of private arrangements and their effectiveness and failures, we provide below a detailed discussion of an episode from the US, the panic of 1907, where the private rescue of distressed banks was hampered by competitive behavior among banks.

1907 panic in the US: Sprague (1910) provides a detailed discussion of the 1907 panic in New York. He provides facts that support the view that the initial reluctance of banks in the organization of a private rescue of trust companies that experienced difficulties might have lied in the fact that other banks were not adversely affected from trust companies' difficulties or even benefited by attracting their depositors.

The immediate cause of the panic of 1907 was the collapse of copper stocks. On October 17, depositors started running on the Mercantile National Bank. The bank's president, Heinze, had attempted to corner the stock of United Cooper. Runs spread to banks controlled by other speculators, Morse and Thomas, who were 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 from their position. This action subdued severe runs on banks.

Trust companies, however, were also experiencing difficulties. Depositors who became suspicious about the involvement of trust companies in speculation started running on the Knickerbocker Trust Company on October 21 and on the Trust Company of America on October 23. The New York Clearing House, an organization of banks, did not extend assistance to the trust companies. The Knickerbocker was forced to suspend on October 22, and the Trust Company of America, a solvent institution, had to suffer runs for two weeks due to the lack of organized assistance. On November 6, New York trust companies, urged by J.P. Morgan, raised a fund of $25 million for distressed trust companies and required the Trust Company of America to deposit its shares and assets with a committee of trust company presidents. Runs on the Trust Company of America and other small institutions subsided after the resolution.

The banks controlled by Morgan and his associates experienced only minor difficulties in 1907 because of their reputation for soundness. According to Sprague (1910, pages 262-265), while five banks controlled by Heinze and Morse suffered severe withdrawals of deposits, the six strongest clearing house banks showed slight gains in deposits.

Chernow (1990), in the famous piece *The House of Morgan*, also provides a discussion of how J.P. Morgan benefited from the difficulties of trust companies during the 1907 crisis.[8] On November 2, J.P. Morgan finally organized a rescue package for the distressed Trust Company of America, for Lincoln Trust, and for Moore and Schley. Moore and Schley, a speculative brokerage house that was $25 million in debt, held a big majority stake in the Tennessee Coal and Iron Company as collateral against loans. If Moore and Schley had to liquidate that stake, it might collapse the stock market, and if Moore and Schley, in turn, collapsed, it might pull down other institutions as well.

To save Moore and Schley, J.P. Morgan wanted some benefit for himself and told friends that he had done enough and wanted some *quid pro quo*. J.P. Morgan arranged a deal where U.S. Steel, his favorite creation that could profit from Tennessee Coal's huge iron ore and coal holdings in Tennessee, Alabama and Georgia, would buy Tennessee Coal stock from Moore and Schley if trust company presidents assembled a pool of $25 million to protect weaker trusts. While under normal conditions, the takeover was impossible for antitrust reasons, US Steel managed to secure President Roosevelt's approval and the Sherman Antitrust Act would not be used against U.S. Steel. Wisconsin senator Robert La Follette said that bankers had rigged up the panic for their own profit. Financial analyst John Moody said that the Tennessee Coal and Iron's property had a potential value of about $1 billion, which confirmed the $45-million distressed price being a steal. Later on, Grant B. Schley, head of Moore and Schley, admitted that his firm could have

[8] See pages 126-128.

been rescued by an outright cash infusion rather than the sale of the Tennessee Coal stock.

The 1907 crisis paved the road to 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."[9]

In another case illustrating the hoarding of liquidity by banks, one chapter from the book *Citibank* by Cleveland and Huertas talks about the 1893 and 1907 crises and specifically discusses the strategy of the National City Bank (which became Citibank eventually) to anticipate the crises and to build up liquidity and capital before the crises to benefit from the difficulties of its competitors. Below is the paragraph about the 1907 crisis from this book (page 52):

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 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."

Evidence from other countries: Similar episodes have been observed in the UK as well. Bagehot wrote his famous work *Lombard Street* in 1873 in the aftermath of the Overend Gurney crash in 1866 when there was some suspicion that the unwillingness of the Bank of England, which was actually a private commercial bank at the time, to support that House was due to commercial rivalry. In his discussion of this episode, Bagehot points out that while it was accepted that the Central Bank should only attempt to assist those banks which could expect to be solvent or to regain solvency under normal conditions, a Central Bank should seek to act for the public good, and not simply as a private competitor for business.[10]

Another important example is the financial crisis in Australia in 1893. The Australian

[9] Sinclair, Andrew (1981) *Corsair: The Life of J. Pierpont Morgan*, Boston and Toronto: Little, Brown.

[10] See Chapter VII of Bagehot (1873), mainly the final two pages, and Goodhart and Schoenmaker (1995).

banking system, which was relatively unregulated during the second half of the 19th century with no central bank and no government-provided deposit insurance, experienced a banking crisis in 1893, where eleven commercial banks had failed and the rest had experienced severe bank runs. At the time of the crisis, the Associated Banks of Victoria was a coalition of private banks, just like the Clearing House Association in New York, and was initially set up to coordinate and divide the finances of the colonial governments. Before the crisis, the management of Associated Banks announced that, if and when the occasion arises, they would provide financial assistance to each other.[11] However, during the crisis, this arrangement proved to be ineffective when Federal Bank, a member of the Associated Banks, was allowed to fail without receiving any assistance in January 1893. Pope (1989) suggests that competitive pressures played a major role in the failure of private arrangements since banks had huge incentives not to bail out other banks as they gain from other banks' failures by increasing their market share.

3 The model

The timeline for our model is illustrated in Figure 1. Consider a model with three dates $t = 0, 1, 2$, two banks, Bank A and Bank B, universal risk neutrality and no discounting.[12]

At $t = 0$, Bank A owns 1 units of a risky asset, e.g., loans to the corporate sector. At $t = 2$, each unit of asset yields a random return $\widetilde{R} \in \{0, R\}$. For each unit, the return depends on whether the unit was monitored and on the state of nature ω, where ω is uniformly distributed over $[0, 1]$, as detailed below.

At $t = 1$, with probability x, the asset needs some refinancing of ρ units of cash per unit of asset. If a unit is not refinanced then $\widetilde{R} = 0$. If it is refinanced (or did not need refinancing), $\widetilde{R} = R$ if $\omega \in [0, p]$, and $\widetilde{R} = 0$ otherwise. The bank can affect the probability p by monitoring its loans at $t = 1$: $p = p_H$ if it monitors, and $p = p_L = (p_H - \Delta p)$ otherwise, with $\Delta p > 0$. There is a moral hazard problem because monitoring is non-verifiable and the bank enjoys a private benefit b per unit of asset if it does not monitor, with $\Delta p R > b$. We assume that it is always optimal to refinance each unit of asset, i.e.,

$$p_L R > \rho.$$

Bank B is assumed to have enough excess liquidity to refinance Bank A's assets. The transfer of liquidity can occur in two ways: Bank A can borrow from Bank B or sell it some of its assets.

[11] The Economist, 25 March 1893, page 364.

[12] The model has some similar features to Holmström and Tirole (1998).

Borrowing: Due to limited liability, moral hazard in monitoring limits Bank A's borrowing capacity. Indeed, a loan is a transfer L to Bank A against a repayment r if $\widetilde{R} = R$ and 0 if $\widetilde{R} = 0$. If Bank A is anticipated not to monitor, the assets are worthless and borrowing capacity is zero. For Bank A to choose to monitor, the following incentive compatibility constraint must hold:

$$\Delta p\,(R - r) \geq b. \tag{1}$$

Therefore, the maximum interest satisfying the constraint is:

$$r \leq (R - R_b) \text{ with } R_b \equiv \left(\frac{b}{\Delta p}\right). \tag{2}$$

In other words, Bank A must retain a sufficiently large stake to have an incentive to monitor its loans. Therefore, its borrowing capacity, i.e., the maximum loan it can get against each unit of asset is

$$p_H\,(R - R_b)\,. \tag{3}$$

Asset sales: Ownership of a unit of asset is sold to Bank B at a price P. We assume Bank A to be the most efficient user of its assets, i.e., they are Bank A-specific. This may stem from expertise or learning-by-doing effect for making and administering loans or the specific relationship it builds with its customers. Moreover, Bank A's advantage over Bank B in managing a particular loan may depend on some characteristic of the loan. For instance, smaller loans, or loans relying more on Bank A's relationship with the borrower may be more difficult for Bank B to take over. We assume that the relevant loan characteristic is represented by a variable θ distributed over $(0, +\infty)$ according to the cumulative distribution function (cdf) F. Smaller values of θ correspond to loans that are more difficult to redeploy to Bank B. If Bank B operates a loan of Bank A with characteristic θ, then

$$p = p_B(\theta) \in (p_L, p_H) \quad \text{and} \quad \left(\frac{dp_B(\theta)}{d\theta}\right) > 0.$$

With bank-specific assets, asset sales are less efficient than borrowing.[13] However, we assume that the moral hazard problem is severe (i.e., b large) enough so that Bank A can raise more funds by selling a unit of asset than by pledging some of the return it generates.[14]

[13] Implicitly, we are assuming that acquiring the ownership of the bank but leaving its operations unchanged is impossible, i.e., the change in ownership has real implications. For brevity, we use this reduced form rather than providing a foundation for the effect of ownership.

[14] We need that Bank B is better off liquidating some of Bank A's assets inefficiently. We don't need that it be better off liquidating all assets. For instance, we could assume that assets differ in the extent of moral hazard (i.e., R_b) or, probably more simply, in the inefficiency when run by Bank B (i.e., $p(\theta)$). This way, we can easily get that Bank B is best off liquidating only a fraction of Bank A's assets, but this is still inefficient.

Assumption 1 *For all θ, $p_B(\theta)R > p_H(R - R_b)$.*

We model the interaction of the two banks in the inter-bank lending and the asset markets using a two-stage bargaining game of alternating offer with risk of breakdown in the interim period. The game tree for our bargaining game is illustrated in Figure 2. First, Bank A makes Bank B a take-it-or-leave-it offer with three components: A subset of measure α of Bank A's assets to be acquired by Bank B, a conditional repayment $r \leq (1-\alpha) R$ from Bank A to Bank B, and a transfer T from Bank B to Bank A. This transfer corresponds to an average 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 for a given T, the split between P and L is indeterminate (unless $\alpha \in \{0, 1\}$).

If Bank B accepts the offer, it is implemented and bargaining is over. If Bank B rejects the offer then, with probability $(1-\beta)$, bargaining breaks down and each bank receives its outside option: X_i, for $i = A, B$.[15] With probability β, however, bargaining continues and Bank B gets to make a take-it-or-leave-it offer to Bank A. If Bank A accepts the offer, it is implemented. Otherwise, bargaining breaks down and each bank receives its outside option.

We assume that X_A and X_B are small enough, i.e., there are gains from trade between the banks. We also assume that each unit of capital that Bank B uses at $t = 1$ could have been invested in a project with a return of $(1 + \mu)$. Hence X_B can be written as the sum of the opportunity cost of using the necessary liquidity μT, and the other costs arising from keeping Bank A in business (e.g. that of not being able to steal some of Bank A's business). Hence, we can write $X_B = \mu T + Y_B$.[16,17]

4 Analysis

We solve the bargaining game by backward induction. A formal proof is in the Appendix.

Suppose that Bank B gets the chance to make an offer. Bank B's offer maximizes its payoff under the constraint that Bank A's payoff is not less than its outside option. It is easy to see that the optimal offer will satisfy three further properties. First, it must

[15] Section 5 discusses factors that might affect these outside options.

[16] We assume that Bank B cannot re-sell its claim on Bank A's assets to third parties or use them as collateral to borrow from third parties. Indeed, this would amount to Bank A being able to borrow from third parties. Similarly, Bank B cannot re-sell or borrow against the assets it buys from Bank A. What is needed is that when Bank B uses liquidity, at least part of its investment capacity is destroyed.

[17] For simplicity (and for now), we assume that Bank B does not borrow against its loans to Bank A or against the assets it buys from Bank A.

satisfy the incentive compatibility constraint (2), i.e., $r \leq (R - R_b)$. Indeed, otherwise Bank A has no incentive to monitor its loans and it is more efficient to sell them to Bank B. Second, Bank B's transfer to Bank A must be sufficient to refinance Bank A's remaining assets. Indeed, these assets would otherwise be worthless and it would again be more efficient to sell them to Bank B. Last, Bank B's optimal offer will be for Bank A to sell its most redeployable assets, i.e., all loans with θ above a threshold $\hat{\theta}_B$ (to be determined), that is, we have $\alpha = [1 - F(\hat{\theta}_B)]$. This is because these are the loans whose sale is the least inefficient.

Given these remarks, Bank B's problem can be written as:

$$\begin{array}{ll} \max\limits_{\hat{\theta}_B, r, T} & \int\limits_0^{\hat{\theta}_B} p_H r dF(\theta) + \int\limits_{\hat{\theta}_B}^{+\infty} \left[p_B(\theta)R - \rho\right] dF(\theta) - T \\ s.t. & r \leq (R - R_b) \\ & T \geq F(\hat{\theta}_B)\rho \\ & \int\limits_0^{\hat{\theta}_B} \left[p_H\left(R - r\right) - \rho\right] dF(\theta) + T \geq X_A. \end{array} \tag{4}$$

Lemma 1 *Suppose that Bank B gets to make an offer.*

- *Bank B offers Bank A a transfer* $\hat{T}_B = \left[\left(\frac{X_A}{p_H R_b}\right)\rho\right]$ *against the sale of all loans with* $\theta \geq \hat{\theta}_B$ *and a debt claim* $\hat{r}_B = (R - R_b)$ *where* $\hat{\theta}_B$ *is defined by* $F(\hat{\theta}_B) = \left(\frac{X_A}{p_H R_b}\right)$.
- *Bank B's expected payoff is:*

$$\pi_B = \int\limits_0^{+\infty} \left[p_B(\theta)R - \rho\right] dF(\theta) - X_A + \int\limits_0^{\hat{\theta}_B} \left[p_H - p_B(\theta)\right] R dF(\theta). \tag{5}$$

The intuition for the form of the offer is as follows. Bank B prefers to acquire as much of Bank A's assets as possible subject to Bank A getting its reservation payoff. This is because, under Assumption 1, a transfer of ownership is the most efficient means to transfer value from Bank A to Bank B. For instance, for $X_A = 0$, Bank B acquires all of Bank A's assets for free, i.e., sets $\hat{\theta}_B = +\infty$ and $T = 0$. As X_A increases, Bank B must ensure that Bank A accepts its offer. The most efficient way of increasing Bank A's payoff is for Bank B to leave it with some assets and refinance them, i.e., $T = F(\hat{\theta}_B)\rho$. Because Bank A is best at managing its assets, this is preferred to Bank B making a cash transfer to Bank A in excess of the funding needs. For the same reason, it is always weakly optimal to maximize r, i.e., set $r = (R - R_b)$.

The intuition for Bank B's expected payoff is as follows. The first term is the payoff Bank B would get if it acquired all of Bank A's assets at price $T = 0$, i.e., if $X_A = 0$. When $X_A > 0$, Bank B must "transfer back" value X_A to Bank A. This is the second term, X_A. This transfer is efficient since Bank A is the assets' best user. Therefore, leaving value X_A to Bank A costs less than X_A to Bank B. This is reflected in the third term.

Now consider the previous stage, when Bank A makes the first offer. For Bank B to accept an offer, it must ensure that Bank B receives an expected payoff at least equal to

$$E(\pi_B) = \beta\pi_B + (1-\beta)X_B. \tag{6}$$

As before, the optimal offer will satisfy three additional properties: Bank A will sell its most redeployable assets, i.e. the loans with θ above some threshold θ^*, and set $r \leq (R - R_b)$ and $T \geq F(\theta^*)\rho$. Hence, Bank A's problem can be stated as:

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

Proposition 1 *In equilibrium, Bank A and Bank B agree on a sale of all assets with $\theta \geq \theta^*$ and a debt contract with $r^* = (R - R_b)$ against a transfer $T^* = F(\theta^*)\rho$, and Bank A's payoff is $\pi_A = p_H R_b F(\theta^*)$, where θ^* is defined by*

$$\int_{\theta^*}^{+\infty} [p_B(\theta)R - p_H(R - R_b)]\, dF(\theta) = E(\pi_B) + \rho - p_H(R - R_b). \tag{8}$$

The expression for θ^* is intuitive. In equilibrium, Bank B must contribute ρ to refinance all of Bank A's loans, and enjoy an expected payoff $E(\pi_B)$. Part of $[E(\pi_B) + \rho]$ is funded with claims of Bank B in Bank A. Due to moral hazard, the maximum value of the claims Bank B can hold in Bank A is $p_H(R - R_b)I$. Therefore the RHS is simply the shortfall that Bank A can only bridge by selling assets. Indeed owning one unit of asset is more valuable to Bank B than the maximum claim it can hold against that asset, i.e., $p_B(\theta)R > p_H(R - R_b)$.

We highlight some properties of the negotiation's outcome in the following corollary. Note that in equilibrium, Bank A sells a fraction $[1 - F(\theta^*)]$ of its assets which involves

a deadweight loss of

$$\int_{\theta^*}^{+\infty} \left[\left(p_H - p_B(\theta)\right) R\right] dF(\theta).$$

Each part of the corollary can be derived by taking the derivative of equation (8) with respect to the parameter being varied.

Corollary 1 *The fraction* $[1 - F(\theta^*)]$ *of Bank A's assets sold to Bank B in equilibrium and the associated inefficiency*

- *increase with the liquidity need* ρ*,*
- *increase with Bank B's market power* β*,*
- *increase with Bank B's outside option* Y_B*,*
- *increase with Bank B's opportunity cost of capital* μ*,*
- *decrease with Bank A's outside option* X_A*,*
- *and decreases with Bank B's effectiveness at running Bank A's assets* p_B*.*

The intuition is as follows. Let $\alpha^* = [1 - F(\theta^*)]$.

- $\frac{\partial \alpha^*}{\partial \rho} > 0$, i.e., as ρ increases, Bank A sells more assets.
- $\frac{\partial \alpha^*}{\partial \beta} > 0$, i.e., as β increases, Bank A sells more assets. Indeed, when β increases, so does Banks B's reservation payoff $E(\pi_B)$. Therefore, Bank A must transfer more value to Bank B. Once Bank A has exhausted its borrowing capacity, it must start selling assets to Bank B as, in this case, this is the most effective means of transferring value to Bank B (Assumption 1).
- $\frac{\partial \alpha^*}{\partial X_B} > 0$ and $\frac{\partial}{\partial \beta}\left(\frac{\partial \alpha^*}{\partial X_B}\right) < 0$, i.e., an increase in Bank B's outside option leads to more asset sales, and this effect is stronger when Bank B's bargaining power is small. The intuition is as follows. An increase in X_B increases $E(\pi_B)$ leading to more asset sales. The effect is larger when β is small because X_B represents a smaller fraction of bank B's reservation payoff $E(\pi_B)$.
- $\frac{\partial \alpha^*}{\partial X_A} < 0$ and $\frac{\partial}{\partial \beta}\left(\frac{\partial \alpha^*}{\partial X_A}\right) < 0$, i.e., an increase in Bank A's outside option leads to less asset sales, and this effect is stronger when Bank B's bargaining power is large. The intuition is as follows. An increase in X_A reduces $E(\pi_B)$ leading to less asset sales. The effect is larger when β is large because X_A represents a smaller fraction of Bank A's payoff.

- $\frac{\partial}{\partial \beta}\left(\frac{\partial \alpha^*}{\partial b}\right) > 0$ with $\frac{\partial \alpha^*}{\partial b} < 0$ for low values of β and $\frac{\partial \alpha^*}{\partial b} > 0$ for high values of β: There are two countervailing effects of a worsening of the moral hazard problem, i.e., of an increase in private benefit b.

- $\frac{\partial \alpha^*}{\partial p_B} < 0$, i.e., the more effective Bank B is at managing Bank A's assets, the less asset sales will occur in equilibrium. There are two countervailing effects. On the one hand, an increase in p_B increases Bank B's payoff π_B when it makes the offer, which in turns increases its reservation payoff $E(\pi_B)$ when Bank A makes the offer. On the other hand, for a given reservation payoff, Bank A needs to sell less assets to ensure that Bank B accepts the offer.

5 Outside options

We discuss factors affecting the banks' outside options, relating them to the extent of specificity of Bank A's assets and to the possibility of a Central Bank intervention.

5.1 Loan size distribution

We now model explicitly the fact that Bank A has access to competitive outside markets for borrowing and asset sales. We assume that Bank B has an advantage over outsiders both for using Bank A's assets and for lending against them, which we model as follows.

Asset sales: We assume that if an outsider operates a loan of Bank A with characteristic θ then $p = p_o(\theta) \in (p_L, p_H)$. We assume that Bank B has an advantage over outsiders both for managing Bank A's assets, i.e., $p_o(\theta) < p_B(\theta)$, and that this advantage decreases with θ, i.e.,

$$\frac{dp_o(\theta)}{d\theta} > \frac{dp_B(\theta)}{d\theta}.$$

In other words, those projects 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. Said differently, we assume that Bank A-specificity of loans and bank-specificity of loans (relative to outsiders) are correlated. Note that this assumes a special role of banks relative to outsiders, e.g., banks are better monitors of small, relationship-specific loans (Fama, 1985, James, 1987, James and Houston, 1996, among others).

Borrowing: We assume that Bank B is potentially more effective than outsiders at making loans to Bank A in that it can better monitor Bank A's small loans compared

to outsiders.[18,19] In particular, we assume that when borrowing from outsiders, Bank A's benefit from not monitoring is $b_o \geq b$. Hence, when borrowing from outsiders, Bank A must retain a larger exposure to the loan to have an incentive to monitor, i.e., $R_b^o = \left(\frac{b_o}{\Delta p}\right) > R_b$.

Suppose that bargaining has broken down and consider Bank A and Bank B's payoffs. For now, we assume that Bank B's outside option X_B is independent of Bank A's distribution of loan characteristics, i.e., of the cdf F.[20] As before, it will optimally sell to outsiders all loans with θ above a certain threshold $\hat{\theta}_o$.

Lemma 2 *Suppose that bargaining between Bank A and Bank B breaks down.*

- *Bank A and outsiders agree on a sale of all assets with $\theta \geq \hat{\theta}_o$ and a debt contract $\hat{r}_o = (R - R_b^o)$ against a transfer $\hat{T}_o = F(\hat{\theta}_o)\rho$, where $\hat{\theta}_o$ is defined by*

$$\int_{\hat{\theta}_o}^{+\infty} [p_o(\theta)R - p_H(R - R_b^o)]\, dF(\theta) = \rho - p_H(R - R_b^o). \tag{9}$$

- *Bank A's payoff (i.e., its outside option) is given by*

$$X_A = p_H \left[R_b^o F(\hat{\theta}_o)\right]. \tag{10}$$

These expressions for $\hat{r}_o$, $\hat{T}_o$ and $\hat{\theta}_o$ can be obtained using the analysis in Proposition 1 by substituting outsiders for Bank B, and its intuition is therefore similar. Indeed, the offer that Bank A makes to the outsiders is similar to that it would make to Bank B if Bank B 's outside option were $E(\pi_B) = 0$, and its ability to manage assets and lend against assets were the same as that of outsiders, i.e., $p_B(\theta) = p_o(\theta)$ and $R_b = R_b^o$. The expression of X_A is also intuitive. Because selling assets is inefficient, Bank A will sell as few as possible and borrow as much as possible against the assets it retains. This means that the only claim it will hold on each unit of asset is the absolute minimum R_b^o.

As a corollary, we get the effect of the distribution of loan characteristics on Bank A's outside option X_A. Specifically, we characterize the effect on X_A of a shift of the cdf towards higher values of θ in the sense of first order stochastic dominance (FOSD).

[18] Several papers in the literature focus on the role of peer monitoring in interbank markets (see Rochet and Tirole, 1996, and Freixas and Holthausen, 2005 for theoretical models based on this assumption, and Furfine, 2001 for empirica analysis in support of the assumption). Peer monitoring among banks is considered important because of the large and unsecured nature of the inter-bank loans. Also, inter-bank lending relationships are perceived to help overcome agency problems.

[19] Also for now, we assume that a party's ability to monitor is independent of Bank A's asset mix.

[20] This will not be the case, for instance, if Bank B has an easier time stealing one type of loans if bargaining breaks down.

Corollary 2 *Bank A's outside option X_A increases with the outsiders' ability to monitor loans to Bank A (i.e., decreases with b_o) and with a shift of the distribution F of loan characteristics towards higher values in the sense of FOSD.*

We can now analyze the bargaining game between Bank A and B and derive properties of the equilibrium outcome. Recall that Bank A sells all its loans with θ above a threshold θ^*. This threshold does depend on the distribution of loan characteristics. Therefore the fraction $[1 - F(\theta^*)]$ of assets sold by Bank A to Bank B and the associated deadweight loss

$$\int_{\theta^*}^{+\infty} [(p_H - p_B(\theta))\, R]\, dF(\theta),$$

depend on F directly but also through its effect on the threshold θ^*.

Proposition 2 *An improvement of the outsiders' ability to monitor loans to Bank A (i.e., a decrease in b_o) and a shift of the distribution F of loan characteristics towards higher values in the sense of FOSD have the following effects:*

- *The threshold θ^* over which loans are sold to Bank B increases.*
- *The fraction of loans $[1 - F(\theta^*)]$ sold to Bank B decreases.*
- *The deadweight loss associated with the liquidity transfer decreases.*

The effect of a decrease in b_o is fairly straightforward. Indeed, such a change increases X_A but keeps all other variables constant. Therefore, this result is a simply implication of Corollary 1. The effect of a shift of 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 that need liquidity have a large share of their portfolio in small, relation-specific loans, as this decreases the outside option of cash-stricken banks, giving cash-rich banks a better opportunity to exert market power and exploit cash-stricken banks' difficulties.

6 Central Bank

Goodfriend and King (1988) argue that with efficient interbank markets, Central Banks should refrain from lending to individual banks, rather, they should provide sufficient liquidity via open market operations and the interbank market would provide an efficient allocation of liquidity among banks. So far, we showed how strategic behavior among banks can lead to failures in the efficient functioning of the interbank market. An important implication is that aggregate liquidity being sufficient is not a guarantee that liquidity will find its way to those that are in need of it. In this context, we analyze how a Central Bank acting as a LOLR can provide an outside option to liquidity-stricken banks when liquidity-rich banks try to exploit their market power. We analyze under what circumstances, a Central Bank can improve market outcomes, i.e., reduce excessive asset sales, in a number of related ways. We also discuss some alternative policies briefly.

6.1 Lender of Last Resort (LOLR)

In this section, we analyze the LOLR role of the central bank. During this analysis, several interesting points arise. First, the Central Bank would not have to actually extend loans in equilibrium: It is sufficient that it provides potential competition to Bank B who would then have to lower the cost of liquidity. Therefore, the Central Bank could be effective at little cost. Second, unless the Central Bank is a more effective lender than outsiders, these loans would have to be loss-making. This in turn raises several issues: (i) if the Central Bank stands as a LOLR, it will have incentives to improve its ability to make loans, e.g., its ability to assess and monitor borrowing banks, possibly over and above that of outsiders; and (ii) it may be optimal to assign other tasks (e.g., supervision) to the Central Bank if they provide expertise in monitoring loans.[21] In the analysis to follow, we assume for simplicity that the outside option of Bank A is to generate liquidity from the Central Bank only, rather than both from outside markets as well from the Central Bank. While the latter case is more realistic, we focus on the simpler case as it has qualitatively similar implications.

6.1.1 Case 1: LOLR with no supervision and no loss-making loans

Suppose that the central bank is exactly as effective as outsiders in monitoring Bank A's assets, that is, $b_{CB} = b_o$. Furthermore, suppose that the central bank is not willing to accept any expected losses from the loans it makes to Bank A. In that case, Bank A's outside option by going to the central (X_A^{CB}) is exactly equal to the outside option when

[21] Note that this argument is different from that saying that since the Central Bank is a LOLR, it ought to supervise/monitor banks so as to avoid that they be in a position to need the LOLR.

Bank A goes to the outsiders, that is,

$$X_A^{CB} = X_A = p_H \left[R_b^o F(\hat{\theta}_o) \right]. \tag{11}$$

Hence, in this case, the outcome does not change and the same amount of Bank A's assets are sold to Bank B.

Proposition 3 *A Central Bank that does not make any loss-making loans to Bank A and is no better than outsiders in monitoring Bank A cannot ameliorate the inefficiency arising from the market power of Bank B.*

6.1.2 Case 2: LOLR with some loss-making loans, but no supervision

Now, suppose that the central bank is exactly as effective as outsiders in monitoring Bank A's assets, but is willing to accept some expected losses, which can be viewed as the central bank extending the range of collateral it accepts for its LOLR facility. Suppose that the central bank injects funds of T^{CB} to Bank A. We assume that this results in a cost of $L(T^{CB})$ for the central bank, where $L(x)$ is an increasing function of x with $L(0) = 0$. As a result of the injection of funds of T^{CB} from the central bank, Bank A can now keep a larger share of its assets, that is, Bank A can keep the assets with $\theta \in (0, \theta(T^{CB}))$, where $\theta(T^{CB}) > \theta^*$. The central bank chooses the amount T^{CB} to inject that maximizes

$$\int_{\theta^*}^{\theta(T^{CB})} \left[(p_H - p_B(\theta))\, R \right] dF(\theta) - L(T^{CB}). \tag{12}$$

6.1.3 Case 3: LOLR with supervision

In this section, we analyze how supervision of banks can provide an improvement and limit central bank's losses. Suppose that the Central Bank, by supervising banks, can monitor banks better than outsiders, i.e., $b \leq b^{CB} \leq b_o$, where b^{CB} is the private benefit when Bank B borrows from the Central Bank.[22,23]

[22] Our results would be stronger if we allow the Central Bank to be more efficient that other banks in monitoring. However, what we derive is a stronger result as we show that even a Central Bank that is not necessarily as efficient as other banks in monitoring can decrease the inefficiency in liquidation.

[23] Berger et al. (2000) test the hypothesis that supervisors have more accurate information than the market on the soundness of financial institutions using data from the US. They show that shortly after supervisors have inspected a bank, supervisory assesment of the bank is more accurate than the market. However, for periods where the supervisory information is not up-to-date, market has more accurate information than supervisors.

From equation (2), if the lending party is better than outsiders at monitoring Bank A, Bank A does not need to retain as large an exposure for incentive reasons, i.e., $R_b \leq R_b^{CB} < R_b^o$. Hence, Bank A's borrowing capacity is larger. This, in turn, eases the liquidity constraint of Bank A and increases its outside option, which eventually decreases inefficient liquidations.

Furthermore, as Bank A can pledge a larger fraction of its return to the central bank, it follows that in order to leave the same fraction of assets with Bank A, the central bank needs a smaller amount of funds to be transfered to Bank A, that is, $\left(\frac{\partial T^{CB}}{\partial b_{CB}}\right) < 0$. Hence, by supervision, the central bank can limit its losses. However, there may be a cost of monitoring and the central bank may incur a cost of $c(b_{CB} - b_o)$ for its monitoring activities. If $c(\cdot)$ is increasing and sufficiently convex, there exists an interim value for the optimal level of supervision the central bank performs.

6.1.4 Outsiders as monitors

The analysis begs the natural question of why outsiders do not monitor banks and assume some of the roles of the regulator. One potential reason for this is that banks may be more forthcoming to disclose information to the regulator, knowing that such information may not be used against them in the market, whereas outsiders, who may be participants of similar markets as banks, may not be credible in not using such information for their own advantage. Hence, banks may not be willing to disclose information to outsiders, whereas they may be more forthcoming to do so when they deal with the regulator.

Furthermore, it may be the case that with some probability, the Central Bank actually has to make the loan. The Central Bank may be willing to take that risk while outsiders are not. Also, it may be that in order to commit to being able to make the loan, the Central Bank has to tie up some capital, which is a cost outsiders would not want to incur.

6.2 Alternative policies

In this section, we briefly discuss some alternative policies the regulator can employ to prevent excessive liquidation of Bank A's assets.

6.2.1 Price caps

First, the Central Bank can put a cap on the price that Bank B charges Bank A for the provision of liquidity. Note that this type of regulation would have to take the entire set of transactions between Bank A and Bank B into account. That is, regulating the lending rate only would not be effective since for a given α the same transfer T can be achieved with many pairs (L, P). Hence, the regulator needs to introduce caps in the lending as well as the asset market.

However, introducing such price caps and enforcing them can be costly as the underlying parameters that affect these prices keep on changing in reality. Hence, introducing price caps may not be a robust policy.

6.2.2 Intervention in the asset market

One other alternative policy the regulator can use is to intervene in the asset markets as the cash-rich banks can exploit their power and force excessive liquidations in this market. The regulator can intervene in the asset market and allocate Bank A's assets to Bank B on the condition that Bank B will lend to Bank A at competitive rates. This way, Bank A can borrow from Bank B at competitive rates and excessive liquidation of Bank A's assets is prevented.

7 Discussion

7.1 Ex-ante market for liquidity transfers

In Allen and Gale (2000), banks insure each other against uncertain liquidity shocks that are imperfectly correlated across banks. While the interbank market can help transfer liquidity from cash-rich banks to cash-stricken banks, it cannot create additional liquidity. Hence, the interbank market is inherently fragile in that when there is an aggregate shortage of liquidity, banks' cross holdings act as shock transmitters, spreading the initial shock to the entire banking system.

Leitner (2005) builds a model of financial networks where linkages can lead to contagion as in Allen and Gale (2000). However, the threat of contagion resulting from bank failures induce private-sector bailouts in which liquid banks bail out illiquid banks. He shows that when formal commitments are impossible, the possibility of private bailouts may make linkages optimal ex-ante since linkages allow banks to obtain mutual insurance. As in our

model, he shows that when liquidity is concentrated among a small group of banks, the whole network may collapse as bailing out distressed banks may be too costly for banks with excess liquidity. However, in our model, the failure of private arrangements result from the benefit cash-rich banks can get in the asset market resulting from their market power in the lending market, which are some differentiating aspects of our model that lend our model some richness and generality.

7.2 Evidence of competitor gains in post-Federal Reserve banking system

The empirical event studies test whether bad news, such as a failure, the announcement of an unexpected increase in loan-loss reserves, seasoned stock issue announcements, etc., adversely affect other firms. If the effect is negative, the empirical literature calls it the "contagion effect." If the effect is positive, it is termed the "competitive effect." The intuition is that demand for the surviving competitors' products (deposits, in the case of banks) can increase.

Saunders and Wilson (1996) examine deposit flows in 163 failed and 229 surviving banks over the Depression era of 1929–1933 in the U.S. They find evidence for flight to quality for years 1929 and 1933: withdrawals from the failed banks during these years were associated with deposit increases in surviving banks. While the authors show that, for the period 1930–1932, deposits in failed banks as well as surviving banks decreased, they find that the deposit decrease in the failed banks exceeded those at the surviving banks. Saunders (1987) studies the Continental Illinois episode and shows that the announcement made by the U.S. Office of the Comptroller of the Currency on May 10th 1984 to deny "rumors" about Continental seems to have triggered a flight to quality.[24]

Slovin, Sushka and Polonchek (1999) examine share price reactions to announcements of dividend reductions and regulatory enforcement actions for commercial banks and their rivals that are traded on the New York or American Stock Exchange over the period 1975 through 1992. They find that while dividend reductions at money center banks gener-

[24]In further supporting evidence, Schumacher (2000) examines the 1995 banking crisis in Argentina triggered by the 1994 Mexican devaluation and finds evidence for flight to quality. In particular, she runs a regression of deposit flows on systemic and bank-specific risk components such as ratio of peso deposits to dollar deposits, the share of time deposits in total deposits, and a series of dummy variables on bank characteristics such as domestic versus foreign, retail versus wholesale, etc. She shows that after the failure of some domestic wholesale banks, surviving domestic wholesale banks suffered significant deposit losses whereas foreign retail banks, and to some extent large domestic banks, had significant increases in their deposits during the crisis. In particular, she finds that after adjusting for the composition of their deposits, retail foreign banks increased their total deposits on average 6% per month during the panic period between December 1994 and May 1995.

ate industry-wide contagion effects, such reductions at regional banks generate positive competitive effects on banks in the same geographic area. These competitive effects are observed when dividend reductions reflect bank-specific causes, and are magnified in concentrated markets. They show that while enforcement actions against money center banks have no intra-industry effects, actions against regional banks generate positive competitive effects on geographic rivals, paralleling regional bank dividend reduction results.[25]

7.3 Application to capital markets

In the last ten years, we have experienced two well-known episodes in the capital markets, the collapse of two hedge funds, Long Term Capital Management (LTCM) in 1998 and that of Amaranth in 2006. In both of these episodes, there is suggestive evidence that other players in markets tried to benefit from the difficulties of LTCM and Amaranth. Below, we provide a discussion of these two episodes in conjunction with some recent related studies.

After its remarkable success during 1994-1997, LTCM began to experience difficulties during the financial turmoil triggered by the Russian default in August 1998. During the crisis, LTCM had to buy large amounts of Treasury bond futures contracts to unwind its short position. With correct anticipation of the direction of LTCM's trades and the advantage of being able to observe customer order flow, market makers had incentives to engage in front running, i.e., trading in the same direction as LTCM knowing that the order will be coming and then unwinding the position afterwards to profit from the price impact of the expected order.

For example, *Business Week*[26] 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." In a recent empirical study, Cai (2003) uses a unique dataset to examine the trading behavior of market makers in the Treasury bond futures market when LTCM faced binding margin constraints in 1998 and finds evidence 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 various features of LTCM's trades through Bear

[25] Lang and Stulz (1992) investigates the effect of bankruptcy announcements on the equity value of bankrupt firm's competitors. They find that the competitive effect is dominant for highly concentrated industries with low leverage, suggesting that in such industries competitors benefit from the difficulties of the bankrupt firm. In particular, using the Herfindahl index of industry concentration as a proxy for the degree of imperfect competition, they show that the value of competitors' equity actually increases by 2.2% in more concentrated industries with low leverage.

[26] *Business Week*, February 26, 2001, "The Wrong Way to Regulate Hedge Funds."

Stearns. That is, market makers traded on their own accounts in the same direction as PI7 customers did, but one or two minutes beforehand. Furthermore, a significant percentage of market makers made abnormal profits on most of the trading days during the crisis.

Eventually, fearing that the fall of LTCM might lead to costly disruptions in the financial markets, the Federal Reserve Bank of New York hosted a meeting of fourteen financial institutions that led to a private sector recapitalization of LTCM. The private recapitalization of LTCM relaxed its binding constraints and helped LTCM avoid fire sales, and this, in turn, reversed the profitability of speculative trading against LTCM.

Similarly a recent article in the *Wall Street Journal*[27] discusses Amaranth LLC's failure and the efforts of other players in the energy market to benefit from its difficulties. When the risky bets Amaranth took in the energy market turned out to be unfavorable, it started to lose value and by the end of Friday, September 15, 2006, it 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 non-energy investments but thinking that some of these investments could not be liquidated quickly, Amaranth started negotiations with Wall Street banks to raise cash. After lengthy negotiations, Amaranth secured a deal with Goldman Sachs that would require Amaranth to pay nearly $1.85 billion to take toxic trades off its hands. Amaranth intended to use the cash, amounting to $1 billion to $2 billion, held by J.P. Morgan in a margin account, to pay Goldman Sachs for the deal. However, J.P. Morgan 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, and this killed the deal.

Later on, J.P. Morgan got into the game and agreed to jointly assume most of Amaranth's energy positions with a partner, Citadel Investment Group. 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 from huge losses during the process, J.P. Morgan earned an estimated $725 million from the deal. In a speech in November 2006, Mr. Dimon, J.P. Morgan's CEO, said that the Amaranth deal produced a "very nice increment to fixed-income trading" and in January 2007, the *RISK* magazine named J.P. Morgan "Energy Derivatives House of the Year."

To summarize, these two episodes illustrate that market for liquidity transfers are often ridden by inefficiencies even in the broader landscape of financial institutions (not

[27] *Wall Street Journal*, 30 Jan, 2007, "Amid Amaranth's Crisis, Other Players Profited".

just banks), especially when stakes from strategic behavior in liquidity transfers are high.

Some recent papers model such strategic behavior. Brunnermeier and Pedersen (2005) build a model of predatory trading where traders exploit the difficulties of other traders that face forced liquidations. They show that if a distressed large investor is forced to 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. Similarly, Carlin, Lobo and Vishwanathan (2007) analyze the breakdown in cooperation between traders, which manifests itself in predatory trading leading to a liquidity crunch in the market. They build a repeated game where traders cooperate most of the time through repeated interaction and provide liquidity to each other. However, cooperation can break down, especially when the stakes are high, which leads to predatory trading. While our paper has similarities with these studies, our model is not exclusively about predatory trading or the break-down of cooperation that has been established through repeated interaction, but is about the ability to exploit market power in one market (inter-bank lending market) to benefit in another market (market for asset sales). More broadly, our model shows that when liquidity is distributed asymmetrically and surplus liquidity is concentrated in the hands of a few players, market failures in liquidity transfers can arise, a point that should find resonance and application in many settings, not just in the context of banking.

8 Conclusion

In this paper, we propose that during crises, surplus banks may not lend efficiently to needy banks due to the strategic gains to be made upon the closure of troubled banks or more generally, upon the liquidation of their assets. This problem was shown to be more acute the weaker the market for assets outside of the banking sector, a scenario that would arise, for instance, in liquidation of information-sensitive and specific loans made to small borrowers.

Such strategic behavior describes well the crises episodes in the pre-Federal Reserve era and provides a rationale for the existence of the Central Bank. A Central Bank, that is credible in providing liquidity to banks in need at competitive rates, can eliminate the bargaining power of surplus banks in the inter-bank market and thereby restore the efficiency of liquidity transfers and asset sales. This lender-of-last-resort rationale is complementary to the traditional rationale for existence of the Central Bank which is as a lender of last resort when there is an aggregate shortage of liquidity. Our model illustrates

that the public provision of liquidity can improve the private provision of liquidity even when there is no aggregate shortage of liquidity. More broadly, our model also provides a rationale for the Central Bank or a similar regulator to play the role of coordinating liquidity injection to needy institutions, if required, through moral suasion.

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Appendix

Proof of Lemma 1: It is easy to see that the problem can be written as:

$$\begin{array}{ll} \max\limits_{\hat{\theta}_B} & \int\limits_0^{\hat{\theta}_B} p_H(R-R_b)dF(\theta) + \int\limits_{\hat{\theta}_B}^{+\infty} \left[p_B(\theta)R\right] dF(\theta) - \rho \\ s.t. & F(\hat{\theta}_B)\left(p_H R_b\right) \geq X_A \end{array}. \tag{13}$$

From Assumption 1, the FOC can be written as:

$$p_H(R-R_b) - p_B(\theta)R < 0,$$

so that the constarint is binding. Hence, we have $F(\hat{\theta}_B) = \left(\frac{X_A}{p_H R_b}\right)$. Thus, we can write Bank B's expected payoff as:

$$\pi_B = \int\limits_0^{+\infty} \left[p_B(\theta)R - \rho\right] dF(\theta) - X_A + \int\limits_0^{\hat{\theta}_B} \left[p_H - p_B(\theta)\right] RdF(\theta). \tag{14}$$

■

Proof of Proposition 1: Bank B's participation constraint is binding since otherwise, Bank A can always increase the transfer from Bank B. Hence, we have:

$$T = F(\theta^*)\left[p_H(R-R_b)\right] + \int\limits_{\theta^*}^{+\infty} \left[p_B(\theta)R - \rho\right] dF(\theta) - E\left(\pi_B\right). \tag{15}$$

In turn, we can write the maximization problem as:

$$\begin{array}{ll} \max\limits_{\theta^*} & \int\limits_0^{\theta^*} \left[p_H R\right] dF(\theta) + \int\limits_{\theta^*}^{+\infty} \left[p_B(\theta)R\right] dF(\theta) - \rho - E\left(\pi_B\right). \\ s.t. & T \geq F(\theta^*)\rho \end{array}. \tag{16}$$

Since $p_H > p_B(\theta)$ for all $\theta \in (0, +\infty)$, the objective increases in θ^*. Hence, by combining the two constarints from the original problem, Bank A's problem can be written as

$$\begin{array}{ll} \max\limits_{\theta^*} & \theta^* \\ s.t. & \int\limits_0^{\theta^*} \left[p_H(R-R_b)\right] dF(\theta) + \int\limits_{\theta^*}^{+\infty} \left[p_B(\theta)R\right] dF(\theta) - E\left(\pi_B\right) - \rho \geq 0 \end{array}. \tag{17}$$

Note that the left-hand side of the constraint is decreasing in θ^* since from Assumption 1, we have $p_H(R - R_b) < p_B(\theta)R$. Hence, the constraint is binding so that $T^* = F(\theta^*)$ and θ^* satisfies:

$$\int_{\theta^*}^{+\infty} [p_B(\theta)R - p_H(R - R_b)]\, dF(\theta) = E(\pi_B) + \rho - p_H(R - R_b). \tag{18}$$

■

Proof of Corollary 2: Let F and G be two cdfs for θ, with the property that F FOSD G. Let $\hat{\theta}_o^F$ and $\hat{\theta}_o^G$ be the threshold values under F anf G, respectively. By FOSD, we have:

$$\int_{\widehat{\theta}_o^F}^{+\infty} [p_o(\theta)R]\, dF(\theta) - \int_{\widehat{\theta}_o^G}^{+\infty} [p_o(\theta)R]\, dG(\theta) = p_H(R - R_b^o) \left[F(\widehat{\theta}_o^F) - G(\widehat{\theta}_o^G) \right]. \tag{19}$$

TO BE COMPLETED. ■

Proof of Proposition 2: TO BE COMPLETED. ■

Table 1: Interest rates during panic periods (high/average/low)

Year	**1873**	**1884**	**1890**	**1893**	**1907**	**1914**	**1933**
Begin and end weeks	**38-47**	**20-21**	**46-50**	**26-31**	**43-52**	**31-49**	**9-13**
1 week before the panic	11/10/5	6/4/2	25/6/3	25/9/3	10/5/3	3.87	1.00
First week of the panic	548/162/5	127/49/2	186/8/3	74/15/4	125/40/5	7.00	2.06
Extreme value attained	548/162/7	188/66/2	186/8/3	74/15/4	125/50/6	7.00	4.31
Last week of the panic	23/17/6	188/66/1	186/6/2	51/9/2	25/20/6	4.25	3.60
1 week after the panic	11/9/6	8/4/1	6/4/2	6/5/2	9/6/2	3.50	1.91
13 weeks after the panic	5/4/3	3/2/1	4/3/2	2/2/1	2/2/1	2.00	1.00

Reproduced from Donaldson (1992) (Table I, page 66).
Beginning and ending dates: *Financial Review* Retrospects of 1873, 1884, 1890, 1893, and 1907, and Friedman and Schwartz (1963).
Interest rate: the rate charged on a call loan at the New York Stock Exchange during the week in question as reported in the Financial Review and Banking and Monetary Statistics. The average is available on for 1914 and 1933.

Table 2: Determinants of the interest rate

Constant	Cash reserves	Deposit changes	Stock changes	Panic constant	Panic cash reserves	Panic deposit changes	Panic stock changes	*F* test for structural change	R^2
				1867-1933					
4.179*	-0.012*	-0.054	-0.004	1.164	-0.054*	-1.899*	-0.131	196.0*	0.22
(53.99)	(-12.1)	(-1.64)	(-0.11)	(1.990)	(-8.82)	(-14.1)	(-0.85)	(43475)	
				1867-1913					
4.192*	-0.013	-0.087	0.003	14.41	-0.011	-6.534	-0.202	252.5	0.42
(44.45)	(-12.4)	(-1.93)	(0.051)	(7.770)	(-1.46)	(-26.4)	(-0.93)	(42386)	
				1914-1933					
4.197*	-0.001	-0.014	-0.002	-1.114	-0.021	-0.090	0.159	0.55	0.01
(59.21)	(-0.44)	(-0.58)	(-0.10)	(-0.87)	(-0.80)	(-0.80)	(1.171)	(41032)	

Reproduced from Donaldson (1992) (Table II, page 67).
The table reports results from the OLS regression:

$$r_t = \beta_0 + \beta_1 C_t + \beta_2 D_t + \beta_3 S_t + \gamma_0 P_t + \gamma_1 P_t C_t + \gamma_2 P_t D_t + \gamma_3 P_t S_t + u_t,$$

where *r* is the average interest rate on a call loan at the NYSE, *C* is the percentage deviation from trend in the excess cash reserves of the New York reserve banks, *D* is the percentage rate of change in bank deposits, *S* is the percentage rate of change in stock prices, P is the dummy variable (1 for panic, 0 for non-panic periods), u is a random shock, and the βs and γs are parameters to be estimated. *t* statistic or degrees of freedom are in parentheses. An asterisk notes that the null hypothesis of a zero coefficient or of no structural change rejected at 95%. All data were measured at weekly intervals from 1867 to1933.

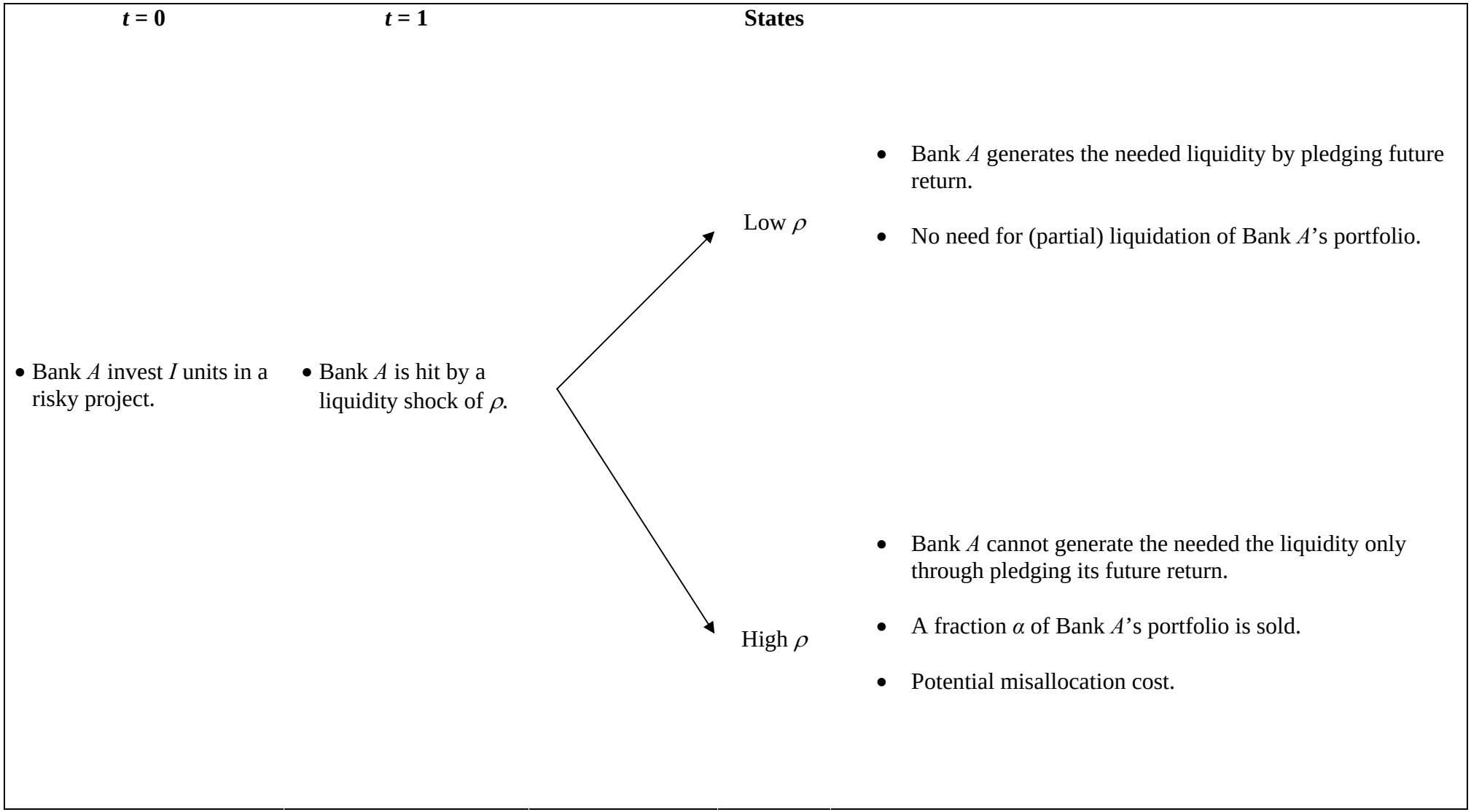

Figure 1: Timeline of the model.

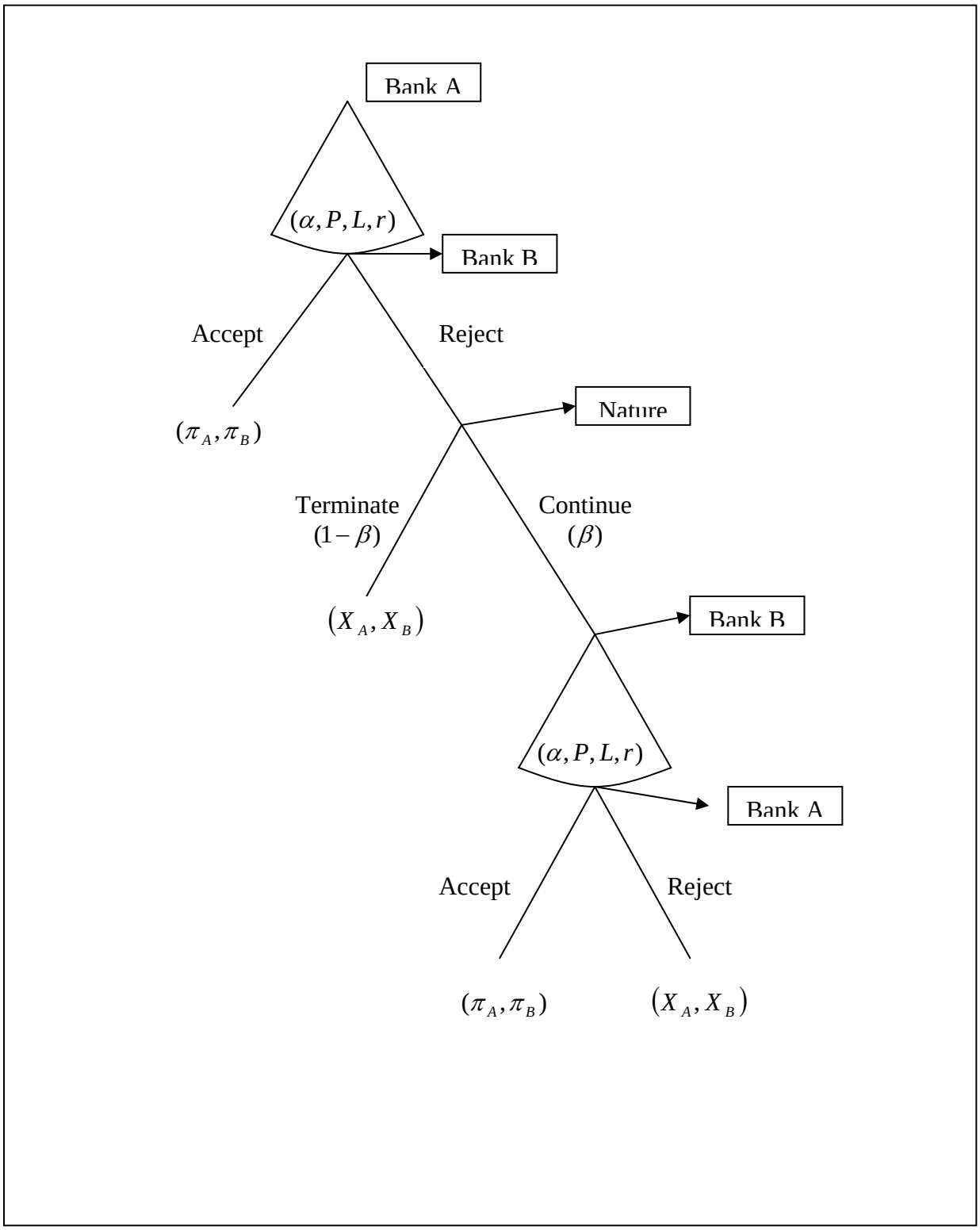

Figure 2: Game tree for the bargaining game.