Coordination Failures and the Lender of Last Resort: Was Bagehot Right After All?*

Jean-Charles Rochet[1]
and
Xavier Vives[2]

November 17, 2002

Abstract

The classical doctrine of the Lender of Last Resort, elaborated by Bagehot (1873), asserts that the Central Bank should lend to "illiquid but solvent" banks under certain conditions. Several authors have argued that this view is now obsolete: when interbank markets are efficient, a solvent bank cannot be illiquid. This paper provides a possible theoretical foundation for rescuing Bagehot's view. Our theory does not rely on the multiplicity of equilibria that arises in classical models of bank runs. We build a model of banks' liquidity crises that possesses a unique Bayesian equilibrium. In this equilibrium, there is a positive probability that a solvent bank cannot find liquidity assistance in the market. We derive policy implications about banking regulation (solvency and liquidity ratios) and interventions of the Lender of Last Resort as well as on the disclosure policy of the Central Bank. Furthermore, we find that public (bail-out) and private (bail-in) involvement are complementary in implementing the incentive efficient solution and that Bagehot's Lender of Last Resort facility has to work together with institutions providing prompt corrective action and orderly failure resolution. Finally, we derive the implications for an international Lender of Last Resort.

Keywords: Central Bank policy, interbank market, prudential regulation, liquidity ratio, solvency ratio, transparency, prompt corrective action, orderly failure resolution, global games, supermodular games

*We are grateful to Sudipto Bhattacharya, Ramon Caminal, Xavier Freixas, Martin Hellwig, Haizhou Huang, John Moore, Bruno Parigi, Hyun Shin, Elu von Thadden, Jean Tirole, and seminar participants at Bank of Italy, ESEM at Venice, ECB, Institute for Advanced Studies at Princeton, IMF, INSEAD, New York Fed, and UCL for helpful discussions and comments.

[1] LSE, Houghton Street, London WC2A 2AE, UK and IDEI, Université de Toulouse, Place Anatole France, 31042 Toulouse Cedex, France. Email: rochet@cict.fr

[2] INSEAD, Boulevard de Constance, 77305 Fontainebleau Cedex, France. E mail: xavier.vives@insead.edu

1 Introduction

There have been several recent controversies about the need for a Lender of Last Resort (LLR) both within national banking systems (Central Bank) and at an international level (IMF).[3] The concept of a LLR was elaborated in the XIXth century by the governor of the Bank of England, Thornton, and by the editor of *The Economist*, Bagehot. An essential point of the "classical" doctrine associated to Bagehot asserts that the LLR role is to lend to "solvent but illiquid" banks under certain conditions.[4]

Banking crises have been recurrent in most financial systems. The LLR facility and deposit insurance were instituted precisely to provide stability to the banking system and avoid the consequences for the real sector. Indeed, financial distress may cause important damage to the economy as the example of the Great Depression makes clear.[5] Traditional banking panics were eliminated with the LLR facility and deposit insurance by the end of the XIX century in Europe, after the crisis of the 1930s in the US and also mostly in emerging economies, which have suffered numerous crises until today.[6] Modern liquidity crises associated to securitized money or capital markets have also required the intervention of the LLR. Indeed, the Federal Reserve intervened in the crises provoked by the failure of Penn Central in the US commercial paper market in 1970, by the stock market crash of October 1987 and by Russia's default in 1997 and subsequent collapse of LTCM (in the latter case a "lifeboat" was arranged by the New York Fed). For example, in October 1987 the Federal Reserve supplied liquidity to banks with the discount window.[7]

The function of the LLR of providing emergency liquidity assistance has been criticized for provoking moral hazard on the banks' side. Perhaps more importantly, Goodfriend and King (1988) (see also Bordo (1990), Kaufman (1991) and Schwartz (1992)) remark that Bagehot's doctrine was elaborated at a time where financial markets were underdeveloped. They argue that, while central banks interventions on aggregate liquidity

[3] See for instance Calomiris (1998a,b), Kaufman (1990), Fisher (1999), Mishkin (1998), and Goodhart and Huang (1999a,b).

[4] The LLR should lend freely against good collateral, valued at pre-crisis levels, and at a penalty rate. Bagehot (1873), also presented for instance in Humphrey (1975) and Freixas et al. (1999).

[5] See Bernanke (1983) and Bernanke and Gertler (1989).

[6] See Gorton (1988) for US evidence and Lindgren et al (1996) for evidence on IMF member countries.

[7] See Folkerts-Landau and Garber (1992). See also Freixas et al. (1998) for a modeling of the interactions between the discount window and the interbank market.

(monetary policy) are still warranted, individual interventions (banking policy) are not anymore: "with sophisticated interbank markets, banking policy has become redundant".

Open market operations can provide sufficient liquidity which is then allocated by the interbank market. The discount window is not needed. In other words, Goodfriend and King argue that when financial markets are efficient, a solvent institution cannot be illiquid. Banks can finance their assets with interbank funds, negotiable certificates of deposit (CDs) and repurchase agreements (repos). Well informed participants in this interbank market will make out liquidity from solvency problems. This view has consequences also for the debate about the need of an international LLR. Indeed, Chari and Kehoe (1998) claim, for example, that such an international LLR is not needed because the joint action of the Federal Reserve, the European Central Bank and the Bank of Japan can take care of any international liquidity problem.[8]

Those developments have led qualified observers to dismiss bank panics as a phenomenon of the past and express confidence on the efficiency of financial markets, in particular the interbank market, to resolve liquidity problems of financial intermediaries. This is based on the view that participants in the interbank market are the most well informed agents to ascertain the solvency of an institution with liquidity problems.[9]

The main objective of this article is to provide a theoretical foundation for Bagehot's doctrine in a model that fits the modern context of sophisticated and presumably efficient financial markets. We are thinking of a short time horizon that corresponds to liquidity crises. We shift emphasis from maturity transformation and liquidity insurance of small depositors to the "modern" form of bank runs where large well-informed investors refuse to renew their credit (CDs for example) on the interbank market. The decision not to

[8] Jeanne and Wyplosz (2001) compare the required size of an international LLR under the "open market-monetary policy" and the "discount window-banking policy" views.

[9] For example, Tommaso Padoa-Schioppa, member of the Executive Committee of the European Central Bank in charge of banking supervision, has gone as far as saying that classical bank runs may occur only in textbooks, precisely because measures like deposit insurance and capital adequacy requirements have been put in place. Furthermore, despite recognizing that "rapid outflows of uninsured interbank liabilities" are less unlikely, Padoa-Schioppa states that "However, since interbank counterparties are much better informed than depositors, this event would typically require the market to have a strong suspicion that the bank is actually insolvent. If such a suspicion were to be unfounded and not generalised, the width and depth of today's interbank market is such that other institutions would probably replace (possibly with the encouragement of the public authorities as described above) those which withdraw their funds" (Padoa-Schioppa (1999)).

renew credit may arise as a result on an event (failure of Penn Central, October 1987 crash or LTCM failure) which puts in doubt the repayment capacity of an intermediary or a number of intermediaries. The Central Bank may then decide to provide liquidity to those troubled institutions. The question arises about whether such intervention is warranted. At the same time it is debated whether central banks should disclose the information they have on potential crisis situations (or the predictions of their internal forecasting models) and what degree of transparency should a Central Bank's announcements have.[10] We also hope to shed some light on these issues of transparency and optimal disclosure of information by the Central Bank.

Since Diamond and Dybvig (1983) (and Bryant (1980)), banking theory has insisted on the fragility of banks due to possible coordination failures between depositors (bank runs). However it is hard to base any policy recommendation on their model, since it systematically possesses multiple equilibria. Furthermore, a run equilibrium needs to be justified with the presence of sunspots that coordinate the behavior of investors. Indeed, otherwise no one would deposit in a bank that will be subject to run. This view of banking instability has been disputed by Gorton (1985) and others who argue that crises are related to fundamentals and not to self-fulfilling panics. In this view, crises are triggered by bad news about the returns to be obtained by the bank. Gorton (1988) studies panics in the National Banking Era in the US and concludes that crises were predictable by indicators of the business cycle.[11] There is an ongoing empirical debate about whether crises are predictable and their relation to fundamentals.[12]

Our approach is inspired by Postlewaite and Vives (1987), who display an incomplete information model with a unique Bayesian equilibrium with a positive probability of bank runs, and the model is adapted from the "global game" analysis of Carlsson and Van Damme (1993) and Morris and Shin (1998).[13] This approach builds a bridge between the "panic" and "fundamentals" view of crises by linking the probability of occurrence of a crisis to the fundamentals. A crucial property of the model is that, when the private

[10] See, for example, Tarkka and Mayes (2000).

[11] The phenomenon has been theorized in the literature on information-based bank runs such as Chari and Jagannathan (1988), Jacklin and Bhattacharya (1988) and Allen and Gale (1998).

[12] See also Kaminsky et al (1999) and Radelet and Sachs (1998) for perspectives on international crisis.

[13] See also Heinemann and Illing (2000) and Corsetti et al (2000).

information of investors is precise enough, the game among them has a unique equilibrium. Moreover, at this unique equilibrium there is an intermediate interval of values of the bank's assets for which, in the absence of intervention by the Central Bank, the bank is solvent but can fail by the fact that a too large proportion of depositors withdraw their money. In other words, in this intermediate range for the fundamentals there is the potential for a coordination failure. Furthermore, the range in which such coordination failure occurs diminishes with the ex ante strength of fundamentals.

Given that this equilibrium is unique and based on the fundamentals of the bank, we are able to provide some policy recommendations on how to avoid such failure. More specifically, we discuss the articulation between ex-ante regulation of solvency and liquidity ratios and ex-post provision of emergency liquidity assistance. It is found that liquidity and solvency regulation can solve the coordination problem but typically the cost is too high in terms of foregone returns. This means that prudential measures have to be complemented with emergency discount window loans.

We also introduce a public signal and discuss the optimal disclosure policy of the Central Bank. Indeed, the Central Bank typically has information about banks that the market does not have (and, conversely, market participants have also information complementary to the Central Bank knowledge).[14] The model allows for the information structures of the Central Bank and investors to be non-nested. Our discussion has a bearing on the slippery issue of the optimal degree of transparency of Central Bank announcements. Indeed, Alan Greenspan has become famous for his oblique way of saying things, fostering an industry of "Greenspanology" or interpretation of his statements. Our model may rationalize oblique statements by central bankers that seem to add noise to a basic message. Indeed, we will show that, precisely because the Central Bank may be in a unique position to provide information that becomes common knowledge, it has the capacity to destabilize expectations in the market (which in our context means to move the interbank market to a regime of multiple equilibria). By fudging the disclosure of information, the Central Bank makes sure that somewhat different interpretations of the release will be made preventing destabilization. The potential damaging effects of public information is a theme also developed in Morris and Shin (2001).

[14] See Peek et al (1999), De Young et al (1998), and Berger et al (1998).

We endogenize banks' short-term debt structure as a way to discipline bank managers because of a moral hazard problem. The framework allows us to discuss early closure policies of banks and the interaction of the LLR, prompt corrective action and orderly resolution of failures. We can study then the adequacy of Bagehot's doctrine in a richer environment and derive the complementarity between public (LLR and other facilities) and private (market) involvement in crisis resolution.

Finally, we provide a reinterpreation of the model in terms of the banking sector of a small open economy and derive lessons for a international LLR facility.

The rest of the article is organized as follows:

- Section 2 presents the model.
- Section 3 discusses runs and solvency.
- Section 4 characterizes the equilibrium of the game between investors.
- Section 5 studies the properties of this equilibrium and the effect of prudential regulation on coordination failure.
- Section 6 makes a first pass at the LLR policy implications of our model and the relations with Bagehot's doctrine.
- Section 7 introduces a public signal and discusses transparency.
- Section 8 sketches how to endogenize the liability structure and proposes a welfare-based LLR facility with attention to crisis resolution.
- Section 9 provides the international reinterpretation of the model and discusses the role of an international LLR and associated facilities.
- Concluding remarks end the paper.

2 The Model

Consider a market with three dates: $\tau = 0, 1, 2$. At date $\tau = 0$ the bank possesses own funds E, and collects uninsured wholesale deposits (CDs for example) for some amount D_0, normalized to 1. These funds are used in part to finance some investment I in risky assets (loans), the rest being held in cash reserves M. Under normal circumstances, the returns RI on these assets are collected at date $\tau = 2$, the CDs are repaid, and the stockholders of the bank get the difference (when it is positive). However, early withdrawals may occur at an interim date $\tau = 1$, following the observation of private signals on the future realization of R. If the proportion x of these withdrawals exceeds the cash reserves M of the bank, the bank is forced to sell some of its assets. To summarize our notation, the bank's balance sheet at $\tau = 0$ is represented as follows:

I	$D_0 = 1$
M	E

where:

- D_0 $(= 1)$ is the volume of uninsured wholesale deposits, normally repaid at $\tau = 2$ but that can also be withdrawn at $\tau = 1$. The nominal value of deposits upon withdrawal is $D \geq 1$ independently of the withdrawal date. So, early withdrawal entails no cost for the depositors themselves (when the bank is not liquidated prematurely).
- E represents the value of equity (or more generally long term debt; it may also include insured deposits[15]).
- I denotes the volume of investment in risky assets, which have a random return R at $\tau = 2$.
- Finally, M is the amount of cash reserves (money) held by the bank.

We assume that the withdrawal decision is delegated to fund managers who typically prefer to renew the deposits (i.e. not to withdraw early) but are penalized by the depositors if the bank fails. Suppose that fund managers obtain a benefit $B > 0$ if they get the money back or if they withdraw and the bank fails. They get nothing otherwise. However, to withdraw involves a cost $C > 0$ for the managers (for example because their reputation suffers if they have to recognize that they have made a bad investment). The net expected

[15] If they are fully insured, these deposits have no reason to be withdrawn early and can thus be assimilated to stable resources.

benefit of withdrawing is $B - C > 0$ while the one of not withdrawing is $(1 - P)B$, where P is the probability that the bank fails. Accordingly, fund managers adopt the following behavioral rule: withdraw if and only if they anticipate $P > \gamma = C/B$, where $\gamma \in (0, 1)$.

At $\tau = 1$, uninsured fund manager i privately observes a signal $s_i = R + \varepsilon_i$, where the $\varepsilon_i s$ are i.i.d. and also independent of R. As a result, a proportion x of them decides to "withdraw" (i.e. not to renew their CDs). By assumption there is no other source of financing for the bank (except maybe the Central Bank, see below) so if $x > \frac{M}{D}$, the bank is forced to sell a volume y of assets:[16] if the needed volume of sales y is greater than the total of available assets I the bank fails at $\tau = 1$. If not, the bank continues until date 2. Failure occurs at $\tau = 2$ whenever

$$R(I - y) < (1 - x)D. \tag{1}$$

Our modeling tries to capture in the simplest possible way the main institutional features of modern interbank markets. In our model, banks essentially finance themselves by two complementary sources: equity (or long term debt) and uninsured short term deposits (or CDs), which are uncollateralized and involve fixed repayments. However, in case of a liquidity shortage at date 1, banks also have the possibility to sell some of their assets (or equivalently borrow against collateral) on the repo market. This secondary market for bank assets is assumed to be informationally efficient, in the sense that the secondary price aggregates the decentralized information of investors about the quality of the bank's assets.[17] Therefore we assume that the resale value of the bank's assets depends on R. However bank owners cannot obtain the full value of these assets but only a fraction of this value $\frac{1}{1+\lambda}$, with $\lambda > 0$. Accordingly the volume of sales needed to face withdrawals x is given by:

$$y = (1 + \lambda)\frac{[xD - M]_+}{R}$$

where $(xD - M)_+ = \max(0, xD - M)$.

[16] These sales are typically accompanied with a repurchase agreement or repo. They are thus equivalent to a collateralized loan.

[17] We can imagine for instance that the bank organizes an auction among investors for the sale of its assets. The investors bid optimally given their private signals s_i. Since we assume that there is a large number of such depositors and that their signals are independent, the law of large numbers implies that the equilibrium price p of this auction is a deterministic function of R .

The parameter λ measures the cost of "fire sales" in the secondary market for bank assets. It is crucial for our analysis, and can be explained by considerations of asymmetric information or liquidity problems.[18]

Asymmetric information problems may translate into limited commitment of future cash flows (as in Hart and Moore (1994) or Diamond and Rajan (2001)), moral hazard (as in Holmstrom and Tirole (1997)), or adverse selection (as in Flannery (1996)). We have chosen to stress the last explanation, because it gives a simple justification for the superiority of the Central Bank over financial markets in the provision of liquidity to banks in trouble. Suppose that the risky assets of the bank consist of a continuum of infinitesimal loans indexed by $j \in [0, 1]$ of returns Rv_j where the $v_j s$ are i.i.d. and uniformly distributed on the interval $[\frac{1}{1+\lambda}, \frac{1+2\lambda}{1+\lambda}]$. Suppose also that individual investors are all infinitesimal (so that they can only buy one of the loans) and cannot observe the $v_j s$ (which are privately observed by the bank). Each individual investor is therefore afraid to get the lowest quality loan, thus the maximum price he is ready to pay is $\frac{R}{1+\lambda}$. The superiority of the Central Bank resides in its large financial capacity, and thus its ability to eliminate the adverse selection problem by buying the entire portfolio (or a representative sample) at a unit price of R.

The parameter λ can also be interpreted as a liquidity premium, i.e. the interest margin that the market requires for lending on a short notice.[19] In a generalized banking crisis we would have a liquidity shortage implying a large λ. Interpreting λ as a market rate, λ can also spike temporarily in response to exogenous events, such as September 11.

In our model we will be thinking mostly of the financial distress of an individual bank (a bank is close to insolvency when R is small) although for correlated enough portfolio returns of the banks the interpretation could be broadened. Symplifying somewhat we could say that asymmetric information problems (adverse selection) will lead naturally to discount window interventions while liquidity shortages will lead naturally to open market interventions.

[18] For a similar assumption in a model of an international lender of last resort, see Goodhart and Huang (1999b).

[19] See Allen and Gale (1998) for a model where costly asset sales arise due to the presence of liquidity constrained speculators in the resale market.

We do not assume any direct inefficiency of interbank markets since operations on these markets do not involve any physical liquidation of bank assets. However, we will show that when a bank is close to insolvency (R small) or when there is a liquidity shortage (λ large) the interbank markets do not suffice to prevent early closure of the bank. Early closure involves the physical liquidation of assets and this is costly. We model this liquidation cost (not to be confused with the fire sales premium λ) as proportional to the future returns on the bank's portfolio. If the bank is closed at $\tau = 1$, the (per unit) liquidation value of its assets is νR, with $\nu \ll \frac{1}{1+\lambda}$.

3 Runs and solvency

We focus in this section on some features of banks' liquidity crises that cannot be properly taken into account within the classical Bryant-Diamond-Dybvig (BDD) framework. In doing so we take the banks' liability structure (and in particular the fact that an important fraction of these liabilities can be withdrawn on demand) as exogenous. A possible way to endogenize the bank's liability structure is to introduce a disciplining role for liquid deposits. In Section 8 we explore such an extension.

We adopt explicitly the short time horizon (say 2 days) that corresponds to liquidity crises. This means that we shift the emphasis from maturity transformation and liquidity insurance of small depositors to the "modern" form of bank runs, i.e. large investors refusing to renew their CDs on the interbank market.

A second element that differentiates our model from BDD is that our bank is not a mutual bank, but a corporation that acts in the best interest of its stockholders. This allows us to discuss the role of equity and the articulation between solvency requirements and provision of emergency liquidity assistance. However a proper modeling of the role of equityholders remains to be done.

As a consequence of these assumptions, the relation between x, the proportion of early withdrawals, and the failure of the bank is different from that in BDD. To see this, let us recapitulate the different cases:

- $xD \leq M$: there is no sales of assets at $\tau = 1$. In this case there is failure at $\tau = 2$

if and only if

$$RI + M < D \Leftrightarrow R < R_s = \frac{D - M}{I} = 1 - \frac{1 + E - D}{I}.$$

R_s can be interpreted as the solvency threshold of the bank. It is a decreasing function of the solvency ratio $\frac{E}{I}$.

- $M < xD \leq M + \frac{RI}{1+\lambda}$: there is partial sales of assets at $\tau = 1$. Failure occurs at $\tau = 2$ if and only if

$$RI - (1 + \lambda)(xD - M) < (1 - x)D \Leftrightarrow R < R_s + \lambda\frac{xD - M}{I} = R_s\left[1 + \lambda\frac{xD - M}{D - M}\right].$$

This formula illustrates how, because of the premium λ , solvent banks can fail when the proportion x of early withdrawals is too big[20]. Notice however an important difference with BDD: when the bank is "supersolvent" ($R > (1 + \lambda)R_s$) it can never fail, even if everybody withdraws ($x = 1$).

- Finally, when $xD > M + \frac{RI}{1+\lambda}$, the bank is closed at $\tau = 1$ (early closure).

The failure thresholds are summarized in Figure 1 below:

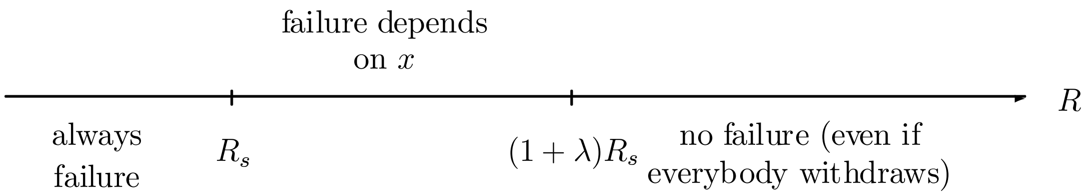

Figure 1

Several comments are in order:

- In our model, early closure is never ex post efficient because to physically liquidate assets is costly. However, as discussed in Section 8, early closure may be ex ante efficient to discipline bank managers and induce them to exert effort.

[20]Note that we can interpret that to obtain resources $xD - M > 0$ we need to liquidate a fraction of the portfolio $\mu = \frac{xD-M}{RI}(1 + \lambda)$ and therefore at $\tau = 2$ we have left $R(1 - \mu)I = RI - (1 + \lambda)(xD - M)$.

- The perfect information benchmark of our model (where R is common knowledge at $\tau = 1$) has different properties than in BDD: the multiplicity of equilibria only arises in the median range $R_s \leq R \leq (1+\lambda)R_s$. When $R_s > R$ everybody runs ($x = 1$), when $R > (1+\lambda)R_s$ nobody runs ($x = 0$) and only in the intermediate region both equilibria coexist.[21] As we will see, and following the ideas introduced by Carlsson and Van Damme (1993), this pattern is crucial for being able to selecting a unique equilibrium through the introduction of private noisy signals (when noise is not too important, as in Morris and Shin (1998)).[22]

The different regimes of the bank, as a function of R and x, are represented in Figure 2.

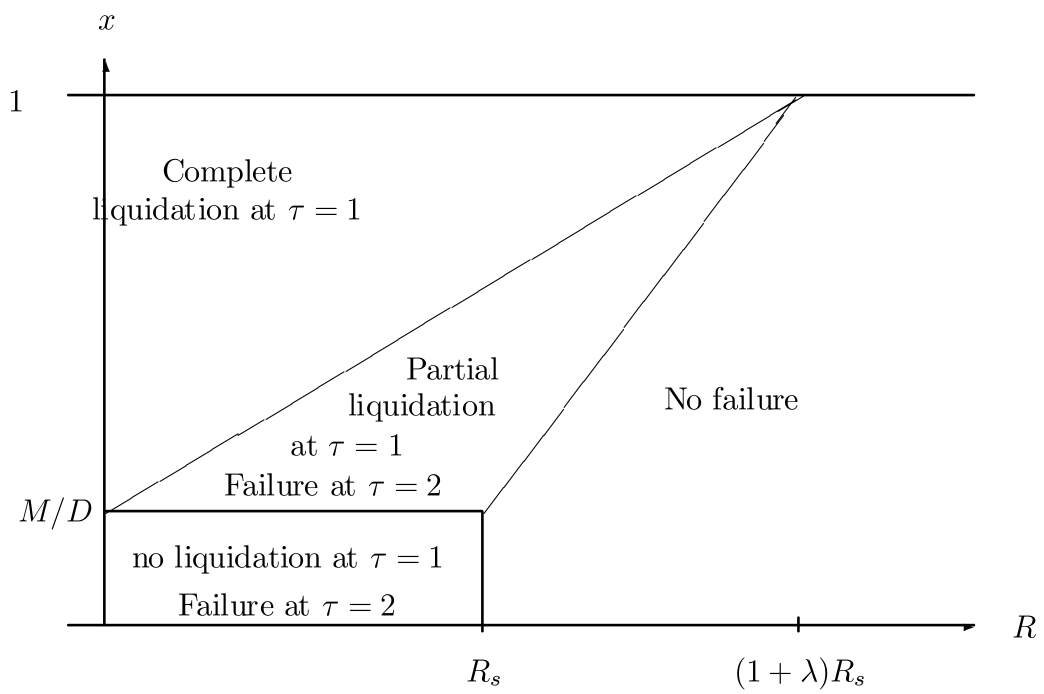

Figure 2

[21] When $R_s > R$ fund managers get $B - C > 0$ by withdrawing and nothing by waiting. When $R > (1+\lambda)R_s$ fund managers by withdrawing get $B - C$ and by waiting B. Note that if depositors made directly the investment decisions the equilibria would be the same provided that there is a small cost of withdrawal.

[22] Goldstein and Pauzner (2000) adapt the same methodology to the BDD model, in which the perfect information game always has two equilibria, even for very large R. Accordingly, they have to make an extra assumption, namely that "there exists an external lender who would be willing to buy any amount of the investment... if she knew for sure that the long-run return was excessively high" (Goldstein and Pauzner (2000), p.11), in order to obtain a unique equilibrium in the presence of private signals with small noise. See also Morris and Shin (2000).

The critical value of R below which the bank is closed early is given by:

$$R_{ec}(x) = (1+\lambda)\frac{(xD-M)_+}{I}.$$

The critical value of R below which the bank fails is given by:

$$R_f(x) = R_s + \lambda\frac{(xD-M)_+}{I}. \tag{2}$$

The parameters R_s, M and I are not independent. Since we want to study the impact of prudential regulation on the need for Central Bank intervention, we will focus on R_s (a decreasing function of the solvency ratio E/I) and $m = \frac{M}{D}$ (the liquidity ratio). Replacing I by its value $\frac{D-M}{R_s}$, we obtain:

$$R_{ec}(x) = R_s(1+\lambda)\frac{(x-m)_+}{1-m}, \text{ and}$$

$$R_f(x) = R_s(1+\lambda\frac{(x-m)_+}{1-m}).$$

It should be obvious that $R_{ec}(x) < R_f(x)$ since early closure implies failure while the converse is not true (see Figure 2).

4 Equilibrium of the investors' game

In order to simplify the presentation, we concentrate on "threshold" strategies, in which each fund manager decides to withdraw if and only if his signal is below some threshold t.[23] As we will see later this is without loss of generality. For a given R, a fund manager withdraws with probability

$$\Pr[R+\varepsilon < t] = G(t-R),$$

where G is the c.d.f. of the random variable ε. Given our assumptions, this probability also equals the proportion of withdrawals $x(R,t)$.

[23] It is assumed that the decision on whether to witdraw is taken before the secondary market is organized and thus before fund managers have the opportunity to learn about R from the secondary price. (On this issue see Atkeson's comments on Morris and Shin (2000).)

A fund manager withdraws if and only if the probability of failure of the bank (conditional on the signal s received by the manager and the threshold t used by other managers) is large enough. That is, $P(s,t) > \gamma$, where

$$\begin{aligned} P(s,t) &= \Pr[\text{failure}|s,t] \\ &= \Pr[R < R_f(x(R,t))|s]. \end{aligned}$$

Before we analyze the equilibrium of the investor's game let us look at the region of the plane (t, R) where failure occurs. For this, transform Figure 2 by replacing x by $x(R,t) = G(t-R)$. We obtain Figure 3 below.

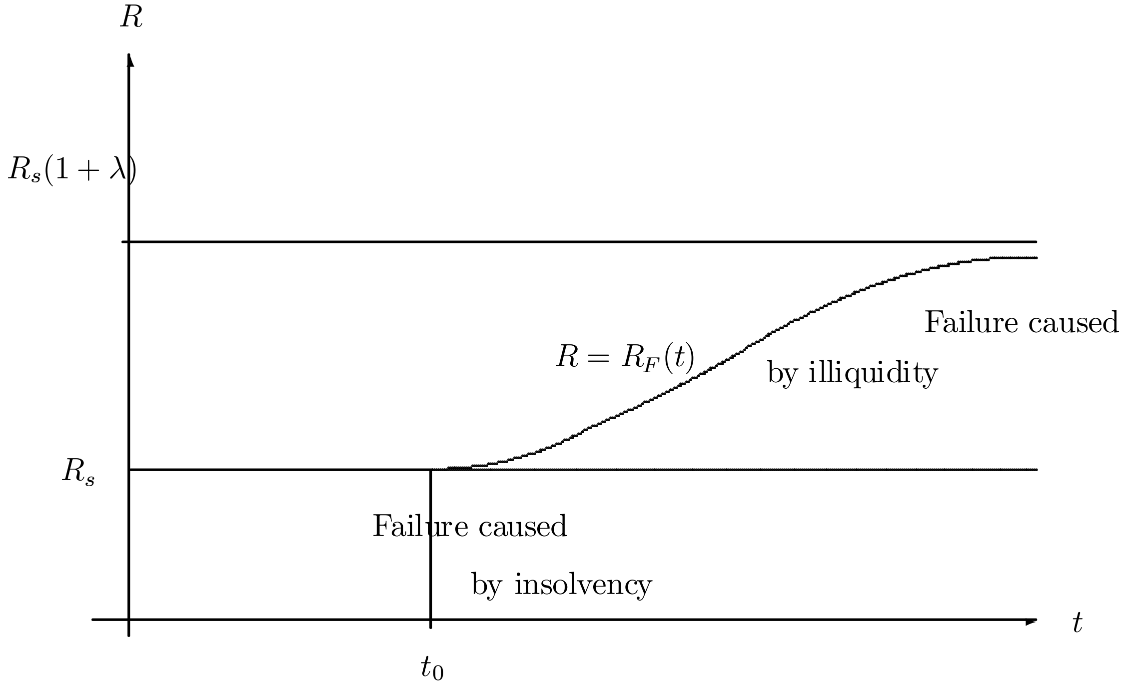

Figure 3

Notice that $R_F(t)$, the critical R that triggers failure is equal to the solvency threshold R_s when t is low and fund managers are confident about the strength of fundamentals:

$$R_F(t) = R_s \quad \text{if} \quad t \leq t_0 = R_s + G^{-1}(m).$$

However, for $t > t_0$, $R_F(t)$ is an increasing function of t and is defined implicitly by

$$R = R_s(1 + \lambda[\frac{G(t-R)-m}{1-m}]).$$

Let us denote by $G(.|s)$ the c.d.f. of R conditional on signal s :

$$G(r|s) = \Pr[R < r|s].$$

Then given the definition of $R_F(t)$

$$P(s,t) = \Pr[R < R_F(t)|s] = G(R_F(t)|s) \tag{3}$$

It is natural to assume that $G(r|s)$ is decreasing in s: the higher s, the lower the probability that R lies below any given threshold r. Then it is immediate that P is decreasing in s and nondecreasing in t: $\frac{\partial P}{\partial s} < 0$ and $\frac{\partial P}{\partial t} \geq 0$. This means that the depositors' game is one of strategic complementarities. Indeed, given that other fund managers use the strategy with threshold t the best response of a manager is to use a strategy with threshold $\overline{s}$: withdraw if and only if $P(s,t) > \gamma$ or equivalently if and only if $s < \overline{s}$ where $P(\overline{s}, t) = \gamma$. Let $\overline{s} = S(t)$. Now we have that $S' = -\frac{\partial P/\partial t}{\partial P/\partial s} \geq 0$, a higher threshold t by others induces a manager to use also a higher threshold.

The strategic complementarity property holds for general strategies. For a fund manager all that matters is the conditional probability of failure for a given signal and this depends only on the aggregate withdrawals. Recall that the differential payoff to a fund manager for withdrawing over not withdrawing is given by $PB - C$ where $C/B = \gamma$. A strategy for a fund manager is a function $a(s) \in \{\text{not withdraw, withdraw}\}$. If more managers withdraw then the probability of failure conditional on receiving signal s increases. This just means that the payoff to a fund manager displays increasing differences with respect to the actions of others. The depositor's game is a supermodular game and there will exist a largest and a smallest equilibrium. In fact, the game is symmetric (that is, exchangeable against permutations of the players) and therefore the largest and smallest equilibria are symmetric.[24] At the largest equilibrium every fund manager withdraws in the largest number of occasions, at the smallest equilibrium every fund manager withdraws in the smallest number of occasions. The largest (smallest) equilibrium can be identified then with the highest (lowest) threshold strategy $\overline{t}(\underline{t})$.[25] These extremal equilibria bound the

[24] See Remark 15, p.34 in Vives (1999). See also Chapter 2 in the same reference for an exposition of the theory of supermodular games.

[25] The extremal equilibria can be found with the usual algorithm in a supermodular game (Vives

set of rationalizable outcomes. That is, strategies outside this set can be eliminated by iterated deletion of dominated strategies.[26] We will make assumptions so that $\bar{t} = \underline{t}$ and equilibrium will be unique.

The threshold $t = t^*$ corresponds to a (symmetric) Bayesian Nash equilibrium if and only if $P(t^*, t^*) = \gamma$. Indeed, suppose that funds managers use the threshold strategy t^*. Then for $s = t^*$, $P = \gamma$ and since P is decreasing in s for $s < t^*$ we have that $P(s, t^*) > \gamma$ and the manager withdraws. Conversely, if t^* is a (symmetric) equilibrium then for $s = t^*$ there is no withdrawal and therefore $P(t^*, t^*) \leq \gamma$. If $P(t^*, t^*) < \gamma$ then by continuity for s close but less than t^* we would have $P(s, t^*) < \gamma$, a contradiction. It is clear then that the largest and the smallest solutions to $P(t^*, t^*) = \gamma$ correspond respectively to the largest and smallest equilibrium.

An equilibrium can also be characterized by a couple of equations in two unknowns (a withdrawal threshold $t^*$and a failure threshold R^*):

$$G(R^*|t^*) = \gamma, \text{ and} \tag{4}$$

$$R^* = R_s(1 + \lambda[\frac{G(t^* - R^*) - m}{1 - m}]_+). \tag{5}$$

Equation (4) states that conditionally on observing a signal $s = t^*$, the probability that $R < R^*$ is γ. Equation (5) states that, given a withdrawal threshold t^*, R^* is the critical return (i.e. the one below which failure occurs). Equation (5) implies that R^* belongs to $[R_s, (1 + \lambda)R_s]$. Notice that early closure occurs whenever $x(R, t^*)D > M + \frac{IR}{1+\lambda}$,where $x(R, t^*) = G(t^* - R)$. This happens if and only if R is smaller than some threshold $R_{EC}(t^*)$. We will have that $R_{EC}(t^*) < R^*$ since early closure implies failure, while the converse is not true, as remarked before.

In order to simplify the analysis of this system we are going to make distributional assumptions on returns and signals. More specifically, we will assume that the distributions of R and ϵ are normal, with respective means $\bar{R}$ and 0, and respective precisions (i.e.

(1990)), starting at the extremal points of the strategy sets of players and iterating using the best responses. For example, to obtain $\bar{t}$ let all investors withdraw for any signal received (that is, start from $\bar{t}_0 = +\infty$ and $x = 1$) and applying iteratively the best response $S(\cdot)$ of a player obtain a decreasing sequence $\bar{t}_k$ that converges to $\bar{t}$. Note that $S(+\infty) = \bar{t}_1 < +\infty$ where $\bar{t}_1$ is the unique solution to $P(t, +\infty) = G(R_s(1 + \lambda)|t) = \gamma$ given that G is (strictly) decreasing in t.

[26] See Morris and Shin (2000) for an explicit demonstration of the outcome of iterative elimination of dominated strategies in a similar model.

inverse variances) α and β. Denoting by Φ the c.d.f. of a standard normal distribution the equilibrium is characterized then by a pair (t^*, R^*) such that:

$$\Phi\left(\sqrt{\alpha+\beta}R^* - \frac{\alpha\bar{R}+\beta t^*}{\sqrt{\alpha+\beta}}\right) = \gamma, \tag{6}$$

and

$$R^* = R_s\left(1+\lambda\left[\frac{\Phi(\sqrt{\beta}(t^*-R^*))-m}{1-m}\right]_+\right). \tag{7}$$

We now can now state our first result.

Proposition 1 *When β (the precision of the private signal of investors) is large enough relative to α (prior precision), there is a unique t^* such that $P(t^*, t^*) = \gamma$. We conclude that the investor's game has a unique (Bayesian) equilibrium. In equilibrium, fund managers use a strategy with threshold t^*.*

Proof of Proposition 1: We show that $\varphi(s) \stackrel{\text{def}}{=} P(s,s)$ is decreasing for $\beta \geq \beta_0 \stackrel{\text{def}}{=} \frac{1}{2\pi}\left(\frac{\lambda\alpha}{I}\right)^2$ with $I = \frac{D-M}{R_s}$. Under our assumptions R conditional on signal realization s follows a normal distribution $N(\frac{\alpha\bar{R}+\beta s}{\alpha+\beta}, \frac{1}{\alpha+\beta})$. Denoting by Φ the c.d.f. of a standard normal distribution, it follows that

$$\begin{aligned}\varphi(s) &= P(s,s) = \Pr[R < R_F(s)|s] \\ &= \Phi\left[\sqrt{\alpha+\beta}R_F(s) - \frac{\alpha\bar{R}+\beta s}{\sqrt{\alpha+\beta}}\right].\end{aligned} \tag{8}$$

This function is clearly decreasing for $s < t_0$ since, in this region, we have $R_F(s) \equiv R_s$. Now if $s > t_0$, $R_F(s)$ is increasing and its inverse is

$$t_F(R) = R + \frac{1}{\sqrt{\beta}}\Phi^{-1}\left(\frac{I}{\lambda}(R-R_s)+m\right).$$

The derivative of t_F is

$$t_F'(R) = 1 + \frac{1}{\sqrt{\beta}}\frac{I}{\lambda}\left[\Phi'\left(\Phi^{-1}\left(\frac{I}{\lambda}(R-R_s)+m\right)\right)\right]^{-1}.$$

Since Φ' is bounded above by $\frac{1}{\sqrt{2\pi}}$, t_F' is bounded below:

$$t_F'(R) \geq 1 + \sqrt{\frac{2\pi}{\beta}}\frac{I}{\lambda}.$$

Thus

$$R'_F(s) \leq \left[1 + \sqrt{\frac{2\pi}{\beta}}\frac{I}{\lambda}\right]^{-1}.$$

Given formula (8), $\varphi(s)$ will be decreasing provided that

$$\sqrt{\alpha+\beta}\left(1 + \sqrt{\frac{2\pi}{\beta}}\frac{I}{\lambda}\right)^{-1} \leq \frac{\beta}{\sqrt{\alpha+\beta}},$$

which, after simplification, gives: $\beta \geq \frac{1}{2\pi}\left(\frac{\lambda\alpha}{I}\right)^2$. If this condition is satisfied, there is at most one equilibrium. Existence is easily shown. When s is small $R_F(s) = R_s$ and equation (6) implies that $\lim_{s\to-\infty}\varphi(s) = 1$. On the other hand, when $s \to +\infty$, $R_F(s) \to (1+\lambda)R_s$ and $\varphi(s) \to 0$. ■

The limit equilibrium when β tends to infinity can be characterized as follows: From equation (6) we have that $\lim_{\beta\to+\infty}\sqrt{\beta}(R^*-t^*) = \Phi^{-1}(\gamma)$. Given that $\Phi\{-z\} = 1-\Phi\{z\}$ we obtain that in the limit $t^* = R^* = R_s(1+\frac{\lambda}{1-m}[\max\{1-\gamma-m, 0\}])$. The critical cutoff R^* is decreasing with γ and ranges from R_s for $\gamma \geq 1-m$ to $(1+\lambda)R_s$ for $\gamma = 0$. It is also nonincreasing in m. As we establish in the next section, these features of the limit equilibrium are also valid for $\beta \geq \beta_0$.

It is worth noting also that with a diffuse prior ($\alpha = 0$), the equilibrium is unique for any private precision of investors (indeed, we have that $\beta_0 = 0$). From (6) and (7) we obtain immediately that $R^* = R_s(1+\frac{\lambda}{1-m}[\max\{1-\gamma-m, 0\}])$ and $t^* = R^* - \frac{\Phi^{-1}(\gamma)}{\sqrt{\beta}}$. Both the cases $\beta \to +\infty$ and $\alpha = 0$ have in common that each investor faces the maximal uncertainty about the behavior of other investors at the switching point $s_i = t^*$. Indeed, it can be easily checked that in either case the distribution of the proportion $x(R, t^*) = \Phi(\sqrt{\beta}(t^* - R))$ of investors withdrawing is uniformly distributed over $[0, 1]$ conditional on $s_i = t^*$. This contrasts with the certainty case with multiple equilibria when $R \in (R_s, (1+\lambda)R_s)$ where, for example, in a run equilibrium an investor thinks that with probability one all other investors will withdraw. It is precisely the need to entertain a wider range of behavior of other investors in the incomplete information game that pins down a unique equilibrium as in Carlsson and Van Damme (1993) or Postlewaite and Vives (1987).

5 Coordination failure and prudential regulation

For β large enough, we have just seen that there exists a unique equilibrium whereby investors adopt a threshold t^* characterized by

$$\Phi\left(\sqrt{\alpha+\beta}R_F(t^*) - \frac{\alpha\bar{R}+\beta t^*}{\sqrt{\alpha+\beta}}\right) = \gamma,$$

or

$$R_F(t^*) = \frac{1}{\sqrt{\alpha+\beta}}\left(\Phi^{-1}(\gamma) + \frac{\alpha\bar{R}+\beta t^*}{\sqrt{\alpha+\beta}}\right). \tag{9}$$

For this equilibrium threshold, the failure of the bank will occur if and only if:

$$R < R_F(t^*) = R^*.$$

This means that the bank fails if and only if fundamentals are weak, $R < R^*$. When $R^* > R_s$ we have an intermediate interval of fundamentals $R \in [R_s, R^*)$ where there is coordination failure: the bank is solvent but illiquid. The occurrence of coordination failure can be controlled by the level of the liquidity ratio m as the following proposition shows.

Proposition 2 *There is a critical liquidity ratio of the bank $\overline{m}$ such that for $m \geq \overline{m}$ we have that $R^* = R_s$, which means that only insolvent banks fail (there is no coordination failure). Conversely, for $m < \overline{m}$ we have that $R^* > R_s$. This means that for $R \in [R_s, R^*)$ the bank is solvent but illiquid (there is a coordination failure).*

Proof of Proposition 2: For $t^* \leq t_0 = R_s + \frac{1}{\sqrt{\beta}}\Phi^{-1}(m)$, the equilibrium occurs for $R^* = R_s$. By replacing in formula (6) this gives:

$$(\alpha+\beta)R_s \leq \sqrt{\alpha+\beta}\Phi^{-1}(\gamma) + \alpha\bar{R} + \beta R_s + \sqrt{\beta}\Phi^{-1}(m),$$

which is equivalent to:

$$\Phi^{-1}(m) \geq \frac{\alpha}{\sqrt{\beta}}(R_s - \bar{R}) - \sqrt{1+\frac{\alpha}{\beta}}\Phi^{-1}(\gamma). \tag{10}$$

Therefore, the coordination failure disappears when $m \geq \overline{m}$, where

$$\overline{m} = \Phi\left(\frac{\alpha}{\sqrt{\beta}}(R_s - \bar{R}) - \sqrt{1+\frac{\alpha}{\beta}}\Phi^{-1}(\gamma)\right).\blacksquare$$

Notice that, since R_s is a decreasing function of $\frac{E}{I}$, the critical liquidity ratio $\overline{m}$ decreases when the solvency ratio $\frac{E}{I}$ increases.[27]

The equilibrium threshold return R^* is determined (when (10) is not satisfied) by the solution to:

$$\phi(R) = \alpha(R - \bar{R}) - \sqrt{\beta}\Phi^{-1}\left(\frac{1-m}{\lambda R_s}(R - R_s) + m\right) - \sqrt{\alpha+\beta}\Phi^{-1}(\gamma) = 0. \qquad (11)$$

When $\beta \geq \beta_0$, $\phi'(R) < 0$ and the comparative statics properties of the equilibrium threshold R^* are straightforward. Indeed, we have that $\partial\phi/\partial m < 0$, $\partial\phi/\partial R_s > 0$, $\partial\phi/\partial\lambda > 0, \partial\phi/\partial\gamma < 0$ and $\partial\phi/\partial\overline{R} < 0$. The following proposition states the results.

Proposition 3 Comparative statics *of R^* (and of the probability of failure):*

- *R^* is a decreasing function of the liquidity ratio m and the solvency (E/I) of the bank, of the critical withdrawal probability γ and of the expected return on the bank's assets $\bar{R}$.*
- *R^* is an increasing function of the fire sales premium λ and of the face value of debt D.*

We have thus that stronger fundamentals, as indicated by a higher prior mean $\bar{R}$ also imply a lower likelihood of failure. In contrast, a higher fire sales premium λ increases the incidence of failure. Indeed, for a higher λ a larger portion of the portfolio must be liquidated to meet the requirements of withdrawals. We have also that R^* is decreasing with the critical withdrawal probability γ and as $\gamma \to 0$, $R^* \to (1+\lambda)R_s$.

The effect of an increase in the precision of the prior α is potentially ambiguous. This is so because $\partial\phi/\partial\alpha = R - \bar{R} - \frac{\Phi^{-1}(\gamma)}{2\sqrt{\alpha+\beta}}$, whose sign depends on whether $R^* \lesseqgtr \bar{R}$ and $\gamma \lesseqgtr 1/2$

[27] More generally, it is easy to see that in our model, the regulator can control the probabilities of illiquidity ($\Pr(R < R^*)$) and insolvency ($\Pr(R < R_s)$) of the bank by imposing minimum liquidity and solvency ratios.

(recall that $\Phi^{-1}(\gamma) \lesseqgtr 0$ as $\gamma \lesseqgtr 1/2$). We should expect that the cost of withdrawal C is small in relation to the continuation benefit for the fund managers B. Therefore, we can always assume that $\gamma = C/B < 1/2$. This means that when the prior fundamentals are bad ($\bar{R}$ low) we will have $R^* > \bar{R}$ and $\partial\phi/\partial\alpha > 0$. In consequence, increasing α will increase R^*. Indeed, to have more precise prior information about a bad outcome worsens the coordination problem. It follows also that $\partial \Pr[R < R^*]/\partial\alpha > 0$. On the other hand, when the prior fundamentals are good ($\bar{R}$ high) and $R^* < \bar{R}$ the outcome is ambiguous unless $R^* << \bar{R}$, in which case $\partial\phi/\partial\alpha < 0$. Then a more precise prior information about a very good outcome alleviates the coordination problem. It follows also that $\partial \Pr[R < R^*]/\partial\alpha < 0$.

A similar analysis applies to changes in the precision of private information of investors β. The reason is that the sign of $\{\partial\phi/\partial\beta\}$ depends on the sign of $\Phi^{-1}\left(\frac{1-m}{\lambda R_s}(R - R_s) + m\right)$and of $\Phi^{-1}(\gamma)$ and we may have $\frac{1-m}{\lambda R_s}(R - R_s) + m \lesseqgtr 1/2$ and/or $\gamma \lesseqgtr 1/2$. For example, for β large enough it can be seen that sign $\{\partial\phi/\partial\beta\}$ = sign $\Phi^{-1}(\gamma)$.[28] Then an improved precision of private signals decreases (increases) R^* and the failure rate, if the relative cost of withdrawal for the fund managers is small, $\gamma < 1/2$ (large, $\gamma > 1/2$). If we think as before that the reasonable case is to have $\gamma < 1/2$ then an improvement in the private precision of investors (when it is already high) makes failure less likely.

6 Coordination failure and LLR Policy

The main contribution of our paper so far has been to show the theoretical possibility of a solvent bank being illiquid, due to a coordination failure on the interbank market. We are now going to explore the lender of last resort policy of the Central Bank and present a scenario where it is possible to give a theoretical justification to Bagehot's doctrine.

We start by considering simple Central Bank (alternative) objectives:

1. Eliminate the coordination failure with minimal involvement.
2. Avoid the complete liquidation of the bank at $\tau = 1$ (early closure).

[28] For β large we have that, for $R = R^*$, sign $\{\partial\phi/\partial\beta\}$ = sign $\left\{\frac{\Phi^{-1}(\gamma)}{2}\left(\frac{1}{\sqrt{\beta}} - \frac{1}{\sqrt{\alpha+\beta}}\right)\right\}$ = sign $\Phi^{-1}(\gamma)$.

We analyse a more elaborate welfare-oriented objective in Section 8.

With regard to the first objective, we have shown in Section 5 that a high enough liquidity ratio m eliminates the coordination failure altogether by inducing $R^* = R_s$. This is so for $m \geq \overline{m}$. However, it is likely that imposing $m \geq \overline{m}$ might be too costly in terms of foregone returns (recall that $I + M = 1 + E$, where I is the investment in the risky asset). Therefore, we now look at forms of Central Bank intervention that can eliminate the coordination failure when $m < \overline{m}$.

Let us see how open market operations (monetary policy) can eliminate the coordination failure.[29] Suppose the Central Bank announces it will lend at rate $r \in (0, \lambda)$, and without limits, but only to solvent banks. The Central Bank is not allowed to subsidize banks and is assumed to observe R. The knowledge of R may come from the supervisory knowledge of the Central Bank or perhaps by observing the amount of withdrawals of the bank.[30] Then the optimal strategy of a (solvent) commercial bank will be to borrow exactly the liquidity it needs, i.e. $D(x - m)_+$. Whenever $x - m > 0$, failure will occur at date 2 if and only if:

$$\frac{RI}{D} < (1 - x) + (1 + r)(x - m).$$

Given that $\frac{D}{I} = \frac{R_s}{1-m}$, we obtain that failure at $t = 2$ will occur if and only if:

$$R < R_s(1 + r\frac{(x - m)_+}{1 - m}).$$

This is exactly analogous to our previous formula giving the critical return of the bank, only that the interest rate r replaces the liquidation premium λ. As a result, this type of intervention will be fully effective (yielding $R^* = R_s$) only when r is arbitrarily close to zero. Note also that whenever the Central Bank lends at a very low rate the collateral of the bank is evaluated under "normal circumstances". That is, when there is no coordination failure. Consider as an example the limit case of β tending to infinity. The equilibrium

[29] Open market operations typically involve performing a repo operation with primary security dealers. The Federal Reserve auctions a fixed amount of liquidity (reserves) and, in general, does not accept bids by dealers below the Federal funds Rate target.

[30] The empirical evidence points at the superiority of the Central Bank information because of its access to supervisory data (Peek et al (1999), for example). Romer and Romer (2000) find evidence of asymmetric information in favor of the Federal Reserve in relation to commercial forecasters in forecasting inflation.

with no Central Bank help is then $t^* = R^* = R_s(1 + \frac{\lambda}{1-m}[\max\{1-\gamma-m, 0\}])$. Suppose that $1-\gamma > m$ so that $R^* > R_s$. We have that withdrawals are $x = 0$ for $R > R^*$, $x = 1-\gamma$ for $R = R^*$, and $x = 1$ for $R < R^*$. Whenever $R > R_s$ the Central Bank will help avoiding failure and evaluating the collateral as if $x = 0$. This effectively changes the failure point to $R^* = R_s$.

This intervention with open market operations makes sense if a high λ is due to a temporary spike of the market rate, that is, a liquidity crunch, or a situation where a large number of banks are in trouble. For example, after September 11 open market operations by the Federal Reserve accepted dealers' bids at levels well below the Federal Funds Rate target and pushed the effective lending rate to lows of zero in several days.[31]

With respect to the second objective, avoiding early closure, a second type of intervention, perhaps more in the spirit of Bagehot, is discount window lending. The Central Bank lends then at a very low interest rate, $r = 0$ in our model, but only to illiquid banks, and for the amount that they could not borrow in the interbank market in order to meet their payment obligations at $\tau = 1$. It is easy to see that in this case the equilibrium between fund managers is not modified. This is so because Central Bank intervention does not change the instances of failure of the bank (indeed, when a bank is helped at $\tau = 1$ because $x(R, t^*)D > M + \frac{IR}{1+\lambda}$, it will fail at $\tau = 2$). In this case the coordination failure is not eliminated but its effects (on early closure) are neutralized by the intervention of the Central Bank. The main difference with Bagehot's doctrine is that the Central Bank does not lend at a penalty rate.[32] This type of intervention may provide a rationale for the apparently strange behavior of the Federal Reserve of lending below the market rate (but with a "stigma" associated to it so that banks use it only when they can not find liquidity in the market).[33]

[31] See Markets Group of the Federal Reserve Bank of New York (2002).

[32] Typically, the lending rate is kept at a penalty level to discourage arbitrage and perverse incentives. Those considerations lie outside the present model. For example, in a repo operation the penalty for not returning the cash on loan is to keep paying the lending rate. If this lending rate is very low the incentive to return the loan is very small. See Fisher (1999) for a discussion of why lending should be at a penalty rate.

[33] The discount window policy of the Federal Reserve is to lend 50 basis points below the target Federal Funds Rate. Martin (2002) contrasts the classical prescription of lending at a penalty rate with the Fed's response to September 11, namely to lend at a very low interest rate. He argues that penalty rates were needed in Bagehot's view because the Gold Standard implied limited reserves for the central bank.

In Section 8 we will provide a precise welfare objective for this discount window policy.

In some circumstances the Central Bank may not be able to infer R exactly because of noise (be it in the supervisory process or in the observation of withdrawals). Then the Central Bank will only obtain an imperfect signal of R. In this case the Central Bank will not be able to distinguish perfectly between illiquid and insolvent banks (as in Goodhart and Huang (1999a)) so that, whatever the lending policy chosen, taxpayers' money may be involved with some probability. This situation is realistic given the difficulty in distinguishing between solvency and liquidity problems.[34] We will not pursue this avenue more but concentrate in the next section on the effects of public information.

It may be argued also that our LLR function could be performed by private lines of credit forming a private LLR. Banks providing a line of credit would then have an incentive to monitor the borrowing institution and reduce the fire sales premium. The need for a LLR remains but it may be privately provided. Goodfriend and Lacker (1999) draw a parallel between central bank lending and private lines of credit and put emphasis on the commitment problem of the central bank to limit lending.[35] However, the Central Bank typically acts as LLR in all the economies we know most likely because it has a natural superiority in terms of financial capacity and supervisory knowledge. For example, in the LTCM case the New York Fed had access to information that the private sector, not even the members of the lifeboat operation, did not. This unique capacity to inspect a financial institution made possible the lifeboat operation orchestrated by the New York Fed.

[34] We may even think that the Central Bank can not help ex post once withdrawals have materialized but that it receives a noisy signal s_{CB} about R at the same time that investors. Indeed, in many countries, the Central Bank has also a supervisory role, and thus can be expected to estimate R with a good precision. The central bank then can act preventively and inject liquidity into the bank contingent on the signal received $L(s_{CB})$. In this case also the risk exists that an insolvent bank ends up being helped. The game of the fund managers changes because the liquidity injection modifies the failure region.

[35] If this commitment problem is very acute then the private solution may be superior but even Goodfriend and Lacker (1999) state that "We are agnostic about the ultimate role of CB lending in a welfare-maximizing steady state".

7 Public Information and Transparency

Suppose now that fund managers have available also a public signal $v = R + \eta$, where $\eta \sim N\left(0, \frac{1}{\beta_p}\right)$ is independent from R and the error terms ε_i of the private signals. This public signal may come, for example, from an announcement made by the Central Bank.

In this case we may think that $\beta_p \gg \beta$. That is, private signals are not useless given the public signal v but the precision of the latter may be much higher. Despite this the collective information of investors reveals R and therefore dominates the public signal.

The information set of investor i now consists of his private signal s_i and the public signal v. The conditional distribution of R given v is $N(\widehat{R}, \frac{1}{\widehat{\alpha}})$ where : $\widehat{R} = \frac{\alpha\overline{R}+\beta_p v}{\alpha+\beta_p}$ and $\widehat{\alpha} = \alpha + \beta_p$.

Let us examine the new form of equilibrium conditions:

- The second equation (equation (7)) is unchanged, given that the conditional distribution of signals given R does not depend on v.
- However, the first equation now depends on v,

$$\Pr[R < R^* | s = t^*, v] = \gamma.$$

Because of normality, this can be written :

$$\Phi\left[\frac{\alpha(R^* - \overline{R}) + \beta_p(R^* - v) + \beta(R^* - t^*)}{\sqrt{\alpha + \beta_p + \beta}}\right] = \gamma,$$

or

$$\Phi\left[\frac{\widehat{\alpha}(R^* - \widehat{R}) + \beta(R^* - t^*)}{\sqrt{\widehat{\alpha} + \beta}}\right] = \gamma.$$

Comparing with equation (6), we see that, as expected, the only impact of the public signal v is to replace the unconditional moments $\overline{R}$ and $\frac{1}{\alpha}$ of R by its conditional moments $\widehat{R}$ and $\frac{1}{\widehat{\alpha}}$. Indeed, the prior on R can be interpreted as the observation of $\overline{R}$ with precision α.

The condition for a unique equilibrium becomes therefore:

$$\beta \geq \frac{1}{2\pi}\left(\frac{\lambda R_s}{1-m}\right)^2 \widehat{\alpha}^2.$$

We observe that, as before, the uniqueness property is lost if public information is precise enough. When $\beta = 0$, corresponding to the case of common knowledge (public information only), multiplicity prevails. Uniqueness is also lost if we move along a ray of positive slope from the origin in the plane (β, β_p), $\beta_p = k\beta$ with $k > 0$. This corresponds to a situation where the precision β of private signals grows without bound but the ratio β_p/β remains strictly positive. This means that, asymptotically, some information is still brought by the public signal. Then for β large enough there are three equilibria. However, as in Morris and Shin, if we keep β_p constant then as β tends to infinity the uniqueness property holds. All these results are in line with a recent contribution by C. Hellwig (2000) who questions the robustness of the results of Morris and Shin.

Here we will not interpret the multiplicity arising from the presence of public information as a lack of robustness of the uniqueness result but rather from the perspective of the lessons that can be drawn for Central Bank policy in relation to transparency. Indeed, even if we were to think that public forecasts are always interpreted in an idiosyncratic way, the case could be made that the central bank may have the unique ability to make an announcement that becomes common knowledge. Should the central bank then announce his signal to the public?

The common wisdom is that a Central Bank has to be as transparent as possible. However, it is evident that this need not be the case in our model. Indeed, while in the initial game without a public signal we may well be in the uniqueness region, adding a precise enough public signal we will have three equilibria.

For example, in the case $\beta_p = k\beta$ with $k > 0$ it is easily checked that for γ in $(0, 1)$, if $R_s < v < (1 + \lambda)R_s$ for β large enough there are three equilibria. There is an interior equilibrium with threshold at the public signal (with x in $(0, 1)$ and $t^* = R^* = v$) and two "corner" equilibria. In one corner equilibrium everybody runs ($x = 1$, with $t^* > R^* > v, R^* = (1 + \lambda)R_s$, and in the other nobody runs ($x = 0$, with $t^* < R^* < v$, $R^* = R_s$).[36]

[36] An equilibrium pair (R, t) has to fulfill:

At the interior equilibrium we have a similar result than with no public information but run and no-run equilibria also exist. We may therefore end up in an "always run" situation when disclosing (or increasing the precision of) the public signal while the economy was sitting in the interior equilibrium without public disclosure. In other words, public disclosure of a precise enough signal may be destabilizing. This means that a Central Bank that wants to avoid entering in the "unstable" region may have to add noise to its signal if it is "too" precise.

Summarizing the discussion on transparency:

- If we take the view that extra information (on top of the prior with precision $\alpha > 0$) is interpreted in an idiosyncratic way then more transparency (entailing private signals of higher precision β) reduces the incidence of coordination failure for β large (under the assumption that $\gamma < 1/2$).
- If there is public information that becomes common knowledge, perhaps through Central Bank disclosure, then the public signal cannot have too high a precision β_p since otherwise multiple equilibria reappear. Furthermore, even if we remain in the uniqueness region increasing the precision of public information will aggravate the coordination failure when fundamentals are weak (low $E[R|v]$, and under the assumption that $\gamma < 1/2$).

8 Endogenizing the liability structure and crisis resolution

In this section we sketch a possible way to endogenize the short term debt contract assumed in our model according to which depositors can withdraw at $\tau = 1$ or otherwise

$\Phi\left[\frac{\alpha(R-\overline{R})+\beta_p(R-v)+\beta(R-t)}{\sqrt{\alpha+\beta_p+\beta}}\right] = \gamma$, and $R = R_s(1+\lambda[\frac{\Phi(\sqrt{\beta}(t-R))-m}{1-m}]_+)$.

As $\beta \to \infty$ and given that $\gamma \in (0,1)$ and $\beta_p = k\beta$, $k > 0$, we obtain from the first equation that $t = (k+1)R - kv$. Assume that $R_s < v < (1+\lambda)R_s$. Let $\Gamma = \lim_{\beta \to +\infty} \sqrt{\beta}(t-R)$. We have that if in the limit $t > (<) R$, $\Gamma = +\infty$ ($-\infty$). Note that $x = \Phi(\Gamma)$ when $\beta \to \infty$. At the interior equilibrium Γ remains bounded and $t = R = v$. At the run equilibrium $R = (1+\lambda)R_s$, $t = (k+1)(1+\lambda)R_s - kv, \Gamma = \infty$ (because $t = (k+1)(1+\lambda)R_s - kv > (1+\lambda)R_s$ if an only if $(1+\lambda)R_s > v$). At a no-run equilibrium $R = R_s$, $t = (k+1)R_s - kv, \Gamma = -\infty$ (because $t = (k+1)R_s - kv < R_s$ if and only if $R_s < v$).

wait until $\tau = 2$. We have seen that the ability of investors to withdraw at $\tau = 1$ creates a coordination problem. We argue here that this potentially inefficient debt structure may be the only way investors can discipline a bank manager subject to a moral hazard problem.

Suppose indeed that investment in risky assets requires the supervision of a bank manager and that the distribution of returns of the risky assets depends on the effort undertaken by the manager. For example, the manager can either exert or not exert effort, $e \in \{0, 1\}$, and $R \sim N(\overline{R}_0, \alpha^{-1})$ when $e = 0$, and $R \sim N(\overline{R}, \alpha^{-1})$ when $e = 1$ with $\overline{R} > \overline{R}_0$. That is, exerting effort yields a return distribution that first order stochastically dominates the one obtained by not exerting effort. The bank manager incurs in a cost if he chooses $e = 1$; if he chooses $e = 0$ the cost is 0. The manager also receives a benefit from continuing the project until date 2. Assume for simplicity that the manager does not care about monetary incentives. The manager's effort cannot be observed so his willingness to undertake effort will depend on the relationship between his effort and the probability that the bank continues at date 1. Withdrawals may enforce then the early closure of the bank and provide incentives to the bank manager.[37]

In the banking contract, short term debt/demandable deposits can improve upon long term debt/nondemandable deposits. With long term debt incentives cannot be provided to the manager, because there is never liquidation, and therefore the manager does not exert effort. Furthermore, incentives cannot be provided either with renegotiable short term debt because early liquidation is ex post inefficient. Dispersed short term debt (i.e. uninsured deposits) is what is needed.

Let us assume that it is worthwhile to induce the manager to exert effort. This will be true for $\overline{R} - \overline{R}_0$ large enough and the (physical) cost of asset liquidation not too large. Recall that we model this liquidation cost as proportional to the future returns on the bank's portfolio. The banking contract will have short-term debt and will maximize the expected profits of the bank, choosing the investment in risky and safe assets and deposit payment, subject to the resource constraint, the individual rationality constraint of investors (zero

[37] This approach is based on Grossman and Hart (1982) and is followed in Gale and Vives (2002). See also Calomiris and Kahn (1991), Diamond and Rajan (1997) and Carletti (1999).

expected return), the incentive compatibility constraint of the bank manager,[38] and the (early) closure rule associated with the (unique) equilibrium in the investors' game. This early closure rule is defined by the property: $x(R,t^*)D > M + \frac{IR}{1+\lambda}$, which is satisfied if and only if R is smaller than $R_{EC}(t^*)$. As stated before, $R_{EC}(t^*) < R^*$ since early closure implies failure, while the converse is not true. Now, an interesting question is how the banking contract compares with the incentive efficient solution, which we now describe.

Given that the pooled signals of investors reveal R , we can define the incentive-efficient solution as the choice of investment in liquid and risky assets and probability of continuation at $t = 1$(as a function of R) which maximize expected surplus subject to the resource constraint and the incentive compatibility constraint of the bank manager.[39] Furthermore, given the monotonicity of the likelihood ratio $\frac{g(R\,|e=0)}{g(R\,|e=1)}$, the optimal region of continuation is of the cutoff form. More specifically, the optimal cutoff will be the smallest R, say R^o, that fulfills the incentive compatibility constraint of the bank manager. The cutoff R^o will be (weakly) increasing with the extent of the moral hazard problem that bank managers face. Since $R_{EC}(t^*)$ must also fulfil the incentive compatibility constraint of the bank manager, we will have that at the optimal banking contract with no LLR, $R_{EC}(t^*) \geq R^o$. In fact we will typically have a strict inequality, since there is no reason that the equilibrium threshold t^* satisfies $R_{EC}(t^*) = R^o$. This means that the market solution will lead to too many early closures of banks.[40]

Therefore the role of a modified LLR can be viewed, in this context, as correcting these market inefficiencies while maintaining the incentives of bank managers. By announcing its commitment to provide liquidity assistance (at a zero rate but only for the liquidity needs that exceed the amount that can be lent by the market) in order to avoid inefficient liquidation at $\tau = 1$, the LLR can implement the incentive efficient solution. We have

[38] More precisely, we assume as in the previous sections that the face value of the debt contract is the same in periods $t = 1, 2$ (equal to D) and we suppose also that investors in order to trust their money to fund managers need to be guaranteed a minimum expected return.

[39] We disregard here the welfare of the bank manager and of the funds managers.

[40] Moreover, the market solution will involve inefficient hoarding of liquidity as compared with the incentive efficient solution. The incentive-efficient solution solves $\text{Max}_m \left\{(1+E-Dm)(\overline{R}-(1-\nu)E(R \mid R < R^o)+Dm\right\}$

where R^o is the minimal return cutoff that incentivates the bank manager. If $(\overline{R}-(1-\nu)E(R \mid R < R^o) > 1$ we have that $m^o = 0$. Thus at the incentive-efficient solution it is optimal not to hold any reserves. This should come as no surprise because we assume that there is no cost of intervention argued already in Section 6 that the equilibrium of the investor's game will not be modified by such a discount window intervention. In order to implement the incentive efficient solution the modified LLR has to care about avoiding inefficient liquidation at $\tau = 1$ and not about avoiding failure of the bank. Now the solvency threshold R_s has no special meaning. The modified LLR helps the bank in the range $(R^o, R_{EC}(t^*))$ in the amount $D.x(t^*, R) - (M + \frac{IR}{1+\lambda}) > 0$. It is worth noting that the LLR help (bail-out) complements the money raised in the interbank market $\frac{IR}{1+\lambda}$(bail-in).

This modified LLR facility leads to a view on the LLR that differs from Bagehot's doctrine and introduces interesting policy questions. Indeed, R^o will typically be different from R_s. The reason is that R_s is determined by the promised payments to investors, cash reserves and investment in the risky asset, while R^o is just the minimum threshold that incentivates the banker to behave. We will have that $R^o > R_s$ when the moral hazard problem for bank managers is severe and $R^o < R_s$ when the moral hazard problem for bank managers is moderate.

Whenever $R^o > R_s$ there is a region (specifically, for R in (R_s, R^o)) where there should be early intervention (or prompt corrective action, to use the terminology of banking regulators). Indeed, in this region a solvent bank should be intervened to control moral hazard of the banker. When $R^o < R_s$, in the range (R^o, R_{EC}) the bank should be helped and it may be insolvent. More precisely, an insolvent bank in the range $(R^o, \min\{R_s, R_{EC}\})$ should be helped. If the Central Bank cannot help in this situation, because of its charter, then another institution (Deposit Insurance Fund, Regulatory Agency, Treasury) should come to the rescue.

When $R^o > R_s$ a Central Bank that can commit to a LLR policy can implement help restricted to the range (R^o, R_{EC}). However, if the Central Bank cannot commit and instead optimizes ex post (be it because to build a reputation is not possible or because of weakness in the presence of lobbying), it will intervene too often. Some additional institutional arrangement is needed in the range (R_s, R^o) to implement prompt corrective action (i.e. early closure of banks that are still solvent).

When $R^o < R_s$ the Central Bank, being prevented from subsidising banks, can only intervene when the bank is solvent. That is, in the range (R_s, R_{EC}) when $R_s < R_{EC}$.

Therefore another institution (financed by taxation or insurance premiums) is needed to provide an "orderly resolution of failure" when R is in the range $(R^o, \min\{R_s, R_{EC}\})$. This could be interpreted, as in corporate bankruptcy practice, as a way to preserve the going-concern value of the institution as well as allowing its owners and managers a fresh start after the crisis.

An important implication of our analysis is the complementarity between bail-ins (interbank market) and bail-outs (LLR) as well as other regulatory facilities (prompt corrective action, orderly resolution of failure) in crisis management.

In summary:

- No bail-in, no bail-out. With neither a LLR nor an interbank market, liquidation takes place whenever $x > mD$, which limits inefficiently investment I.
- Bail-in but no bail-out. With an interbank market but no LLR (as advocated by Goodfriend and King) the closure threshold is $R_{EC}(t^*)$ and there is excessive failure whenever $R_{EC}(t^*) > R^o$.
- Bail-in and bail-out. With both a LLR facility and an interbank market:
  - When $R^o > R_s$ (severe moral hazard problem for the banker) the incentive-efficient solution can be implemented complementing the LLR with a policy of prompt corrective action in the range (R_s, R^o).
  - When $R^o < R_s$ (moderate moral hazard problem for the banker), a different institution (financed by taxation or by insurance premiums) is needed to complement the Central Bank and implement the incentive-efficient solution. The Central Bank helps whenever the bank is solvent and the other institution provides an "orderly resolution of failure" in the range $(R^o, \min\{R_s, R_{EC}(t^*)\})$.

9 An International Lender of Last Resort

In this section we reinterpret the model in an international setting and provide a potential rationale for an International Lender of Last Resort (ILLR) à la Bagehot.

An ILLR can follow a policy of injecting liquidity in international financial markets (going from the proposal of establishing a global central bank issuing an international currency to the mere coordination of the intervention of the three major central banks[41]) or can act to help particular banking systems in trouble much like a central bank acts to help individual banking institutions. The last approach is developed in several proposals that adapt Bagehot's doctrine to international lending (see, for example, the Meltzer Report (IFIAC (2000)) and Fisher (1999)). As pointed out by Jeanne and Wyplosz (2001), a major difference between the approaches is on the required size of the ILLR. In the first case an issuer of international currency is needed while in the second the intervention is bounded by the difference between the short-term foreign exchange liabilities of the banking sector and the foreign reserves of the country in question. We will look here at the second approach.

9.1 A reinterpretation of the model

Suppose now that the balance sheet of Section 2 corresponds to the banking system of a small open economy where D_0 is the foreign denominated short-term debt, M is the amount of foreign reserves, I is the investment in risky local entrepreneurial projects, E equity and long-term debt, and D is the face value of the foreign denominated short-term debt.[42] Our fund managers are now international fund managers operating in the international interbank market. The liquidity ratio $m = M/D$ is now the ratio of foreign reserves to foreign short-term debt, a crucial ratio according to empirical work in determining the probability of a country crisis. Indeed, Radelet and Sachs (1998), and Rodrik and Velasco (1999) find that the ratio of short-term debt to reserves is a robust predictor of financial crisis (in the sense of a sharp reversal of capital flows).[43] The parameter λ represents now the fire sales premium associated to early sales of foreign short-term bank assets in the secondary market. Furthermore, for a given amount of withdrawals by fund managers $x > m$, there are critical thresholds for the return R of banking assets below which the banking sector needs to be restructured ("liquidated") at $\tau = 1$ ($R_{ec}(x)$) or is bankrupt

[41] See Eichengreen (1999) for a survey of the different proposals.

[42] A somewhat bolder interpretation would be to think that the balance sheet corresponds to the whole private sector of the country.

[43] The latter also find that a greater short-term exposure aggravates the crisis once capital flows reverse.

$(R_f(x))$.

9.2 Results

- There is a range or realizations of the return R of the banking sector (R_s, R^*) for which coordination failure occurs. This happens when the amount of withdrawals by foreign fund managers is so large that the banking sector is bankrupt even though it is (in principle) solvent.

- For a high enough foreign reserve ratio m there is no coordination failure of international investors.

- The probability of bankruptcy of the banking sector is:

  - decreasing in the foreign reserve ratio, the solvency ratio, the relative reputation cost of withdrawal for international fund managers (C/B), and the expected mean return of the country investment;
  - increasing in the fire sales premium and the face value of foreign short-term debt; and
  - increasing in the precision of public information about R when public news are bad and decreasing in the precision of private information (both provided C/B is not too large).

- An ILLR that follows Bagehot's prescription can minimize the incidence of coordination failure among international fund managers provided that is well informed about R. One possibility is that the ILLR has supervisory knowledge of the banking system of the country where the crisis occurs.[44]

- The disclosure of a public signal about country return prospects may introduce multiple equilibria. A well-informed international agency may want to be cautious and not disclose publicly too precise information to avoid a rally of expectations in a run equilibrium.

[44] Although this seems more farfetched than in the case of a domestic LLR, the IMF, for example, is trying to enhance its monitoring capabilities with the Financial Sector Assessment Programs.

- In the presence of a moral hazard problem for bank managers, foreign short-term debt serves the purpose of disciplining bank managers. Note that domestic currency denominated short-term debt will not discipline bank managers because it can be inflated away. There will be an optimal cutoff point R^o below which the banking sector should be restructured. The following scenarios can be considered:

  - No bail-in, no bail-out. With no ILLR and no access to the international interbank market country projects are liquidated whenever withdrawals by foreign fund managers are larger than foreign reserves. This limits inefficiently investment.
  - Bail-in but no bail-out. With no ILLR but access to the international interbank market some costly project liquidation is avoided with fire sales of assets but still there will be excessive liquidation of entrepreneurial projects.
  - Bail-in and bail-out. With ILLR and access to the international interbank market:
    * In the range $(R^o, R_{EC}(t^*))$ public (bail-out) and private (bail-in) involvement are complementary to implement the incentive efficient solution.
    * When the moral hazard problem for country bank managers is severe ($R^o > R_s$), a policy of prompt corrective action in the range (R_s, R^o) is needed to complement the ILLR facility. A solvent country may need to restructure its banking system when returns are close to the solvency threshold.
    * When the moral hazard problem for country bank managers is moderate ($R^o < R_s$), on top of the ILLR help for a solvent country an orderly resolution of failure process is needed in the range $(R^o, \min\{R_s, R_{EC}(t^*)\})$. An insolvent banking system should be helped when not too far away from the solvency threshold. This may be interpreted as a mechanism similar to the sovereign debt restructuring mechanim (SDRM) of the sort currently studied by the IMF with the objective of restructuring unsustainable debt.[45] In our case this would be the foreign short-term debt of the banking sector

[45] See Bolton (2002) for a discussion of SDRM type facilities from the perspective of corporate bankruptcy theory and practice.

(or of the private sector more in general). In the range $(R^o, \min\{R_s, R_{EC}\})$ an institution like an international bankruptcy court could help.

Again, an important insight from the analysis is the complementarity between the market (bail-ins) and an ILLR facility (bail-out) together with other regulatory facilities to provide for promt corrective action and orderly failure resolution.

10 Concluding remarks

In this paper we have provided a rationale for Bagehot's doctrine of helping illiquid but solvent banks in the context of modern interbank markets. Indeed, investors in the interbank market may face a coordination failure and intervention may be desirable. We have examined the impact of public intervention along the following four dimensions:

- solvency and liquidity requirements (at $\tau = 0$);
- Lender of Last Resort policy (at the interim date $\tau = 1$);
- transparency and public disclosure of central bank's information, and
- closure rules, which can consist of two types of policy: orderly resolution of failures or prompt corrective action.

The coordination failure can be avoided by appropriate solvency and liquidity requirements. However, the cost of doing so will typically be too large in terms of foregone returns and ex ante measures will only help partially. This means that prudential regulation needs to be complemented by a Lender of Last Resort policy. The paper shows how discount window loans can eliminate the coordination failure (or alleviate it if for incentive reasons some degree of coordination failure is optimal). It also sheds lights on when open market operations will be appropriate.

When the Central Bank has access to a public signal it is shown that the effects of its disclosure depend on whether its signal becomes common knowledge or not. If it does then disclosure of a signal of high enough precision could be destabilizing. An oblique statement by a central banker may be optimal in that it either provides information without creating a common knowledge signal or, even if it does, it adds enough noise so that the information does not become destabilizing. In any case, increasing the precision of public information may aggravate the coordination failure whenever the fundamentals are weak.

Finally, a main insight of the analysis is that public and private involvement are complementary in implementing the incentive efficient solution. Furthemore, the implementation of this solution may require also to complement the Bagehot's LLR facility with prompt corrective action (intervention on a solvent bank) or orderly failure resolution (help to an insolvent bank).

The model, when given an interpretation in an international context, provides a rationale for an international LLR, as well as orderly failure resolution facilities, and points at the complementarity between bail-ins and bail-outs in crisis resolution.

References

Allen, F. and D. Gale (1998), "Optimal Financial Crises", *Journal of Finance*, 53, 1245-1284.

Bagehot, W. (1873), *Lombard Street*, London, H.S. King.

Bernanke, B. (1983), "Nonmonetary Effects of the Financial Crisis in the Propagation of the Great Depression", *American Economic Review*, 73, 257-263.

Bernanke, B. and M. Gertler (1989), "Agency Costs, Net Worth, and Business Fluctuations," *American Economic Review*, 79, 14-31.

Berger, A., N. S. Davies and M. Flannery (1998), "Comparing Market and Supervisory Assessments of Bank Performances: Who Knows What When?", Finance and Economics Discussion Series no. 1998-32, Federal Reserve Board of Governors.

Bolton, P. (2002), "Towards a Statutory Approach to Sovereign Debt Restructuring: Lessons from Corporate Bankruptcy Practice around the World", mimeo.

Bordo, M.D. (1990), "The Lender of Last Resort: Alternative Views and Historical Experience", Federal Reserve Bank of Richmond, *Economic Review*, 18-29.

Bryant, J. (1980), "A Model of Reserves, Bank Runs and Deposit Insurance", *Journal of Banking and Finance*, 4, 335-344.

Calomiris, C. (1988a), "The IMF's Imprudent Role as a Lender of Last Resort", *Cato Journal*, 17, 2, February.

Calomiris, C. (1988b), "Blueprints for a New Global Financial Architecture", Joint Economics Committee, United States Congress, Washington D.C. (October 7th).

Calomiris, C. and C. Kahn (1991), "The Role of Demandable Debt in Structuring Optimal Banking Arrangements", *American Economic Review* , 81(3), 497-513.

Carletti, E. (1999), "Bank Moral Hazard and Market Discipline", FMG Discussion Paper, LSE, London UK.

Carlsson, H. and E. Van Damme (1993), "Global Games and Equilibrium Selection", *Econometrica,* 61(5), 989-1018.

Chari, V.V. and R. Jagannathan (1988), "Banking Panics, Information, and Rational Expectations Equilibrium", *Journal of Finance*, 43(3), 749-761.

Chari, V. and P. Kehoe (1998), "Asking the Right Questions about the IMF," *Public Affairs*, 13, 3-26.

Corsetti, G., A. Dasgupta, S.Morris and H.S. Shin (2000), "Does One Soros make a Difference? The Role of a Large Trader in Currency Crises", mimeo.

DeYoung, R, M. Flannery, W. Land and S. Sorescu (1998), "The Informational Advantage of Specialized Monitors: The Case of Bank Examiners", mimeo.

Diamond, D. and P. Dybvig (1983), "Bank Runs, Deposit Insurance and Liquidity", *Journal of Political Economy*, 91, 3, 401-419.

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

Eichengreen, Barry, *Toward a New International Financial Architecture: A Practical Post-Asia Agenda*, Institute for International Economics, 1999.

Fisher, S. (1999), "On the Need for an International Lender of Last Resort," *The Journal of Economic Perspectives*, 13, 85-104.

Flannery, M. (1996), "Financial Crises, Payment Systems Problems, and Discount Window Lending", *Journal of Money, Credit and Banking* 28, 4, 804-824.

Folkerts-Landau, D. and P. Garber (1992), "The ECB: a Bank or a Monetary Policy Rule?", in M.B. Canzoneri, V. Grilland, P.R. Masson, (Eds), CEPR, Cambridge University Press, *Establishing a Central Bank: Issues in Europe and Lessons from the US*, Chapter 4 , 86-110.

Freixas, X., C. Giannini, G. Hoggarth and F. Soussa (1999) "Lender of Last Resort-A Review of the Literature"*Financial Stability Review, Bank of England, 7,151-167.*

Freixas, X., B. Parigi and J.C. Rochet (1998), "The Lender of Last Resort : A Theoretical Foundation", mimeo, University of Toulouse.

Gale, D. and X. Vives (2002), "Dollarization, Bailouts, and the Stability of the Banking System", CEPR D.P. No. 2901, *Quarterly Journal of Economics,* 117, 2, 467-502.

Goldstein, I. and A. Pauzner (2000), "Demand Deposit Contracts and the Probability of Bank Runs", Discussion Paper, Tel-Aviv University.

Goodfriend, M. and R. King (1988), "Financial Deregulation, Monetary Policy and Central Banking", in *Restructuring Banking and Financial Services in America*, Haraf W. and R.M. Kushmeider eds., *AEI Studies* , 481, Lanham Md, USA.

Goodfriend, M. and M. Lacker (1999), "Limited Commitment and Central Bank Lending", Federal Reserve Bank of Richmond WP 99-2.

Goodhart, C. (1995), The Central Bank and the Financial System, Cambridge, MA : MIT Press.

Goodhart, C. and H. Huang (1999a), "A Model of the Lender of Last Resort", FMG, LSE Discussion Paper 313, London.

Goodhart, C. and H. Huang (1999b), "A Simple Model of an International Lender of Last Resort", FMG, LSE Discussion Paper 336, London.

Gorton, G. (1985), "Bank Suspension of Convertibility", *Journal of Monetary Economics*, 177-193.

Gorton, G. (1988), "Banking Panics and Business Cycles", *Oxford Economic Papers* 40, 751-781.

Grossman, S. and O. Hart (1982), "Corporate Financial Structure and Managerial Incentives," in J. McCall (ed.) *The Economics of Information and Uncertainty*, 107 - 137. Chicago: University of Chicago Press.

Hart, O. and J. Moore (1994), "A Theory of Debt Based on the Inalienability of Human Capital", *Quarterly Journal of Economics*, 109, 4, 841-879.

Heinemann, F. and G. Illing (2000), "Speculative Attacks: Unique Sunspot Equilibrium and Transparency", mimeo, CFS, Frankfurt.

Hellwig, C. (2000),"Public Information, Private Information and Coordination Failures: A Note on Morris and Shin", FMG discussion papers, LSE, London UK.

Holmstrom, B. and J.Tirole (1997), "Financial Intermediation, Loanable Funds, and the Real Sector", *Quarterly Journal of Economics*, 112, 3, 663-691.

Humphrey, T. (1975), "The Classical Concept of the Lender of Last Resort", *Economic Review*, 61.

International Financial Institution Advisory Commission (2000), *Report of the International Financial Institution Advisory Commission*, Allan H. Meltzer, Chairman, Washington DC, March.

Jacklin, C. and S. Bhattacharya (1988), "Distinguishing Panics and Information-Based Bank Runs: Welfare and Policy Implications", *Journal of Political Economy* 96(3), 568-592.

Jeanne, O. and C.Wyplosz (2001), "The International Lender of Last Resort: How Large is Large Enough?", NBER WP 8381.

Kaminsky, G. L. and C. Reinhart, (1999), "The Twin Crises: The Causes of Banking and Balance-of-Payments Problems", *American Economic Review* , 89, 473-500.

Kaufman, G. (1991), "Lender of Last Resort: a Contemporary Perspective", *Journal of Financial Services Research*, 5, 95-110.

Lindgren, C.-J., G. Garcia and M. Saal (1996), *Bank Soundedness and Macroeconomic Policy*, IMF, Washington, D.C.

Markets Group of the Federal Reserve Bank of New York (2002), "Domestic Open Market Operations During 2001", Federal Reserve Bank of New York.

Martin, A. (2002) " Reconciling Bagehot with the Fed's response to Sept. 11", FRB of Kansas City, October.

Mishkin, F. (1998), "Systemic Risk, Moral Hazard and the International Lender of Last Resort", NBER and Columbia University, April.

Morris, S. and H.S. Shin (1998), "Unique Equilibrium in a Model of Self-Fulfilling Currency Attacks", *American Economic Review*, 88, 587-597.

Morris, S. and H. S. Shin (2000), "Rethinking Multiple Equilibria in Macroeconomic Modelling", NBER *Macroeconomics Annual*.

Morris, S. and H. S. Shin (2001), "The CNBC Effect: Welfare Effects of Public Information", mimeo.

Padoa-Schioppa, T. (1999), "EMU and Banking Supervision", Lecture at the London School of Economics, Financial Market Group.

Peek, J. E. Rosengren and G. Tootell (1999), "Is Bank Supervision Central to Central Banking", *Quarterly Journal of Economics*, 114 (2), 629-53.

Postlewaite, A. and X. Vives (1987), "Bank Runs as an Equilibrium Phenomenon", *Journal of Political Economy*, 95(3), 485-491.

Radelet, S. and J. Sachs (1998), "The Onset of the Asian Financial Crisis", mimeo, Harvard Institute for International Development.

Rodrik, D. and A. Velasco (1999), "Short-Term Capital Flows", World Bank 1999 ABCDE Conference.

Romer, C. and D. Romer (2000), "Federal Reserve Information and the Behavior of Interest Rates", *American Economic Review*, 90, 3, 429-453.

Schwartz, A. J. (1992), "The Misuse of the Fed's Discount Window", *Federal Reserve Bank of St. Louis Review*, September/October, 58-69.

Tarkka, J. and D. Mayes (2000), "The Value of Publishing Official Central Bank Forecasts", mimeo, Bank of Finland.

Thornton, H. (1802), *An Enquiry into the Nature and Effects of Paper Credit of Great Britain*, London, Hatchard.

Vives, X. (1990),"Nash Equilibrium with Strategic Complementarities", *Journal of Mathematical Economics*, 19, 3, 305-321.

Vives, X. (1999), *Oligopoly Pricing: Old Ideas and New Tools,* MIT Press, Boston and London.