Monitoring, liquidity provisions, and financial crises

By

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ABSTRACT

This paper analyzes central bank policies on the monitoring of banks in distress in which liquidity provisions are conditional on performance when a bad shock occurs. A sequential game model is used to analyze two policies: the first one in which the central bank acts with discretion and the second in which the optimal monitoring policy rule is made public and institutionalized. The results show that banks exert less effort and take higher risks with a discretionary monitoring policy. With public information about monitoring rules, there is more central bank monitoring and less need to provide emergency funding. Public information about monitoring resolves the multiple equilibria that arise with discretion in fact, a unique equilibrium emerges in which the probability of a banking crisis is reduced.

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1. Introduction

The handling of financial crises is now at the top of the agenda for economists and policymakers alike. Worldwide, we have recently experienced a large number of bank failures as well as the provisions of massive emergency funding from central banks to financial institutions in distress. These events are forcing analysts to reconsider the role and responsibilities of central banks or regulators in general.[1] Should the central bank or the relevant regulator have the authority and responsibility to institute, follow and enforce *rules* over time in order to achieve financial stability? Or should instead the central bank or the regulator take corrective actions *only* when a crisis is imminent? How would the central bank or regulator decide which banks should be allowed to fail? These issues are, indeed, crucial and controversial. An optimal course of action must aim in any case to avoid both crisis and moral hazard.

There is much disagreement in the Economics profession about what is an optimal policy; in the meantime, unorthodox policy measures are taken on an ad hoc basis. The economic analyses on ex-post measures have so far only centered on the type of policy that should be implemented to resolve such crises once they have occurred. For example, some studies look at the effects of government assistance (e.g., liquidity provisions) or other mechanisms (e.g., regulations) without any conditionality with regard to the ex-post resolution of financial crises. Other studies include conditionality in their analyses but still encounter time-inconsistency and moral hazard problems. This is not surprising, since it is well known that discretionary policies, even when they are made conditional, can risk exacerbating moral hazard problems. Some studies analyze the ex-ante measures that aim to prevent such crises by focusing on the role of the BIS and its Basel Accords, while others focus on the effect of

[1] This paper does not deal with the division of labor and power between different regulators. This is an interesting and relevant topic and we will study it in another research paper.

the Federal Deposit Insurance Corporation Improvement Act (FDICIA) of 1991. The Basel II Framework describes a measurable minimum standard for capital adequacy, which is intended to guarantee a solid international financial architecture and to help avoid systemic risk. The FDICIA of 1991 mandates annual, full-scope examinations of banks by regulators. Note that these regulatory examinations and audits are predicated on the basis of the information that ratings-based classifications, such as CAMELS ratings, reveal about a bank's true financial health, and not on basis of a direct evaluation by the relevant regulators themselves. How informative CAMELS ratings are in assessing a bank's financial condition is an open question, see Greenbaum and Thakor (2007) and Gasbarro, Sadguna and Zumwalt (2002). Studies analyzing government ex-ante commitments to specific measures if a crisis occurs, have generally come to reach two contradictory conclusions. First, ex-ante commitments face time-inconsistency problems, and secondly, the lack of commitment by governments induces a bank behavior (i.e., moral hazard) that increases the likelihood of systemic banking crises.

This paper shows that moral hazard problems, even in the presence of conditionality, will always arise with ex-ante or ex-post measures if there is no mechanism for monitoring or supervision. The monitoring mechanism is a key concern of this paper. We in addition find it necessary that the *optimal monitoring policy* does not *only* becomes a public announcement but has *rule-like features* so as to i) effectively allow the regulator to implement conditionality and determine which financial institution is the justifiable candidate to obtain liquidity provisions; ii) dissuade authorities from implementing discretionary policies and avoid time-inconsistency problems; iii) reduce uncertainty about the central bank's actions. Once the rule is institutionalized, it is hard to think of a time inconsistency situation in which central banks can suddenly and easily announce that they have changed their minds without causing bewildering. We think that it will be extremely difficult to persuade the public that a central bank cannot follow the rule one time just because the financial sector has been badly run and hard to monitor. Our results are important and new in the financial market context, and should be taken into account in the literature that considers both the resolution and prevention of financial crisis. Nevertheless, we must recall that the theory of monetary policy has indeed dealt with similar problems and debates when focusing on the potential trade-offs between short-run increases in output and maintaining a credible *rule* of low and stable inflation (see Plosser (2009)). To our knowledge, the theories of financial crisis resolution are not yet taking into account the lesson learned from such theory: specifying in advance the states of the world under which the central bank will intervene is an essential first step. We pursue that here.

The central bank is here assumed to have the opportunity to conditionally provide outside liquidity (Holmstrøm and Tirole (2001)) to enable a troubled institution to fulfill its obligations toward its depositors and investors and keep its charter.[2] We first consider a case in which the central bank acts with discretion and determines ex-post the optimal monitoring level. In the second case, the central bank determines and makes public the optimal monitoring level before banks make decisions. This optimal monitoring rule is one that minimizes moral hazard problems, costs of providing liquidity, and risks of financial crisis mainly because the central bank can influence financial institutions behavior while establishing its optimal rule at an early stage. This is not possible with discretionary policy because these institutions behaviors are taken as given. The paper then compares these two cases by focusing on the moral hazard effects of the two policies. Note again that making public the rule for monitoring, as in monetary economics modeling, puts pressure on the central bank to provide emergency funding to only the deserving banks (i.e., banks without moral hazard problems). Here, it is optimal to let those banks engaged in moral hazard fail,

[2] One may think of the policy of providing liquidity as an example of emergency assistance to financial institutions in distress. Other types of assistance could be very well considered in the framework of our model. The most important feature in our model is rather the monitoring policy.

even if it is ex-post optimal to let them continue. We thus present an important approach that has not yet been considered in the relevant literature of financial markets.

The model considers the sequence of optimal decisions of the central bank and banks as well as the outcomes under discretionary and public monitoring policies. To study such dynamics, a three-stage, sequential game model is used in which the optimal strategies are found through backward induction. The degree of monitoring is endogenously derived from a well-specified objective function of the central bank. The model analyzes bank behavior when there are first, ex-post discretionary monitoring policies, and second, public rules for monitoring. Banks have well-specified objective functions as well.

The most important results are as follows. First, with a *discretionary* policy, there will be self-fulfilling expectations and multiple equilibria, including "good" and "bad" equilibria. The "bad" equilibria are associated with (self-fulfilling) expectations that there will be little or no monitoring when a bad shock occurs. The "good" equilibria are associated with expectations that there will be high levels of monitoring, independent of a shock. In the bad equilibria, there will be significant moral hazard problems and greater needs for emergency funding. Second, when the monitoring policy *rule* is made public, in the event of a bad shock, the optimal solution is one in which the central bank monitors more. In this case, moral hazard problems and each bank's probability of becoming insolvent are reduced because risk-taking behavior is ameliorated. There will be then much less need for emergency funding.

The research of Perotti and Suarez (2002) and Acharya and Yorulmazer (2007, 2008) is closely related to our work. They proposed certain types of ex-post central bank assistance policies and regulations conditional on performance. Perotti and Suarez (2002) considered the effect of implementing discretionary policies on bank entry and merging during banking crises conditional on the risks that competing banks have taken. They conclude that with such policies, banks can be motivated to behave prudently in order to be able to take over the business of failed banks. Such a result, however, depends on the crucial assumption that there is not ex-ante uncertainty that such discretionary policies will be implemented when banks make decisions on risk. Acharya and Yorulmazer (2007) model the effects of so-called "too-many-to-fail" guarantees as an ex-post policy, while Acharya and Yorulmazer (2008) consider ex-post liquidity provision policies for surviving banks aimed at allowing these banks to acquire failing banks. They emphasize that the behavior of banks depends on their expectations of the regulator's future polices. They do not consider, as we do here, any monitoring policy. They find that the ex-post bailout policies give banks incentives to exhibit herding behavior (Acharya and Yorulmazer (2007)) and have highly correlated portfolios (Acharya and Yorulmazer (2008)), thus increasing the risk of having many banks failing together ex-post, encouraging "too-many-to-fail" guarantees from the central bank. They also discuss the case in which the regulator wishes ex-ante to implement the ex-post optimal guarantee policies and yet induce a low correlation among banks. They conclude that such ex-ante regulation is time-inconsistent which as they argue, arises when the regulator faces extremely high liquidity provision costs ex-post due to the bank failure rate being very high. An important issue is the application of their analysis to financial problems such as the one that we are experiencing now. One needs not only to weigh the costs of providing liquidity with the costs of letting financial institutions fail, but also the role that monitoring will play in reducing such costs as well as solving agency problems. Our model is careful in considering this balance.

Another related work is by Goodhart and Huang (2005), who explicitly represent the classic "social cost-moral hazard" trade-off. They show that the central bank has incentives to provide Lender of Last Resort (LOLR) assistance when concerns about the contagious effects of crises are weighted more strongly than moral hazard considerations. They do not examine polices adequate for addressing moral hazard problems. Freixas (2000) finds that depending on the characteristics of the bank's balance sheets and the social cost of bank failure, the optimal policy may be either a systematic bailout using discretion or a mixed strategy; the latter provides a theoretical foundation for the "constructive ambiguity" doctrine (i.e., the adoption of ambiguous policy in response to a financial crisis). The analysis of this paper moves away from "constructive ambiguity" by making monitoring information public in order to resolve uncertainties. Cordella and Yeyati (2003) find that the ”constructive ambiguity” approach often recommended to attenuate moral hazard is always dominated by a policy in which the LOLR announces with certainty that it will rescue failing banks conditional upon an adverse aggregate shock. This conditionality is, however, not set based on bank behavior, as we do here. Monitoring is not either considered. Mailath and Mester (1994) look at incentives for a distressed bank to invest in excessively risky projects and show that when regulators cannot commit to future actions, forbearance arises as an equilibrium outcome. Note that they do not present solutions to moral hazard and agency problems as we do here.

Indeed, schemes for assisting banks in distress can make the probability of surviving less dependent on each bank's choice of risk, and more dependent on the central bank's assistance. In contrast to the above papers, our model not only seriously considers that emergency assistance be made conditional on the occurrence of a bad shock as well as on bank performance, but it also demonstrates that central bank monitoring is necessary to reduce moral hazard problems and bank failures. Discretionary policies cannot eliminate the uncertainty about a regulator's future policies, and in general do not induce good bank behavior. Again, a better outcome is obtained when the monitoring policy becomes public information.

Section 2 presents the economic environment. Section 3 derives the optimal decisions of banks, while Section 4 explains the central bank's problem. Section 5 describes the three-stage, sequential game-theoretical model. Section 6 presents the solution for the equilibrium in which the central bank acts with discretion. The case in which the central bank makes its monitoring policy public knowledge is presented in Section 7. Section 8 concludes the paper.

2. The economic environment

We present a three-stage, sequential game in which the players include the central bank and the private banks. At the last stage of the game, a shock occurs. This could be a bad shock, *b*, or a good shock, *g*, which occurs with probability *q* and *(1 – q)*, respectively. Thus, in the bad state, *b* occurs and banks face negative returns and liquidity problems unless there is no central bank assistance. In the good state, *g* occurs and banks' returns are positive.

Banks make decisions about their amount of risky investment and effort to screen investments and pay sufficient attention to risk management with the aim of achieving a certain level of reputation. We say that a bank has moral hazard problems if it engages in excessive risky investment and exert low effort because it expects to receive financial assistance but not to be monitored in the bad state. Such type of bank does not therefore care much about its reputation. Our world here has two groups of banks, and in each group, banks are heterogeneous. Of the total population of banks, n_1 banks are always transparent and never have moral hazard problems. They are very much concerned about their reputation. This group of banks is called *T* for transparent. The rest of the banks, n_2, behave strategically: they will have moral hazard problems and be less transparent in the absence of sufficient incentives. Reputational effects are less important for this type of banks. This group of banks is called *S* for strategic. The focus here is on differentiating between the behaviors of banks in groups *T* and *S*, and we consider the decisions of banks in group *T* as our benchmark for the socially optimal risk-taking. Our analysis focuses on determining how different decisions banks in group *S* may become from those of banks in group *T* a result of central bank policies.

Returns on each individual bank's investments are not directly observable. The probability distribution of the returns in the population of banks in groups *T* and *S* can, however, be observed. Financial assistance by the central bank is always conditional on the fact that a bank is not detected as type *S* when a bad shock, *b*, has occurred. To recognize bank type, the central bank needs to engage in monitoring, denoted by *m*. The idea behind imposing such conditionality is to penalize insolvency when there are moral hazard problems. When an *S* bank reports its losses and searches for assistance, the central bank can only recognize with probability $\rho(m)$ to which return distribution the bank belongs to, and $\rho'(m) = d\rho/dm > 0$.[3]

We consider two types of monitoring policy. With the first type, the central bank acts with discretion, in which case bank actions are taken as given when determining the optimal level of monitoring intensity, *m*. Note that this also means that the central bank takes as given the return distributions. The second type is one with which the monitoring policy is made public before banks form expectations and make decisions. It is only in this case that the central bank's optimal decisions about *m* aim to influence the bank decisions and return distributions.

As we will see, the central bank's roles as monitor and LOLR are interrelated: monitoring is relevant when liquidity provision is needed. The characteristics of this interrelationship depend on whether monitoring rules are publicly established at an early stage or not.

3. The bank's problem

Each bank decides on its optimal amount of risky investment, *L*, and effort, *e*. Unless the central bank makes public its monitoring policy, banks make optimal decisions on the basis of their expectations about future shocks and the central bank's policies on monitoring and liquidity assistance.

Optimal investments of the transparent banks, L^T, and of strategic banks, L^S, are less profitable in the bad state than in the good state. In the good state, a bank j belonging to group *T,* will obtain a positive returns $R_g^T(j)$ (j=1,…,n_1), while if bank i belongs to group *S*, it will

[3] Since banks in group S are transparent, they can be always recognized its type not matter the level of m.

obtain a positive returns equal to $R_g^S(i)$ (i=1,…,n_2). However, when *b* occurs, banks in group *T* will obtain negative returns $R_b^T(j)$, they will receive liquidity assistance since they have no moral hazard problems and are highly transparency, independent of the degree of central bank's monitoring. Banks in *S*, will achieve negative returns $R_b^S(i)$, but their possibilities of receiving liquidity however, depend on the central bank's intensity of monitoring. When these banks are found to have moral hazard problems, they will not receive emergency funding and will lose their charters.

3.1 Banks' optimal decisions are independent of the liquidity provision policy

Banks in group T, our benchmark banks, make decisions about their investment, L^T, and effort, e^T. Each of them (j=1,…,n_1) maximizes the following expected net return function $E(R^T)$, where the j subscript is dropped to remove formula redundancy:

$$E\left(R^T\right) = qR_b^T\left(L^T, e^T\right) + (1-q)R_g^T\left(L^T, e^T\right) - C^T(e^T). \tag{1}$$

The return functions, R_b^T and R_g^T, are concave in the control variables, L^T and e^T. $C^T(e^T)$ is the cost function of effort which is concave and increasing, satisfying $C_e^T > 0$ and $C_{ee}^T \geq 0$.

The optimal level of e^T that maximizes (1) is determined from the following first-order condition:

$$qR_{b,e}^T + (1-q)R_{g,e}^T = C_e^T. \tag{2}$$

Without loss of generality, we assume that bank returns are an increasing function of effort for a given L^T, that is, $R_{g,e}^T > 0$ and $R_{b,e}^T > 0$. At the optimal level of effort, the expected marginal return of effort equals the marginal cost of effort.

The optimal level of L^T that maximizes (1) is determined from the following first-order condition:

$$\frac{R_{b,L}^T}{R_{g,L}^T} = -\left[{(1-q)}/{q}\right] < 0. \tag{3}$$

The left-hand side in (3) is the ratio between the marginal returns at the optimal investment L^T in the bad ($R_{b,L}^T$) and good ($R_{g,L}^T$) states, respectively. Now, since the returns are only negative in the bad state for every j=1,…,n_1, the marginal return at the L^T will only be negative in the bad state ($R_{b,L}^T < 0$) and positive in the good state ($R_{g,L}^T > 0$).

3.2 Banks' optimal decisions depend on the liquidity provision policy

The emergency funding that the central bank provides could be only a fraction Φ [$\Phi \in (0, 1)$] of banks' net losses or negative returns.[4] Each of the banks (j=1,…,n_2) that belong to group S will maximize the following expected net return function $E(R^S)$:

$$E\left(R^S\right) = q\left\{(1-\Phi)(1-\rho(m))R_b^S\left(L^S, e^S\right) + \rho(m)R_b^S\left(L^S, e^S\right)\right\} + \\ (1-q)R_g^S\left(L^S, e^S\right) - C^S\left(e^S\right) \quad . \tag{4}$$

The return functions, R_b^S, R_g^S, and cost function $C^S(e^S)$ are here also concave and well behaved. At a certain monitoring intensity, m, there is a probability $(1 - \rho(m))$ ($\rho(m)$) that a bank will not (will) be detected as a member of group S. In the event of a bad shock, b, (4) indicates that with probability $q(1-\rho(m))$, banks in S will face losses equal to $(1-\Phi)R_b^S(L^S,e^S)$ after receiving emergency funding, but equal to $R_b^S(L^S,e^S)$ with the probability $q(\rho(m))$.

Proposition 1 In equilibrium, for a given e^S, m, and Φ, the equilibrium amount of risky investment will be higher for banks in group S than in group T. The returns will consequently be more negative in the bad state for banks in S than for banks in T.

Proof of Proposition 1

Maximizing (4) with respect to L^S yields the following first-order condition for L^S:

[4] One could also interpret Φ as a percentage of recapitalization up to an optimal standard in accordance with the central bank's objectives.

$$\frac{R^S_{b,L}}{R^S_{g,L}} = -\left[\frac{(1-q)}{q\big(1-\Phi(1-\rho(m))\big)}\right] < 0 \ . \tag{5}$$

(5) is similar to (3), except that now *Φ* and *ρ(m)* affect the ratio in (5). For given expected emergency funding (i.e., given level of *Φ*) and level of monitoring *m* by banks, the marginal return at the optimal solution L^S is more negative for banks in S than the marginal return at the optimal solution L^T for banks in T. That is, $R_{b,L}{}^S < R_{b,L}{}^T$ which implies that $L^S > L^T$, and that returns will be more negative for banks in S than for those in T in equilibrium ■

Proposition 2 For a given e^S, *m*, and *Φ*, the equilibrium level of effort will be lower for banks in S than for banks in T.

Proof of Proposition 2

Maximizing (4) with respect to bank effort, e^S, the first-order condition for e^S will be:

$$qR^S_{b,e}\big((1-\Phi(1-\rho(m))\big) + (1-q)R^S_{g,e} = C^S_e \ . \tag{6}$$

Note that $R_{g,e}{}^S > 0$ and $R_{b,e}{}^S > 0$. For a moment, let the marginal cost of effort for banks in S, $C_e{}^S$, be equal to the marginal cost of effort for banks in T, $C_e{}^T$. For a given anticipated *Φ* and *m*, $R_{g,e}{}^S$ and $R_{b,e}{}^S$ will be higher for banks in S than for banks in T at the equilibrium level of effort, e^S. Therefore, $e^S < e^T$. These results are also confirmed by taking into account that $C_e{}^S$ is likely higher than $C_e{}^T$ since banks in S have moral hazard problems because they care less about their reputation ■

Corollary 1 The moral hazard problems of banks in S worsen (are reduced) if it is expected a low (high) level of monitoring, *m*, and high (low) level of liquidity provision, *Φ*:

- When an increase in *Φ* is anticipated, the S banks will choose a higher level of risky investment, L^S. If in addition, *m* is expected to be low, moral hazard problems will worsen, and L^S will be even higher.

From (5), liquidity provisions affect L^S as follows:

$$\frac{\partial L^S}{\partial \Phi} = \frac{q(1-\rho(m))R^S_{b,L}}{q[1-\Phi(1-\rho(m))]R^S_{b,LL} + (1-q)R^S_{g,LL}} > 0\,. \tag{7}$$

Since $R_{bL}{}^S < 0$ from (5) and $R_{g,LL}{}^S < 0$, $R_{b,LL}{}^S < 0$ by the concavity of the return functions.

- Expectations of lower *m* will increase the level of risky investment, L^S.

  Considering (5), monitoring intensity will affect L^S, as follows:

$$\frac{\partial L^S}{\partial m} = \frac{-q\,\Phi\,\rho'(m))R^S_{b,L}}{q[1-\Phi(1-\rho(m))]R^S_{b,LL} + (1-q)R^S_{g,LL}} < 0\,. \tag{8}$$

- The greater the expected *Φ* is, the lower the effort e^S will be. e^S will be further reduced if lower levels of *m* are expected, in which case the moral hazard problems will worsen.

  From (6), *Φ* will affect e^S as follows:

$$\frac{\partial e^S}{\partial \Phi} = \frac{qR^S_{b,e}(1-\rho(m))}{q[1-\Phi(1-\rho(m))]R^S_{b,ee} + (1-q)R^S_{g,ee} - C^S_{ee}} < 0\,. \tag{9}$$

  Higher anticipated levels of Φ will decrease effort, since $R_{b,e}{}^S > 0$, $R_{g,ee}{}^S < 0$, $R_{b,ee}{}^S < 0$ based on the strict concavity assumption of the return function, and $C^S{}_{ee} > 0$ due to the strict convexity of the cost function for effort.

- Expectations of lower *m* will decrease the amount of effort exerted, e^S.

  Considering (6), the intensity of monitoring will affect e^S as follows:

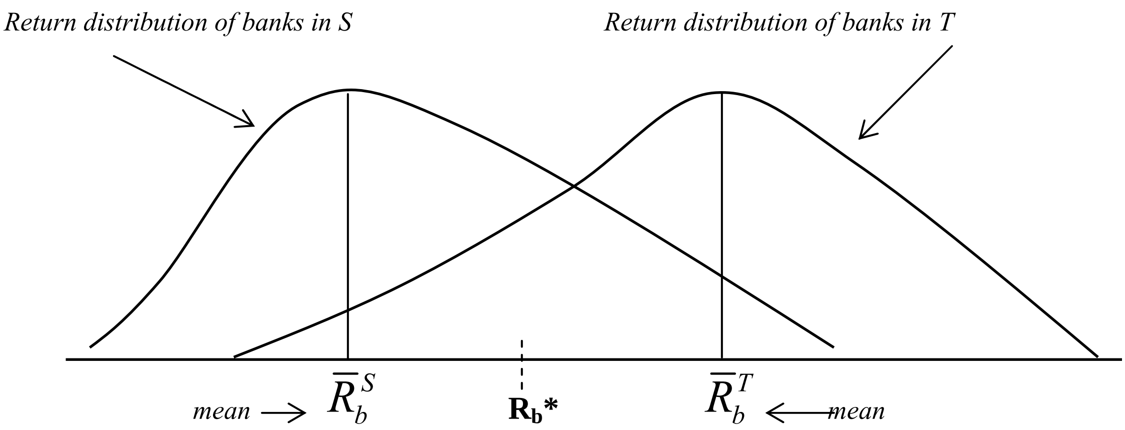
$$\frac{\partial e^S}{\partial m} = \frac{-q\,\Phi\,\rho'(m)\,R^S_{b,e}}{q[1-\Phi(1-\rho(m))]R^S_{b,ee} + (1-q)R^S_{g,ee} - C^S_{ee}} > 0 \;\blacksquare \tag{10}$$

Corollary 2 An anticipated higher (lower) liquidity provision *Φ* and lower (higher) monitoring *m*, results in smaller (larger) returns when a bad shock occurs as a result of moral hazard problems.

Such effects can be seen by analyzing (5) and (6). When banks expect larger Φ and lower m, (5) will be more negative. Thus, in the bad state, the marginal return on a risky investment will be lower which implies higher L^S. (6) indicates that expectations of larger Φ and smaller m results in a larger marginal return on effort in the bad state and therefore a lower effort ■

The returns across banks in each group have distributions with means $\overline{R}_g^T$ (> 0), $\overline{R}_g^S$ (> 0), $\overline{R}_b^T$ (< 0), and $\overline{R}_b^S$ (< 0) with corresponding variances, all of which is public information. Bank characteristics and decisions, as described above, determine the return distributions. Figure 1 illustrates possible return distributions when a bad shock occurs for banks in T (on the right) and S (on the left).

Figure 1. Distributions of returns in the bad state across banks in T and S



Note that if banks in S expect decreases in Φ and/or increases in m, the distribution of returns of banks in S will shift to the right (see Corollary 2). This means that the average returns of banks in S, $\overline{R}_b^S$, will increase and be close to the average returns of banks in T, $\overline{R}_b^T$. Thus, expressions (5) and (6) become closer to (3) and (6) respectively, and banks in S will be more similar to banks in T. In such a case, there will not be banks with moral hazard problems and all banks will be qualified to obtain financial assistance when needed.[5] If the return distributions are as above, and a bank requests financial assistance having a return equal to R_b*, the central bank will need to monitor in order to find out to which return distribution this bank belongs.

The main conclusion at this point is that optimal decisions and final returns of banks in S depend not only on expectations regarding the types of shocks that may occur, but also about the central bank's decisions regarding monitoring and emergency funding. Expectations of low levels of monitoring and high levels of emergency funding will induce banks to have portfolios with a larger number of risky investments and to exert less effort, which only means more moral hazard problems.

It is worthwhile to remark already here, as we show below, that the return distribution of banks in group S will be necessarily affected when the central bank makes public the monitoring policy. That is, it shifts the return distribution of banks in S toward the right and consequently increasing $\overline{R}_b^S$. This contrasts the case in which the central bank acts with discretion with regard to monitoring because in such a case, the return distributions are taken as given by the central bank.

4. The central bank's problem

Recall first that the central bank can only observe $\overline{R}_b^T$ and $\overline{R}_b^S$. The central bank's payoffs in the event of good and bad shocks are W_g and W_b, respectively.

The payoff W_g requires no further attention here, since in the good state there should be no banking failures, and the central bank will be passive. W_b, however, is influenced by the optimal choices of Φ and m. W_b will depend on the functions V, Ψ, and Ω:

[5] Notice also the limit case in which there is not overlapping of the return distributions at all. In this case, the central bank can more easily distinguish the bank type with any level of monitoring.

$$W_b(\Phi, m) = V[m\Phi + \Phi)] - \Psi\left[\underbrace{\Phi\overline{R}_b^T + (1-\rho(m))\Phi\overline{R}_b^S}_{BC}\right] - \Omega[m]$$
$$s.t. \begin{cases} \Phi > 0 \\ m \geq 0. \end{cases} \qquad (11)$$

In (11), *V(Φm+Φ)* indicates that the central bank derives certain value from *Φ* and *m*. If *Φ* is zero, monitoring, *m*, does not contribute to increasing *V*, no matter how big *m* is. Monitoring is only important when emergency funding (i.e., *Φ* > 0) is provided, in order to identify the deserving banks. A nonzero *Φ* however, contributes positively to the central bank's value *V* and its payoffs, even when *m* = 0, because by providing liquidity to troubled banks, the central bank avoids systemic risks and liquidity shortages. Nevertheless, when *Φ* is nonzero, the central bank will derive a higher value of *V* if *m* > 0 because, through monitoring, the central bank will have a higher probability of correctly recognizing to which return distribution a bank belongs. This is socially desirable.

Ω(m) is the central bank's indirect costs of monitoring which is concave and increasing. The provision of liquidity is also costly not only because it involves larger fiscal costs and/or higher costs to the taxpayers but also because scarce resources may be given to non-deserving banks. These costs are represented by function *Ψ*. *Ψ* is a convex function increasing in *BC* [=$\Phi\overline{R}_b^T$ + $(1-\rho(m))\Phi\overline{R}_b^S$]. For a given *m*, *Ψ* increases as average bank returns become more negative. The term $(1-\rho(m))\Phi\overline{R}_b^S$ can be viewed as the penalty to the central bank for providing emergency liquidity with inadequate monitoring, especially when *m* and *ρ(m)* are low.

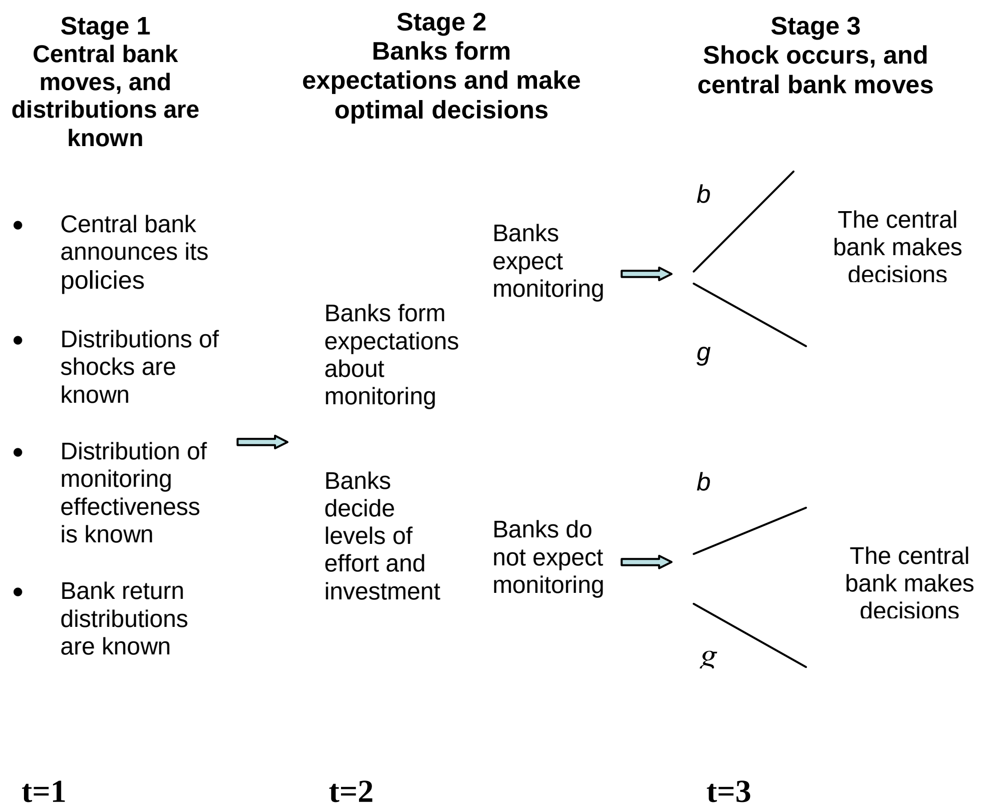
5. A three-stage sequential-game theoretical model

The sequential game is solved using backward induction. The timeline for the model is illustrated in Figure 2.

Stage 1

At this stage, the following factors become known: the probability distribution of the returns of banks in T and S, the probability distribution of the type of shock that will occur in the last stage, and the probability distribution of detecting the bank type at each different level of monitoring, given known return distributions. At this stage, the central bank also announces that it will either act with discretion when deciding policies about monitoring, or it makes public its policies on monitoring.

Figure 2. Timeline: the three-stage sequential game



Stage 2

At this stage, banks make their optimal decisions. After the central bank announces that it will act with discretion, banks must form expectations about the type of shock that will occur at the last stage of the game, while only banks in S must in addition form expectations about the monitoring before making optimal decisions. In contrast, if the central bank makes its monitoring policy public at stage 1, bank uncertainty about future central bank decisions is resolved at this stage.

Stage 3

During this stage, either *b* or *g* occurs, and only the central bank moves. The possible outcomes depend on whether it has decided to act with discretion or to make public its optimal monitoring policy. If the central bank has decided to act with discretion, it takes as given bank decisions when maximizing its payoffs. However, when the central bank has made public knowledge its optimal monitoring policy, its optimal decisions will affect bank decisions and minimize the moral hazard problems of banks. This is possible because the central bank takes into consideration the reaction of banks to information on monitoring policy, instead of taking bank actions as given when maximizing its payoffs.

6. Equilibrium when the central bank acts with discretion

The optimal decisions about monitoring intensity, *m*, and liquidity provisions, *Φ*, are determined at stage 3. The possible sub-game equilibria are found through backward induction.

Lemma 1 If banks in S do not expect to be monitored by the central bank, they will have greater moral hazard problems and more negative returns than when they expect monitoring.

Proof of Lemma 1 Equations (5) and (6) from section 3.2 above are modified to take into account the case in which monitoring is not expected:

$$\frac{R^S_{b,L}}{R^S_{g,L}} = -\left[\frac{(1-q)}{q\left(1-\Phi\right)}\right] < 0\,; \tag{5a}$$

$$qR^S_{b,e}\left(1-\Phi\right) + (1-q)R^S_{g,e} = C^S_e\,. \tag{6a}$$

By comparing (5) with (5a) and (6) with (6a), it is clear that if banks expect to receive emergency funding but not to be monitored, the amount of risky investment will be higher, and effort will be lower. This will lead to more negative individual and average returns in the bad state across S banks (see Propositions 1 and 2), and consequently an increase in banking failure incidences. These large negative average returns are denoted by $\tilde{R}_b^S$ $(< \bar{R}_b^S)$ ■

Lemma 2 In the absence of monitoring by the central bank, the optimal level of liquidity provisions will decrease at its minimum.

Proof of Lemma 2 Using (11), the central bank's payoff function in the absence of monitoring in the bad state is:

$$W_b(\Phi, 0) = V[\Phi] - \Psi\left[\underbrace{\Phi(\tilde{R}_b^T + \tilde{R}_b^S)}_{BC}\right]. \tag{12}$$

The first-order condition for Φ that maximizes (12) is:

$$\frac{dW_b}{d\Phi} = V_\Phi[\Phi] - \underbrace{\frac{\partial \Psi}{\partial BC}}_{(-)} \bullet \underbrace{\frac{\partial BC}{\partial \Phi}}_{(-)} = V_\Phi[\Phi] - \underbrace{\frac{\partial \Psi}{\partial BC}}_{(-)} \bullet \underbrace{(\tilde{R}_b^T + \tilde{R}_b^S)}_{(-)} = 0\,. \tag{13}$$

Now, if the returns of S banks decrease from $\bar{R}_b^S$ to $\tilde{R}_b^S$ (since there is no monitoring), the marginal value of providing liquidity, V_Φ, must increase to restore equilibrium. For this to happen, the optimal Φ must be smaller. Thus, the central bank does not benefit much from providing liquidity when it does not monitor. Let us denote this optimal equilibrium level by $\tilde{\Phi}$ ■

Lemma 3 The central bank will provide more liquidity as bank losses increase, but only if there is some monitoring.

Proof of Lemma 3 The optimal level of *Φ* is obtained from the following first-order condition, which maximizes (11):

$$\frac{dW_b}{d\Phi} = V_\Phi[m\Phi + \Phi)] - \underbrace{\frac{\partial \Psi}{\partial BC}}_{(-)} \bullet \underbrace{(\overline{R}_b^T + (1-\rho(m)\overline{R}_b^S)}_{(-)} = 0 \,. \tag{14}$$

For a *given level of m* (and *ρ(m)*), V_Φ should increase when the average returns become more negative in order to satisfy the first-order condition which implies that *Φ* should decrease. Note, though, that for the same increase in bank losses, the central bank will provide more liquidity if the amount of monitoring increases. Moreover, at the highest level of *m, ρ(m)* is close to one and the central bank will only incur in the costs of providing liquidity to banks in T. Thus, the lower the monitoring, the more expensive becomes to provide liquidity. The central bank however aims to minimize such costs ■

Lemma 4 If monitoring by the central bank is expected, this monitoring will increase as bank losses become larger.

Proof of Lemma 4 The central bank's optimal solution for *m* is found by maximizing (11) with respect to *m*. Thus, *m* can be solved from the following first-order condition:

$$\frac{dW_b}{dm} = \underbrace{V_m\left(m\Phi + \Phi\right)}_{(+)} - \underbrace{\left[\underbrace{\Omega_m(m)}_{(+)} - \underbrace{\frac{\partial \Psi}{\partial BC}}_{(-)} \times \underbrace{\rho'(m)}_{(+)} \Phi \underbrace{\overline{R}_b^S}_{(-)} \right]}_{MgC\ of\ monitoring} = 0 \,. \tag{15}$$

The optimal level of *m* is found when the marginal value of monitoring, V_m, equals the total marginal costs of monitoring, $\left(MgC = \left[\Omega_m(m) - \frac{\partial \Psi}{\partial BC} \times \rho'(m)\Phi\overline{R}_b^S \right] \right)$. Now, *only* when monitoring is expected, if the average S bank *returns becomes more negative* than $\overline{R}_b^S$, the central bank's total marginal costs of monitoring, *MgC*, will decrease. The attainment of a new equilibrium (i.e. (15) holds with equality) must reflect the value that the central bank derives from monitoring, V_m. Thus, V_m must decrease to establish a new equilibrium, which means that m should increase ■

Proposition 3 If the central bank acts with discretion when banks expect emergency funding but do not expect to be monitored, the central bank's best response to such expectations is not to monitor.

Proof of Proposition 3 First of all, when monitoring is expected, the average return for S banks in the bad state is equal to $\bar{R}_b^S$, and the optimal level of monitoring is determined by equation (15). Now, if monitoring is not expected, the average return is rather $\tilde{R}_b^S$ (see Lemmas 1 and 2) and therefore, the central bank cannot optimally set the level of monitoring in accordance to (15). It is only optimal to set $m = 0$. Secondly, banks in S cannot rationally make optimal decisions under the assumption that they will be monitored if in fact they do not expect to be monitored. They understandably believe that there is not risk of having moral hazard problems and requesting emergency funding. Notice also that when banks do not expect to be monitored, the average return for S banks when a bad shock occurs is negative and equal to $\tilde{R}_b^S$ (see Lemma 1). This is the smallest possible value for average returns which will result in the smallest liquidity provision by the central bank: $\tilde{\Phi}$, in order to satisfy the first-order condition (13) (see Lemma 2.) ■

Corollary 3 When the central bank acts with discretion and banks do not expect to be monitored; there are two possible non-cooperative, Nash equilibria. These are illustrated in Figure 3 below. At Node (1), none of the banks is monitored, but when a bad shock, *b*, occurs, all banks receive emergency funding because the central bank is unable to recognize to which of the two return distributions each bank belongs. At Node (2), the central bank does not need to monitor or provide liquidity when a good shock, g, occurs.

The intuition behind Node (1) in Corollary 3 is self-explanatory from Proposition 3. Node (2) is explained by the fact that the central bank is passive in the good state. In this state, there is no need for central bank intervention ■

Proposition 4 If the central bank acts with discretion and banks expect to be monitored, then the central bank's best strategy is to monitor banks.

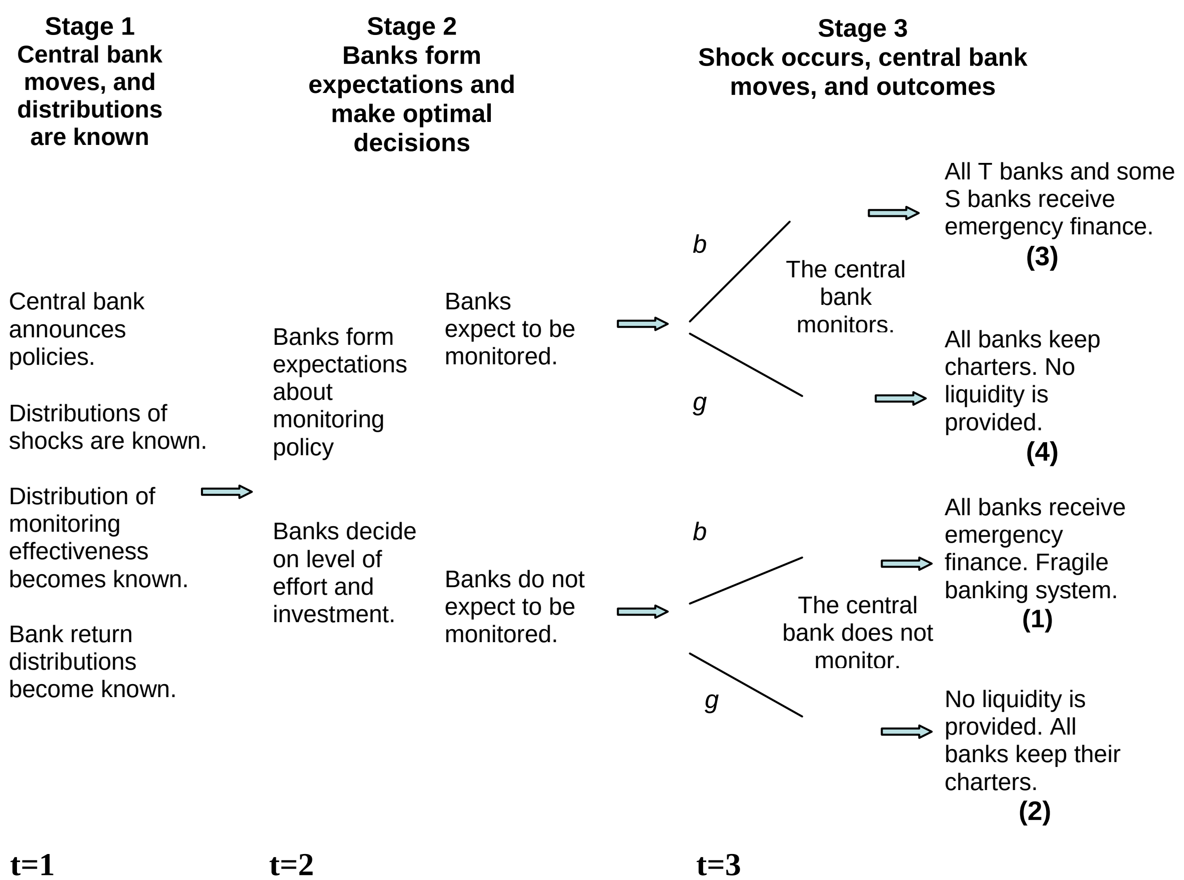
Proof of Proposition 4 Here, when monitoring is expected, the average return for *S* banks in the bad state is equal to $\overline{R}_b^S$, and the optimal level of monitoring will be accordingly determined by equation (15). Secondly, when monitoring is expected by S banks, they will always determine optimal levels of risky investment and effort according to (5) and (6) and never according to (5a) and (6a). Otherwise, they will face the risk of becoming ineligible to receive emergency funding if a bad shock occurs. Also, when a bad shock occurs, such optimal decisions will yield average returns across these banks equal to $\overline{R}_b^S > \tilde{R}_b^S$ ■

Corollary 4 When the central bank acts with discretion and banks expect to be monitored; there are two possible non-cooperative Nash equilibria. One corresponds with Node (3) at which shock S_b occurs; the other corresponds with Node (4) at which shock S_g occurs (see Figure 3). When S_b occurs, the optimal level of monitoring, m, determines the number of banks that will receive financial assistance and thus keep their charters. This number is equal to $n_1 + (1 - \rho(m))n_2$ banks. The remaining $\rho(m)n_2$ banks will have liquidity problems. When S_g occurs, the central bank is always passive. These results are illustrated in Figure 3 ■

The main conclusions are as follows. First, banking crises can be driven by self-fulfilling expectations about the monitoring policy, resulting in multiple equilibria. For example, if banks expect no monitoring, a rational central bank will not monitor them. Second, higher levels of liquidity provisions are only justified with higher levels of monitoring. Thus, at the Nash equilibrium in which the central bank engages in monitoring, financial assistance will be larger, but fewer banks in S will wrongly receive such assistance in comparison to the Nash equilibrium in which there is no monitoring. Third, there will always be uncertainty about the level of monitoring, and the final equilibrium depends on bank expectations about monitoring.

The analysis above raises the following questions. How can the central bank implement a policy that resolves the uncertainty that banks have about monitoring? What would that policy be? Would such a policy induce good bank behavior and avoid the multiple equilibria dilemma found above? Would that policy put beneficial constraints on the central bank to act with discretion? The next section attempts to answer these questions.

Figure 3. Possible outcomes in the three-stage sequential game when the central bank acts with discretion



7. Equilibrium when the central bank makes its monitoring policy public

The discretionary policy described above does not eliminate uncertainty regarding the level of monitoring, and it does not necessarily induce good behavior among financial institutions, mainly because their actions are taken as a given by the central bank when acting with discretion. The discretionary model in section 6 unmistakably describes the recent actions taken by governments around the world to rescue financial firms in distress. It has become suddenly urgent to make emergency funding available in different ways to financial institutions. At the same time, there are also calls for tougher or new regulations and supervision. These ex-post measures have not avoided and will hardly avoid further moral hazard problems. Moreover, it is not entirely certain that the financial institutions now receiving emergency funding deserve it, or whether measures are being taken in an orderly manner.

This section analyzes the case in which the central bank makes public its optimal monitoring policy, thereby eliminating multiple equilibria that arise when there is uncertainty about the monitoring policy, resolving moral hazard problems and reducing the scope of time-inconsistency problems. Such a policy also enables the central bank to impose conditions when providing liquidity. The implementation of such a policy requires the institutionalization of the monitoring regulations through which the central bank can enforce its rule. The central bank will be then obliged to monitor and avoid discretionary decisions.

Before this model is formally presented, the timeline of events described in Figure 3 must be reviewed in order to consider the nature of publicly announcing a monitoring policy. The central bank must make public its optimal level of monitoring[6] at the first stage of the game, before banks make decisions and form expectations, which occur at stage 2. The roles of the central bank as both LOLR and supervisor are linked as follows. If the central bank stands as

[6] One can call this supervision, but the main idea is that authorities must be transparent about it.

an LOLR, it should have incentives to engage in monitoring that is sufficient to reduce moral hazards and able to provide assistance only to deserving banks. At the outset, it should be understood that if the central bank is unable to make public its policy, then the only option for the central bank is to act with discretion. This latter situation may perhaps describe the current stance of the rescue polices around the world in the aftermath of the recent financial crises.

Here, the central bank must take into account the following:

i) There is a probability, *q,* that the central bank will incur the costs of providing emergency funding and monitoring if *b* occurs in the last stage of the game. This means that there will be a probability, *q*, that the central bank will face a payoff equal to W_b (see (11)) at stage 3.

ii) The intensity of monitoring affects the capacity to detect which banks have moral hazard problems.

iii) A higher (lower) liquidity provision and/or lower (higher) monitoring intensity increases (decreases) moral hazard problems of S banks. These problems reduce (increase) the individual and average returns for these banks in the bad state. These issues have been addressed in Propositions 1 and 2 and in Corollary 1.

Let us find the central bank's optimal decisions on liquidity provisions and monitoring at stage 1 in anticipation of *b*. Since the central bank is passive in the good state, it is only relevant to consider the central bank's maximization of the payoff function, $\Gamma_b = q\{W_b(\cdot)\}$:

$$\Gamma_b = q\left\{V[\Phi^C, m^C] - \Psi\left[\Phi^C \overline{R}_b^T + (1-\rho(m^C))\Phi^C \overline{R}_b^S\right] - \Omega(m^C)\right\}. \quad (16)$$

Φ^C and m^C represent the optimal liquidity provisions and monitoring intensity that the central bank will announce at stage 1 to maximize (16). Note that the central bank makes its optimal decisions regarding Φ^C and m^C taking into account how banks would respond to its decisions.

By maximizing (16) with respect to Φ^C, the following first-order condition is obtained:

$$\frac{d\Gamma_b}{d\Phi^C} = \underbrace{\frac{dW_b}{d\Phi^C}}_{=f.o.c.(14)} \underbrace{-\underbrace{\frac{\partial\Psi}{\partial BC}}_{(-)} \bullet \underbrace{(1-\rho(m^C))\Phi^C}_{\frac{\partial BC}{\partial \bar{R}_b^S}} \bullet \frac{d\bar{R}_b^S}{d\Phi}}_{moral\ hazard\ effects\ of\ \Phi} = 0; \quad or \tag{17a}$$

$$\frac{d\Gamma_b}{d\Phi^C} = \underbrace{V_\Phi[m^C,\Phi] - \underbrace{\frac{\partial\Psi}{\partial BC}}_{(-)} \bullet (\bar{R}_b^T + (1-\rho(m^C)\bar{R}_b^S)}_{=f.o.c.(14)} \underbrace{- \underbrace{\frac{\partial\Psi}{\partial BC}}_{(-)}(1-\rho(m^C))\Phi^C \bullet \frac{d\bar{R}_b^S}{d\Phi}}_{moral\ hazard\ effects\ of\ \Phi} = 0\,. \tag{17b}$$

The optimal level of monitoring is determined by solving the first order-condition with respect to m^C:

$$\frac{d\Gamma_b}{dm} = \underbrace{\frac{dW_b}{dm}}_{=f.o.c.(15)} \underbrace{-\underbrace{\frac{\partial\Psi}{\partial BC}}_{(-)} \bullet \underbrace{(1-\rho(m^C))\Phi^C}_{\frac{\partial BC}{\partial \bar{R}_b^{NS}}} \bullet \frac{d\bar{R}_b^S}{dm}}_{moral\ hazard\ effects\ of\ m} = 0; \quad or \tag{18a}$$

$$\frac{d\Gamma_b}{dm} = \underbrace{V_m\left(\Phi^C, m^C\right) - \Omega_m(m^C) - \underbrace{\frac{\partial\Psi}{\partial BC}}_{(-)} \bullet \rho'(m^C)\Phi^C \bar{R}_b^S}_{=f.o.c.(15)} \underbrace{- \underbrace{\frac{\partial\Psi}{\partial BC}}_{(-)}(1-\rho(m^C))\Phi^C \bullet \frac{d\bar{R}_b^S}{dm}}_{moral\ hazard\ effects\ of\ m} = 0\,. \tag{18b}$$

Proposition 5 When optimal policies are made public at stage 1, the central bank's optimal decisions should include offering a smaller liquidity provision and more monitoring than under a discretionary policy in order to ameliorate moral hazard problems. If moral hazard problems are not a concern for the central bank, liquidity provisions and the level of monitoring should be the same as under a discretionary policy.

Proof of Proposition 5 This is based in the first order conditions (17) and (18). Note that the central bank faces the same first-order conditions with respect to liquidity provisions and monitoring when it acts with discretion (compare (14) against (17), and (15) against (18)), and additional factors that the central bank must consider if it wants to reduce moral hazard problems. These include: first, the effect of providing liquidity on the moral hazards of banks (i.e., the last term in (17)) and, second, the effect of monitoring on the moral hazards of banks (i.e., last term of (18)). These latter effects can either decrease or increase the central bank's marginal payoffs, but this depends on the signs that $d\overline{R}_b^S/d\Phi^C$ and $d\overline{R}_b^S/dm^C$ take. Corollary 2 indicates that in the presence of moral hazard, anticipated increases in liquidity provisions and/or decreases in monitoring intensity will yield lower returns for S banks in the bad state. As a consequence, the mean of these returns will also decrease; that is, $d\overline{R}_b^S/d\Phi^C < 0$ and $d\overline{R}_b^S/dm^C > 0$. These inequalities indicate that the return distribution for S banks shifts to the left when a bad shock occurs, which only means that higher Φ and lower m have adverse effects (see Figure 1).

Thus, if $d\overline{R}_b^S/d\Phi^C < 0$, in order to satisfy (17), $dW_b/d\Phi^C$ must increase, and this is only possible if liquidity provisions decrease. However, if $d\overline{R}_b^S/dm^C > 0$, then (18) will be satisfied if ($dW_b/d\Phi$) decreases, and this is only possible if monitoring intensity increases. The central bank will therefore monitor more and provide less emergency liquidity to ameliorate moral hazards as much as possible ■

The conclusion is that if the central bank publicly announces its policies at a very early stage *before* banks make their decisions that there will be high levels of monitoring, it will effectively resolve bank uncertainty over ex-post realizations. Such a policy has the following desirable effects: (i) it resolves the dilemma of multiple equilibria and instead achieves a unique equilibrium that is only contingent on the type of shock, e.g., only Nodes (3) and (4) from Figure 3 are attained; (ii) it increases the possibilities for less risk-taking and more effort, thus increasing bank returns and reducing the risks of banking crises; and (iii) it minimizes the need for providing emergency financing. Thus, the public announcement of monitoring allows the central bank to effectively condition any liquidity provision on a bank's performance.

These are important contributions to the relevant literature. Our model illuminates the limitations of monitoring with discretion in comparison to a public monitoring policy.

8. Conclusions

This model analyzes the relationships between a central bank's decisions regarding liquidity provisions and monitoring policy and private bank behaviors. The model is presented as a three-stage sequential game. A financial assistance to a bank occurs only to the extent that it maximizes the central bank's objective function. This assistance is conditional on a bad shock occurring at the last stage of the game and on bank decisions not being adversely dependent on the liquidity provision policy itself (i.e., not showing any moral hazards). There are two groups of banks. T banks are always transparent and never have moral hazard problems, while S banks are not transparent and are generally prone to moral hazard problems, especially when they expect very little or no monitoring. When the central bank acts with discretion, the potential for bank insolvencies and moral hazard problems cannot be reduced, nor can the uncertainty for S banks be resolved. This leads to multiple, non-cooperative Nash equilibria. However, if the central bank makes public the fact that there will be high levels of monitoring before banks make optimizing decisions, it can effectively ameliorate the risk-taking behavior of banks as well as increase bank efforts.

Thus, the main results can be summarized as follows. First, when the central bank acts with discretion and no monitoring is expected, the non-cooperative Nash equilibrium implies that the central bank chooses not to monitor, in which case such expectations become self-fulfilling. When a bad occurs, all banks will receive emergency financing since they will be indistinguishable from each other. Such an outcome implies a worst-case scenario for moral hazard: namely, risky investment increases, and effort decreases. Second, when the central bank acts with discretion and banks expect to be monitored, there will be another non-cooperative Nash equilibrium at which the central bank's best strategy is to monitor the banks and provide higher liquidity than when there is no monitoring. The more monitoring, the fewer banks will wrongly receive liquidity provisions. Here again, when acting with discretion, uncertainty about monitoring is never resolved, and since expectations are always self-fulfilling, there is never a guarantee that there will be sufficient monitoring to avoid inefficiencies. Third, if the central bank announces early enough the optimal level of monitoring that maximizes its payoffs, it will reduce the need for liquidity provisions as well as decrease moral hazard problems. Such a measure reduces bank insolvencies.

Note that making known the central bank's monitoring policy will eliminate time-inconsistency problems because there will most likely be greater pressure on the central bank to provide emergency financing only to deserving banks. This suggests the institutionalization of monitoring rules such that whenever it is necessary to provide liquidity, it is mandatory to apply the announced monitoring policy.

Thus, one of the main conclusions in this study is that in order to provide banks the best ex-ante incentives, the central bank should monitor more *and* make its monitoring public knowledge in order to have the most desirable effects on bank behavior. The recommendation is that the central bank should avoid acting with discretion, especially when the central bank's monitoring policy is uncertain to banks. Discretionary policies make liquidity provisions precipitate financial crises as well as worsen moral hazard problems.

A deposit insurance corporation is not included in this analysis, but even if we were to include it, recall that a deposit insurance corporation is mainly concerned with its exposure to the risk of having to compensate depositors following a bank failure. We concentrate on the role that the central bank has in deciding which bank deserve assistance, thereby minimizing both the probability of banking crises and the costs of liquidity provisions. Moreover, emphasis is shifted here from maturity transformation and liquidity insurance for small depositors to the "modern" form of illiquidity and insolvency in which large, well-informed creditors refuse to renew credit on the interbank market because the repayment capacity of an intermediary or a number of intermediaries is in doubt.

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