POLICIES FOR BANKING CRISES: A THEORETICAL FRAMEWORK

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Abstract

This paper analyzes the effects on ex ante risk-shifting incentives and ex post fiscal costs of three policies that are frequently used in dealing with banking crises, namely, forbearance from prudential regulations, extension of blanket deposit guarantees, and provision of unrestricted liquidity support. In the context of a simple model of information-based bank runs, where banks are funded with both insured and uninsured deposits, the paper shows that the expectation of implementation of any of these policies leads to a reduction in the interest rate of uninsured deposits and in the banks incentives to take risk, but increases the expected fiscal costs of the crises.

JEL Codes: G21, G28, E58.
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1 Introduction

Recent cross-country studies by Honohan and Klingebiel (2003) and Claessens, Klingebiel and Laeven (2004) examine to what extent the fiscal costs incurred in a banking crisis can be attributed to specific measures adopted by the governments during the early stages of the crisis, and conclude that "blanket deposit guarantees, open-ended liquidity support, repeated recapitalizations, debtor bailouts and regulatory forbearance add significantly and sizably to (fiscal) costs."[1]

The purpose of this paper is to provide a theoretical framework that can help to understand the different effects of these policies on ex ante risk-shifting incentives and ex post fiscal costs. Specifically, we set up a *model of information-based bank runs* in which there is a profit-maximizing bank that is funded with insured and uninsured deposits that require an expected return that is normalized to zero. There is a *moral hazard* problem in that after raising these funds, the bank privately chooses the risk of its loan portfolio. Subsequently, the uninsured depositors observe a signal that contains information on the future return of this portfolio, and withdraw their funds if the signal is bad. In such case, the bank is liquidated unless the government provides the required emergency liquidity or extends the insurance to all depositors. Assuming that the adoption of any of these measures is correctly anticipated by the depositors and the bank, we characterize the equilibrium interest rate of the uninsured deposits and the equilibrium choice of risk by the bank.

Our model of information-based bank runs builds on Diamond and Dybvig (1983), Jacklin and Bhattacharya (1988) and Alonso (1996), but while they focus on the characterization of the optimal risk-sharing arrangements between two types of consumers (early and late), our focus is on the analysis of the strategic interaction between the uninsured depositors and the bank. To simplify the presentation, we do not have a short-term safe technology, and to provide a richer model of risk-shifting, we introduce a one-dimensional set of long-term risky technologies that differ in their success

[1] Honohan and Klingebiel (2003, p. 1540).

probability and their success return. Finally, we also assume that deposit insurance premia are equal to zero.

The equilibrium of this model is given by the solution of two equations that correspond to the first-order condition that characterizes the bank's choice of risk and the uninsured depositors' participation constraint. Two important results are obtained. First, a minimum proportion of insured deposits may be required to guarantee the existence of an equilibrium. Second, this minimum proportion is decreasing in the quality of the uninsured depositors' information, so the deposit insurance subsidy may be particularly important to realize the benefits of intermediated finance in less developed economies.[2]

To understand these results it is important to realize that in our model the higher the proportion of insured deposits, the lower the bank's incentives to take risk. The intuition for this can be explained as follows. Consider a setup in which a risk-neutral bank raises a unit of deposits at an interest rate c, and invests these funds in an asset that yields a gross return $R(p)$ with probability p, and zero otherwise. Moreover, suppose that p is privately chosen by the bank at the time of investment, and that $R(p)$ is decreasing in p, so riskier investments yield a higher success return. Under limited liability the bank chooses p in order to maximize $p[R(p)-(1+c)]$. Assuming that $R(p)$ is also concave, the bank's choice of p is characterized by the first-order condition $R(p)+pR'(p)=1+c$. Since the left-hand-side of this condition is decreasing in p, we conclude that the higher the value of c the lower the value of p chosen by the bank. In other words, higher deposit rates lead the bank to invest in a portfolio with a lower success probability and a higher success return.

Applying this result to a situation in which the bank is funded with both insured and uninsured deposits, and assuming that the cost of insured deposits (including any deposit insurance premia) is lower than the cost of uninsured deposits,[3] it trivially

[2] Cull, Senbet and Sorge (2000) find that explicit deposit insurance favorably impacts the level of financial activity, but only in countries with strong institutional development.

[3] Obviously, with actuarially fair deposit insurance premia c would be independent of the proportion of insured deposits. But actuarially fair premia are difficult to implement in a context where

follows that the higher the proportion of insured deposits the lower the average interest rate c and hence the higher the success probability p chosen by the bank.[4] Moreover, to the extent that the adoption of crises policies that bail out uninsured depositors (such as unrestricted liquidity support or blanket deposit guarantees) are anticipated, these depositors will require a lower interest rate and so the bank will have an incentive to choose safer investments.

It should be noticed that the positive relationship between the bank's funding costs and its portfolio risk is not really new, since it is a simple implication of the analysis in the classical paper on credit rationing of Stiglitz and Weiss (1981). In particular, they show how "higher interest rates induce firms to undertake projects with lower probabilities of success but higher payoffs when successful."[5] Applying the same argument to banks instead of firms gives the key result.

Our analysis of the policies for banking crises starts with a benchmark in which such accommodative policy measures are not implemented. In this benchmark, there is a supervisor that observes a signal on the future return of the bank's portfolio. A bad supervisory signal is interpreted as the finding that the bank is violating some key prudential regulations. In the benchmark model the bank is closed when either the signal observed by the uninsured depositors is bad, so they run on the bank, or the signal observed by the supervisor is bad, in which case the bank's license to operate is withdrawn.

Against this benchmark, we proceed to analyze three policies that the supervisor may implement at the outset of a crisis. Under forbearance, we consider a situation in which the uninsured depositors observe a good signal, so they do not run on the bank, and the supervisor observes a bad signal but nevertheless allows the bank to continue operating. Unlike forbearance, the other two policies are responses to a crisis situation in which the uninsured depositors run on the bank and the supervisor

the risk chosen by the bank is not observable.

[4] In line with this argument, Demirgüç-Kunt and Huizinga (2004) show that banks' interest expenses are lower in countries with explicit deposit insurance systems.

[5] Stiglitz and Weiss (1981, p. 393).

reacts by either extending deposit insurance to all depositors or providing unrestricted liquidity to the bank so it can cover the withdrawals. We show that the qualitative effect of the three policies is the same: if they are correctly anticipated, in equilibrium the uninsured depositors will require a lower interest rate, and the bank will choose a higher success probability. We also show that the fiscal cost associated to any of these policies is higher than the fiscal cost in the benchmark model, except when the proportion of insured deposits is very high, because in this case the early closure of the bank implies a large compensation to the insured deposits that would be saved if the bank were allowed to stay open and eventually succeeded. Finally, we analyze a restricted liquidity support policy in which there is a central bank that acts as a traditional lender of last resort, supporting the bank when there is run but only if the supervisory signal is good. This policy is associated with smaller incentive effects and smaller (even negative) fiscal costs.

It is important to stress the limitations of our results. We are not providing a normative analysis because we do not derive the optimal policy in terms of deposit insurance and crisis support. This would require to specify a social welfare function in which the benefits of prudent bank behavior would be traded off against the social cost of the public funds required to cover the losses associated with bank failures.[6] Also, our positive analysis is somewhat incomplete because the decision of the supervisor is not endogenized. A possible way to do this would be to follow the political economy approach of Repullo (2000, 2003) and Kahn and Santos (2001), where government agencies have objective functions that are related to their surpluses or deficits. But this is not done in the paper. Our objective is more modest, namely to provide a simple framework that yields some new insights that can guide future work in this field. In addition, it is important to note that our analysis is based on a model of a single bank, and so it cannot address contagion and systemic issues.[7] Incorporating

[6] Obviously, the optimal level of protection would be increasing with the efficiency of the tax system, reaching full coverage if lump-sum taxes were feasible.

[7] See Goodhart and Illing (2002, Part III) for various models of bank runs and contagion.

these issues into our framework seems a priority for future research.

The paper is organized as follows. Section 2 presents the model of information-based runs. Section 3 analyzes the effects of the policies for dealing with banking crises, and Section 4 offers some concluding remarks. Proofs of the results are contained in the Appendix.

2 A Model of Information-Based Bank Runs

Consider an economy with three dates ($t = 0, 1, 2$) and three classes of agents: a large number of risk-neutral *depositors*, a risk-neutral *bank*, and a government agency called the *supervisor*. The bank raises one unit of deposits at $t = 0$, and invests these funds in a risky asset that yields a random *gross return* R at $t = 2$. The probability distribution of R is described by

$$R = \begin{cases} R_0, & \text{with probability } 1-p, \\ R_1, & \text{with probability } p, \end{cases} \tag{1}$$

where $p \in [0, 1]$ is a parameter chosen by the bank at $t = 0$. We assume that $R_0 < 1 < R_1$, so $1 - p$ measures the riskiness of the bank's portfolio. The risky asset is illiquid in that there is no secondary market for it to be traded at $t = 1$. However, the asset can be fully liquidated at $t = 1$, which yields a *liquidation value* $L \in (0, 1)$.

Depositors are interested in consuming at $t = 2$, and have the option of withdrawing their funds at $t = 1$ and invest them in a safe asset with zero net return.[8] A given fraction $D \in (0, 1)$ of the bank's deposits are insured by the supervisor, while the rest, $1 - D$, are uninsured. Uninsured deposits are assumed to be junior to the insured deposits. To simplify the presentation, deposit insurance premia will be set equal to zero.

Both insured and uninsured depositors require an expected net return equal to the return of the safe asset. Consequently, the interest rate of the insured deposits

[8] The withdrawal option could be justified by introducing preference shocks à la Diamond-Dybvig (1983), so the early consumers would use it. In this case, the bank should invest a fraction of their portfolio in the safe asset. For simplicity, we will not distinguish between early and late consumers.

will be zero, while the interest rate of the uninsured deposits, denoted by r, will be such that their expected net return is equal to zero.

At $t = 1$ uninsured depositors observe a *signal* $s \in \{s_0, s_1\}$ on the return of the bank's risky asset. We assume that the uninsured depositors run on the bank if and only if they observe the (bad) signal s_0.[9] In such case, the bank is liquidated at $t = 1$, and since they are junior to the insured deposits they get $\max\{L - D, 0\}$.

We introduce the following assumptions.

Assumption 1 $R_0 = 0$ *and* $R_1 = R(p)$, *where* $R(p)$ *is decreasing and concave, with* $R(1) \geq 1$ *and* $R(1) + R'(1) \leq 0$.

Assumption 2 $\Pr(s_0 \mid R_0) = \Pr(s_1 \mid R_1) = q \in [\frac{1}{2}, 1]$.

Assumption 1 implies that the expected final return of the risky asset, $E(R) = pR(p)$, reaches a maximum at $\widehat{p} \in (0, 1]$ which is characterized by the first-order condition

$$R(\widehat{p}) + \widehat{p}R'(\widehat{p}) = 0. \tag{2}$$

To see this, notice that the first derivative of $pR(p)$ with respect to p equals $R(0) > 0$ for $p = 0$ and $R(1) + R'(1) \leq 0$ for $p = 1$, and the second derivative satisfies $2R'(p) + pR''(p) < 0$. Thus, increases in p below (above) $\widehat{p}$ increase (decrease) the expected final return of the risky asset. Moreover, we have $\widehat{p}R(\widehat{p}) \geq R(1) \geq 1$. Assumption 1 is borrowed from Allen and Gale (2000, Chapter 8), and allows to analyze in a continuous manner the risk-shifting effects of different institutional settings.

Assumption 2 introduces a parameter q that describes the quality of the uninsured depositors' information.[10] This information is only about whether the return R of the bank's risky asset will be low (R_0) or high (R_1), and not about the particular value $R(p)$ taken by the high return. By Bayes' law, it is immediate to show that

$$\Pr(R_1 \mid s_0) = \frac{(1-q)p}{q + (1-2q)p}, \tag{3}$$

[9] See Alonso (1996) for a formal analysis of the decision of the uninsured depositors.

[10] More generally, we could have $\Pr(s_0 \mid R_0) \neq \Pr(s_1 \mid R_1)$, but this would not change the results.

and

$$\Pr(R_1 \mid s_1) = \frac{qp}{1 - q - (1 - 2q)p}. \tag{4}$$

Hence when $q = \frac{1}{2}$ we have $\Pr(R_1 \mid s_0) = \Pr(R_1 \mid s_1) = p$, so the signal is uninformative, while when $q = 1$ we have $\Pr(R_1 \mid s_0) = 0$ and $\Pr(R_1 \mid s_1) = 1$, so the signal completely reveals whether the return R will be R_0 or R_1. Since $\Pr(R_1 \mid s_0) < p < \Pr(R_1 \mid s_1)$ for $p < 1$ and $q > \frac{1}{2}$, s_0 and s_1 will be called the bad and the good signal, respectively.

By limited liability, the bank gets a zero payoff if it is liquidated at $t = 1$ or fails at $t = 2$, and gets $R(p) - D - (1 - D)(1 + r)$ if it succeeds at $t = 2$. This event happens when the uninsured depositors observe the good signal s_1 (so they do not run at $t = 1$) and the return of the risky asset is $R_1 = R(p)$. By Assumption 2 we have $\Pr(s_1, R_1) = \Pr(s_1 \mid R_1) \Pr(R_1) = qp$, so the bank's payoff function is

$$V(p; r) = qp[R(p) - D - (1 - D)(1 + r)], \tag{5}$$

The uninsured depositors get $\max\{L - D, 0\}$ when they observe the bad signal s_0 and run on the bank at $t = 1$, they get $(1 - D)(1 + r)$ when the bank succeeds at $t = 2$ (that is, when they observe the good signal s_1 and the return of the risky asset is R_1), and they get zero when the bank fails at $t = 2$ (that is, when they observe the good signal s_1 and the return of the risky asset is R_0). By Assumption 2 we have $\Pr(s_0) = q + (1 - 2q)p$ and $\Pr(s_1, R_1) = \Pr(s_1 \mid R_1) \Pr(R_1) = qp$, so the payoff of the uninsured depositors is given by

$$U(r; p) = [q + (1 - 2q)p] \max\{L - D, 0\} + qp(1 - D)(1 + r). \tag{6}$$

An *equilibrium* is a pair (r^*, p^*), where r^* is the interest rate of the uninsured deposits and p^* is the success probability chosen by the bank, such that p^* maximizes the bank's payoff function $V(p; r^*)$ and r^* satisfies the uninsured depositors' participation constraint

$$U(r^*; p^*) = 1 - D. \tag{7}$$

In this definition it is important to realize that the interest rate r^* is set before the bank's choice of risk, and is such that, taking into account the bank's equilibrium success probability p^*, the expected net return of the uninsured deposits is equal to zero.

The first-order condition that characterizes the equilibrium success probability p^* is

$$R(p^*) + p^* R'(p^*) = D + (1 - D)(1 + r^*). \tag{8}$$

Since $R(p) + pR'(p)$ is decreasing by Assumption 1, it follows from (2) and (8) that p^* is strictly below the first-best $\widehat{p}$, so the bank will be choosing too much risk. This is just the standard risk-shifting effect that follows from debt financing under limited liability.

An equilibrium exists if equations (7) and (8) have a solution. It is easy to check that the interest rate r^* that satisfies the participation constraint (7) is decreasing in the success probability p^*, because the higher the success probability the lower the interest rate required by the uninsured depositors. Also, the success probability p^* that solves the first-order condition (8) is decreasing in the interest rate r^*, because the higher the interest rate the lower the success probability chosen by the bank. As shown in Figure 1, the fact that these two derivatives are negative imply that in general we may find multiple equilibria: high (low) rates induce the bank to choose high (low) risk, rationalizing the depositors' expectations.

In cases where there are multiple equilibria, we focus on the equilibrium which is closest to the first-best $\widehat{p}$, that is, the one with the highest value of p^* (and the lowest value of r^*). For this equilibrium we can prove the following result.

Proposition 1 *The success probability p^* is increasing and the interest rate r^* is decreasing in the proportion D of insured deposits (whenever $D \geq L$) and in the quality q of the uninsured depositors' information.*

The intuition for this result is the following. When the proportion D of insured deposits is greater than the liquidation value L, having more insured deposits reduces

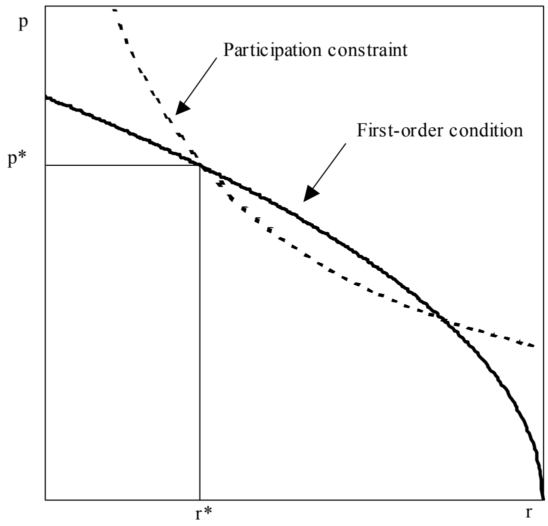

Figure 1: Characterization of equilibrium

the overall cost of funding. This reduces the bank's incentives to take risk, which translates into a lower interest rate of uninsured deposits. On the other hand, when the proportion D of insured deposits is below L, there is an opposite effect, because since insured deposits are senior, having more insured deposits reduces the payoff of the uninsured depositors when they run on the bank, so they may require a higher compensation. This may increase the bank's overall cost of funding and, consequently, its incentives to take risk. On the other hand, a better quality of the uninsured depositors' information increases their expected payoff, and leads to a reduction in the interest rate that they require, which in turn reduces the bank's incentives to take risk.

The supervisor has to pay to the insured depositors $\max\{D-L,0\}$ when the bank is liquidated at $t=1$ and D when the bank fails at $t=2$. By Assumption 2 the first event happens with probability $\Pr(s_0)=q+(1-2q)p$ and the second event happens with probability $\Pr(s_1,R_0)=\Pr(s_1\mid R_0)\Pr(R_0)=(1-q)(1-p)$,[11] so the equilibrium

[11]We are implicitly assuming that $D<1$, because when all deposits are insured ($D=1$) the bank is never liquidated at $t=1$, in which case $C^{*}=\Pr(R_0)=1-p^{*}$.

expected cost for the supervisor is given by

$$C^* = [q + (1-2q)p^*] \max\{D - L, 0\} + (1-q)(1-p^*)D. \tag{9}$$

Since the supervisor is a government agency that does not get any income (recall that we are assuming that deposit insurance premia are zero), this cost has to be funded by general tax revenues, so it may be called the *fiscal cost* of bank failure.

The effect of an increase the proportion D of insured deposits on the fiscal cost C^* is ambiguous because, although it directly increases the two terms in the right-hand-side of (9), by Proposition 1 it may also increase the equilibrium success probability p^* chosen by the bank, an effect that operates in the opposite direction.[12] In contrast, an increase in the quality q of the uninsured depositors' information always reduces the fiscal cost C^*, because in this case both the direct and the indirect effects go in the same direction.[13]

Given that some of the comparative statics results are ambiguous, in what follows we work out a simple example. The focus is on the qualitative effects, so we will not calibrate the model to get plausible numerical results, but instead choose simple functional forms and round parameter values.

Specifically, suppose that $R(p) = 3 - p^2$, and let $L = 0.50$.[14] Figure 2 shows the equilibrium success probability p^* and the corresponding fiscal cost C^* as a function of the proportion D of uninsured deposits and for two different values, $q = 0.60$ and $q = 0.65$, of the quality of the uninsured depositors' information.

A number of results are worth noting. First, a minimum proportion of insured deposits is required for the existence of an equilibrium, and this critical share is decreasing in the quality q of the uninsured depositors' information. Second, the

[12] However, since $C^* = 0$ for $D = 0$ and $C^* > 0$ for $D > 0$, if there is an equilibrium for all D, the fiscal cost C^* must be increasing for some range of values of D.

[13] The direct effect is negative since $\partial C^*/\partial q = (1-p^*)[\max\{D-L, 0\} - D] - p^* \max\{D-L, 0\} < 0$, and the indirect effect is also negative since $\partial C^*/\partial p^* = (1-2q)\max\{D - L, 0\} - (1-q)D < 0$ and $\partial p^*/\partial q > 0$ by Proposition 1.

[14] Clearly, $R(p) = 3 - p^2$ is decreasing and concave, with $R(1) = 2 \geq 1$ and $R(1) + R'(1) = 0 \leq 0$, so Assumption 1 is satisfied.

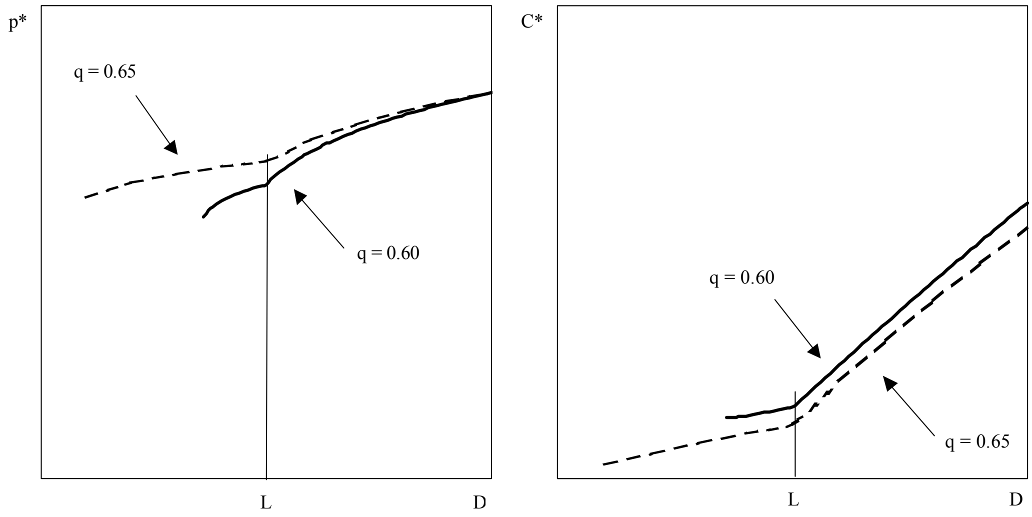

Figure 2: Equilibrium success probabilities and fiscal costs

success probability p^* is everywhere increasing in the proportion D of insured deposits (even for $D < L$). Third, when the proportion D of insured deposits converges to 1 (full deposit insurance), the success probability p^* converges to a limit that is independent of the quality q of the uninsured depositors' information.[15] Fourth, the fiscal cost C^* is everywhere increasing in the proportion D of insured deposits.[16] Finally, the success probability p^* is increasing and the fiscal cost C^* is decreasing in the quality q of the uninsured depositors' information. Hence having better informed uninsured depositors also ameliorates the bank's risk-shifting incentives, so policies designed to increase information disclosure (like those in Pillar 3 of the new regulation of bank capital proposed by the Basel Committee on Banking Supervision (2004)), would be beneficial.

The main implication of these results is that, contrary to the conventional view, the provision of deposit insurance serves to ameliorate the bank's risk-shifting incentives,

[15] To explain this result, notice that when D tends to 1 the first-order condition (8) converges to $R(p^*)+p^*R'(p^*) = 1$, an equation that does not depend on q and whose solution is $p^* = \sqrt{2/3} = 0.82$.

[16] However, as noted in footnote 11, the fiscal cost C^* is not continuous at $D = 1$. In fact, for $L = 0.50$ one can show that C^* jumps down in the limit if and only if $q < p^*$.

and hence to reduce the probability of a banking crisis. The flip side is that deposit insurance has a fiscal cost that is increasing in the proportion of insured deposits. To the extent that the social cost of public funds, which derives from tax distortions, is positive, it would be possible to derive an optimal level of insurance, but we will not pursue this here.

A second interesting implication is that for economies with poor information (low q), where the moral hazard problem is particularly severe, having a minimum proportion of insured deposits may be essential to realize the benefits of intermediated finance.

Summing up, we have set up a model of a bank that chooses the riskiness of its portfolio and is funded with exogenously given proportions of insured and uninsured deposits. The uninsured depositors observe a signal on the quality of the bank's portfolio, and run on the bank when the signal is bad, which leads to its early liquidation. The interest rate of the uninsured deposits is determined by a participation constraint that equals their expected return to a given constant. We have characterized the equilibrium of the model and shown how it depends on the proportion of insured deposits and the quality of the uninsured depositors' information. Although the model is designed to study the effects of different policies for banking crises, some interesting results on the beneficial effects on risk-shifting incentives of deposit insurance and the quality of the uninsured depositors' information have been obtained.

3 Policies for Banking Crises

This section uses our model of information-based runs to analyze the effects of three policies that the supervisor may implement at the outset of a crisis. Two of them, namely extending the coverage of deposit insurance to all depositors and providing unrestricted liquidity support to the bank, are responses to a crisis situation in which the uninsured depositors observe the bad signal and run on the bank. The other is different in that there is no bank run, but the supervisor has confidential information showing that the bank is not satisfying some key prudential regulations, and may decide to act on this information or to forbear.

We assume that the supervisor observes at $t = 1$ a signal $s' \in \{s'_0, s'_1\}$ on the return of the bank's risky asset, which is interpreted as the outcome of banking supervision. We make the following assumption.

Assumption 3 $\Pr(s'_0 \mid R_0) = \Pr(s'_1 \mid R_1) = q' \in [\frac{1}{2}, 1]$ *and* $\Pr(R \mid s, s') = \Pr(R \mid s')$.

Assumption 3 introduces a new parameter q' that describes the quality of the supervisory information. In addition, it states that adding signal s to signal s' does not change the conditional distribution of the return of the bank's risky asset, so the supervisory signal incorporates the uninsured depositor's information.[17] This implies the following result.

Lemma 1 *The quality q' of the supervisory information is greater than or equal to the quality q of the uninsured depositors' information. Moreover we have*

$$\delta = \Pr(s_0 \mid s'_0) = \Pr(s_1 \mid s'_1) = 1 - \frac{q' - q}{2q' - 1}. \tag{10}$$

Hence, if the two signals were perfectly correlated, we would have $\delta = 1$ and $q' = q$. Otherwise, $\delta < 1$ and $q' > q$, which is what will be assumed henceforth.[18]

As before, by Bayes' law we have

$$\Pr(R_1 \mid s'_0) = \frac{(1 - q')p}{q' + (1 - 2q')p}, \tag{11}$$

and

$$\Pr(R_1 \mid s'_1) = \frac{q'p}{1 - q' - (1 - 2q')p}, \tag{12}$$

which implies $\Pr(R_1 \mid s'_0) < p < \Pr(R_1 \mid s'_1)$ for $p < 1$ and $q' > \frac{1}{2}$, so s'_0 and s'_1 will be called the bad and the good signal, respectively.

[17] This is without loss of generality, since the uninsured depositors' signal, s_0 or s_1, is perfectly correlated with their behavior, run or not run.

[18] Assumption 3 also implies $\Pr(R, s \mid s') = \Pr(R \mid s, s') \Pr(s \mid s') = \Pr(R \mid s') \Pr(s \mid s')$, so conditional on the supervisory signal s', the asset return R and uninsured depositors' signal s are independent.

In what follows we examine the effects on risk-shifting incentives and fiscal costs of bank failure of each of the three policies for banking crises mentioned above. Importantly, we do not derive the use of any of these policies from the maximization of an objective function for the supervisor, but simply look at their incentive and budgetary implications.

The *benchmark model* for the three policies is one in which the supervisor does nothing to prevent the failure of the bank following a run. Moreover, the bad supervisory signal s'_0 is interpreted as the finding that the bank is not properly accounting for the deterioration of its assets, which leads to the violation of some key prudential regulations. Although these regulations are not spelled out in detail, it is convenient to think about minimum capital requirements. The benchmark model also assumes that the bank shareholders do not have the ability or the incentives to recapitalize the bank, and that the supervisor does not forbear, which leads to the withdrawal of the license and the closure of the bank.

Therefore, in the benchmark model the bank is liquidated at $t = 1$ when either the uninsured depositors observe the bad signal s_0 or the supervisor observes the bad signal s'_0, an event that by Assumptions 3 and Lemma 1 happens with probability

$$\begin{aligned} \Pr(s_0 \text{ or } s'_0) &= 1 - \Pr(s_1, s'_1) \\ &= 1 - \Pr(s_1 \mid s'_1) \Pr(s'_1) = 1 - \delta[1 - q' - (1 - 2q')p]. \end{aligned} \tag{13}$$

The bank fails at $t = 2$ when the uninsured depositors observe the good signal s_1, the supervisor also observes the good signal s'_1, and the return of the risky asset is R_0, an event that by Assumption 3 and Lemma 1 happens with probability

$$\begin{aligned} \Pr(s_1, s'_1, R_0) &= \Pr(R_0 \mid s_1, s'_1) \Pr(s_1, s'_1) \\ &= \Pr(R_0 \mid s'_1) \Pr(s_1 \mid s'_1) \Pr(s'_1) \\ &= \Pr(s_1 \mid s'_1) \Pr(s'_1, R_0) \\ &= \Pr(s_1 \mid s'_1) \Pr(s'_1 \mid R_0) \Pr(R_0) = \delta(1 - q')(1 - p). \end{aligned} \tag{14}$$

And the bank succeeds at $t = 2$ when the uninsured depositors observe the good signal s_1, the supervisor also observes the good signal s'_1, and the return of the risky asset is R_1, an event that by Assumption 3 and Lemma 1 happens with probability

$$
\begin{aligned}
\Pr(s_1, s'_1, R_1) &= \Pr(R_1 \mid s_1, s'_1)\Pr(s_1, s'_1) \\
&= \Pr(R_1 \mid s'_1)\Pr(s_1 \mid s'_1)\Pr(s'_1) \\
&= \Pr(s_1 \mid s'_1)\Pr(s'_1, R_1) \\
&= \Pr(s_1 \mid s'_1)\Pr(s'_1 \mid R_1)\Pr(R_1) = \delta q' p. \qquad (15)
\end{aligned}
$$

By limited liability, the bank gets a zero payoff if it is liquidated at $t = 1$ or fails at $t = 2$, and gets $R(p) - D - (1 - D)(1 + r)$ if it succeeds at $t = 2$, so its payoff function is given by

$$V^0(p; r) = \delta q' p[R(p) - D - (1 - D)(1 + r)]. \qquad (16)$$

The uninsured depositors get $\max\{L - D, 0\}$ when the bank is liquidated at $t = 1$, they get $(1 - D)(1 + r)$ when the bank succeeds at $t = 2$, and they get zero when the bank fails at $t = 2$, so their payoff function is given by

$$U^0(r; p) = [1 - \delta(1 - q' - (1 - 2q')p)]\max\{L - D, 0\} + \delta q' p(1 - D)(1 + r). \qquad (17)$$

A *equilibrium for the benchmark model* is a pair (r^0, p^0) such that p^0 maximizes the bank's payoff function $V^0(p; r^0)$ and r^0 satisfies the uninsured depositors' participation constraint $U^0(r^0; p^0) = 1 - D$.

As in the previous section, there may be multiple equilibria, in which case we focus on the equilibrium with the highest success probability p^0, for which one can prove the same result as in Proposition 1: p^0 is increasing in the proportion D of insured deposits whenever $D \geq L$, the effect being ambiguous otherwise.

The supervisor pays to the insured depositors $\max\{D - L, 0\}$ when the bank is liquidated at $t = 1$ and D when the bank fails at $t = 2$, so the fiscal cost in the benchmark equilibrium is

$$C^0 = [1 - \delta(1 - q' - (1 - 2q')p^0)]\max\{D - L, 0\} + \delta(1 - q')(1 - p^0)D. \qquad (18)$$

We are now ready to analyze the effects of three policies that the supervisor may implement at the outset of a crisis. Since some of the effects are ambiguous, we rely on numerical solutions using the functional form $R(p) = 3 - p^2$ and the parameter values $L = 0.50$, $q = 0.65$, and $q' = 0.75$, which by Lemma 1 imply $\delta = \Pr(s_0 \mid s'_0) = \Pr(s_1 \mid s'_1) = 0.80$.

3.1 Forbearance

Consider a situation in which at $t = 1$ the uninsured depositors observe the good signal s_1, so they do not run on the bank, but the supervisor observes the bad signal s'_0. This is interpreted as the violation of some key prudential regulations, so the supervisor may decide either to close the bank (the benchmark case) or to forbear.

In the forbearance case, the supervisory information is completely irrelevant. Hence we are in the same situation as in the model of Section 2. The bank is only liquidated at $t = 1$ when the uninsured depositors observe the bad signal s_0, it fails at $t = 2$ when they observe the good signal s_1 and the return of the risky asset is R_0, and it succeeds at $t = 2$ when they observe the good signal s_1 and the return of the risky asset is R_1. Therefore, as in (5) and (6), the payoff functions of the bank and the uninsured depositors are given by

$$V^F(p; r) = qp[R(p) - D - (1 - D)(1 + r)], \tag{19}$$

and

$$U^F(r; p) = [q + (1 - 2q)p] \max\{L - D, 0\} + qp(1 - D)(1 + r). \tag{20}$$

It is important to stress that in these expressions we are assuming that both the bank and the uninsured depositors correctly anticipate the supervisory forbearance.

An *equilibrium with forbearance* is a pair (r^F, p^F) such that p^F maximizes the bank's payoff function $V^F(p; r^F)$ and r^F satisfies the uninsured depositors' participation constraint $U^F(r^F, p^F) = 1 - D$.

To compare the equilibrium (r^F, p^F) with the benchmark equilibrium (r^0, p^0) we have to examine what happens to the two conditions that characterize these equilibria, namely the bank's first-order condition and the uninsured depositors' participation constraint. Since the only difference between $V^0(p;r)$ and $V^F(p;r)$ in (16) and (19) is that the constant that multiplies the term $p[R(p) - D - (1-D)(1+r)]$ is $\delta q'$ instead of q, it follows that the two first-order conditions are identical. Therefore, in order to compare the two equilibria we only have to find out what happens to the relationship between r and p in the participation constraints $U^0(r;p) = 1 - D$ and $U^F(r;p) = 1 - D$, which is done in the following result.

Proposition 2 *$p^F > p^0$ and $r^F < r^0$, whenever $D \geq L$.*

Hence, when the proportion of insured deposits is sufficiently large, regulatory forbearance reduces the interest rate required by uninsured depositors and increases the probability of success chosen by the bank. The intuition for this result is that when $D \geq L$ the uninsured depositors only get a positive payoff if the bank succeeds at $t = 2$, but since $\Pr(s_1, R_1) > \Pr(s_1, s_1', R_1)$ the probability of getting $(1-D)(1+r)$ is higher under forbearance, which in equilibrium implies a lower deposit rate and a higher probability of success. In terms of Figure 1, the explanation is that the participation constraint curve shifts to the left, so the chosen equilibrium moves up along the first-order condition curve. On the other hand, when $D < L$ there is an opposite effect, because since $\Pr(s_0) < \Pr(s_0 \text{ or } s_0')$ the probability of getting $\max\{L - D, 0\}$ is lower under forbearance.

The fiscal cost in the forbearance case is computed as follows. The supervisor pays the insured depositors $\max\{D - L, 0\}$ when the bank is liquidated at $t = 1$ and D when the bank fails at $t = 2$. Since $\Pr(s_0) = q + (1-2q)p^F$ and $\Pr(s_1, R_0) = \Pr(s_1 \mid R_0)\Pr(R_0) = (1-q)(1-p^F)$, the fiscal cost with forbearance is

$$C^F = [q + (1-2q)p^F]\max\{D - L, 0\} + (1-q)(1-p^F)D. \tag{21}$$

The comparison between the fiscal cost C^F for the forbearance model and the fiscal cost C^0 for the benchmark model is not straightforward. The numerical solution for our parametric specification is depicted in Figure 3, which shows the equilibrium

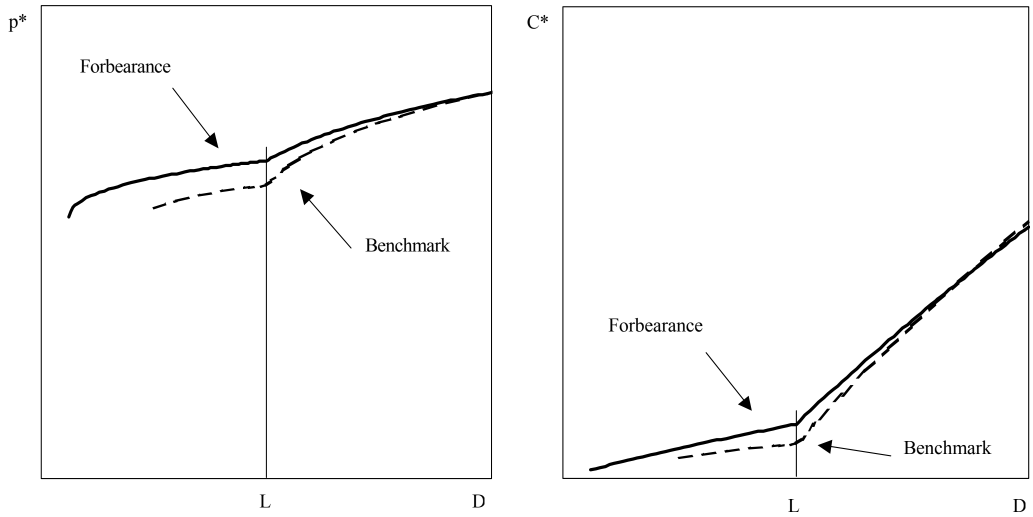

Figure 3: Equilibrium success probabilities and fiscal costs in the forbearance and benchmark cases

success probabilities, p^F and p^0, and the corresponding fiscal costs, C^F and C^0, as a function of the proportion D of insured deposits.

Figure 3 shows that the expectation of supervisory forbearance reduces the minimum value of the proportion D of insured deposits that is required for the existence of an equilibrium. Moreover, the success probabilities p^F and p^0 are everywhere increasing in the proportion D of insured deposits, with $p^F > p^0$ except in the limit when $D = 1$ (full deposit insurance) where $p^F = p^0$. The fiscal costs C^F and C^0 are also everywhere increasing in D, with $C^F > C^0$ except for high values of D where $C^F < C^0$. The reason for this result is that when the proportion D of insured deposits is large, the early closure of the bank by the supervisor in the benchmark model (when $s' = s'_0$) implies a large compensation to the insured depositors that would be saved if the bank were allowed to stay open and eventually succeeded.[19]

[19]This effect would not obtain for high values of the quality q' of the supervisory information, because in this case early closure would always be cheaper for the supervisor.

3.2 Deposit guarantees

Consider now a situation in which, after the uninsured depositors observe the bad signal s_0 at $t = 1$, the supervisor may decide either to extend the insurance coverage to all depositors or let the bank fail (the benchmark case).

If the supervisor extends the insurance regardless of the signals of the uninsured depositors and the supervisor there will be no liquidation at $t = 1$. Hence the bank gets $R(p) - D - (1 - D)(1 + r)$ with probability $\Pr(R_1) = p$, so its payoff function is given by

$$V^G(p; r) = p[R(p) - D - (1 - D)(1 + r)]. \tag{22}$$

Assuming that the supervisor only insures the principal (and not the interest initially offered), the uninsured depositors get $(1 - D)(1 + r)$ when the bank succeeds at $t = 2$, they get $1 - D$ when they observe the bad signal s_0 and the bank fails at $t = 2$ (because of the extension of the insurance coverage), and they get zero when they observe the good signal s_1 and the bank fails at $t = 2$ (because in this case they are not insured). Since $\Pr(R_1) = p$ and $\Pr(s_0, R_0) = \Pr(s_0 \mid R_0) \Pr(R_0) = q(1 - p)$, their payoff function is given by

$$U^G(r; p) = q(1 - p)(1 - D) + p(1 - D)(1 + r). \tag{23}$$

As in the forbearance case, it important to stress that in (22) and (23) we are assuming that both the bank and the uninsured depositors correctly anticipate the behavior of the supervisor.

An *equilibrium with extended deposit guarantees* is a pair (r^G, p^G) such that p^G maximizes the bank's payoff function $V^G(p; r^G)$ and r^G satisfies the uninsured depositors' participation constraint $U^G(r^G, p^G) = 1 - D$.

To compare the equilibrium (r^G, p^G) with the benchmark equilibrium (r^0, p^0) we have to examine what happens to the two conditions that characterize these equilibria, namely the bank's first-order condition and the uninsured depositors' participation constraint. Since the only difference between $V^0(p; r)$ and $V^G(p; r)$ in (16) and (22) is that the constant that multiplies the term $p[R(p) - D - (1 - D)(1 + r)]$ is $\delta q'$ instead of 1, it follows that the two first-order conditions are identical. Therefore, in order to compare the two equilibria we only have to find out what happens to the relationship between r and p in the participation constraints $U^0(r; p) = 1 - D$ and $U^G(r; p) = 1 - D$, which is done in the following result.

Proposition 3 $p^G > p^0$ *and* $r^G < r^0$, *whenever* $D \geq L$.

The intuition for this result is that when $D \geq L$ the uninsured depositors get a higher payoff when they observe the bad signal s_0 and the bank fails at $t = 2$, because they are covered by the extension of the insurance, and they also get a higher payoff when they observe the good signal s_1, the supervisor observes the bad signal s'_0, and the bank succeeds at $t = 2$, because in the benchmark case the bank would have been closed by the supervisor. In equilibrium both effects imply a lower deposit rate and a higher probability of success. In terms of Figure 1, the explanation is that the participation constraint curve shifts to the left, so the chosen equilibrium moves up along the first-order condition curve. On the other hand, when $D < L$ there is an opposite effect, because when the uninsured depositors observe the good signal s_1, the supervisor observes the bad signal s'_0, and the bank fails at $t = 2$, they get $\max\{L - D, 0\}$ in the benchmark case and zero in the extended deposit guarantees case.

The corresponding fiscal cost is computed as follows. The supervisor pays D to the insured depositors when the bank fails at $t = 2$, and it pays $1 - D$ to the uninsured depositors when they observe the bad signal s_0 and the bank fails at $t = 2$. Since $\Pr(R_0) = 1 - p^G$ and $\Pr(s_0, R_0) = \Pr(s_0 \mid R_0) \Pr(R_0) = q(1 - p^G)$, the fiscal cost is

$$C^G = (1 - p^G)D + q(1 - p^G)(1 - D). \tag{24}$$

The comparison between the fiscal cost C^G for the extended deposit guarantees model and the fiscal cost C^0 for the benchmark model is in principle ambiguous. The numerical solution for our parametric specification is depicted in Figure 4, which

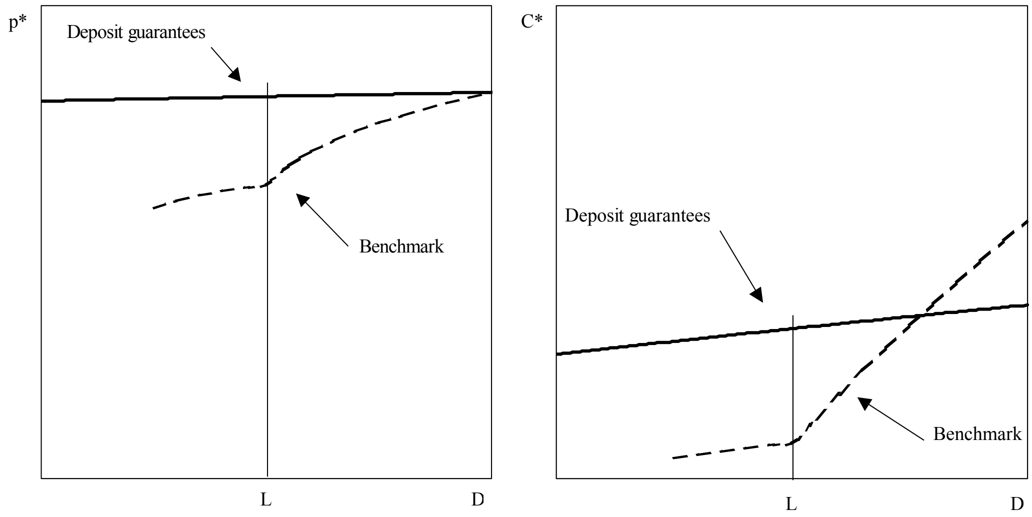

Figure 4: Equilibrium success probabilities and fiscal costs in the extended depostit guarantees and the benchmark cases

shows the equilibrium success probabilities, p^G and p^0, and the corresponding fiscal costs, C^G and C^0, as a function of the proportion D of insured deposits.

Figure 4 shows that the expectation of the extension of deposit guarantees to all depositors reduces (to zero) the minimum value of the proportion D of insured deposits that is required for the existence of an equilibrium. The success probability p^G is slightly increasing in the proportion D of insured deposits, with $p^G > p^0$ except in the limit when $D = 1$ (full deposit insurance) where $p^G = p^0$. The fiscal cost C^G is also increasing in D, with $C^G > C^0$ except for high values of D where $C^G < C^0$. The reason for this result is that when the proportion D of insured deposits is large, the early closure of the bank by either the uninsured depositors (when $s = s_0$) or the supervisor (when $s' = s'_0$) in the benchmark model implies a large compensation to the insured depositors, which would be saved if the bank were allowed to stay open and eventually succeeded.

3.3 Liquidity support

Consider next a situation in which, after the uninsured depositors observe the bad signal s_0 at $t = 1$, the supervisor, acting as a lender of last resort, may decide either to provide emergency liquidity to cover the withdrawal of uninsured deposits or let the bank fail (the benchmark case). To simplify the presentation, we assume that the lender of last resort charges the bank the same interest rate r initially required by the uninsured depositors.

If the supervisor provides the emergency liquidity regardless of the signals of the uniformed depositors and the supervisor there will be no liquidation at $t = 1$. Hence the bank will get $R(p) - D - (1 - D)(1 + r)$ with probability $\Pr(R_1) = p$, so its payoff function is the same as in the case of extended deposit guarantees, that is

$$V^L(p;r) = p[R(p) - D - (1 - D)(1 + r)]. \tag{25}$$

Assuming that the uninsured depositors can only claim at $t = 1$ the principal (and not the interest initially offered), the uninsured depositors get $1 - D$ when they observe the bad signal s_0 and withdraw their funds at $t = 1$, they get $(1 - D)(1 + r)$ when they observe the good signal s_1 and the bank succeeds at $t = 2$, and they get zero when they observe the good signal s_1 and the bank fails at $t = 2$. Since $\Pr(s_0) = q + (1 - 2q)p$ and $\Pr(s_1, R_1) = \Pr(s_1 \mid R_1)\Pr(R_1) = qp$, their payoff function is given by

$$U^L(r;p) = [q + (1 - 2q)p](1 - D) + qp(1 - D)(1 + r). \tag{26}$$

An *equilibrium with unrestricted liquidity support* is a pair (r^L, p^L) such that p^L maximizes the bank's payoff function $V^L(p; r^L)$ and r^L satisfies the uninsured depositors' participation constraint $U^L(r^L, p^L) = 1 - D$.

To compare the equilibrium (r^L, p^L) with the benchmark equilibrium (r^0, p^0) we note that by our previous arguments the bank's first-order conditions are identical, so we only have to find out what happens to the relationship between r and p in the participation constraints $U^0(r;p) = 1 - D$ and $U^L(r;p) = 1 - D$, which is done in the following result.

Proposition 4 *$p^L > p^0$ and $r^L < r^0$, whenever $D \geq L$.*

The intuition for this result is that when $D \geq L$ the uninsured depositors get a higher payoff when they observe the bad signal s_0 and the bank fails at $t = 2$, because they are able to withdraw their funds at $t = 1$, and they also get a higher payoff when they observe the good signal s_1, the supervisor observes the bad signal s'_0, and the bank succeeds at $t = 2$, because in the benchmark case the bank would have been closed by the supervisor. In equilibrium both effects imply a lower deposit rate and a higher probability of success. In terms of Figure 1, the explanation is that the participation constraint curve shifts to the left, so the chosen equilibrium moves up along the first-order condition curve. On the other hand, when $D < L$ there is an opposite effect, because when the uninsured depositors observe the good signal s_1, the supervisor observes the bad signal s'_0, and the bank fails at $t = 2$, they get $\max\{L - D, 0\}$ in the benchmark case and zero in the unrestricted liquidity support case.

The corresponding fiscal cost is computed as follows. The supervisor pays the insured depositors D when the bank fails at $t = 2$, it loses its loan $1 - D$ when the uninsured depositors observe the bad signal s_0 and the bank fails at $t = 2$, and it gains $(1-D)r^L$ when the uninsured depositors observe the bad signal s_0 and the bank succeeds at $t = 2$. Since $\Pr(R_0) = 1-p^L$, $\Pr(s_0, R_0) = \Pr(s_0 \mid R_0)\Pr(R_0) = q(1-p^L)$, and $\Pr(s_0, R_1) = \Pr(s_0 \mid R_1)\Pr(R_1) = (1-q)p^L$, the fiscal cost is

$$C^L = (1-p^L)D + q(1-p^L)(1-D) - (1-q)p^L(1-D)r^L. \tag{27}$$

The comparison between the fiscal cost C^L for the unrestricted liquidity support model and the fiscal cost C^0 for the benchmark model is in principle ambiguous. The numerical solution for our parametric specification gives a result that is very similar to that of the model with extended deposit guarantees depicted in Figure 4, except for the fact that p^L and C^L are slightly below p^G and C^G.[20]

[20] The effect on p is easy to explain: From (26) and (23) it follows that $U^L = U^G - p(1-q)(1-D)r <$

The previous analysis assumes that the supervisor directly provides the liquidity support. An alternative setup is one in which there is a *central bank*, different from the deposit insurer, that supervises the bank and is willing to support it when the uninsured depositors observe the bad signal s_0 but only if the supervisory signal is s_1'. The interpretation is that the central bank requires "good banking securities" (using Bagehot's (1873) terminology) for its last resort lending. In addition, we assume that the central bank does not forbear, so it closes the bank when it observes the bad signal s_0'.

In this setup the bank is liquidated at $t = 1$ when the central bank observes the bad signal s_0', an event that happens with probability $\Pr(s_0') = q' + (1 - 2q')p$. The bank fails at $t = 2$ when the central bank observes the good signal s_1' and the return of the risky asset is R_0, an event that happens with probability $\Pr(s_1', R_0) = \Pr(s_1' \mid R_0)\Pr(R_0) = (1 - q')(1 - p)$. And the bank succeeds at $t = 2$ when the central bank observes the good signal s_1' and the return of the risky asset is R_1, an event that happens with probability $\Pr(s_1', R_1) = \Pr(s_1' \mid R_1)\Pr(R_1) = q'p$. Hence the payoff function of the bank is given by

$$V^{CB}(p; r) = q'p[R(p) - D - (1 - D)(1 + r)]. \tag{28}$$

The uninsured depositors get $\max\{L - D, 0\}$ when the central bank observes the bad signal s_0' (because the bank is liquidated at $t = 1$), they get $1 - D$ when they observe the bad signal s_0 and the central bank observes the good signal s_1' (because they are able to withdraw their funds), they get $(1 - D)(1 + r)$ when they observe the good signal s_1, the supervisor also observes the good signal s_1', and the return of the risky asset is R_1, and they get zero when they observe the good signal s_1, the supervisor also observes the good signal s_1', and the return of the risky asset is R_0. Since $\Pr(s_0') = q' + (1 - 2q')p$, $\Pr(s_0, s_1') = \Pr(s_0 \mid s_1')\Pr(s_1') = (1 - \delta)[1 - q' - (1 - 2q')p]$

U^G, so in terms of Figure 1 the participation constraint in the liquidity support case is shifted out relative to the participation constraint in the deposit guarantees case, which gives $p^L < p^G$. On the other hand, the result $C^L < C^G$ is explained by the interest payment in the liquidity support case, which compensates the decrease in p.

and by (15) we have $\Pr(s_1, s_1', R_1) = \delta q' p$, their payoff function is given by

$$\begin{aligned} U^{CB}(r;p) &= [q' + (1-2q')p] \max\{L - D, 0\} \\ &\quad + (1-\delta)[1 - q' - (1-2q')p](1-D) + \delta q' p(1-D)(1+r). \quad (29) \end{aligned}$$

An *equilibrium with restricted (central bank) liquidity support* is a pair (r^{CB}, p^{CB}) such that p^{CB} maximizes the bank's payoff function $V^{CB}(p; r^{CB})$ and r^{CB} satisfies the uninsured depositors' participation constraint $U^{CB}(r^{CB}, p^{CB}) = 1 - D$.

To compare the equilibrium (r^{CB}, p^{CB}) with the benchmark equilibrium (r^0, p^0) we note, once again, that by our previous arguments the bank's first-order conditions are identical, so we only have to find out what happens to the relationship between r and p in the participation constraints $U^0(r;p) = 1 - D$ and $U^{CB}(r;p) = 1 - D$, which is done in the following result.

Proposition 5 *$p^{CB} > p^0$ and $r^{CB} < r^0$.*

The intuition for this result is that the uninsured depositors get a higher payoff when they observe the bad signal s_0 and the supervisor observes good signal s_1', because they are able to withdraw their funds at $t = 1$, getting $1 - D$ instead of $\max\{L - D, 0\}$ as in the benchmark case. In terms of Figure 1, the participation constraint curve always shifts to the left, so the chosen equilibrium moves up along the first-order condition curve.

The fiscal cost for the consolidated entity comprising the central bank and the deposit insurer is computed as follows. The deposit insurer pays the insured depositors $\max\{D - L, 0\}$ when the bank is liquidated at $t = 1$ and D when the bank fails at $t = 2$. The central bank loses its loan $1 - D$ when the uninsured depositors observe the bad signal s_0, the central bank observes the good signal s_1', and the bank fails at $t = 2$, and it gains $(1 - D)r^{CB}$ when the uninsured depositors observe the bad signal s_0, the central bank observes the good signal s_1', and the bank succeeds at $t = 2$. Since $\Pr(s_0') = q' + (1-2q')p^{CB}$, $\Pr(s_1', R_0) = \Pr(s_1' \mid R_0)\Pr(R_0) = (1-q')(1-p^{CB})$, and by Assumption 3 and Lemma 1 we have

$$\begin{aligned}
\Pr(s_0, s_1', R_0) &= \Pr(R_0 \mid s_0, s_1') \Pr(s_0, s_1') \\
&= \Pr(R_0 \mid s_1') \Pr(s_0 \mid s_1') \Pr(s_1') \\
&= \Pr(s_0 \mid s_1') \Pr(s_1', R_0) \\
&= \Pr(s_0 \mid s_1') \Pr(s_1' \mid R_0) \Pr(R_0) = (1-\delta)(1-q')(1-p^{CB}),
\end{aligned}$$

and similarly $\Pr(s_0, s_1', R_1) = (1-\delta)q'p^{CB}$, the fiscal cost is

$$\begin{aligned}
C^{CB} &= [q' + (1-2q')p^{CB}] \max\{D-L, 0\} + (1-q')(1-p^{CB})D \\
&\quad +(1-\delta)(1-q')(1-p^{CB})(1-D) - (1-\delta)q'p^{CB}(1-D)r^{CB}. \qquad (30)
\end{aligned}$$

The comparison between the fiscal cost C^{CB} for the restricted liquidity support model and the fiscal cost C^0 for the benchmark model is in principle ambiguous. The numerical solution for our parametric specification is depicted in Figure 5, which shows the equilibrium success probabilities, p^{CB} and p^0, and the corresponding fiscal costs, C^{CB} and C^0, as a function of the proportion D of insured deposits.

Figure 5 shows that the expectation of the provision of liquidity support by the central bank reduces (to zero) the minimum value of the proportion D of insured deposits that is required for the existence of an equilibrium. The success probability p^{CB} is increasing in the proportion D of insured deposits, with $p^{CB} > p^0$ except in the limit when $D = 1$ (full deposit insurance) where $p^{CB} = p^0$. The fiscal costs C^{CB} is also increasing in D. Interestingly, we have $C^{CB} < C^0$, with C^{CB} becoming negative (i.e., a positive expected revenue) for low values of D. The reason for this result is that in this case the cost to the deposit insurer is small, while the central bank is lending only when it observes the good signal s_1', which implies that interest payment when the bank succeeds more than offsets the losses when the bank fails.

We have assumed until now that the supervisor or the central bank only charge the normal market interest rate for their last resort lending, in contrast with the classical doctrine on the lender of last resort put forward by Bagehot (1873) that required that

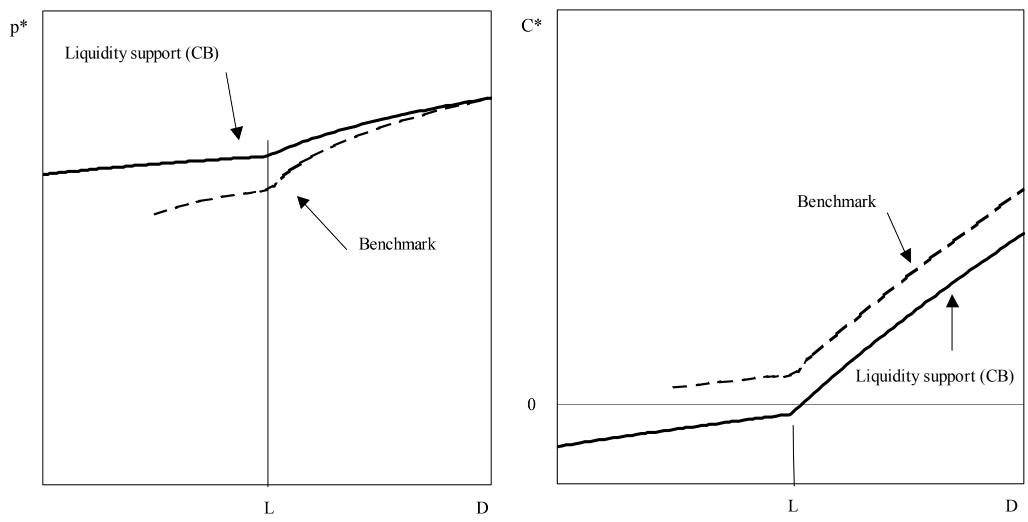

Figure 5: Equilibrium success probabilities and fiscal costs in the restricted liquidity support and benchmark cases

"these loans should only be made at a very high interest rate." However, the effect of penalty rates on the bank's choice of risk is straightforward: they increase the expected interest payments when the bank succeeds at $t = 2$ and, consequently, the bank reacts to this higher cost by choosing a higher risk and higher return portfolio. Thus, in line with the results in Repullo (2004), penalty rates increase the bank's incentives to take risk.

To close this section, we briefly comment on one feature of banking in the real world that has been absent from our model, namely bank capital. Introducing the possibility of raising equity capital at $t = 0$ would not change our results, because if the cost of capital is greater than or equal to the return required by depositors it is never optimal for the bank owners to provide any capital. Moreover, the effect of a minimum capital requirement k would be the same as in Repullo (2004): the bank's success payoff would become $R(p) - (1-k)D - (1-k)(1-D)(1+r)$, so the first-order condition that characterizes the bank's choice of risk would be

$$R(p^*) + p^* R'(p^*) = (1-k)[D + (1-D)(1+r^*)].$$

Since the left-hand-side of this expression is decreasing in p^*, it follows that capital requirements reduce the bank's incentives to take risk.

4 Concluding Remarks

Most of the literature on the design of the financial safety net has repeatedly argued that any form of insurance creates moral hazard and hence leads to greater risk-taking. However, as noted by Demirgüç-Kunt and Kane (2002, p. 176), "this insight has been persistently emphasized by academics, but mostly dismissed or denigrated by policymakers." This paper shows that the intuition of policymakers may not have been wrong after all. Our result follows from two arguments: (i) insured depositors require a lower interest rate for their funds, and (ii) as in the model of Stiglitz and Weiss (1981) a lower cost of funding reduces the banks' incentives to take risks.

The stark contrast between our result and the extant literature deserves further discussion. It is true that in general any form of insurance has the potential to create a moral hazard problem. However, the point is that in the context of banking the absence of deposit insurance does not eliminate the moral hazard that comes from the fact that the choice of investment is done (or may be changed) after the funds are raised, and this choice is in general not verifiable so deposit rates cannot be made contingent on it. The traditional story is based on the idea that even though deposit rates cannot be made explicitly contingent on risk, monitoring by uninsured depositors can make them contingent ex post, so by reducing the incentives to monitor banks deposit insurance is an important source of moral hazard.

A simple way to formalize this argument would be as follows. Suppose that instead of observing a signal s on the return of the bank's risky asset, the uninsured depositors observe the bank's choice of p. Furthermore, suppose that they can make the deposit rate r contingent on the choice of p (for example, by threatening to withdraw their funds). In this case, the bank would maximize its payoff function

$$p[R(p) - D - (1 - D)(1 + r(p))]$$

subject to the uninsured depositors' participation constraint

$$p(1-D)(1+r(p)) = 1-D.$$

Substituting this constraint into the bank's objective function yields

$$p[R(p)-D]-(1-D),$$

so the first-order condition that characterizes the success probability $\widetilde{p}$ chosen by the bank is

$$R(\widetilde{p})+\widetilde{p}R'(\widetilde{p}) = D. \tag{31}$$

Since we have assumed that $R(p)+pR'(p)$ is decreasing, it follows from (31) that $\widetilde{p}$ is decreasing in the proportion D of insured deposits. Moreover, comparing (31) with (2), it also follows that the success probability $\widetilde{p}$ chosen by the bank converges to the first-best $\widehat{p}$ when the proportion of insured deposits D tends to zero. Thus, in this setting having no deposit insurance would be optimal.

Two objections can be made to this argument. The standard one is that small depositors do not have the ability or the incentives to monitor banks.[21] The non-standard one that we are putting forward in this paper is that one should distinguish between the *monitoring of actions* and the *monitoring of the consequences of those actions*.[22] As noted above, the former eliminates the moral hazard problem in the absence of deposit insurance. The latter, however, does not eliminate this problem. In our model, this monitoring yields signal s which changes the bank's payoff function from

$$p[R(p)-D-(1-D)(1+r)]$$

to

$$qp[R(p)-D-(1-D)(1+r)],$$

[21] As forcefully argued by Corrigan (1991, pp. 49-50), "I think it is sheer fantasy to assume that individual investors and depositors –and perhaps even large and relatively sophisticated investors and depositors– can make truly informed credit judgements about highly complex financial instruments and institutions."

[22] See Prat (2003) for a detailed discussion of the related distinction between signals on actions and signals on the consequences of actions.

where $q = \Pr(s_1 \mid R_1)$ is the quality of the uninsured depositors' information. Clearly, multiplying the payoff function by a constant does not have any effect on the first-order condition that characterizes the bank's choice of risk. Moreover, the higher the proportion of insured deposits D the lower the bank's average cost of funds, and hence the lower the banks' incentives to take risks.

Since arguably the second is the most plausible type of monitoring,[23] we conclude that there should be no presumption that deposit insurance worsens the bank's risk-shifting incentives.[24] Similarly, accommodative resolution policies for banking crises need not induce banks to take greater risks. On the contrary, to the extent that they reduce the interest rate required by uninsured depositors, they could in fact ameliorate the bank's risk-shifting incentives, but at the expense of higher fiscal costs. At any rate, this is an important policy area where further research, both theoretical and empirical, is much needed.

[23] Also, this is the one that has been studied in the literature. For example, Martinez-Peria and Schmukler (2001) show that depositors in Argentina, Chile, and Mexico punish banks when their fundamentals deteriorate (not when they pursue riskier strategies), both by withdrawing their deposits and by requiring higher interest rates.

[24] Interestingly, Gropp and Vesala (2004) find evidence that the introduction of explicit deposit insurance in the European Union may have significantly reduced banks' risk-taking.

Appendix

Proof of Proposition 1 Differentiating (7) and (8) gives

$$\begin{bmatrix} a_{11} & a_{12} \\ a_{21} & a_{22} \end{bmatrix} \begin{bmatrix} dr^* \\ dp^* \end{bmatrix} = \begin{bmatrix} a_{13} & a_{14} \\ a_{23} & 0 \end{bmatrix} \begin{bmatrix} dD \\ dq \end{bmatrix},$$

where

$$\begin{aligned}
a_{11} &= -qp^*(1-D) < 0, \\
a_{12} &= (2q-1)\max\{L-D,0\} - q(1-D)(1+r^*) \\
&< (2q-1)(1-D) - q(1-D) = (q-1)(1-D) < 0, \\
a_{13} &= 1 - [q + (1-2q)p^*] - qp^*(1+r^*) \\
&= [q + (1-2q)p^*]\left(\frac{\max\{L-D,0\}}{1-D} - 1\right) < 0, \quad \text{if } D < L, \\
a_{13} &= 1 - qp^*(1+r^*) = 0, \quad \text{if } D \geq L, \\
a_{14} &= (1-2p^*)\max\{L-D,0\} + p^*(1-D)(1+r^*) > 0, \quad \text{if } p \leq \tfrac{1}{2}, \\
a_{14} &= (1-2p^*)\max\{L-D,0\} + p^*(1-D)(1+r^*) \\
&> (1-2p^*)(1-D) + p^*(1-D) = (1-p^*)(1-D) > 0, \quad \text{if } p > \tfrac{1}{2}, \\
a_{21} &= -(1-D) < 0, \\
a_{22} &= 2R'(p^*) + p^*R''(p^*) < 0, \\
a_{23} &= -r^* < 0.
\end{aligned}$$

Since the equilibrium with the highest value of p^* (and the lowest value of r^*) is characterized by the condition $a_{11}a_{22} - a_{12}a_{21} > 0$, we conclude that

$$\begin{aligned}
\frac{\partial r^*}{\partial D} &= \frac{a_{13}a_{22} - a_{12}a_{23}}{a_{11}a_{22} - a_{12}a_{21}} \lesseqgtr 0 \quad \text{and} \quad \frac{\partial p^*}{\partial D} = \frac{a_{11}a_{23} - a_{13}a_{21}}{a_{11}a_{22} - a_{12}a_{21}} \lesseqgtr 0, \quad \text{if } D < L, \\
\frac{\partial r^*}{\partial D} &= \frac{-a_{12}a_{23}}{a_{11}a_{22} - a_{12}a_{21}} < 0 \quad \text{and} \quad \frac{\partial p^*}{\partial D} = \frac{a_{11}a_{23}}{a_{11}a_{22} - a_{12}a_{21}} > 0, \quad \text{if } D \geq L, \\
\frac{\partial r^*}{\partial q} &= \frac{a_{14}a_{22}}{a_{11}a_{22} - a_{12}a_{21}} < 0 \quad \text{and} \quad \frac{\partial p^*}{\partial q} = \frac{-a_{14}a_{21}}{a_{11}a_{22} - a_{12}a_{21}} > 0.
\end{aligned}$$

Proof of Lemma 1 By the definition of conditional probabilities and Assumption 3 we have

$$\Pr(s \mid R, s') = \frac{\Pr(R \mid s, s') \Pr(s \mid s')}{\Pr(R \mid s')} = \Pr(s \mid s'),$$

which implies

$$\begin{aligned}
\Pr(s \mid R) &= \Pr(s \mid R, s'_0) \Pr(s'_0 \mid R) + \Pr(s \mid R, s'_1) \Pr(s'_1 \mid R) \\
&= \Pr(s \mid s'_0) \Pr(s'_0 \mid R) + \Pr(s \mid s'_1) \Pr(s'_1 \mid R).
\end{aligned}$$

Substituting $s = s_0, s_1$ and $R = R_0, R_1$ in this result, and using the definitions of q and q', we get the following system linear equations:

$$\begin{aligned}
q &= \Pr(s_0 \mid s'_0)q' + \Pr(s_0 \mid s'_1)(1-q'), \\
1-q &= \Pr(s_1 \mid s'_0)q' + \Pr(s_1 \mid s'_1)(1-q'), \\
q &= \Pr(s_1 \mid s'_0)(1-q') + \Pr(s_1 \mid s'_1)q', \\
1-q &= \Pr(s_0 \mid s'_0)(1-q') + \Pr(s_0 \mid s'_1)q',
\end{aligned}$$

whose solution gives

$$\delta = \Pr(s_0 \mid s'_0) = \Pr(s_1 \mid s'_1) = 1 - \frac{q'-q}{2q'-1}.$$

Moreover, since δ is a probability we have $\delta \leq 1$, which implies $q' \geq q$.

Proof of Proposition 2 Using the fact that by Assumptions 2 and 3 and Lemma 1 we have

$$\begin{aligned}
\Pr(s_0 \text{ or } s'_0) &= \Pr(s_0) + \Pr(s'_0) - \Pr(s_0, s'_0) \\
&= \Pr(s_0) + \Pr(s'_0) - \Pr(s_0 \mid s'_0) \Pr(s'_0) \\
&= q + (1-2q)p + (1-\delta)[q' + (1-2q')p],
\end{aligned}$$

so (17) can also be written as

$$U^0(r;p) = [q + (1-2q)p + (1-\delta)(q' + (1-2q')p)] \max\{L-D, 0\} + \delta q' p (1-D)(1+r).$$

But then using the definition (20) of $U^F(r;p)$ we have

$$\begin{aligned} U^0(r;p) &= U^F(r;p) + (1-\delta)[q' + (1-2q')p)] \max\{L-D, 0\} \\ &\quad -(q-\delta q')p(1-D)(1+r). \end{aligned}$$

Since $q - \delta q' = (1-\delta)(1-q') > 0$ by the proof of Lemma 1, if $\max\{L-D, 0\} = 0$ we have $U^0(r;p) < U^F(r;p)$, so the participation constraint in the forbearance case is shifted to the left, which implies $p^F > p^0$ and $r^F < r^0$. On the other hand, if $\max\{L-D, 0\} > 0$ the second term in the previous expression is positive while the third is negative, so we have $U^0(r;p) \gtreqless U^F(r;p)$, and the result is ambiguous.

Proof of Proposition 3 Using the expression of $U^0(r;p)$ in the proof of Proposition 2 and the definition (23) of $U^G(r;p)$ we have

$$\begin{aligned} U^0(r;p) &= U^G(r;p) + [(1-q)p + (1-\delta)(q' + (1-2q')p)] \max\{L-D, 0\} \\ &\quad -q(1-p)[(1-D) - \max\{L-D, 0\}] - (1-\delta q')p(1-D)(1+r). \end{aligned}$$

Hence, if $\max\{L-D, 0\} = 0$ we have $U^0(r;p) < U^G(r;p)$, so the participation constraint in the unlimited deposit guarantees case is shifted to the left, which implies $p^G > p^0$ and $r^G < r^0$. On the other hand, if $\max\{L-D, 0\} > 0$ the second term in the previous expression is positive while the third and the fourth are negative, so we have $U^0(r;p) \gtreqless U^G(r;p)$, and the result is ambiguous.

Proof of Proposition 4 Using the expression of $U^0(r;p)$ in the proof of Proposition 2 and the definition (26) of $U^L(r;p)$ we have

$$\begin{aligned} U^0(r;p) &= U^L(r;p) + (1-\delta)[q' + (1-2q')p] \max\{L-D, 0\} \\ &\quad -[q + (1-2q)p][(1-D) - \max\{L-D, 0\}] - (q-\delta q')p(1-D)(1+r). \end{aligned}$$

Since $q - \delta q' = (1-\delta)(1-q') > 0$ by the proof of Lemma 1, if $\max\{L-D, 0\} = 0$ we have $U^0(r;p) < U^L(r;p)$, so the participation constraint in the unrestricted liquidity support case is shifted to the left, which implies $p^L > p^0$ and $r^L < r^0$. On the other hand, if $\max\{L - D, 0\} > 0$ the second term in the previous expression is positive while the third and the fourth are negative, so we have $U^0(r;p) \gtrless U^L(r;p)$, and the result is ambiguous.

Proof of Proposition 5 Using the definitions (17) and (26) of $U^0(r;p)$ and $U^L(r;p)$ we have

$$U^0(r;p) = U^{CB}(r;p) - (1-\delta)[1-q' - (1-2q')p][(1-D) - \max\{L-D,0\}] < U^{CB}(r;p).$$

Hence, the participation constraint in the central bank liquidity support case is shifted to the left, which implies $p^{CB} > p^0$ and $r^{CB} < r^0$.

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