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POLICY IMPLICATIONS OF USING AUDITS TO DETECT BANK INSOLVENCIES

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Abstract

We present a model where a regulator has to decide how to tackle the potential insolvency of a bank in a context of asymmetric information. We show that, when it can audit the bank, the regulator is unlikely to choose a policy of bailout to induce the bank to reveal its insolvency. We show that, in some circumstances, the regulator can induce the bank to reveal its insolvency by threatening to randomize its decision to nationalize the bank.

Resumen

Presentamos un modelo donde un regulador debe decidir cómo enfrentar la potencial insolvencia de un banco en un contexto con asimetrías de información. Demostramos que, cuando el regulador tiene la capacidad de auditar la situación financiera del banco, sería poco probable que decidiera llevar a cabo un salvataje de éste para inducir a sus dueños a revelar su insolvencia. Bajo algunas circunstancias, el regulado podría lograr dicha revelación amenazando con nacionalizar el banco utilizando una regla aleatoria.

We thank an anonymous referee for helpful comments. E-mail: jhurtubia@yahoo.it and claudio.sardoni@uniroma1.it.

1. Introduction

Many have dealt with the problem of the determination of optimal policies to tackle bank insolvency. In particular, attention has been paid to the reasons why policies based on bailouts should be adopted.

One strand of the literature considers bailouts as a way to tackle bank insolvency in a context of asymmetric information. Regulators cannot observe when a bank is insolvent and, therefore, it is difficult for them to make a commitment to implement 'tough' policies like nationalization or closure. Bankers will hide their insolvency and give rise to inefficiencies like 'creditor passivity', which amounts to not liquidate non-viable loans (Mitchell (2001); Aghion, Bolton, and Fries (1999)), or 'risk shifting', which implies an increase in the risk of their portfolios (Jensen and Meckling (1976); Myers (1977); Gorton and Huang (2004); Osano (2002)). In conditions of asymmetric information, the possibility to be bailed out may induce a banker to reveal the bad portfolio. In this way, the distortions mentioned above can be eliminated. For these reasons, some authors (e.g. Aghion, Bolton, and Fries (1999)) are in favor of the explicit introduction of bailouts into financial safety nets.

However, in many cases policymakers (regulators) are reluctant to adopt strategies based on bailout and even less so to introduce bailout practices explicitly in safety net institutions.[1] Our paper offers a rationale for this type of behavior.

We argue that, when the regulator can audit the bank, there are two pre-commitment options available to induce the revelation of insolvency: (i) pre-commit to bailout the bank, or (ii) pre-commit to randomize the decision to nationalize the bank. The regulator can influence the outcome in favor of the second type of pre-commitment by under investing in bank supervision and keeping a high degree of discretion.

We arrive to these results by developing a signaling model between a regulatory agency (the regulator) and one bank which is managed and owned by a risk-neutral banker. The banker invests the bank's resources in a loan portfolio. Then, nature reveals the quality type of

[1]Goodhart and Huang (1999)) highlight that policymakers prefer to rely on 'constructive ambiguity' when making their bailout decisions. They argue that policymakers can improve welfare if they can introduce an element of uncertainty over which policy they will choose to tackle bank insolvency.

the loan portfolio to the banker, which can be either good or bad. This information is private to the banker. The regulator and depositor only observe the probability distribution associated to both states of nature. An important feature of the model is that a bad loan portfolio type induces the banker to risk-shift (Jensen and Meckling (1976); Myers (1977)), i.e. to increase the risk of the portfolio's return.

The regulator will want to detect the bank's bad result to prevent the banker from shifting the bank's risk because, following the literature (see for example Gorton and Huang (2004) and Osano (2002)), we will assume that a change in the risk profile is inefficient: the expected return of the new and riskier portfolio is lower compared to the original one.

The regulator uses bank audits to detect the portfolio quality type. The banker sends a signal about the quality of the bank's portfolio, which then the regulator scrutinizes by conducting an in-situ inspection to the bank. When the regulator detects a bad portfolio he must choose a policy. The regulator may nationalize the bank, bail it out, or decide to do nothing.

The model is first solved assuming that the banker and the regulator cannot pre-commit. We highlight a type of equilibria where the banker and the regulator play mixed strategies. The banker uses mixed strategies in his decision to reveal the bad portfolio, and the regulator in his decision to nationalize the bank. Two features of the model explain this type of equilibria: (i) the regulator chooses his policy after observing the result of the in-situ inspection and his choice is not constrained by the outcome of the inspection, and (ii) when the bank is nationalized, the banker suffers private costs only if he previously declared the good portfolio type (if he decides to reveal a bad portfolio type he suffers no private costs).

The mixed strategy equilibrium occurs when the bad state of nature is likely to happen and the efficacy of the audit is low. The banker and the regulator cannot anticipate what the other is playing, and therefore they randomize their choices. The logic is the following. When the audit is not effective enough and the portfolio is likely to be bad, the banker hides bad portfolios and therefore the regulator has incentives to nationalize the bank independently of the outcome of the in-situ inspection. As a consequence, the banker would be better off by revealing bad portfolios, instead of hiding them, in order to avoid the private costs associated to nationalization. If this was the case, however, it would be convenient for the regulator only to nationalize the bank when the banker reveals a bad portfolio, instead of nationalizing in every event. This changes again the incentives of the banker, as he would deviate and hide the bad portfolios taking advantage of regulator's belief. It is clear that, under these circumstances, pure strategy equilibria are not possible. For both agents the best response differs depending on what they perceive their counterpart is playing. Only mixed strategies are possible.

The relevance of this type of equilibria, where mixed strategies are used, is made clear when we solve the model assuming that the banker and the regulator can pre-commit. In this case, the regulator can achieve full revelation by threatening to randomize his decision to nationalize the bank in the future, if the banker does not reveal truthfully. The banker would have incentives to reveal truthfully in order to avoid the potential expropriation associated to the randomization policy.

We then go on to highlight that the regulator faces a policy problem when, in the game with pre-commitment, there is also a bailout equilibrium that induces truthful revelation. The banker would prefer the bailout solution and therefore could decide to hide bad portfolios in order to renegotiate a policy shift by the regulator. The policy that is ultimately chosen will depend on the regulator's ability to convince the banker that the bank will not be bailed out. We show that under some circumstances the regulator may under invest in bank supervision in order to bias the outcome in favor of the threat to randomize.

Our paper is related to the financial literature that deals with public policies to induce the revelation of bank insolvency (see Aghion, Bolton, and Fries (1999); Osano (2002); Mitchell (1998, 2001); Gorton and Huang (2004)).

Aghion, Bolton, and Fries (1999) and Osano (2002) show that, under some circumstances, the regulator can induce the revelation of bank insolvency by designing a bailout scheme with non-linear cash transfers. Aghion, Bolton, and Fries (1999) present a model where a bailout induces bankers to reveal bad portfolios, but creates an adverse selection problem because solvent banks would want to benefit from public capitalizations as well. A bailout with a non-linear cash transfer scheme solves the adverse selection problem. In Osano (2002) bankers reveal bad portfolios when: (i) the banker benefits from a compensation scheme based on stock options, and (ii) the cash injection is coped with repayment schedules that punish, in relative terms, banks that risk-shifted.

In our paper we shift the emphasis away from non-linear cash transfers, in order to concentrate on how audits can induce full revelation. In Aghion, Bolton, and Fries (1999) the regulator is unable to conduct audits. In Osano (2002) the audit does not play an important role because the regulator's behavior is constrained by its outcome: the bank can only be taken over if the audit detects the insolvency. In our paper, the outcome of the audit does not put a constraint on the regulator's policy choice; it only allows the regulator to actualize his beliefs. By providing the regulator with the flexibility to choose any policy after the audit is conducted, we allow the regulator to make threats that can induce the banker to reveal truthfully.

The other papers in this literature, Gorton and Huang (2004), Mitchell (1998), and Mitchell (2001), focus on different issues. Gorton and Huang (2004) show that the expectation of a bailout increases economic efficiency because it allows society to invest its savings in productive assets, rather than liquid but unproductive assets, because there is no need to create the liquidity to purchase the bank's non-performing assets. Mitchell (1998) shows that banks can take advantage of asymmetries of information, by coordinating to act passively with debtors, to create a case of "too-many-to-fail", and induce the regulator to bailout banks. Mitchell (2001) applies a cost benefit analysis to determine the best way to tackle the insolvency of banks, by focusing in the a-priori probability distribution of the bank's portfolio returns.

There is a set of papers that study policies to deal with bank insolvency in the absence of asymmetries of information. These papers agree that a bailout protects the value of the bank's assets by avoiding a fire sale to agents outside the banking sector (see Diamond (2001), Acharya and Yorulmazer (2007b), and Acharya and Yorulmazer (2007a)).[2] In our model we leave this issue aside by assuming that the bank will not

[2]For example, Diamond (2001) argues that bank recapitalization protects valuable bank-client relationships, while Acharya and Yorulmazer (2007a) shows that bailouts avoid "cash-in-market" pricing of bank's non performing assets when there is a systemic crisis. Acharya and Yorulmazer (2007b) justifies bailouts on the same

be allowed to fail under any circumstance. Therefore, the policy problem is reduced to determining who manages the insolvent bank: the private banker (with bailout) or the regulator (with nationalization). In this framework, the policy choice is influenced by asymmetries of information.

The model is described in section 2. In section 3 we solve the model without pre-commitment. In section 4 we discuss possible pre-commitment options to solve the revelation problem. In sections 5 and 6 we present policy implications, and in section 7 a short discussion of the model's assumptions. Section 8 concludes.

2. The model

A regulator, a banker, and a depositor interact along three periods of time: $t = 0, 1, 2$. The banker and the depositor are risk neutral. We assume that the banker is financed only with deposits, whose amount is normalized to 1.[3] Deposits are fully guaranteed by the regulator and the interest rate on them is normalized to zero.

At the beginning of $t = 0$ the bank invests in a loan portfolio that matures in $t = 2$. At the end of $t = 0$ nature reveals the portfolio type to the banker: either good or bad. After this, at the beginning of $t = 1$, the banker must decide either to keep the same loan portfolio or modify it by increasing its risk.

The return of the loan portfolio at $t = 2$ is a random variable $\widetilde{R}$ defined as:

(2.1)

$$\widetilde{R} = \begin{cases} A + r_0 & \text{if the banker keeps the original portfolio} \\ A + r_0 + r_2 & \text{if the banker plays the risky bet in } t = 1. \end{cases}$$

$\widetilde{R}$ depends of an average return $A > 1$ plus two *independent* random variables r_0 and r_2, where the subscripts 0 and 2 denote the periods in which the random variables are realized.

The expected return $\widetilde{R}$, as defined above, is conditional on the loan being collected at $t = 2$. We assume that the banker has no choice

grounds but goes on to argue that bailouts can have the undesirable effect of increasing the chances of a systemic crisis, as banks increase the correlation of their portfolio returns.

[3]Following Acharya and Yorulmazer (2007b) we assume that equity funding is not possible due to problems associated to asymmetries of information as presented in Myers and Majluf (1984).

of collecting early, even if the original portfolio is maintained, as the liquidation value of the loan portfolio at $t = 1$ is zero. It is also assumed that outsiders would not be willing to buy the loan portfolio. [4]

The realization of r_0 determines the loan portfolio type: good or bad. The return r_0 is $R_G > 0$ for a good portfolio and $R_B < 0$ for a bad one; so that $r_0 \in \{R_G, R_B\}$ with $R_G > 0 > R_B$. The probability of the good type is $p(R_G) = \delta_0$ while the probability of the bad type is $p(R_B) = 1 - \delta_0$. The nature of the portfolio is private information to the banker; the depositor and the regulator cannot observe it.

For simplicity we assume that the expected return in $t = 0$ of the original portfolio is A, implying that,

A1: $\delta_0 R_G + (1 - \delta_0) R_B = 0.$

At the beginning of $t = 1$, after observing the portfolio's type, the banker can decide to change, for the remaining period, the return profile of the loan portfolio. If the banker keeps the original portfolio the return in $t = 2$ remains unchanged. If the banker plays a risky bet, the payoffs in $t = 2$ are defined by $r_2 \in \{R_G, R_B\}$. The probabilities of the good and bad outcome in $t = 2$ are equal to δ_2 and $1 - \delta_2$ respectively. The bet is assumed to be inefficient as $\delta_2 < \delta_0$,[5] therefore,

A2: $\delta_2 R_G + (1 - \delta_2) R_B < 0.$

A key feature of the model is that the banker will have incentives to take the risky bet, even if inefficient, if nature reveals to him a bad portfolio type at $t = 0$. Such behavior has been analyzed by Jensen and Meckling (1976) and Myers (1977) and requires additional assumptions,

A3: In $t = 1$, the bank is technically insolvent if nature reveals a bad portfolio type: $A + R_B < 1$; and,

A4: If the banker plays the risky bet in $t = 1$, the bank will be insolvent at the end of the game only if both the portfolio type and the outcome of the bet turn to be bad. Formally, $A + r_0 + r_2 < 1$ only if $r_0 = r_2 = R_B$.

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[4] This is justified by assuming that the banker benefits from an on-going relationship with its debtors that gives him the know-how to collect the loan in $t = 2$. This information cannot be transferred if the loan is sold to outsiders.

[5] The riskier portfolio bet cannot have a higher expected return when compared to the original portfolio, otherwise a risk neutral banker would have preferred to invest in it at the beginning of the game in $t = 0$.

A banker with a bad portfolio will choose the risky bet because it gives him the chance to recover the bank's solvency.

Assumptions $A1 - A4$ restrict the probability density functions of r_0 and r_2 to the following:

$$-\tfrac{\delta_0}{2\delta_0-1}(A-1) < R_B < -(A-1), \tag{2.2}$$

$$\tfrac{1-\delta_0}{\delta_0}(A-1) < R_G < \tfrac{1-\delta_0}{2\delta_0-1}(A-1), \tag{2.3}$$

$$R_G = \tfrac{1-\delta_0}{\delta_0}(-R_B), \tag{2.4}$$

$$\delta_0 > 1/2, \text{and } \delta_0 > \delta_2. \tag{2.5}$$

The regulator has the incentive to detect the bad portfolio, when it occurs, in order to stop the banker from choosing the risky and inefficient bet. For the purpose he uses audits. Audits take place at the end of period $t = 0$, after the portfolio's type is revealed to the banker and before he can modify the portfolio's risk (see figure 1). The audit consists of two steps,

-The banker must declare the portfolio type to the regulator;
-The regulator checks the banker's report by conducting an in-situ inspection, and observes $\widetilde{r_0} \in \{\widetilde{R_G}, \widetilde{R_B}\}$.

Let us define $p(\widetilde{r_0}|r_0)$ as the probability that the in-situ inspection observes $\widetilde{r_0}$ conditional on the true portfolio type being r_0. Since we assume that the banker can hide bad portfolios but cannot hide good portfolios,[6] there are only two options: either the banker conceals bad outcomes by declaring always good results or declares truthfully.

We will assume that if the banker declares truthfully, the in-situ inspection always confirms banker's declaration:

$$p(\widetilde{R_G}\,|R_G) = 1 \quad \text{and} \quad p(\widetilde{R_B}\,|R_G) = 0;$$
$$p(\widetilde{R_G}\,|R_B) = 0 \quad \text{and} \quad p(\widetilde{R_B}\,|R_B) = 1.$$

When the banker hides a bad portfolio, the in-situ inspection detects it with probability γ or confirms banker's declaration with probability $1-\gamma$:

$$p(\widetilde{R_G}\,|R_B) = 1-\gamma \quad \text{and} \quad p(\widetilde{R_B}\,|R_B) = \gamma.$$

[6]We do not consider the possibility of hiding good outcomes because we are not interested in the problems of over capitalization associated to bailouts. Aghion, Bolton, and Fries (1999) dealt with this issue and concluded that bankers find it difficult to hide good outcomes if this requires the liquidation of their good loans.

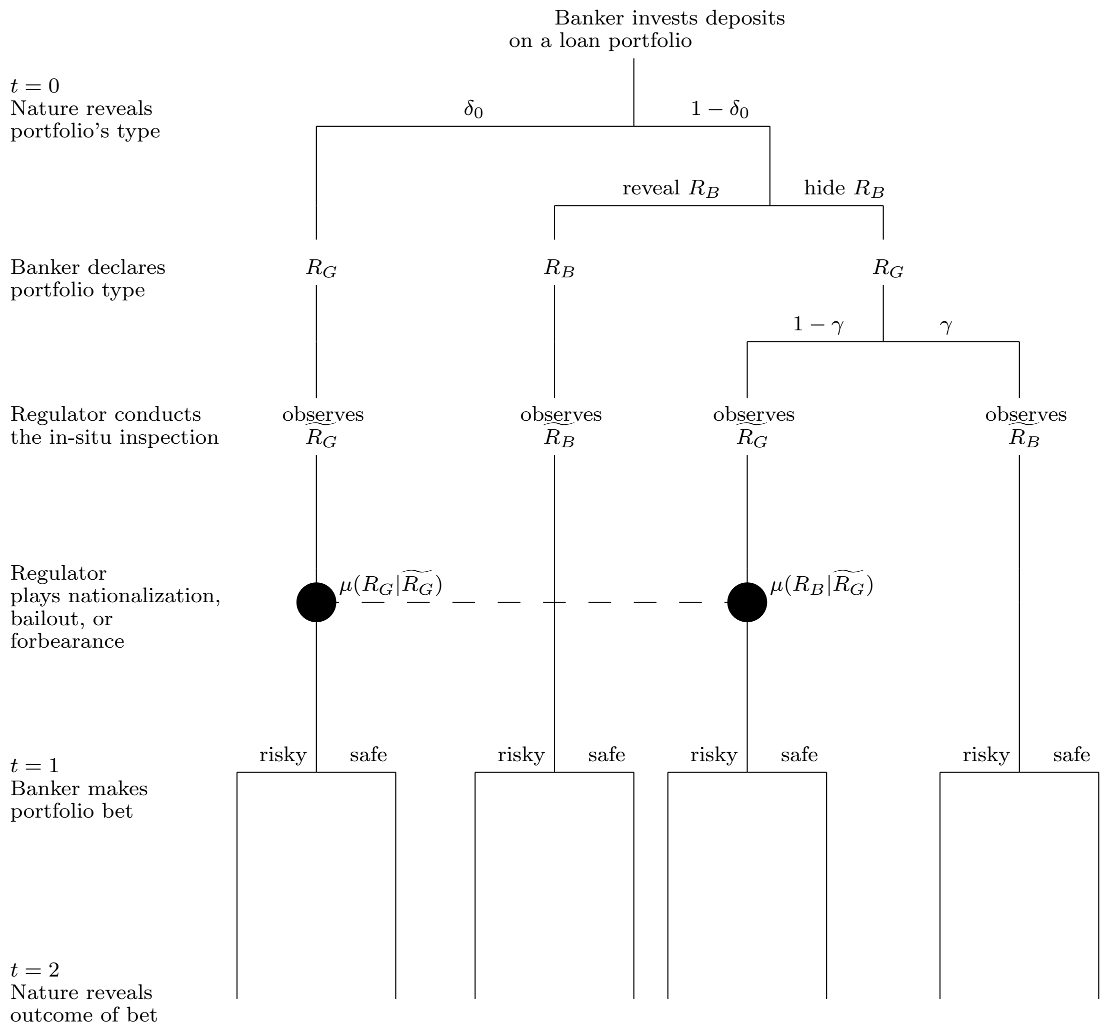

FIGURE 1. Timing of events

After the audit is completed and before the banker can make the bet at $t = 1$, the regulator chooses the policy to deal with the possible bad type portfolio (see figure 1). He can resort to nationalization, bailout, or forbearance.

With nationalization the regulator takes over the ownership of the bank. If the banker concealed the bad portfolio, the regulator has to engage in a legal and judicial process for its nationalization. We assume that this process implies a fiscal cost $g > 0$ for the regulator and a private cost $c > 0$ for the banker. If the banker reveals the bad portfolio, the nationalization can be made without bearing these costs. [7] After the nationalization, the regulator can observe the true portfolio type. If the portfolio is good, the regulator must compensate the banker with a payment equal to the expected net value of the bank plus the private cost $c > 0$.

With a bailout the banker remains in control of the bank and the regulator transfers to the bank a non-tradable bond with maturity at $t = 2$ that pays ΔK. With forbearance the regulator does nothing.

After regulator's policy is implemented and the banker makes the portfolio bet in $t = 1$, the final return of the portfolio is determined in $t = 2$. After this, the bank is closed. The deposits are paid off with $\widetilde{R}$ and the income from the non-tradable bond (if applicable). When these resources are insufficient to cover the deposits, the regulator must pay the difference to honor the deposit guarantee.

The regulator's objective is to maximize the expected return of the bank's portfolio, $\widetilde{R}$, minus the deadweight costs of the public funds transferred to the bank, λF,

$$\Omega = \widetilde{R} - \lambda F. \tag{2.6}$$

The public funds F include the payment of the deposit guarantee, the capitalization of the bank ΔK, the legal and judicial process of nationalization g, and the compensation to the banker of a solvent bank that is nationalized, P_c. The unitary deadweight costs of fiscal funds are denoted by scalar $-\lambda$. Following Acharya and Yorulmazer (2007b) we justify the introduction of this term in the regulator's objective function due to the negative effects of increasing taxes and/or fiscal deficits.

The banker's objective is to maximize π, the expected value of bank's net worth minus the expected private costs of bank nationalization:

[7]The c and g scalars represent institutions in place to protect property rights. A high private cost c protects the depositor from the banker's risky bet, while the g parameter represents the institutions that limit the regulator's discretion to nationalize a bank that declared itself to be solvent.

(2.7)

$$\pi = \begin{cases} max(0, \widetilde{R} + \Delta K - 1) + I_{R_G}\eta & \text{if banker controls the bank} \\ -c + P_c & \text{if a solvent bank is nationalized} \\ -c & \text{if banker hides bad portfolio and bank is nationalized} \\ 0 & \text{if banker declares bad portfolio and bank is nationalized} \end{cases}$$

When the private banker controls the bank, he is entitled to the bank's net value, $max(0, \widetilde{R} + \Delta K - 1)$, and has private benefits η from managing a bank with a good portfolio type (if the loan portfolio is good). The inclusion of η in the banker's objective function follows Aghion, Bolton, and Fries (1999) and Osano (2002). In their models bankers value positively the control of the bank because they like power. However, differently from these authors, we assume that the banker enjoys private benefits only when the bank has a good portfolio. As a consequence, function I_{R_G} assumes the value 1 when the portfolio is good, and zero otherwise. When the banker declares the good portfolio and the bank is nationalized, he suffers private costs $-c$ due to the legal and judicial process of nationalization. After the nationalization, if the regulator finds out that the bank had in fact a good portfolio, the banker receives a compensation payment P_c from the regulator. If the bank was insolvent the compensation payment is zero. If the banker reveals the bad portfolio, he gets zero as he looses control when the bank is nationalized.

3. Solution of the model without pre-commitment

The model is solved using backwards induction. We start by solving the model in $t = 1$ for the banker's decision to modify the return profile of the bank's portfolio. We then turn to consider the period $t = 0$ and solve for the banker's optimal signal and the regulator's optimal policy response to the bank's insolvency.

3.1. **The banker's portfolio decision at $t = 1$.** The banker's decision to keep the original portfolio or bet for the risky portfolio in $t = 1$ will be conditioned by the regulator's policy choice and by the portfolio's type.

First, consider the case in which the regulator has chosen to do nothing (forbearance). Define $E_1(\pi_R^F)$ and $E_1(\pi_S^F)$ as the expected pay-offs of the banker if he plays the risky bet (R) or plays safe by keeping the original portfolio (S), when the regulator has chosen to do nothing. Solving for both terms we have:

$$\begin{aligned} E_1(\pi_R^F) &= \delta_2(\max(0, A + r_0 + R_G - 1) + I_{R_G}\eta) + \\ &\quad +(1-\delta_2)(\max(0, A + r_0 + R_B - 1) + I_{R_G}\eta) \\ E_1(\pi_S^F) &= \max(0, A + r_0 - 1) + I_{R_G}\eta \end{aligned}$$

The indicator function I_{R_G} takes the value of 1 if nature reveals a good portfolio and 0 otherwise. The choice between safe and risky depends on the portfolio's return r_0 at $t = 0$. When the portfolio is good, $r_0 = R_G$, assumption A4 guarantees that,

$$\max(0, A + r_0 + R_B - 1) = A + R_G + R_B - 1 > 0$$

The banker keeps the original portfolio because, when the portfolio type is good, the difference $E_1(\pi_R^F) - E_1(\pi_S^F) = \delta_2 R_G + (1-\delta_2)R_B$ is negative (by assumption $A2$).

When the portfolio is bad, $r_0 = R_B$, assumption $A4$ guarantees that:

$$\max(0, A + r_0 + R_B - 1) = 0.$$

In this case the banker prefers the risky bet because it provides the chance to recover the bank's solvency if the outcome of the bet is good, $E_1(\pi_R^F) = \delta_2(A + R_B + R_G - 1) > 0$. If the banker does not take the bet, the bank will be insolvent for sure in $t = 2$.

Our model leads to risk shifting because the depositor does not demand interest rate premia for the higher risk, as the bank's deposits are benefited with a credible public guarantee. The existence of asymmetries of information also explain why no fair deposit guarantee premia can be designed by the regulator.

When the regulator chooses nationalization, he takes over the bank and keeps the original portfolio. The banker's pay-off depends on the circumstances under which the nationalization takes place. Define $E_1(\pi^N)$ as the banker's expected pay-off when the bank is nationalized.
(3.1)

$$E_1(\pi^N) = \begin{cases} A + R_G - 1 & \text{if the portfolio is good} \\ -c & \text{if the banker hides a bad portfolio} \\ 0 & \text{if the banker reveals a bad portfolio} \end{cases}$$

When the regulator nationalizes a bank with a good portfolio, he must compensate the banker for the net value of the bank plus the private cost of the judicial process, $P_c = A + R_G - 1 + c$. Therefore, $-c + P_c = A + R_G - 1$.[8]

With a bailout, the banker's decision depends on the type of portfolio and the level of capitalization. Define $E_1(\pi_R^{Bail})$ and $E_1(\pi_S^{Bail})$ as the expected pay-offs of the banker of playing the risky bet (R) or keeping the original portfolio (S) when the regulator offers a bailout:

$$\begin{aligned} E_1(\pi_R^{Bail}) &= \delta_2(max(0, A + r_0 + \Delta K + R_G - 1) + I_{R_G}\eta) + \\ &\quad +(1-\delta_2)(\max(0, A + r_0 + \Delta K + R_B - 1) + I_{R_G}\eta) \\ E_1(\pi_S^{Bail}) &= max(0, A + r_0 + \Delta K - 1) + I_{R_G}\eta \end{aligned}$$

When the portfolio is good ($r_0 = R_G$), the banker always plays safe and zero capitalization is required as $E_1(\pi_R^{Bail}) - E_1(\pi_S^{Bail}) = \delta_2 R_G + (1 - \delta_2)R_B$ is negative (assumption $A2$). If the portfolio is bad ($r_0 = R_B$) the sign of $E_1(\pi_R^{Bail}) - E_1(\pi_S^{Bail})$ depends on the level of capitalization offered. The banker keeps the original portfolio only if

$$E_1(\pi_R^{Bail}) - E_1(\pi_S^{Bail}) = \delta_2 R_G - (1-\delta_2)(A + R_B + \Delta K - 1)$$

is negative, which is the case when the capitalization offer respects the following condition:

$$\Delta K \geq -R_B + \frac{\delta_2}{1-\delta_2} R_G - (A - 1). \tag{3.2}$$

3.2. **The banker's signal and the regulator's policy decision at $t = 0$.** At $t = 0$ the banker and the regulator play a signaling game. The banker declares the bank's portfolio type, the regulator performs the in-situ inspection and observes $\widetilde{r_0}$. On the basis of this observation, the regulator forms its ex-post beliefs $\mu(r_0 \,|\widetilde{r_0})$ about the portfolio types. The regulator then chooses between nationalization, bailout or forbearance.[9]

In equilibrium the banker can play three type of signaling strategies: *separating, pooling and hybrid*. Define α as the probability that

[8] We assume that private benefits of controlling the bank η are not observable, consequently cannot be included in the compensation payment to the banker.

[9] It must be highlighted that we do not consider bank closure as a possibility for the regulator. The regulator will not close the bank because, in our framework, the liquidation of the loan portfolio yields zero in $t = 1$, and the commitment to the deposit guarantee is binding.

the banker hides the bad portfolio type. In the *pooling equilibria* the banker always hides the bad portfolio types, therefore $\alpha = 1$. In the *separating equilibria* the banker never hides a bad portfolio, in other words $\alpha = 0$. In the *hybrid equilibria* the banker randomizes between hiding and revealing the bad portfolio type, $0 < \alpha < 1$.

First, we describe regulator's policy decision, then we describe banker's decision to reveal or hide a bad portfolio type, and finally the different equilibria.

3.2.1. *Regulator's policy choice.* Regulator's expected pay-off, when choosing policy j, is conditional on the portfolio type observed with the in-situ inspection ($\widetilde{r_0}$):

$$E_0(\Omega^j|\widetilde{r_0}) = \mu(R_G|\widetilde{r_0})E_0(\Omega^j|R_G) + \mu(R_B|\widetilde{r_0})E_0(\Omega^j|R_B). \tag{3.3}$$

The expected pay-off will be equal to the average of the pay-offs that the regulator gets when the portfolio type is in fact good ($E_0(\Omega^j|R_G)$) and bad ($E_0(\Omega^j|R_B)$). These terms are weighted by the actualized probabilities $\mu(\ |\widetilde{r_0})$, which are influenced by the outcome of the inspection and by the regulator's belief regarding what kind of strategy is the banker playing.

If the regulator chooses to play forbearance (F), the expected pay-off is equal to:

$$E_0(\Omega^F|\widetilde{r_0}) = \mu(R_G|\widetilde{r_0})(A + R_G) +$$
$$+\mu(R_B|\widetilde{r_0})(A + R_B + \delta_2 R_G + (1 - \delta_2)R_B - \lambda(1 - \delta_2)(1 - A - 2R_B)).$$

With forbearance, if the portfolio type is good, the regulator's pay-off is $A + R_G$ because the banker keeps the original portfolio and the payment of the public deposit guarantee is zero. If the portfolio type turns to be bad, the banker plays the risky bet inducing an expected return of the loan portfolio equal to $A + R_B + \delta_2 R_G + (1 - \delta_2)R_B$. Additionally, the regulator has to honor the deposit guarantee if the outcome of the risky bet turns to be bad. This makes the expected value of the deposit guarantee payment equal to $(1-\delta_2)(1-A-2R_B)$.

If the regulator chooses nationalization (N), the expected pay-off can be expressed as:

$$\begin{aligned} E_0(\Omega^N|\widetilde{r_0}) &= \mu(R_G|\widetilde{r_0})(A + R_G - \lambda(g + c)) + \\ &\quad +\mu(R_B|\widetilde{r_0})(A + R_B - \lambda(1 - A - R_B) - \lambda I_{hide} g). \end{aligned}$$

With nationalization, and if the portfolio type is good, the regulator keeps the original portfolio, therefore the expected return of the assets is $A+R_G$. In this case, however, the regulator has to undergo fiscal costs to nationalize the bank g and to compensate the private banker for the net value of the bank $A+R_G-1$ plus private costs c. Consequently, the net fiscal costs for the regulator are represented by $\lambda(g+c)$. If the portfolio type was bad, the assets' return is $A+R_B$ and the payment of the deposit guarantee is equal to $1-A-R_B$. The function I_{hide} takes value of 1 when the banker hides the bad portfolio and the in-situ inspection detects it. Otherwise, it takes the value of 0. This function indicates that the regulator only spends g to nationalize a bank if the banker concealed the bad portfolio. [10]

If the regulator chooses to bailout the bank (Bail), the expected payoff is:

$$
\begin{aligned}
E_0(\Omega^{Bail}|\widetilde{r_0}) &= \mu(R_G|\widetilde{r_0})(A+R_G-\lambda\Delta K)+ \\
&\quad +\mu(R_B|\widetilde{r_0})(A+R_B-\lambda\Delta K)
\end{aligned}
$$

With a bailout the banker will always keep the original loan portfolio, therefore the portfolio's value will be either $A+R_G$ or $A+R_B$ depending if nature reveals the good or bad type. The regulator in both cases will have to endure fiscal costs equivalent to the amount of the capitalization, $\Delta K = -R_B + \delta_2/(1-\delta_2)R_G - (A-1)$. [11]

There are three possible circumstances under which the regulator must choose the policy:

- when the banker hides the bad portfolio but the in-situ inspection detects it,
- when the banker reveals the bad portfolio,
- when the in-situ inspection observes the good portfolio.

Below we describe the regulator's policy decision in each one of these circumstances.

If the banker conceals the bad portfolio and the in-situ inspection detects it, the regulator will be convinced that the portfolio is bad.

[10] We implicitly assume that the banker and regulator cannot renegotiate after the audit detects a bad portfolio in order to reduce the costs of the legal process.

[11] With the bailout the regulator chooses the minimum capitalization that disciplines the banker to keep the original portfolio, $\Delta K = -R_B+\delta_2/(1-\delta_2)R_G-(A-1)$. A bailout with a lower capitalization does not make sense as it has no impact on the banker's behavior, and a higher capitalization is redundant.

The regulator actualizes his beliefs to

$$\mu(R_B|\widetilde{R_B}) = 1$$
$$\mu(R_G|\widetilde{R_B}) = 0.$$

In this case, when comparing the expected pay-offs associated to each policy, nationalization is the strictly dominant policy if:

$$-\lambda g + \frac{\delta_2}{1-\delta_2} R_G > 0 \tag{3.4}$$

$$-(C_e + \lambda B) - \lambda g > 0, \tag{3.5}$$

where

$$C_e = \delta_2 R_G + (1-\delta_2) R_B$$
$$B = (1-2\delta_2) R_B - \delta_2 (A-1).$$

Inequalities 3.4 and 3.5 are both fulfilled if the costs associated to the legal and judicial process are low enough, [12]

$$g < \min(\left(\frac{\delta_2}{1-\delta_2}\right) R_G, -\frac{C_e}{\lambda} - B). \tag{3.6}$$

In the rest of the paper we assume that

A5: condition 3.6 is true,

in order to introduce the required incentives for the banker to reveal truthfully. If this condition is breached, the banker will always find convenient to hide bad portfolios, as the regulator never nationalizes the bank due to the high costs of the legal and judicial process. [13]

If the banker decides to reveal the bad portfolio, the regulator would believe in the banker's declaration. Nationalization would be, again, the strictly dominant policy. Notice that conditions 3.4 and 3.5 are also true if we substitute $g = 0$ (as $C_e < 0$ and $B < 0$).

If the in-situ inspection observes the good portfolio type, $\widetilde{R_G}$, the regulator actualizes his beliefs according to the expectation of what type of strategy the banker is playing. If the regulator thinks that the

[12] We know that $\delta_2 R_G + (1-\delta_2)R_B < 0$ and $(1-2\delta_2)R_B - \delta_2(A-1) < 0$. $(1-2\delta_2)R_B - \delta_2(A-1)$ denotes the difference between the payment of the deposit guarantee when the bank is nationalized and the payment in the case of forbearance. We know that $(1-2\delta_2)R_B - \delta_2(A-1)$ is negative due to the characteristics of the probability density function of r_2.

[13] If this was the case, audits would become superfluous and bailouts would remain the only effective means to correct banker's risk shifting behavior.

banker is revealing truthfully, i.e. playing $\alpha = 0$, then the beliefs are actualized to:

$$\begin{aligned} \mu(R_B|\widetilde{R_G}) &= 0 \\ \mu(R_G|\widetilde{R_G}) &= 1. \end{aligned}$$

In this case the regulator chooses forbearance. Recall that the banker never makes the risky bet when the portfolio type is good, therefore it does not make sense for the regulator to intervene.

If the regulator observes $\widetilde{R_G}$ but thinks the banker is not revealing truthfully, i.e. the banker is using either the pooling or hybrid strategy ($0 < \alpha \leq 1$), then he cannot be sure whether the portfolio type is good or bad. The beliefs would be actualized to:

$$\begin{aligned} \mu(R_G|\widetilde{R_G}) &= \frac{\delta_0}{\delta_0 + \alpha(1-\gamma)(1-\delta_0)} \\ \mu(R_B|\widetilde{R_G}) &= \frac{\alpha(1-\gamma)(1-\delta_0)}{\delta_0 + \alpha(1-\gamma)(1-\delta_0)}. \end{aligned}$$

In this case, the regulator chooses only among forbearance or nationalization because, by condition 3.6, bailout is strictly dominated.

Define ϵ as the probability that the regulator decides to nationalize a bank with $\widetilde{R_G}$. The net benefits of nationalizing, $E_0(\Omega^N|\widetilde{R_G}) - E_0(\Omega^F|\widetilde{R_G})$, become:

$$(3.7) \quad \begin{aligned} &-\frac{\delta_0}{\delta_0 + \alpha(1-\gamma)(1-\delta_0)}\lambda(c+g) - \\ &-\frac{\alpha(1-\gamma)(1-\delta_0)}{\delta_0 + \alpha(1-\gamma)(1-\delta_0)}(C_e + \lambda B + \lambda g). \end{aligned}$$

The term $\lambda(c+g)$ represents the costs that the regulator endures if the nationalized bank happens to be solvent, due to the compensation payments that the regulator has to provide to the banker. The term $-(C_e + \lambda B + \lambda g)$ represents the benefits of nationalizing the bank, if it happens to be insolvent, in terms of the risk-shifting inefficiencies that are avoided. The regulator will choose nationalization, $\epsilon = 1$, if the net benefits are positive. If the net benefits are negative the regulator prefers forbearance, $\epsilon = 0$, and if the net benefits are zero then the regulator randomizes, $0 < \epsilon < 1$.

The sign of $E_0(\Omega^N|\widetilde{R_G}) - E_0(\Omega^F|\widetilde{R_G})$ depends on δ_0, g,γ, c, and λ. The regulator prefers nationalization if the probability δ_0, costs g and c, and probability γ are low enough. The value of λ has an ambiguous effect because its impact on both the expected benefits and costs of choosing nationalization has a positive sign. We can conjecture, however, that if the values of δ_0 and γ are high, then λ has a higher impact on the costs of nationalization. Therefore, a low λ biases the regulator's choice in favor of nationalization.

3.2.2. *Banker's decision to reveal bad portfolio types.* The banker reveals the portfolio type truthfully when the pay-offs of revealing outweigh the pay-offs of hiding. The pay-offs of hiding a bad portfolio are:

$$\gamma(-c) + (1-\gamma)(-\epsilon c + (1-\epsilon)\delta_2(A + R_B + R_G - 1)). \tag{3.8}$$

The in-situ inspection detects the bad portfolio with probability γ and does not detect it with probability $1-\gamma$. Condition 3.6 guarantees that, if the bad portfolio type is detected, the banker looses the ownership of the bank and suffers the private costs associated to the legal and judicial process of nationalization: $-c$. When the in-situ inspection does not detect the bad portfolio, the regulator plays nationalization with probability ϵ, and plays forbearance with probability $1-\epsilon$. Consequently, with probability $(1-\gamma)\epsilon$ the banker suffers private costs $-c$ and with probability $(1-\gamma)(1-\epsilon)$ the banker is allowed to take the risky bet with an expected payoff of $\delta_2(A + R_B + R_G - 1)$.

The banker's pay-off after revealing the bad portfolio type is zero. So, when the benefits of hiding the bad portfolio are grater than zero, the banker will hide the bad portfolio: $\alpha = 1$. When the benefits of hiding the bad portfolio are negative, the banker will reveal bad portfolios: $\alpha = 0$. When the benefits of hiding are equal to zero, the banker would randomize his decision to reveal: $0 < \alpha < 1$.

3.2.3. *Equilibria.* There will be separating equilibria if the regulator believes that the banker declares truthfully, and if the banker expects the bank to be nationalized only if he declares the bad portfolio type. In other words, when the banker declares the portfolio type to be good, he will expect the regulator to choose forbearance, $\epsilon = 0$. Thus, the only requirement for separating equilibria is that, when $\epsilon = 0$, the banker must have no incentives to deviate from truthful declaration:

$$\gamma(-c) + (1-\gamma)\delta_2(A + R_B + R_G - 1) < 0. \tag{3.9}$$

The banker would reveal truthfully when the probability γ of detection is above a threshold $\gamma > \gamma^{**}$, where

$$\gamma^{**} = \frac{\delta_2(A + R_B + R_G - 1)}{c + \delta_2(A + R_B + R_G - 1)}.$$

The pooling equilibria are possible when the regulator decides to play forbearance, $\epsilon = 0$, after the in-situ inspection observes the good portfolio, although he knows that the banker is playing the hiding strategy, $\alpha = 1$. If the banker expects that the bank will be nationalized only if the inspection detects the bad portfolio type, then it makes sense for the banker to conceal the bad portfolio.

The sufficient conditions for the pooling equilibrium to be possible are that: (i) Assuming that the regulator plays $\epsilon = 0$, the benefits for the banker of hiding the bad portfolio must outweigh the benefits of revealing it, and (ii) When the regulator knows that the banker plays $\alpha = 1$, the expected costs of nationalizing a bank with $\widetilde{R_G}$ must outweigh the benefits. Formally:

$$\gamma(-c) + (1-\gamma)\delta_2(A + R_B + R_G - 1) > 0. \tag{3.10}$$

$$-\tfrac{\delta_0}{\delta_0 + (1-\gamma)(1-\delta_0)}\lambda(c+g) - \\ -\tfrac{(1-\gamma)(1-\delta_0)}{\delta_0 + (1-\gamma)(1-\delta_0)}(C_e + \lambda B + \lambda g) < 0. \tag{3.11}$$

In the hybrid equilibria, the banker randomizes his decision to reveal the bad portfolio, and the regulator his decision to nationalize the bank with $\widetilde{R_G}$. There exists a pair (ϵ^*, α^*), with $\epsilon^* \in (0,1)$ and $\alpha^* \in (0,1)$, that makes the regulator indifferent between nationalizing the bank or playing forbearance (after observing the good portfolio type), and makes the banker indifferent between revealing or hiding the bad portfolio:

$$\gamma(-c) + (1-\gamma)(-\epsilon^* c + (1-\epsilon^*)\delta_2(A + R_B + R_G - 1)) \equiv 0 \tag{3.12}$$

$$-\tfrac{\delta_0}{\delta_0 + \alpha^*(1-\gamma)(1-\delta_0)}\lambda(c+g) - \\ -\tfrac{\alpha^*(1-\gamma)(1-\delta_0)}{\delta_0 + \alpha^*(1-\gamma)(1-\delta_0)}(C_e + \lambda B + \lambda g) \equiv 0. \tag{3.13}$$

It is evident that the above conditions are possible only if:

$$\gamma(-c) + (1-\gamma)\delta_2(A + R_B + R_G - 1) > 0, \text{and} \tag{3.14}$$

$$-\tfrac{\delta_0}{\delta_0+(1-\gamma)(1-\delta_0)}\lambda(c+g)- \tag{3.15}$$
$$-\tfrac{(1-\gamma)(1-\delta_0)}{\delta_0+(1-\gamma)(1-\delta_0)}(C_e+\lambda B+\lambda g)>0.$$

When condition 3.15 is true, the regulator prefers to nationalize the bank with $\widetilde{R_G}$, if he thinks that the regulator is hiding bad portfolios. As a consequence, pooling equilibria are unfeasible because the banker would prefer to signal truthfully in order to avoid the costs associated to the legal and judicial process of nationalization. Separating equilibria are not possible either because the banker cannot give credibility to his declaration, as he faces incentives to hide the bad portfolio due to condition 3.14. The regulator and the banker cannot be sure of what the other plays, therefore it is optimal for both to randomize.

The conditions that define each type of equilibria, 3.9, 3.10, 3.11, 3.14, and 3.15, can be simplified into constraints on the values of δ_0 and γ. This is presented in the following proposition.

Proposition 1. *The conditions under which the banker plays the different strategies are:*

- **1:** *If $\gamma > \gamma^{**}$, then the banker plays the separating strategy.*
- **2:** *If $\gamma < \gamma^{**}$ and $\delta_0 > \delta^*$; or $\gamma^* < \gamma < \gamma^{**}$ and $\delta_0 < \delta^*$, then the banker plays the pooling strategy.*
- **3:** *If $\gamma < min(\gamma^{**}, \gamma^*)$ and $\delta_0 < \delta^*$, then the banker plays the hybrid strategy.*

where,

$$\begin{aligned}\delta^* &= \frac{-(C_e+\lambda B+\lambda g)}{\lambda(g+c)-(C_e+\lambda B+\lambda g)}\\ \gamma^* &= \frac{\delta_0\lambda(g+c)+(1-\delta_0)(C_e+\lambda B+\lambda g)}{(1-\delta_0)(C_e+\lambda B+\lambda g)}\end{aligned}$$

Proof. Ommited. □

There will be no policy problem associated to the revelation of bad portfolios when γ is higher than the threshold γ^{**}. The banker will have incentives to reveal truthfully in order to avoid the potential costs of the legal and judicial process of being detected hiding a bad portfolio. When the probability of detection γ is lower than γ^{**}, the banker will have incentives to hide the bad portfolios. The pooling strategy is possible if, additionally, the regulator has incentives to play forbearance, when the in-situ inspection observes the good portfolio. The regulator behaves in this way when either δ_0, the probability that the portfolio type is good, or γ, the probability of detection, are high enough (bigger than thresholds δ^* and γ^* respectively). The banker randomizes his decision to reveal or hide the bad portfolio when the probability of detection and the a priori probability that the portfolio type is good are both low enough, i.e. $\gamma < min(\gamma^*, \gamma^{**})$ and $\delta_0 < \delta^*$.

4. Solution of the model with pre-commitment

In the model with pre-commitment we assume that both the regulator and the banker make their decisions assuming a long-run horizon: the regulator and the banker play the game an infinite number of times.[14]

In a repetitive game framework, pre-commitment is possible when it allows both the regulator and the banker to improve their expected payoffs, if compared to the no pre-commitment solution of the game. Both agents play "trigger strategies", which consist in respecting the pre-commitment until the counterpart deviates. Agents punish the defector by choosing the equilibrium play of the no pre-commitment game, driving the solution of the repetitive games to a succession of equilibria with no pre-commitment.

Below we describe two possible equilibria in the model with pre-commitment that solve the revelation problem.

4.1. **Full revelation induced by promising to bailout the bank.** In this type of equilibria the banker always reveals the portfolio type truthfully and the regulator bails out the bank when a bad portfolio is declared.

The banker will never have incentives to deviate because, if the regulator offers a bailout, revealing the bad portfolio strictly dominates any other alternative. The regulator, on the other hand, may be tempted to deviate once the banker reveals a bad portfolio because it would save fiscal resources if the nationalization takes place instead of the bailout. The regulator is disciplined by the banker's threat of not reveling the bad portfolio in the future.

[14]A discussion of this assumption will be conducted in section 7.

The net benefits for the regulator of pre-committing to bailout are calculated by comparing the pay-offs with a bailout and with the no pre-commitment equilibrium. As a consequence, the expression for the net benefits depends on the type of equilibrium that characterizes the no pre-commitment case:

(4.1)

$$\begin{cases} -(1-\delta_0)\lambda\frac{\delta_2}{1-\delta_2}R_G & \text{if } \alpha^*=0 \text{ and } \epsilon^*=0 \\ -(1-\delta_0)[(1-\gamma)C_e+\lambda(\frac{\delta_2}{1-\delta_2}R_G+(1-\gamma)B-\gamma g)] & \text{if } \alpha^*=1 \text{ and } \epsilon^*=0 \\ \lambda(\delta_0 c+g-(1-\delta_0)\frac{\delta_2}{1-\delta_2}R_G) & \text{if } \alpha^*\in(0,1) \text{ and } \\ & \epsilon^*\in(0,1) \end{cases}$$

When we have a separating equilibrium ($\alpha^* = 0$ and $\epsilon^* = 0$) the net benefits of pre-committing to bailout are always negative. With a pooling equilibrium ($\alpha^* = 1$ and $\epsilon^* = 0$), pre-committing to bailout brings the benefit of eliminating risk shifting, $(1-\delta_0)(1-\gamma)C_e$, but at the expense of increasing the fiscal resources channeled to the bank, $(1-\delta_0)\lambda(\frac{\delta_2}{1-\delta_2}R_G+(1-\gamma)B-\gamma g)$. With a hybrid equilibrium, the regulator has incentives to commit to bailout if the fiscal costs of nationalizing a solvent bank, $\lambda(\delta_0 c+g)$, outweigh the excess fiscal costs of paying for the capitalization of an insolvent bank, $(1-\delta_0)\lambda\frac{\delta_2}{1-\delta_2}R_G$.

Even if banker's net benefits of pre-committing to bailout are positive, the regulator may be tempted to defect and nationalize the bank once the banker reveals the bad portfolio. Nationalizing the bank instead of bailing it out would reduce deadweight costs of using fiscal resources by,

$$\text{Benefits of deviation} = (1-\delta_0)\lambda\frac{\delta_2}{1-\delta_2}R_G. \tag{4.2}$$

The regulator must compare this short run benefit against the cost represented by the succession of foregone future benefits represented in condition 4.1.

4.2. **Full revelation induced by the threat to randomize nationalization.** In these type of equilibria the banker always reveals truthfully, and the regulator nationalizes the bank only if a bad portfolio type is declared.

If the banker declares truthfully, it is not convenient for the regulator to nationalize a bank with $\widetilde{R_G}$ because he would have to pay the banker a compensation for the legal and judicial costs of the nationalization.

The banker may face the temptation to conceal a bad portfolio type in order to avoid nationalization. However, the regulator can discipline the banker by threatening to randomize, in future games, his decision to nationalize the bank if he detects a deviation from the banker.

A necessary condition to make the randomization threat credible is:

$$\delta_0 < \delta^* \text{ and } \gamma < min(\gamma^{**}, \gamma^*). \tag{4.3}$$

When condition 4.3 is true, a reversion from the pre-commitment solution to a hybrid equilibrium solution is always costly for the banker.[15] We can show that this is true by comparing the banker's expected payoffs in the pre-commitment equilibrium and in the hybrid equilibrium. The banker's expected payoff when it pre-commits to reveal is equal to:

$$E_0(\pi_{reveal}) = \delta_0(A + R_G - 1 + \eta)$$

When the portfolio is good, the banker reveals it and the regulator responds by doing nothing, which allows the banker to retain the control of the bank and benefit from $(A + R_G - 1 + \eta)$. When the portfolio is bad and the banker reveals it, the regulator nationalizes the bank with a payoff equal to zero for the banker, because no legal and judicial process is needed.

Banker's expected pay-off in the hybrid equilibrium is:

$$E_0(\pi_{hybrid}) = \delta_0[\epsilon^*(A + R_G - 1) + (1 - \epsilon^*)(A + R_G - 1 + \eta)] +$$
$$+(1 - \delta_0)\alpha^*[-\gamma c + (1 - \gamma)(-\epsilon^* c + (1 - \epsilon^*)\delta_2(A + R_B + R_G - 1))].$$

The first term, multiplied by δ_0, represents the expected payoff when the portfolio is good. The second term, multiplied by $1 - \delta_0$, represents the expected payoff when the portfolio is bad and the banker randomizes between revealing and hiding. The regulator also randomizes between nationalization and forbearance when the audit observes the good portfolio type.

[15] If the banker expects the regulator to punish him by randomizing the decision to nationalize a bank with $\widetilde{R_G}$, then it will be optimal for the banker to randomize as well the decision to reveal the bad portfolio. This pushes the outcome of the subsequent games to a hybrid equilibrium.

We can simplify the above term by highlighting that the banker must be indifferent between revealing and hiding the bad portfolio when it randomizes:

$$-\gamma c + (1-\gamma)(-\epsilon^* c + (1-\epsilon^*)\delta_2(A + R_B + R_G - 1)) = 0.$$

When this condition is taken into consideration the banker's expected payoff simplifies to

$$E_0(\pi_{hybrid}) = \delta_0(A + R_G - 1) + (1-\epsilon^*)\delta_0\eta.$$

This implies that the benefits from pre-committing are positive and proportional to η:

$$E_0(\pi_{reveal}) - E_0(\pi_{hybrid}) = \delta_0\epsilon^*\eta > 0. \tag{4.4}$$

Banker's expected payoff when he decides to deviate from the pre-commitment to reveal truthfully is

$$E_0(\pi_{deviate}) = \delta_0(A + R_G - 1 + \eta) + (1-\delta_0)(-\gamma c + (1-\gamma)\delta_2(A + R_B + R_G - 1)).$$

The deviation from the pre-commitment improves the short run banker's pay-off because the difference between $E_0(\pi_{deviate})$ and $E_0(\pi_{reveal})$,

$$\text{Benefits of deviation} = (1-\delta_0)(-\gamma c + (1-\gamma)\delta_2(A+R_B+R_G-1)), \tag{4.5}$$

is always positive when $\gamma < \gamma^{**}$. The banker is disciplined when regulator's randomization creates a succession of foregone benefits $\delta_0\epsilon\eta$ for the subsequent games that outweigh the short run benefit of the deviation, $(1-\delta_0)(-\gamma c + (1-\gamma)\delta_2(A + R_B + R_G - 1))$.

5. Policy implications

Among the two possible pre-commitment options, the regulator prefers the threat of randomizing nationalization in order to achieve banker's full revelation. The regulator has, therefore, the incentives to use policy instruments γ, c, and g to induce the mentioned equilibrium.

The analytical solution of the model with pre-commitment is complex, therefore we use numerical examples to show how γ, c, and g can influence regulator's ability to pre-commit. We present the numerical examples in four different policy scenarios to understand how the policy environment affects the instruments' efficacy. Table 1 presents the scenarios, in terms of the severity of the bank insolvency, δ_2, and the severity of the fiscal situation, λ. A value of δ_2 equal to 0.35 represents a severe case of insolvency and the value 0.6 a moderate case of insolvency. A value of λ equal to 3.5 reflects a tight fiscal situation while a value of 0.5 a loose fiscal situation.

TABLE 1. Scenarios

	1	2	3	4
δ_2	0.35	0.35	0.6	0.6
λ	3.5	0.5	3.5	0.5
A-1	0.1	0.1	0.1	0.1
δ_0	0.7	0.7	0.7	0.7
R_G	0.064	0.064	0.064	0.064
R_B	-0.15	-0.15	-0.15	-0.15
η	0.003	0.003	0.003	0.003
γ	0.3	0.3	0.3	0.3
c	0.01	0.01	0.01	0.01
g	0.01	0.01	0.01	0.01

The numerical examples are included in tables 2, 3, 4, and 5. In each table, we present the net benefits for the regulator of pre-committing to bailout and the net benefits for the banker of pre-committing to reveal truthfully, when the regulator threatens to randomize his decision to nationalize. The tables also include the no pre-commitment equilibria (α^*, ϵ^*).

According to the numerical examples, the regulator faces no policy problems when γ and c are high enough to induce the separating equilibria (represented as $\epsilon^* = 0$ and $\alpha^* = 0$ in the tables). In this case the regulator does not need to pre-commit to any policy because the detection with the in-situ inspection represents already an effective threat to the banker. In scenarios 1 and 2 the revelation problem is solved when $c > 0.01$ and $\gamma > 0.3$. In scenarios 3 and 4, parameters c and γ are required to be above 0.02 and 0.5, respectively. [16]

The more interesting case, however, is to understand the commitment alternatives open to the regulator when separating equilibria are unfeasible.

[16]Parameters γ and c must be higher in scenarios 3 and 4 because bank insolvency is less severe, $\delta_2 = 0.6$. Consequently, the banker has higher incentives to hide bad portfolios because the risky bet is more likely to pay off. In order to stop the banker from taking the bet, the probability of detection and the private costs of detection must be increased to a higher level.

The numerical examples indicate that low parameter values for γ, c, and g allow the regulator to induce full revelation by threatening with random nationalization. What explains this result? Low values for parameters γ, c, and g increase banker's incentives to hide bad portfolios, and increases the regulator's convenience of nationalizing a bank with $\widetilde{R_G}$. Both effects, together, create the conditions for the regulator to randomize nationalization.

It must be highlighted that the ability of the regulator to pre-commit to random nationalization will depend on the scenario in place. The pre-commitment is possible in scenarios 1, 2, and 4. In scenario 3, when bank insolvency is moderate and when the fiscal situation is tight ($\delta_2 = 0.6$ and $\lambda = 3.5$), the pre-commitment to random nationalization is unfeasible. The explanation is straightforward. On the one hand, if the value of δ_2 is high and close to δ_0, risk-shifting does not introduce high distortions. This reduces the expected benefits of nationalizing a bank with $\widetilde{R_G}$, and therefore the ability to threaten the banker with random nationalization. On the other hand, when the probability δ_0 is high, a high level of λ increases the costs of nationalizing a bank with $\widetilde{R_G}$. In the numerical examples we have assumed precisely a high probability δ_0, equal to 0.7. So, when both δ_2 and λ are high, the regulator's incentives to threaten the banker with randomization are at its lowest, and therefore the pre-commitment is unfeasible.

The numerical examples also indicate that often the regulator can pre-commit to both types of policies: bailout and random nationalization. This is the case of scenarios 1 and 2, provided that the parameter values of γ, c, and g are low enough (see tables 2 and 3).

The regulator can pre-commit to bailout only in scenarios 1 and 2, where bank insolvency is severe $\delta_2 = 0.35$, because the regulator can offer a low capitalization to discipline the banker. The banker would accept the offer due to the low probability of success of the risky bet. In scenarios 3 and 4 the risky bet's probability of success is higher $\delta_2 = 0.6$, therefore the capitalization offer has to be higher. In fact, in scenarios 3 and 4 the capitalization of the bank ΔK must be equal to 0.146 while in scenarios 1 and 2 the required capitalization is only 0.0846.

It is interesting to note that the regulator can pre-commit to bailout in scenario 1 even though λ is equal to 3.5. Common wisdom would suggest that a tighter fiscal situation would reduce regulator's incentives to pre-commit to bailout. The results show, however, that the regulator's net benefits of pre-committing to bailout are higher when the value of λ is 3.5 rather than 0.5. The explanation lies in the expression for the net benefits of pre-committing to bailout: condition 4.1. When the expected pay-off associated to bailout is compared with the expected pay-off of an hybrid equilibrium, parameter λ has no impact on the sign of the net benefits, but only on the magnitude of the costs and benefits. [17]

Scenario 4, where bank insolvency is moderate and the fiscal situation loose, is the only case in which the regulator can pre-commit to random nationalization but has no ability to pre-commit to bailout. The regulator cannot pre-commit to bailout because capitalizing the bank is too expensive ($\Delta K = 0.146$). A high δ_2 (equal to 0.6) also reduces the benefits of pre-committing to randomization. In this case, nevertheless, the loose fiscal situation makes possible the randomization threat.

6. The renegotiation problem

The model with pre-commitment generates multiple equilibria in scenarios 1 and 2 but does not include a mechanism to select among them, consequently we can only make conjectures about how the selection takes place. It is evident, however, that a policy problem arises in these scenarios because the agents' preferences regarding the pre-commitment options differ. The regulator prefers the equilibrium with random nationalization, while the banker prefers the equilibrium with bailouts.

Lets assume that the banker and the regulator renegotiate after the first stage game. If the regulator announces at the beginning of the first game his preferred option, the threat to randomize, the banker would have incentives to hide the bad portfolio with the objective of

[17] Recall that the regulator's pay-off with a hybrid equilibrium is equal to the pay-off he would get if nationalization was played in every possible case, because by definition the regulator is indifferent between nationalizing or not a bank with $\widetilde{R_G}$. Therefore, the net benefits of bailout are calculated by comparing how much fiscal resources the regulator has to pay if the nationalized bank is solvent with how much more fiscal resources have to be used for capitalizing the bank if it is insolvent.

renegotiating a policy shift to bailout for the subsequent games. This makes sense for the banker if he can push the regulator to offer bailouts for future games, instead of going through with the punishment by randomizing. If the regulator is convinced that the banker would not reveal truthfully unless a bailout is offered, then the regulator may soften his position because a pre-commitment to bailout is better than no pre-commitment at all.

The regulator will be able to shift the equilibrium to his prefered option if he can make the banker believe that bailout will never be used. An analysis of reputation building, however, escapes the breath and scope of our paper.

The numerical examples show that reducing γ, c or g does not help to solve the renegotiation problem when the severity of the bank insolvency is high, as in scenarios 1 and 2. The only way to avoid the pressure for a bailout, would be to induce a separating equilibrium by increasing γ or c. This option is costly and potentially welfare reducing if the investment costs of introducing the changes are too high.

We highlight here an alternative solution to avoid bailouts without carrying out the improvement in γ. The banker would agree to reveal truthfully, even if γ remained low, provided that there was a credible threat of improving the probability of detection, for example, from γ to γ_I.

To make this point we need to modify the model in two ways. First, we need to allow the regulator and banker to renegotiate after the outcome of the first game is known. We have to provide the regulator also with the chance of investing an amount of fiscal resources I in bank supervision, after the first game was played, and before the subsequent games start. Second, the increase in γ, due to the investment in bank supervision, must have a negative impact on the bank's assets returns, $-\psi$, such that after the investment the expected return of the asset portfolio is lower: $\widetilde{R}' = \widetilde{R} - \psi$. The term $-\psi$ would reflect to some extent the effects of financial repression over the return of the bank's assets.

If the improvement in the probability of detection is high enough such that

$$\gamma_I > \frac{\delta_2(A + R_B + R_G - \psi - 1)}{c + \delta_2(A + R_B + R_G - \psi - 1)}, \tag{6.1}$$

then the regulator would induce, with the investment, separating equilibria in all the subsequent games to be played.

If the banker would hide the bad portfolio and tries to renegotiate a bailout for the subsequent games, the regulator could answer by investing in bank supervision. The regulator would prefer to invest rather than renegotiate (and promise the banker a bailout) if the inefficiency ψ was small enough:

$$\psi < \frac{\lambda}{1+(1-\delta_0)\lambda}((1-\delta_0)\frac{\delta_2}{1-\delta_2}R_G - I). \tag{6.2}$$

It is obvious also that, if the regulator invests in bank supervision, the banker would receive a payoff that is worse than the expected payoff in any of the two possible pre-commitment equilibria without the investment. Therefore, the banker would have no incentives to hide and renegotiate in order to extract bailouts from the regulator.

7. Discussion

Here we will discuss the merits of the assumptions that allowed the regulator, in our model, to pre-commit to randomize his decision to nationalize the bank.

The policy implications of our model depend crucially on the assumption that the regulator and banker make their decisions having a long-run horizon: playing the game infinitely. This assumption may seem unrealistic, as it would be difficult to justify the banker playing the game again after the bank was nationalized. In other words, it would seem more realistic to analyze the policy problem using a repetitive game scenario, where a long run agent, the regulator, interacts with a succession of short run players, the bankers. If this was the case, the regulator would only be able to pre-commit to bailout. The banker, with a short run horizon, would have no means of pre-committing to reveal truthfully if subjected to the threat of randomization.

We argue that our results are still valid if we consider bankers as short run players. If the pre-commitment to reveal truthfully increases banker's expected pay-off, the right incentives would be in place for the creation of institutions that punish bankers that hide bad portfolios. Lets consider, for example, a framework with multiple banks. Bankers would improve their welfare by benefiting the other bankers of the system with interests in their own bank, in order for them to internalize the costs of deviating from the pre-commitment to reveal. Then, hiding a bad portfolio in one bank would hurt the banker's interests in the other banks of the system, if the regulator decides to punish all by randomizing. These arguments, however, go beyond the scope of this paper. One possible line of future research could be oriented to formalize the type of arrangements that would discipline the banker.

In our model, parameter η allowed the banker to credibly commit to reveal truthfully when subjected to the threat of randomization by the regulator. We assumed that η reflects the private benefits that bankers receive when they manage a bank with a good portfolio. Even though the existence of $\eta > 0$ is necessary to arrive to our results, the underlying requirement was that the regulator must value the bank by less than the banker: the price he is willing to pay for the bank is lower than the minimum that the banker would accept under normal circumstances. When the regulator randomizes and nationalizes a solvent bank, the banker would suffer a loss because the regulator would deny any compensation for η. Consequently, we can arrive to the same results with alternative ways of understanding η. For example, an interesting possibility would be to consider η as the superior ability of private bankers to collect debt repayments.

The ability to induce full revelation with random nationalization depends in our model on the regulator having a high level of discretion. This was introduced by condition 3.6, a ceiling on the costs that a regulator has to endure in order to nationalize a bank that has declared itself to be solvent. If the institutions that protect bankers' property rights are strong, such that condition 3.6 is violated, then full revelation would be unfeasible. The results of our paper are valid, therefore, when the regulator can over rule the institutions that protect bankers' property rights.

8. Conclusion

We present a model that describes how a regulator tackles the problem of bank insolvency. We find that, although there exists an equilibrium at which it is optimal for the regulator and the banker to randomize their actions, the regulator's and the banker's payoffs and welfare can be increased by introducing the possibility of two different types of pre-commitment. On the one hand, the regulator can induce the banker to full revelation by pre-committing to benefit the banker with a bailout; on the other hand, the regulator can pre-commit to punish the banker by randomizing his policy choice. The regulator always prefers the second type of arrangement, while the banker prefers the first. The regulator wants to induce the banker to reveal truthfully by convincing him that bailout would not be the chosen policy to tackle the potential insolvency.

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Table 2. Scenario 1: Severe insolvency ($\delta_2 = 0.35$) and fiscal crisis ($\lambda = 3.5$)

	Pre-commitment to Bailout		Pre-commitment to randomize nationalization	
	Regulator's net benefit from pre-committing to bailout	(α^*)	Banker's net benefit from pre-committing to reveal	(ϵ^*)
$\gamma = 0.1$	0.0232	0.567	0.0005	0.259
$\gamma = 0.2$	0.0232	0.638	0.0004	0.167
$\gamma = 0.3$	0.0232	0.729	0.0001	0.048
$\gamma = 0.35$	-0.0363	0	0	0
$\gamma = 0.4$	-0.0363	0	0	0
$\gamma = 0.5$	-0.0363	0	0	0
$\gamma = 0.6$	-0.0363	0	0	0
$c = 0.0025$	0.0048	0.456	0.0011	0.524
$c = 0.005$	0.0109	0.547	0.0006	0.286
$c = 0.01$	0.0232	0.729	0.0001	0.048
$c = 0.0125$	-0.0363	0	0	0
$c = 0.015$	-0.0363	0	0	0
$c = 0.02$	-0.0363	0	0	0
$c = 0.025$	-0.0363	0	0	0
$g = 0.005$	0.0057	0.519	0.0001	0.048
$g = 0.01$	0.0232	0.729	0.0001	0.048
$g = 0.015$	0.0407	0.964	0.0001	0.048
$g = 0.02$	0.0445	1	-0.00015	0
$g = 0.025$	0.0461	1	-0.00015	0
$g = 0.03$	0.0477	1	-0.00015	0
$g = 0.035$	0.0492	1	-0.00015	0

Table 3. Scenario 2: Severe insolvency ($\delta_2 = 0.35$) and no fiscal crisis ($\lambda = 0.5$)

	Pre-commitment to Bailout		Pre-commitment to randomize nationalization	
	Regulator's net benefit from pre-committing to bailout	(α^*)	Banker's net benefit from pre-committing to reveal	(ϵ^*)
$\gamma = 0.1$	0.0033	0.236	0.0005	0.259
$\gamma = 0.2$	0.0033	0.265	0.0004	0.167
$\gamma = 0.3$	0.0033	0.303	0.0001	0.048
$\gamma = 0.35$	-0.0052	0	0	0
$\gamma = 0.4$	-0.0052	0	0	0
$\gamma = 0.5$	-0.0052	0	0	0
$\gamma = 0.6$	-0.0052	0	0	0
$c = 0.0025$	0.0007	0.189	0.0011	0.524
$c = 0.005$	0.0016	0.227	0.0006	0.286
$c = 0.01$	0.0033	0.303	0.0001	0.048
$c = 0.0125$	-0.0052	0	0	0
$c = 0.015$	-0.0052	0	0	0
$c = 0.02$	-0.0052	0	0	0
$c = 0.025$	-0.0052	0	0	0
$g = 0.005$	0.0008	0.222	0.0001	0.048
$g = 0.01$	0.0033	0.303	0.0001	0.048
$g = 0.015$	0.0058	0.388	0.0001	0.048
$g = 0.02$	0.0083	0.476	0.0001	0.048
$g = 0.025$	0.0108	0.569	0.0001	0.048
$g = 0.03$	0.0133	0.667	0.0001	0.048
$g = 0.035$	0.0158	0.769	0.0001	0.048

Table 4. Scenario 3: Non-severe insolvency ($\delta_2 = 0.6$) and fiscal crisis ($\lambda = 3.5$)

	Pre-commitment to Bailout		Pre-commitment to randomize nationalization	
	Regulator's net benefit from pre-committing to bailout	(α^*)	Banker's net benefit from pre-committing to reveal	(ϵ^*)
$\gamma = 0.1$	-0.0661	1	-0.0020	0
$\gamma = 0.2$	-0.0688	1	-0.0015	0
$\gamma = 0.3$	-0.0716	1	-0.0009	0
$\gamma = 0.35$	-0.0729	1	-0.0006	0
$\gamma = 0.4$	-0.0743	1	-0.0003	0
$\gamma = 0.5$	-0.1013	0	0	0
$\gamma = 0.6$	-0.1013	0	0	0
$c = 0.0025$	-0.07155	1	-0.001575	0
$c = 0.005$	-0.07155	1	-0.00135	0
$c = 0.01$	-0.07155	1	-0.0009	0
$c = 0.0125$	-0.07155	1	-0.000675	0
$c = 0.015$	-0.07155	1	-0.00045	0
$c = 0.02$	-0.07155	1	0	0
$c = 0.025$	-0.10125	0	0	0
$g = 0.005$	-0.073125	1	-0.0009	0
$g = 0.01$	-0.07155	1	-0.0009	0
$g = 0.015$	-0.069975	1	-0.0009	0
$g = 0.02$	-0.0684	1	-0.0009	0
$g = 0.025$	-0.066825	1	-0.0009	0
$g = 0.03$	-0.06525	1	-0.0009	0
$g = 0.035$	-0.063675	1	-0.0009	0

TABLE 5. Scenario 4: Non-severe insolvency ($\delta_2 = 0.6$) and no fiscal crisis ($\lambda = 0.5$)

	Pre-commitment to Bailout		Pre-commitment to randomize nationalization	
	Regulator's net benefit from pre-committing to bailout	(α^*)	Banker's net benefit from pre-committing to reveal	(ϵ^*)
$\gamma = 0.1$	-0.0060	0.825	0.0008	0.402
$\gamma = 0.2$	-0.0060	0.928	0.0007	0.327
$\gamma = 0.3$	-0.0064	1	-0.0009	0
$\gamma = 0.35$	-0.0068	1	-0.0006	0
$\gamma = 0.4$	-0.0073	1	-0.0003	0
$\gamma = 0.5$	-0.0145	0	0	0
$\gamma = 0.6$	-0.0145	0	0	0
$c = 0.0025$	-0.0086	0.663	0.0014	0.677
$c = 0.005$	-0.0077	0.795	0.0010	0.474
$c = 0.01$	-0.0064	1	-0.0009	0
$c = 0.0125$	-0.0064	1	-0.0007	0
$c = 0.015$	-0.0064	1	-0.0005	0
$c = 0.02$	-0.0064	1	0	0
$c = 0.025$	-0.0145	0	0	0
$g = 0.005$	-0.0085	0.737	0.0005	0.231
$g = 0.01$	-0.0064	1	-0.0009	0
$g = 0.015$	-0.0061	1	-0.0009	0
$g = 0.02$	-0.0059	1	-0.0009	0
$g = 0.025$	-0.0057	1	-0.0009	0
$g = 0.03$	-0.0055	1	-0.0009	0
$g = 0.035$	-0.0052	1	-0.0009	0

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