

## **Regulatory Practices and the Impossibility to Extract Truthful Risk Information**

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### **ABSTRACT**

We consider a regulator providing deposit insurance to a bank with private information about its investment portfolio. Following current regulatory practices, we assume that the regulator does not commit to audit and sanction after any fraudulent risk report from the bank. We show that, in absence of commitment, the socially optimal contract leads a high-risk bank to misreport its risk with positive probability in most cases. We also isolate cases when truthful risk reporting is optimal. We thus establish that extraction of truthful risk information is not socially optimal in most cases given current regulatory practices.

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*Keywords:* Banking regulation; Partial commitment; Asymmetric information; Adverse selection

## I. INTRODUCTION

Accurate estimates of the risk exposure in the banking industry are critical to regulators. This information allows not only to set precautionary measures to protect the banking industry, but also at individual level to adjust for premia in return for services offered by the regulator such as deposit insurance. However, banks are notoriously reluctant to disclose such information. For instance, banks in financial distress have clear incentives to keep this information private since detection may trigger regulatory intervention leading to severe changes in financial strategies and possibly financial sanctions.

This adverse selection issue has been addressed by the Bank for International Settlement through the Basel Committee, in an attempt to standardize methods to extract such risk information. Starting in 1999, the Fisher II Working Group was mandated to address two issues: 1- the optimal design of a standardized report of portfolio risk, and 2- the design of incentives to extract truthful risk information (see B.I.S. (2004)).

In this paper, we argue that extraction of truthful risk information is most often not socially optimal because of a current regulatory practice, and we isolate conditions under which it is socially optimal to do so. The practice leading to such a situation is the deliberate avoidance to commit to detect and sanction fraudulent reports.

The motivations for the absence of commitment to audit and to sanction fraudulent reports are described in details later in this section, but they represent a common feature of modern regulatory practices. We show that, in the case of a regulator providing deposit insurance to a bank, the socially optimal contract induces a high-risk bank to lie with strictly positive probability in most cases. The only exception we find is when the auditing cost is prohibitive, in which case we show the regulator should optimally implement a truth-telling contract.

### A. Heuristic Results and Intuition

We address the above issues in the context of a regulator providing deposit insurance to a bank. We construe this regulatory relationship as a principal-agent relationship. We model current practices where a regulator first sets capital requirements and deposit level, with the credible threat to retire the operating licence if such requirements are not met. The bank reinvests part of the proceeds into risky loans, whose risk level is private information to the bank.

The regulator requires a report about the risk level, and sets an insurance premium to cover for deposit insurance. Then, without prior commitment and after receiving the report, the regulator may decide to audit at a fixed cost. An audit reveals the actual risk taken by bank, and in case of misreport we assume that the regulator seizes control of the bank profits. The bank seeks to maximize the overall value of its shares, whereas the regulator seeks to maximize social welfare that includes the market value of the bank less the social cost of financial distress.

We first show that the optimal contract can be implemented through a direct mechanism, answering the question of the optimal design of risk report addressed by the BIS. This result is non-trivial because, in absence of commitment to audit, the standard Revelation Principle does not apply and direct truth-telling mechanisms are not always optimal. Bester and Strausz (2001) analyzes this issue in details; the basic

insight of this paper is that, when there is no commitment on some actions in a general contractual setting, the knowledge of the true state of the world stemming from truthful revelation may lead to late choices detrimental to the agent. Therefore, truth-telling may not always be optimal and randomized messages - or equivalently non-direct mechanisms - may compensate for the future exploitation of any available information by the principal. In contrast, when the principal commits to every action, truth-telling cannot be exploited against the agent in a similar way without renegeing on previous commitment.

In absence of commitment in our regulatory setting, we show that two cases can occur at the socially optimal contract. If the auditing cost is too high, then audit does not occur and the regulator prefers to implement truthful report through an incentive compatible mechanism. Otherwise, an audit occurs with positive probability albeit never surely, triggering the following optimal reaction from the bank: with a high risk portfolio a bank systematically misreports with positive probability, but a bank with low risk portfolio always reveals it truthfully.

The intuition of this result is as follows. First, at the optimal contract the insurance premium is higher for a high-risk bank. Thus, a low risk bank has no reason to misreport since its situation matches exactly the objective of the regulator to reduce the social cost of financial distress, and the insurance premium is minimal. However, when audit does not occur for sure as it is always the case at the optimal contract, a high risk bank has no reason to always report truthfully. Indeed, this information would systematically be exploited by the regulator by systematically charging a high premium without having to audit. By randomizing the message about its risk, and hence lying with strictly positive probability, the expected payoff to the bank is strictly higher since randomization naturally exploits the reluctance to always audit.

Finally, we show that a bank cannot extract any informational rent when audit occurs with strictly positive probability. Still, the optimal contract without commitment does not achieve the first-best. Overall, our contribution is two-fold. First, we show that the optimal risk report reduces to direct revelation. There is thus no need to design devices such as self-contradictory reports where a bank cannot misreport without revealing accounting anomalies. Second, we show that partial commitment in regulatory practices designs the incentives for risky banks to misreport. At a theoretical level, we thus establish that extraction of truthful risk information is not compatible with the objective of maximizing social welfare.

## **B. Risk Reports and Lack of Commitment**

We now describe the disclosure requirements as described in the Basel II Capital Agreement, and the practical motivations for the lack of commitment to audit and sanction. The natural aim of the Basel II Capital Agreement is to offer a standardized risk report procedure to harmonize regulatory efforts across countries. The Basel Committee on Banking Supervision (2006) recommends a monthly report, whose requirements are set in the Pillar III. The Committee recommends industry-related disclosure; in the case of credit risk as studied here, the reports ought to include measures of the probability of default, loss given default, the exposure at default, and effective maturity (p.52). The assets that are to be included in the analysis are (a) corporate, (b) sovereign, (c) bank, (d) retail, and (e) equity with various subclasses

(p.52). A typical report for a specified class of risk can be found in Bank of Indonesia (2004), although this early local requirement does not match exactly the Pillar III recommendations.

Failure to meet those requirements leads to ineligibility to use the IRB approach in a broad sense, however the exact nature of the sanctions for fraudulent reports is left to the discretion of the local regulator. The striking aspect of regulation worldwide is that sanctions are not always enforceable, and thus regulatory interventions can greatly vary across countries. The statement on p. 226 makes this very clear:

“Further, there are a number of existing mechanisms by which supervisors may enforce requirements. These vary from country to country and range from “moral suasion” through dialogue with the bank’s management (in order to change the latter’s behavior), to reprimands or financial penalties. The nature of the exact measures used will depend on the legal powers of the supervisor and the seriousness of the disclosure deficiency.”

There are many reasons why a regulator may not be willing to commit to financial sanctions, in top of the natural legal restrictions in place in the country as previously quoted. An interesting example is the official law on regulatory interventions in Switzerland that specifies no particular sanctions in case of fraudulent reports (see Confoederatio Helvetica, 2004). At a more general level, Jordan (1994) argues that excessive regulatory requirements and interventions act as a tax on the banking industry, and it may thus impeded its development. Calzolari (2001) describes the difficulties of regulating, and thus of enforcing sanctions, with multinational banks and insurance companies. Flannery and Sorescu (1996) shows that, for some specific industries, market discipline may work only when lack of regulatory intervention is anticipated. Rochet (2004) finally argues that currently prescribed reporting methods are too complex to be applicable, and thus regulatory forbearance is necessary until all banks can be Basel II compliant.

### **C. Related Literature**

We now survey academic studies related our work. Our findings are in strong contrast with Giammarino et al. (1993), where a similar analysis is carried out under the assumption that the regulator commits to every action. In this case, the Revelation Principle can be used and standard results obtain; that is, truthful risk reports are always optimal and the bank extracts informational rent from the regulator at the optimal contract.

Another important assumption of our work is the severity of punishment in case of detection of misreport (the seizure of the bank’ profits). Other studies have focused on similar types of sanctions under the commitment assumption, for instance Bond and Krishnamurthy (2004). Kahlil (1997) analyzes a simple contractual model, unrelated to regulatory issues, where there is no commitment to audit by the principal. Kahlil does not address the problem of optimal contract, but his findings are nonetheless similar to ours all else equal.

Misreporting of private information is also extensively studied in the literature on consulting. The point of this literature is that incentives contracts leads consultants to misreport so as to match anticipated managerial views (Prendergast, 1993), or so as to manage individual reputation by conforming to common views (Ottaviani and Sørensen)

rensen (2006) argues that misreports can be triggered by herd behavior). Our work differs from Prendergast (1993) in that we show that it is optimal to accept misreports, whereas abandoning incentives contract in this later reference is shown to trigger truthful reports. We exclude the possibility of reputation as in Ottaviani and Sørensen (2006), although this represents a natural and interesting extension of our study.

An extensive literature, started with Chan et al. (1992), has overall findings consistent with ours. Chan et al. (1992) shows that fair pricing of incentive-compatible deposit insurance as studied here is impossible with asymmetry of information. The point of this last reference is that banks will always prefer lower insurance premia for every deposit level, and thus high-risk banks will always seek to hide their type. Freixas and Rochet (1998) shows that incentive-compatible deposit insurance is feasible but inefficient (see Santos, 2006, for a complete discussion and list of references).

## II. THE MODEL

In this section, a formal description of the model is given. The basic model is inspired from that in Giammarino et al. (1993). A regulator providing deposit insurance to a bank seeks to extract risk information about the bank investment portfolio to set the insurance premium. The key feature of our environment, and main departure from Giammarino et al. (1993), is that the regulator does not commit to audit and to possibly sanction when a misreport is detected.

### A. The Interactions

We first describe the agents and the timing of the interactions. The strategy sets and equilibrium concepts will be defined later. There are four periods and three agents: a bank, a regulator and an outside investor all living during these four periods.

In the first period 0, the bank has no outstanding share and a monopoly access to a risky loans market. To simplify matters, we do not explicitly model the customers on the loans market, and we assume that the bank will always find customers for their operations. The overall return on loans is a random variable  $r_q$  that depends on a variable  $q$ , representing the quality of the bank loans market. Formally,  $r_q$  has support  $[\underline{r}, \bar{r}]$  (with  $\bar{r} > \underline{r} > 0$ ) with distribution function  $G(r/q)$  depending on the quality of the loans market  $q$ . We assume that, for the same given mean, an increase in  $q$  leads to an increase in variance of the loans market (in the sense of Second-Order Stochastic Dominance). In other words, we assume that if  $q > q'$  then  $r_q$  is a mean-preserving spread of  $r_{q'}$ .<sup>1</sup>

The loans market has a quality  $q \in Q \equiv \{q_h, q_l\}$ , where  $q_h$  represents a high risk and  $q_l$  a low risk ( $q_h > q_l$ ). The quality is known to the bank in period 1 when choosing a license within the offered menu, for instance through superior information about customers due to local interactions. The bank cannot influence the quality of the market. The quality of loans market, also referred to as the portfolio quality of the bank, is the type of the bank. The regulator does not know the quality of the bank portfolio in this period. We assume that any amount of funds made available by the

bank on this loans market will be taken by entrepreneurs, not modelled to simplify matters.

The regulator offers to the bank a menu of different licenses, one only is to be chosen by the bank. A license specifies a maximum level of deposits  $D$ , a maximum level of equities to be raised  $E$ , a maximum investment level in risk-free asset  $B$ , a maximum number of risky loans  $L$  that the bank is allowed to issue and premium  $P$  to cover for deposit insurance. If the bank stays within those limits, permission to operate is granted. The license offered to the bank will depend on the reported risk level contained in the bank risky loans portfolio, as described later.

**In period 1**, and with full knowledge of the loans quality, the bank chooses a license from the menu offered by the regulator. To make sure that a right to operate is granted for a given a license  $(D, E, L, B, P)$ , the bank proceeds as follows. First, the bank issues  $D$  deposits and sell a fraction of equities  $E$  to the outside investor. To simplify matters, we do not explicitly model depositors and we assume that the bank always find depositors to trade with. With the proceeds, the bank invests  $B$  in illiquid risk-free assets, redeemable in the last period with fixed rate of return  $R^e > 0$ .

Still in period 1, the outside investor can purchase equities from the bank or invest instead his wealth in the same illiquid risk-free asset with return  $R^e > 0$ . The investor is a expected utility maximizer, with utility function  $U$  assumed to be differentiable, increasing and concave (so as to capture the investors' risk aversion in banking operations). We assume that the investor always chooses to purchase equities when indifferent with riskless long-term investments.

**In period 2**, we distinguish two-sub-period. In the first sub-period, the bank is required to report some information about  $q$  in the form a message chosen from an arbitrary message set  $M$ . We assume that  $M$  is a metric space and we denote by  $\mathcal{M}$  the Borel  $\sigma$ -algebra on  $M$ . This arbitrary message set captures all the possible messages that can be sent (such as randomization or any other type of information about the bank' assets); we will later prove that it is optimal to reduce it to the set of types, proving in turn the optimality of direct mechanisms. To simplify matters, and without loss of generality, we assume that the license  $(D, E, L, B, P)$  offered by the regulator is tied to the message, the bank implicitly choosing the message when choosing the license.

The regulator has a prior belief about the portfolio quality, in the form of a probability distribution  $(\gamma_h, \gamma_l)$  such that  $\gamma_i > 0$  for every  $i$  and  $\sum_i \gamma_i = 1$ . The number  $\gamma_i$  is the anticipated probability that the quality is  $q_i$ . After receiving the message, the regulator updates its beliefs about the bank type in a Bayesian manner.

In the second sub-period, and after receiving the message, the regulator audits with probability  $\alpha \in [0, 1]$ , at fixed cost  $c > 0$ . When auditing, the regulator knows with certainty the true type. This assumption simplifies the analysis, see for instance Flannery (1991) and Lucas and McDonald (1987) for cases where unobservable quality components play a significant role. The regulator expects that a type- $i$  bank sends a report in  $M_i(i = l, h)$ , where  $M_i$  is a closed Borel set of strictly positive measure such that  $M_h \cap M_l = \emptyset$  and  $M_h \cup M_l = M$ . Throughout, we use the convention that, for

every  $i$ , the set  $M_{-i}$  denotes the complementary of  $M_i$  in  $M$ . If the result of the audit does not match the report expected from the bank; i.e., if a type  $i$  bank has reported a message in  $M_{-i}$ , we assume that the regulator seizes control of the bank profits. Such a harsh penalty for misreporting the risk is rarely seen in practice, although possible. This penalty level makes our point even stronger, since as shown later even with such a harsh punishment a high-risk bank will misreport at the optimal contractual arrangement.

In the last period 3, cash flows are realized and redistributed to claimants. Two cases can occur: (1) If the cash flow is greater or equal than  $D$ , the bank is solvent and makes the following payments: (a) the amount  $D$  is paid back to depositors, and (b) the residual is paid to the shareholder as dividends. (2) If the cash flow is strictly less than  $D$ , the bank is declared bankrupt and the regulator seizes control of the bank and all of its assets. The regulator pays  $D$  to the depositors, and the shareholder loses his claim.

### B. Definition of Equilibrium

We next describe the strategies for the agents, and the equilibrium concepts used to analyze our game. A strategy or contract for the regulator is 1- a menu of licenses as described earlier, and 2- for every license an audit probability that comes without prior commitment. If the bank exceeds any of the quantities specified in any license, the license is not granted. We denote the menu of a contract by the letter  $x$ . The regulator ties the license  $(D, E, L, B, P)$  to the report received from the bank. Formally, the regulator commits to a menu  $x(m)$  if the received report is  $m \in M$ , but the probability of auditing is chosen after reception without prior commitment. From now on, we represent the choices of  $x$  and  $\alpha$  as measurable functions mapping the message space  $M$  into the positive real line.

In a first step, we assume that the bank chooses its deposit level, equity raised and loans issued to match exactly the prescription of the regulator so that a license is granted. We will show later that this assumption is consistent with equilibrium behavior. Thus, the action of the bank can be reduced to a choice of message. Formally, a strategy for the bank is a report  $\tau \in M$  to be sent to the regulator about the riskiness of its portfolio. Since the bank can choose to randomize among the reports sent, we represent a message strategy as a measurable function  $m: Q \rightarrow \Pi$ , where  $\Pi$  is the set of probability measures over  $M$ . For any given message strategy  $m$ , we define  $\bar{m} = \sum_i \gamma_i m_i$ . (It is straightforward to check that  $\bar{m} \in \Pi$ .)

There are two fundamental equations that are to be satisfied in the model: equity constraint and cash flow constraint. First, the equity constraint must ensure that the outside investor be indifferent between investing in the riskless asset and purchasing shares of the bank. By our previous assumption, the outside investor will purchase bank equities and all banking operations will become feasible. Formally, for a given quality  $q_i$ , together with a portfolio  $(L, B)$  and deposits  $D$ , the equity raised must be such that

$$U(ER^e) = \int_{R_b}^r U[rL + BR^e - D]dG(r/q_i), \quad (1)$$

where  $R^b = \frac{D - BR^e}{L}$  is the break even point below which the bank is bankrupt.<sup>2</sup> The left-hand side of (1) is the expected return if the value of equities is invested in the riskless asset, and the right-hand side is the expected utility to the outside investor in banking operations. Moreover, the bank investment decision must also satisfy the cash flow constraint

$$D + E = B + L + P. \quad (2)$$

The left-hand side of (2) represents the proceeds from deposits and equity raising, and the right-hand side are the investments and payment made by the bank. As justified in Giammarino et al. (1993), we assume without loss of generality that  $D = L$ . Intuitively, this assumption stipulates that equity financing is used only to cover for the default probability.

The bank seeks to maximize the overall value to shareholders, taking into account their risk aversion in banking operations.<sup>3</sup> For a given strategy  $x$  and in absence of audit (i.e.,  $\alpha = 0$ ), the value of the bank with type  $q_i$  and sending a report  $\tau \in M$  is

$$\pi_i(x, \tau/M) = \int_{R^b}^{\bar{r}} U[rL(\tau) + B(\tau)R^e - D(\tau)]dG(r/q_i) - P(\tau). \quad (3)$$

If audits occurs with strictly positive probability, and when using the message strategy  $m$ , the expected payoff to a bank of type  $q_i$  rewrites as

$$\begin{aligned} & \Pi_i(x, \alpha, m/M) \\ & \equiv \int_{M_i} \pi_i(x, \tau/M)dm_i(\tau) + \int_{M_{-i}} [(1 - \alpha(\tau))\pi_i(x, \tau/M) - \alpha(\tau)\pi_i(x, \tau/M)]dm_i(\tau). \end{aligned} \quad (4)$$

The first term in the right-hand side of (4) is the expected payoff to the bank when reporting truthfully, and the second term is the expected payoff in case of misreporting and possible detection by the regulator. Given a strategy form the regulator, the bank chooses a message strategy to maximize the value (4) subject to the cash flow constraint (2).

We next turn to describing the objective of the regulator. The regulator aims to provide deposit insurance while maximizing social welfare. The social welfare reflects bank profits less involvement cost in banking regulation and social cost of financial distress.

For a given strategy  $x$  chosen by the regulator, the social cost of financial distress from a bank with portfolio quality  $q_i$  and sending the report  $\tau$  is measured by

$$F_i(x, \tau/M) \equiv -\int_{R^b}^{\bar{r}} U[(r-1)L(\tau) + B(\tau)]dG(r/q_i). \quad (5)$$

Thus, the social cost of financial distress is the expected payoff in case of bankruptcy. Because of risk-aversion in banking operations, we can notice that Second-Order

Stochastic Dominance implies that

$$F_l(x, \tau/M) \leq F_h(x, \tau/M), \quad (6)$$

for every  $(x, \tau, M)$  (see Mas-Colell et al. (1995) Section 6.D for a detailed explanation). In words, Second-Order Stochastic Dominance together with risk-aversion implies that, for any given menu, a low-risk bank has a lower cost of financial distress than a high-risk bank.

The net expected payoff from providing deposit insurance to a bank with portfolio quality  $q_i$  and sending the report  $\tau \in M$  is

$$S_i(x, \tau/M) \equiv P(\tau) + F_i(x, \tau/M). \quad (7)$$

The above embodies the premium payment from the bank and the social cost of financial distress. The regulator objective also encompasses the net profit to the bank less any penalty resulting from an audit. For sake of simplicity, we assume that there is no social cost of involvement in the deposit insurance program. The overall payoff to the regulator from a quantity strategy  $x$  without audit (i.e.,  $\alpha = 0$ ), after receiving a report  $\tau$  from a type  $i$  bank, can then be described by the welfare function

$$W_i(x, \tau/M) = S_i(x, \tau/M) + \pi_i(x, \tau/M). \quad (8)$$

After receiving a report  $\tau$  from the bank, the regulator posterior belief about the portfolio random quality is represented by the measurable mapping  $p: M \rightarrow \Delta$ , where  $\Delta \equiv \{p \in P_+^2 / \sum_i p_i = 1\}$  is the simplex on  $P^2$ . In words, the principal believes that the portfolio has quality  $q_i$  with probability  $p_i(\tau)$  when receiving the report  $\tau$ . We require that the regulator posterior beliefs be consistent with Bayes' rule on the support of the message strategy  $m$  chosen by the bank. Formally, we require that for every  $i$  and every  $O \in M$  such that  $\bar{m}(O) > 0$ , the following relation holds

$$\int_O p_i \bar{d}m = \gamma_i m_i(O). \quad (9)$$

Thus, the overall expected payoff to the regulator, when facing a message strategy  $m$  and when auditing with probability  $\alpha(\tau)$  after receiving the report  $\tau$  in the support of  $m$ , rewrites as

$$\begin{aligned} & W(x, \alpha, m/M) \\ & \equiv \sum_i \int_M p_i(\tau) W_i(x, \tau/M) dm_i(\tau) \\ & + \sum_i \int_M p_i(\tau) \alpha_i(\tau) \cdot [\pi_{-i}(x, \tau) \int_M p_i(\tau) \bar{d}m(\tau) - c] dm_i(\tau). \end{aligned} \quad (10)$$

In the above, the first term on the right-hand side is the expected payoff from providing deposit insurance, and the second term is the expected payoff from auditing operations.

We next describe our equilibrium concept. We need to capture the idea that the regulator commits first to a menu  $(D(\cdot), E(\cdot), L(\cdot), B(\cdot), P(\cdot))$  as a function of the received report, and then sets the probability of auditing. We will see later the implication of this timing in terms of optimal contract.

**Definition 1.** A Perfect Bayesian Equilibrium, given the message set  $M$ , is a strategy for the regulator  $(x, \alpha)$ , a strategy for the bank  $m$  and a belief function  $p$  such that

1. given  $m$  and  $x$ , the auditing probability  $\alpha(m)$  maximizes (10),
2. given  $x$ , the message strategy  $m_i$  maximizes (4) for every  $i$ , and
3. the belief function  $p$  satisfies (9) given the message strategy  $m$ .

We focus on perfect Bayesian equilibria that minimize the social cost of financial distress (5) while leaving the bank profit constant; i.e., we focus on equilibria  $(x, \alpha, m, p, M)$  such that there is no other perfect Bayesian equilibrium  $(x', \alpha', m', p', M)$  satisfying  $W(x', \alpha', m' / M) > W(x, \alpha, m / M)$  and  $\Pi_i(x', \alpha', m' / M) = \Pi_i(x, \alpha, m / M)$  for every  $i$ . We call any such equilibrium incentive efficient.

We add to the regulator problem the participation constraint for the bank. In our setting, it comes down to making sure that the bank can generate positive profits; i.e., we require that for every  $i$ ,

$$\Pi_i(x, \alpha, m / M) \geq 0. \quad (11)$$

Finally, we say that two perfect Bayesian equilibria  $(x, \alpha, m, p, M)$  and  $(x', \alpha', m', p', M')$  are payoff-equivalent if  $\Pi_i(x', \alpha', m' / M') = \Pi_i(x, \alpha, m / M)$  for every  $i$  and  $W(x', \alpha', m' / M') = W(x, \alpha, m / M)$ .

### III. OPTIMAL MESSAGE SPACE

In this section, we show that any incentive-efficient equilibrium is payoff-equivalent to a perfect Bayesian equilibrium for a message space reduced to  $Q$ , the set of possible portfolio random realizations. In our setting, the absence of full commitment from the regulator does not allow for a direct use of the Revelation Principle (see Myerson (1979)), but we rely on the method described in Bester and Strausz (2001) to derive this result.

**Proposition 1.** Let  $(x, \alpha, m, p, M)$  be incentive-efficient. There exists a perfect Bayesian equilibrium  $(\hat{x}, \hat{\alpha}, \hat{m}, \hat{p}, Q)$  with  $\hat{m}_i(q_i) > 0$  for every  $i$ , which is payoff-equivalent to  $(x, \alpha, m, p, M)$ . Moreover, in the equilibrium  $(\hat{x}, \hat{\alpha}, \hat{m}, \hat{p}, Q)$ , the penalty is imposed by the regulator if the bank is audited and has not truthfully reported its type.

The previous result allows us to simplify the task of finding the socially optimal contract. We can now narrow our search of the optimal contract to a direct mechanism inducing individual rationality and incentive compatibility, together with period 1

optimal decisions for both agents as additional constraints. Nevertheless, the constraint for period 1 optimal decisions does not allow for truth-telling. We will analyze later which bank type has an incentive to lie at the optimal contract.

To solve for the optimal contract, we first reduce the above program and it can be verified later that the solution to the reduced program satisfies all of the above constraints.<sup>4</sup> For purely technical reasons, we assume that  $k$  is large enough so as to offset any gain from risk aversion. The reduced program is such that the regulator never audits when the bank reports a high risk, and the low-risk bank always reports truthfully. The basic intuition for this simplification is that a high-risk bank is charged a higher premium at the optimal contract, and thus has incentives to hide its risk to reduce payments to the regulator. For the same reasons, a low-risk bank has is in the best situation and has no incentive to misreport.

Slightly abusing notations, we denote by  $\alpha = \alpha_1$  the probability of auditing when the type is low, and by  $m = m_h(l)$  the probability that a high type bank lies in its report. From the principal' viewpoint, we thus have that  $p_h = (1-m)\gamma_h$  and  $p_l = \gamma_l + m\gamma_h$ , and also  $p_{l/h} = \frac{m\gamma_h}{m\gamma_h + \gamma_l}$ . To simplify notations, we denote by  $\pi_i(x_j)$  the profit  $\pi_i(x_j, j)$  ( $i, j = h, l$ ). The reduced program, denoted by  $\Sigma$ , rewrites as

$$\text{Max}_{p_h} W_h(x_h, h) + p_l [W_l(x_l, l) + \alpha(p_{l/h}\pi_h(x_l) - c)] \quad (12)$$

subject to

$$\pi_l(x_l) \geq 0, \quad (13)$$

$$(1-m)\pi_h(x_h) + m[(1-\alpha)\pi_h(x_l) - \alpha\pi_h(x_l)] \geq 0, \quad (14)$$

$$m \in \text{Arg max}_{m'} [(1-m')\pi_h(x_h) + m'[(1-\alpha)\pi_h(x_l) - \alpha\pi_h(x_l)]], \quad (15)$$

$$\alpha \in \text{Arg max}_{\alpha'} [p_{l/h} \cdot \pi_h(x_l) - c]. \quad (16)$$

The conditions (13)-(14) represent the individual rationality constraints for both types, condition (15) represents the incentive compatibility constraint for the high type, and condition (16) is period 1 optimal auditing decision.

#### IV. OPTIMAL CONTRACT

We now study the properties of the optimal contract. Depending on the parameters of the program  $\Sigma$ , it may be optimal for the regulator not to audit (i.e.,  $\alpha = 0$ ). We study the cases  $\alpha = 0$  and  $\alpha > 0$  separately.

##### A. The No-audit Contract

We now analyze the case where  $\alpha = 0$  at the solution to  $\Sigma$ . From Condition (16) in the

reduced program, this case typically occurs when the cost of auditing is too high. When such a situation is anticipated by the bank, we know from the Revelation Principle that it is optimal for the regulator to offer a contract inducing truthful reports for both types.

The constraint on individual rationality for the low-risk bank (14) rewrites as

$$\pi_h(x_h) \geq 0. \quad (17)$$

The Incentive Compatibility Constraint (15) to induce truthful report for a high-risk bank rewrites as

$$\pi_h(x_h) \geq \pi_h(x_l). \quad (18)$$

Moreover, since truth-telling is induced, one can simply ignore the auditing constraint (16). Let  $(x_l^n, x_h^n)$  denote the optimal no-audit contract, and let  $(x_l^*, x_h^*)$  denote the first-best allocation. A standard analysis shows that the optimal no-audit contract satisfies

$$\pi_h(x_h^n) = \pi_h(x_l^n), \pi_l(x_l^n) = 0 \text{ and } x_h^n = x_h^*. \quad (19)$$

The optimal non-audit contract induces an informational rent for a high-type bank, whereas all the surplus is extracted from a low-type bank. Moreover, the high-type optimal level is at the first-best level, and the low-type optimal level is strictly less than the first-best to compensate for the informational rent.

## B. The Audit Contract

We now consider the case when it is optimal for the regulator to threaten audit with strictly positive probability. We first start by analyzing the possibility of misreport at the optimal auditing contract. The proof to this result is inspired from Khalil (1997).

**Proposition 2.** At the optimal auditing contract, we have that  $\alpha < 1$  and  $0 < m < 1$ . Proposition 3 says that, at the optimal contract where auditing is optimal, the regulator always randomizes audit decision and the high type bank lies with strictly positive probability. Since it is necessary to randomize auditing and misreporting at the optimal auditing contract, constraints (15) and (16) can be rewritten as

$$\pi_h(x_h) = (1 - \alpha)\pi_h(x_l) - \alpha\pi_h(x_l), \quad (20)$$

$$\pi_h(x_l)p_{l/h} = c. \quad (21)$$

From equation (20), we also have that the optimal auditing decision, as a function of the optimal contract values, is given by

$$\alpha \equiv \frac{\pi_h(x_l) - \pi_h(x_h)}{2\pi_h(x_l)}. \quad (22)$$

Also, equation (21) implies that the equilibrium probability of misreporting is endogenously given by

$$\bar{m} \equiv \frac{\gamma_l}{\gamma_h} \frac{c}{c + \pi_h(x_l)} \quad (23)$$

Therefore, we can use the optimal values found in (23) and (22) to rewrite the regulator problem as

$$\begin{aligned} & \text{Max} \left( (1 - \bar{m}) \gamma_h W_h(x_h, h) \right) \\ & + \left( \gamma_l + \bar{m} \gamma_h \right) \left[ W_l(x_l, l) + \bar{\alpha} \left( \frac{\bar{m} \gamma_h}{\bar{m} \gamma_h + \gamma_l} \pi_h(x_l) - c \right) \right] \end{aligned} \quad (24)$$

subject to

$$\pi_l(x_l) \geq 0, \quad (25)$$

$$\pi_h(x_h) \geq 0. \quad (26)$$

It is straightforward to check that, at the solution to the above program, the constraints (25) and (26) must bind. We have thus established the following result.

**Proposition 3.** At the optimal contract, the bank cannot extract any informational rent.

This result contrasts the well-known results in Contract Theory (or also as shown in Section III.A) with commitment to audit, where a high risk bank would systematically extract some surplus from the information asymmetry. The program of maximizing (24) subject to (25) and (26) can now be solved by numerical methods to pinpoint the optimal values of capital requirements and insurance premium. This requires to take the first-order conditions on the maximization problem above, keeping in mind that the two constraints must bind together with conditions (1) and (2) to tie all the equilibrium variables. We omit this technical issue to simplify the analysis, since it adds nothing to our point.

## V. CONCLUSION

Overall, our work investigates from a theoretical standpoint some questions of banking regulation regarding private risk information. Mostly, we argue that current practices do not allow for an accurate estimate of the risk level in the banking industry, because of lack of commitment to detect and sanction fraudulent reports. Given such practices, we establish that, at the optimal contract, a regulator must tolerate that a high-risk bank misreports.

The practical difficulties to extract accurate risk information are already and implicitly acknowledged in some surveys issued by Bank for International Settlements, for instance in (2003). The point of our study is to show that such difficulties stem from absence of commitment to audit. If other words, we argue that if the objective of a regulator is to obtain an accurate estimate of the risk level in the banking industry, then there must be a political commitment to detect and to sanction fraudulent reports. This implies to change current regulatory practices by adding clear-cut sanctions in case of

detection, and to invest enough funds to carry out large auditing campaigns.

Our study also calls for some empirical testing. In particular, a prediction of our work is that the intensity of an auditing campaign (in terms of funds invested) should be negatively correlated with the relative percentage of fraudulent reports. Similarly, one should expect a similar relationship between the number of regulatory interventions and this same percentage. It would also be of interest to know whether there is a correlation between the aggregate risk in financial markets and the percentage of fraudulent reports.

## APPENDIX

### Proof of Proposition 1

This result is derived from a slight modification of the proof of Proposition 2 in Bester and Strausz (2001). We first state an intermediate result, which is Proposition 1 in this last reference.

**Lemma 4.** Let  $(x, \alpha, m, p, M)$  be incentive efficient. There exists a Perfect Bayesian equilibrium  $(x, \alpha, m', p, M)$  and a set  $M'$ , with  $|M'| \leq |Q|$  and  $\overline{m'}(M') = 1$ , such that  $(x, \alpha, m', p, M)$  and  $(x, \alpha, m, p, M)$  are payoff equivalent. Moreover, the vectors  $(m'_i(\tau))_{i \in Q, \tau \in M'}$  are linearly independent.

With the above lemma, we can now prove Proposition 2. Consider any incentive efficient equilibrium  $(x, \alpha, m, p, M)$  together with the corresponding pair  $(m', M')$  given by Lemma 5. Since the vectors  $(m'_i(\tau))_{i \in Q, \tau \in M'}$  are linearly independent, one can always find a partition of closed non-empty sets  $(M'_l, M'_h)$  of  $M'$  such that a type  $i$  bank lies when sending a message in  $M'_{-i}$ . Therefore, by simply deleting any message set  $H$  such that  $\overline{m'}(H) = 0$ , Lemma 4 and our previous remark directly imply that there exists a Perfect Bayesian Equilibrium  $(x', \alpha', m', p', M')$  with  $M' = M'_l \cup M'_h$ , which is payoff-equivalent to  $(x, \alpha, m, p, M)$ . Consider now the correspondence  $S: M' \rightarrow Q$  defined for every  $\tau \in M'$  as  $S(\tau) = \{q_i / m'_i(\tau) > 0\}$ . A direct application of the Marriage Theorem (see Weyl (1949) for the statement and Bester and Strausz (2001) for the details of the application) shows that there exists a mapping  $\xi: Q \rightarrow M'$  such that 1)  $m'_i(\xi(q_i)) > 0$  for every  $i$ , and 2) for every  $\tau \in M'$  there exists  $q \in Q$  satisfying  $\xi(q) = \tau$ . For any  $\tau \in M'$ , we define the non-empty set  $\Omega(\tau) \equiv \{q / \tau = \xi(q)\}$ . We are now in position to find the direct mechanism that is payoff-equivalent to our original incentive efficient equilibrium. We next define our candidate equilibrium  $(\hat{x}, \hat{\alpha}, \hat{m}, \hat{p}, \hat{Q})$ , with  $\hat{Q}_i = \{q_i\}$  for every  $i$ . We set for every  $i$  and  $j$  the variables

$$\hat{m}_i(q_j) = \frac{m'_i(\xi(q_j))}{|\Omega(\xi(q_j))|}, \hat{p}_i = p'(\xi(q_i)), \hat{x}(q_i) = x'(\xi(q_i)), \hat{\alpha}_i = \alpha'_i(\xi(q_i)), \hat{Q}_i = \{q_i\}.$$

We next show that  $(\hat{x}, \hat{\alpha}, \hat{m}, \hat{p}, \hat{Q})$  is a Perfect Bayesian Equilibrium that is payoff-equivalent to  $(x', \alpha', m', p', M')$ . We first claim that  $\hat{m}_i$  is a probability distribution over  $Q$  for every  $i$ . By construction, we have that

$$\sum_j \hat{m}_i(q_j) = \sum_{\tau \in M'} \sum_{q_j \in \Omega(\tau)} \frac{m'_i(\tau)}{|\Omega(\tau)|} = \sum_{\tau \in M'} m'_i(\tau) = 1,$$

proving the claim. We next claim that the principal beliefs  $\hat{p}$  also satisfies Bayesian consistency in the sense of (9). By construction, we have for every  $i$  and  $j$  that

$$\hat{p}_i(q_j) = p'_i(\xi(q_j)) = \frac{\gamma_i m'_i(\xi(q_j))}{\sum_k \gamma_k m'_k(\xi(q_j))} = \frac{\gamma_i \hat{m}_i(q_j)}{\sum_k \gamma_k \hat{m}_k(q_j)}.$$

Thus, we have that  $(\hat{x}, \hat{\alpha}, \hat{m}, \hat{p}, \hat{Q})$  satisfies Condition 3 in Definition 1. We next show that  $(\hat{x}, \hat{\alpha}, \hat{m}, \hat{p}, \hat{Q})$  and  $(x', \alpha', m', p', M')$  generate the same payoff to the bank. First, we notice that any allocation that a bank induces with message  $q \in Q$  under  $(\hat{x}, \hat{\alpha}, \hat{m}, \hat{p}, \hat{Q})$  can also be induced by the message  $\xi(q) \in M'$  under  $(x', \alpha', m', p', M')$ . Conversely, since for every  $\tau \in M'$  there exists  $q \in Q$  such that  $\xi(q) \in \tau$ , any allocation induced under  $(x', \alpha', m', p', M')$  by a message  $\tau \in M'$  can also be induced by the corresponding  $q$  under  $(\hat{x}, \hat{\alpha}, \hat{m}, \hat{p}, \hat{Q})$ . We have thus shown that  $\Pi_i(x', \alpha', m' / M') = \Pi_i(\hat{x}, \hat{\alpha}, \hat{m} / \hat{Q})$  for every  $i$ .

Moreover, by construction of the selection  $\xi$  we have that  $\hat{m}_i(q) > 0$  if and only if  $m'_i(\xi(q)) > 0$  for every  $i$  and  $q$ . Using this last remark, and together with the payoff equivalence proved above, we have that any strategy  $m$  is weakly dominated by  $\hat{m}$  under  $(\hat{x}, \hat{\alpha}, \hat{m}, \hat{p}, \hat{Q})$ . Thus, we have shown that Condition 2 in Definition 1 is satisfied by  $(\hat{x}, \hat{\alpha}, \hat{m}, \hat{p}, \hat{Q})$ . By the same argument as above, we can also show that  $W(x', \alpha', m' / M') = W(\hat{x}, \hat{\alpha}, \hat{m} / \hat{Q})$  for every  $i$ , and also that  $(\hat{x}, \hat{\alpha}, \hat{m}, \hat{p}, \hat{Q})$  satisfies Condition 1 in Definition 1. We have thus established that  $(\hat{x}, \hat{\alpha}, \hat{m}, \hat{p}, \hat{Q})$  is a perfect Bayesian equilibrium, and that it is payoff-equivalent to  $(x', \alpha', m', p', M')$ . By Lemma 5, it follows that  $(\hat{x}, \hat{\alpha}, \hat{m}, \hat{p}, \hat{Q})$  is also payoff-equivalent to the incentive efficient  $(x, \alpha, m, p, M)$ . Since the sets  $\hat{Q}_i (i = 1, 2)$  correspond to the reference sets upon which the regulator bases its decision to impose penalty, the proof is now complete.

### Proof of Proposition 2

We now show that, when audit occurs at the optimal contract (i.e.,  $\alpha > 0$ ), the regulator never audits for sure and the high-risk bank assigns strictly positive probability to every message. We first show by way of contradiction that  $\alpha < 1$  at the optimal contract. Assume not; i.e., assume that  $\alpha = 1$ . By (16), it must be true that

$$\frac{m\gamma_h}{m\gamma_h + \gamma_l} \pi_h(x_1) \geq c > 0, \quad (27)$$

which implies that  $m > 0$ . However, by (15), if  $\alpha = 1$  then it must be true that  $m = 0$ . This is a contradiction, and thus  $\alpha < 1$ . We next show that  $0 < m < 1$ . We first show that  $m > 0$ . Since we have established that  $0 < \alpha < 1$ , we must have from (16) that

$$\frac{m\gamma_h}{m\gamma_h + \gamma_l} \pi_h(x_1) = c, \quad (28)$$

which directly implies that  $m > 0$  since  $c$  is strictly positive. We next show that  $m < 1$  by way of contradiction. Assume that  $m = 1$ ; i.e., the high risk bank always misreports its type and the regulator offers a low-risk menu to both types of bank. We next claim that the no-audit optimal contract beats any feasible contract such that 1) menus are equal for both types, 2) random audit occurs and 3) high-risk bank lies with probability 1. Consider any such feasible contract. From (12), the highest payoff the regulator can obtain from this contract is  $W_1(x_1^*, 1) + \alpha(\gamma_h \pi_h(x_1^*) - c)$ . Moreover, since such contract is feasible and since  $\alpha > 0$ , it must be true that  $\gamma_h \pi_h(x_1^*) = c$ . Thus the highest payoff to the regulator in this case is  $W_1(x_1^*, 1)$ . However, such payoff can be attained by a feasible allocation in the no-audit optimal contract in Section III.A. From the results in this section, we know that the optimal no-audit contract is such that menus are different. Thus the no-audit contract generates a strictly higher payoff than any contract described above. Since the truth-telling contract is feasible in the reduced program, the regulator can do strictly better by offering this contract in which zero auditing is involved. Thus, we must have that  $\alpha = 0$  is a best-response. This is a contradiction, and we must have  $m < 1$ . The proof is now complete.

### ENDNOTES

1. Formally, we assume that there exists a random variable  $\varepsilon$  with 0-mean such that  $r_q = r_{q'} + \varepsilon$  with equality in the sense of sums of random variables.
2. The premium  $P$  is paid by initial shareholders, not modeled here to simplify the exposition. The same result holds if the premium is charged to the investor.
3. A similar analysis can be done by considering that the bank maximizes the equity value of initial shareholders prior to equity issuance. We omit this issue for simplicity.
4. This approach is similar to that in Khalil (1997).

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