How To Make Banks Reveal Their Risk: the Case of Basel II*

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Abstract

The paper studies implementation of risk-based capital requirements when the bank's risk and actions are private information. Hereby, the impact of commonly used measures (i.e. recapitalization, downsizing, closure and fines) on risk revelation is studied. The paper provides several policy implications: (i) capital requirements should be risk-sensitive in booms and insenstive in downturns, (ii) high transparency of banks' risk positions is needed to implement Basel II, (iii) recapitalization provides more discipline than downsizing involving outside investors and (iv) optimal contract implementing risk-based capital requirements consists of recapitalization and fine. The paper points out that eliminating incentives for risk misreporting and reducing pro-cyclicality of Basel II may not be feasible at the same time.

Keywords: banking, risk based capital requirements, Basel II, adverse selection, moral hazard.

JEL Classification: G21, G28

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1 Introduction

The New Basel Accord, called Basel II, gives banks some scope to determine their capital levels. Under the so-called IRB-approach, banks are required to adjust their capital to their risk profiles, which are assessed using banks' internal risk management models. However, as risk is private information of banks, they may understate their risk exposure in order to save on equity capital.[1] Such a behavior might lead to imbalances between risk profiles and equity capital used to cover them and, furthermore, might be detrimental to stability of banking systems and of economies as a whole. Hence, bank supervisors might be interested in curbing the banks' incentives to underreport their risk exposures. As the recent experience with the 2007 US sub-prime crisis has shown, making banks reveal their risks, before a crisis event hits, could be a challenging task: The crisis has magnified already existing concerns about the prudent use of the internal risk management models for the computation of the risk-based capital requirements (Padoa-Schioppa (2004), p. 48). Moreover, Basel II is silent about instruments facilitating the supervisory review making risk-based capital regulation viable (see also Kaufman (2003)). In the light of these concerns, the paper studies the design of supervisory schemes that can be used to elicit information about the banks' riskiness.

In the paper, I analyze implementation of risk-based capital regulation à la Basel II when risk is banks' private information.[2] Capital requirements are needed to eliminate a moral hazard problem: Inside equity capital provides incentives for banks to behave prudently. However, the capital requirements are costly in welfare terms because capital could be used to finance alternative projects. The supervisor has a choice between risk-insensitive and risk-based capital requirements. Insensitive regulation requires a fixed capital level that imposes excessive capital requirements on low risk banks.

The alternative are the risk-based capital requirements. On the one hand, they allow to reduce capital level of low risk banks. On the other, their consequence is an adverse selection problem

[1] Significance of banks' misreporting incentives is highlighted by Gunther and Moore (2003). They provide evidence on the loss underreporting by banks soon after deterioration of their financial conditions, independently of their initial risk exposure.

[2] Across the paper for the easiness of the exposition, I refer to the project's quality rather than risk. As this is immaterial for the results, it allows me to use the term "risk" in the introduction.

because only banks know their risk profile. This reintroduces the moral hazard issue, because high risk banks mimic low risk banks and take too little capital in order to behave prudently. The supervisor has to design a scheme making high risk banks report their risk truthfully. The two main tools at his disposal are the direct inspection of banks' risk and penalties. Inspection is costly, imperfect, stochastic and must take place early enough in order to detect misreporting.

In the paper, I model the interaction between the bank and the supervisor as a one-shot game, in which the supervisor can punish the bank with recapitalization, downsizing, closure or fines, when he receives a signal that the bank is undercapitalized. The incentive compatible scheme requires an inverse relationship between the level of penalty and the probability of inspection. The supervisor chooses an optimal scale of his intervention, i.e. optimal level of penalty and the probability of inspection, in order to maximize social welfare from enforcing the risk-based capital regulation.

In this framework, I show the following results. First, the necessary condition for viability of the risk-based capital requirements is high quality of inspection. Otherwise, either the high (low) risk bank misreports because probability of being caught on misreporting (of being punished by mistake) is too low (high).

Second, the disciplining effect of penalties depends crucially on the cost of equity capital. High cost of capital makes misreporting less profitable in case of recapitalization and downsizing, despite that it also fuels incentives for misreporting. The reason is that these penalties become more harmful for higher cost of capital. In case of recapitalization, the cost of injecting new equity capital is higher. In case of downsizing, the price of assets sold by the bank decreases because the outside investors finance the purchase at a higher cost. For closure, increase in the cost of capital undermines the incentives to report risk truthfully because the just described disciplining effects do not exist.

Next, I conduct welfare analysis by comparing welfare from the risk-based capital requirements implemented through the above mentioned penalties and from the risk-insensitive capital requirements. First, recapitalization yields higher welfare than downsizing. The reason is that selling of the bank's assets to outside investors generates profits, which are not present while injecting new equity capital. Second, the cost of capital has two effects on welfare: It affects savings on equity capital for the low risk bank and the cost of the supervisory intervention. Hence, risk-based regulation with recapitalization yields the highest welfare when the cost of capital is high, the one with closure when this cost is intermediate, and the insensitive regulation when it is low.

Finally, allowing the supervisor to use fines leads to the result that the optimal supervisory scheme implementing the risk-based capital requirements is a combination of recapitalization and a fine. Recapitalization eliminates moral hazard and the fine provides truthtelling incentives.

The results of my paper allow to draw several policy implications for bank capital regulation, when banks' incentives to misreport their risks threaten their stability. The main implication is that the capital requirements should be risk-sensitive with recapitalization as penalty in booms and risk-insensitive in downturns. Such a prescription follows from welfare analysis and interpretation of the cost of capital, i.e. the opportunity cost of investing in the bank for its shareholders, as a measure of the overall profitability of the projects in an economy, which is cyclical.[3] Moreover, as bank closures may not be feasible in some countries as they involve expropriation of shareholders, the capital requirements should be insensitive whenever the cost of capital is low. It is important to note that making capital requirements risk-sensitive in booms and risk-insensitive in downturns contrasts with proposals advocating dampening of the pro-cyclicality effect of Basel II.[4] As risk is anti-cyclical, these latter proposals advocate an increase of capital requirements in booms to dampen the expansion of credit and their decrease in downturns to reduce its contraction.

The second implication of the paper is that high transparency in banks' risk positions is a necessary condition for successful implementation of Basel II. If either banks are inherently opaque (Furfine (2001), Morgan (2005)) or existing risk management models cannot distinguish between low and high risks in a timely manner (Saidenberg and Schuermann (2003)), the temptation to misreport the risk is increased the probability of being caught on misreporting is small.

Finally, the supervisors should encourage the banks to use rather recapitalization with inside equity rather than interventions which involve outside investors such as downsizing. The reason is

[3]Similar interpretation of the cost of capital as proxy for the outside opportunities of the bank's shareholders is used in Parlour and Plantin (forthcoming).

[4]There is a vast literature on the pro-cyclicality effect of Basel II, see e.g. Kashyap and Stein (2004), Catarineu-Rabell, Jackson and Tsomocos (2005), Gordy and Howells (2006) and Repullo and Suarez (2008).

that the latter lead to lower discipline than the former, due to the fact that downsizing is a source of the banks' profits, which relax banks' incentives to report the risk truthfully.

The main assumptions of the model are justified as follows. Capital requirements arise due to the moral hazard problem (Santos (2000), Tirole (2001)). The inspection before the return realization is proposed in the Principle 2 of the Basel II Accord (BCBS (2004), p. 162).[5] Studied penalties for undercapitalization are the most prevalent ones in the existing supervisory intervention processes, what justifies my approach of maximizing social welfare subject to the constraint on the amount of tools at the supervisor's disposal. Recapitalization is mentioned in the Principle 4 of Basel II Accord (BCBS (2004), p. 165) and in the Prompt Corrective Action (PCA) in the USA, which contains also closure as a penalty.[6] Downsizing is used to restore the banks' equity levels as an alternative for recapitalization. The presumed cyclical behavior of the return on the alternative project (i.e. the cost of inside capital) may be backed by historical data on the return on equity for the biggest U.S. banks provided in Green, Lopez and Wang (2003).[7]

My theoretical framework is a version of the model by Holmstrom and Tirole (1997), which is adapted to study financing needs of a bank with insured deposits[8] and is extended to adverse selection in addition to moral hazard. To my best knowledge, there exist two papers concerned with optimal risk-based capital requirements when risk is banks' private information. However, in both papers penalty for misreporting is taken as given and it is abstracted from optimal design of supervisory intervention. Prescott (2004) obtains capital requirements increasing in risk for low risk levels and flat for high ones in the costly state verification setup studied by Townsend (1979) and Gale and Hellwig (1985). Blum (2007) justifies a proposal to increase capital requirements for low risk in the Basel II Accord by assuming that the penalty for misreporting is not high enough to make the high risk bank report its risk truthfully. My paper complements this literature by

[5]Importance of supervisory inspections is highlighted by Gunther and Moore (2003), and Ashcraft and Bleakley (2006). The first paper shows that the supervisory inspections are a useful tool for detecting misreporting by banks. The second paper stresses that the supervisors have better information than market investors about banks' exposures and the banks are able to use their private information against the market.

[6]See e.g. Nieto and Wall (2006) for the overview of the PCA design.

[7]Comparing this data with the GDP growth rates in the period from 1983 to 1999 suggests that both are positively correlated. Alternatively, if one uses one-year returns on T-bills as proxy for the outside investment opportunities, a similar pattern emerges.

[8]Models which use insured depositors instead of uninsured as it is done in the paper by Holmstrom and Tirole (1997) are also provided by Rochet (2004), and Cerasi and Rochet (2008).

simultaneous design of optimal capital requirements and optimal supervisory schemes, allowing for a broad discussion of policy implications.

The remainder of the paper is organized as follows. Section 2 describes the model. In Section 3 the supervisory scheme for recapitalization is derived. The same is done for downsizing in Section 4 and closure in Section 5. Section 6 presents welfare analysis. Section 7 interprets the results and contains policy implications. Section 8 discusses possible extensions. Section 9 concludes the paper. The Appendix contains proofs of the results.

2 Model

There are three agents: depositors, a bank and a supervisor.

The depositors are fully insured. The net deposit rate is r_D.

The bank is owned and managed by risk neutral shareholders protected by limited liability. Instead of investing in the bank, the shareholders can invest in an alternative project yielding a net return $\delta > r_D$.[9] This assumption is common in the banking literature (see e.g. Hellman, Murdock and Stiglitz (2000) and Repullo (2004)). Deposits are cheaper because they provide special services to depositors (not modelled here), like liquidity, not available by holding stocks.[10] The bank can invest in a project of size 1 financed with equity capital k and deposits $1 - k$.

The project's type $i = H, L$ is determined by nature and H occurs with probability π. i is a bank's private information. The gross return on the project i is deterministic and denoted as $1 + r_i$. It holds that $r_H > r_L > 0$ meaning that both projects have positive net present value and H is more valuable than L. The model can be easily extended to random project returns, but it is omitted for simplicity.[11]

Instead of operating the project i, the bank can earn private benefits b, which are socially

[9] From now on, terms bank and shareholders mean the same.

[10] Microfoundations for the assumption about deposits being cheaper than equity capital are given by Van den Heuvel (2008).

[11] I could assume the following return structure: The project yields $1 + r$ with probability $1 - p_i$ and $1 - \lambda$ with p_i, where λ is the loss given default. The projects H and L would differ in p_i. Such a structure could be interpreted as a reduced form of a model underlying the Basel II capital requirements. For a full description of this model see Repullo and Suarez (2004). Such a modelling would allow to use the term "risk" explicitly.

inefficient: $1 > b$.[12] In such a case the project of the bank fails.

The timing is as follows. First, nature chooses i. Second, the bank learns i and raises deposits and equity. Third, the bank decides, whether to operate the project i or earn private benefits. Fourth, the returns are realized.[13]

The unregulated bank finances itself only with deposits because they are cheaper than equity capital. This may be the source of a moral hazard problem, when the deposit rate is too high. The unregulated bank prefers private benefits, if the profits from the project i are lower than b:

$$1 + r_i - (1 + r_D) = r_i - r_D < b. \tag{1}$$

From now on, (1) is assumed to hold for both i.[14] Furthermore, I assume that operating the project i is profitable under 100% equity financing:

$$r_i - \delta > 0. \tag{2}$$

The behavior of the unregulated bank resulting in its default makes the deposit insurance liable against the depositors and leads to social costs. These costs encompass systemic consequences of a bank failure like disruptions in payment systems or contagion effects. Given the presence of insured deposits, there arises a need for regulation of the bank, which aims at avoiding these social costs of its failure. The power to regulate the bank belongs to a supervisor, who maximizes social welfare. The supervisor cannot observe whether the bank operates the project i, but he can observe the bank's capital level.[15] He can use this ability to eliminate the moral hazard problem by introducing capital requirements. When the shareholders' stake k in the bank is high enough the bank chooses

[12] Alternatively, I could assume that the bank can engage in inefficient excessive risk taking. The results remain unchanged.

[13] The steps 1 and 2 could be reversed. This would make the model more complex without affecting its qualitative results.

[14] (1) is a simplified version of equation (3) in Holmstrom and Tirole (1997), which introduce the need for financing the bank with inside equity.

[15] Of course, the supervisor would observe ex post that the bank has failed but then it is too late.

to operate the project i. Formally, the profits from operating the project i cannot be lower than b:

$$1 + r_i - (1 - k)(1 + r_D) \geq b.$$

Solving this inequality yields the following Lemma, which establishes the minimum capital requirements eliminating the moral hazard problem.

Lemma 1 *The minimum capital requirements eliminating the moral hazard problem are* $k_i = \frac{b - r_i + r_D}{1 + r_D}$. *It holds that* $k_H < k_L$.

The minimum capital requirements depend on i and it holds that $k_H < k_L$, because the project L yields a lower return, for which private benefits are more desirable. k_i increases, when b and r_D increase, and r_i decreases. Each change of the parameters making the project i less attractive against b requires increase in k_i.

The supervisor maximizing social welfare would like to set the lowest possible capital requirements, because equity financing is socially costly. It is so because instead of financing the alternative project yielding δ the shareholders invest in the bank.[16] However, introducing the minimal capital requirements, k_H and k_L, would lead to an adverse selection problem because i is bank's private information. In such a case, the bank L would save on capital by choosing k_H and appropriate b. The bank H would choose k_H and operate the project H.

The supervisor has two possibilities in order to solve this adverse selection problem. The first one is to introduce an insensitive capital requirement of k_L. This eliminates moral hazard, but it is burdensome for the bank H. The second possibility is to implement a supervisory scheme, which would make the capital requirements based on i viable (I call them "sensitive capital requirements").[17] The supervisory scheme consists of two instruments: An inspection taking place upon the bank's report of i and a penalty. Inspection has a cost m, is stochastic and noisy. Without loss of generality, I focus on the case in which the supervisor inspects with probability q when the

[16] One could imagine that the model concerns a representative bank in an economy. Then, the alternative project refers to new opportunities to invest the wealth of banks' shareholders with other borrowers (similar interpretation is proposed in Parlour and Plantin (forthcoming)). Implicating the shareholders' wealth in financing of the bank leads to forgoing these new opportunities and to lower lending in scale of the whole economy.

[17] As I do not introduce formally the notion of riskiness, calling these capital requirements "risk-based" would be an abuse. Using the structure proposed in the footnote 4 would allow for this.

bank reports H and there is no inspection when the bank reports L. The supervisor detects the true i with probability $\gamma > 1/2$ and receives a false signal with probability $1-\gamma$.[18] When the supervisor receives a signal contrary to the bank's report, he can impose a penalty on the bank. In the next three sections I study the following types of penalties: Recapitalization, downsizing and closure. Later I allow for optimal penalty design. Moreover, I assume that the supervisor designs the supervisory scheme taking the minimum capital requirements k_i as given. Hence, I abstract from the general problem of designing capital requirements and supervisory scheme at the same time.

The timing of the moves under regulation is as follows. First, the supervisor announces and commits to the supervisory scheme consisting of the probability of inspection q and a penalty. Second, nature chooses $i = L, H$. Third, the bank learns i, raises financing and reports i to the supervisor. Fourth, inspection is conducted, when the report is H. The supervisor punishes the bank when he receives a signal contrary to the report. Fifth, the bank decides whether to operate the project i or earn private benefits. Sixth, the returns are realized.

Finally, I introduce the following notation. If the bank operates the project i under the capital level k_i, V_i denotes its value and is equal to

$$V_i = 1 + r_i - (1-k_i)(1+r_D) - k_i(1+\delta) = r_i - r_D - (\delta - r_D)k_i.$$

3 Recapitalization

When the supervisor penalizes the bank L for misreporting with recapitalization, he orders to increase the capital level from k_H to x. When the truthful reporting is guaranteed the supervisor punishes the bank H with probability $q(1-\gamma)$. The bank H loses the difference between the cost of equity and of deposits on this additional capital level, $(\delta - r_D)x$.[19] Social welfare is the expected

[18] In a general case the probability of mistake would differ across i, but it is not essential for the results.

[19] Increase in capital means on the one hand that the bank has to repay less deposits, but it has to forgo the return on the alternative project.

value of the bank minus the implementation cost of the sensitive capital requirements:

$$W_1 = \pi V_H + (1-\pi)V_L - \pi\left[q(1-\gamma)(\delta - r_D)x + qm\right].$$

The implementation cost (the term in the square brackets) is the sum of social cost of punishing the bank H and the expected inspection cost.

The incentive compatibility (IC) constraints for truthful reporting depend on the level of x. If $x \in (0; \Delta k)$, where $\Delta k = k_L - k_H$, the IC constraint for the bank L reads

$$V_L \geq b - k_H(1+\delta) - q\gamma(1+\delta)x.$$

The right hand side of the constraint is the value of the bank L if it misreports. It always appropriates b because it is either not caught on misreporting, or misreporting is detected with probability $q\gamma$ but the increase in capital level to $k_H + x < k_L$ is not sufficient to make it operate the project L. The last constraint is equivalent to $x \geq \frac{\Delta k}{q\gamma} > \Delta k$, which is not compatible with $x \in (0; \Delta k)$.[20] Hence, the punishment cannot be lower than Δk. Furthermore, x cannot be higher than $1 - k_H$ following the assumption that the supervisor punishes only with recapitalization.[21] For $x \in [\Delta k; 1 - k_H]$ the IC constraints read

$$V_H - q(1-\gamma)(\delta - r_D)x \geq r_H - r_D - (\delta - r_D)k_L,$$

and

$$V_L \geq (1 - q\gamma)\left[b - k_H(1+\delta)\right] + q\gamma\left[V_L - (\delta - r_D)(x + \Delta k)\right]. \tag{3}$$

The first (second) constraint is for the bank H (L). The left hand side of each constraint is the bank's value under the truthful report of i. In such a case the bank H is punished with probability $q(1-\gamma)$. The constraints' right hand side is the bank's value in case of misreporting. If the bank H reports L, it operates the project H under the equity level of k_L. The bank L can earn b with

[20] Simplification is obtained by using the definition of k_i from Lemma 1.

[21] In a more general setup the penalty would be bounded by the participation constraint. This is explored in Subsection 8.1.

probability $1 - q\gamma$ and operates the project L under the capital level of $k_H + x$ with probability $q\gamma$. Both constraints can be rewritten as:

$$\frac{\Delta k}{q(1-\gamma)} \geq x \tag{4}$$

for the bank H and

$$x \geq \frac{\Delta k}{\delta - r_D}\left(\frac{1+\delta}{q\gamma} - (1 + r_D)\right) \tag{5}$$

for the bank L. x has to be high enough to make the bank L report its true type. However, it has to be bounded from above in order not to discourage the truthful report by the bank H, which may be punished if it reports truthfully. Formally, the supervisory scheme induces truthful reporting for both types, when x lies in the interval implied by (4) and (5). This interval is not empty if the upper bound on x from (4) is not smaller than the lower one from (5). This is equivalent to the following restriction on q:

$$q \geq \frac{1}{1-\gamma}\left(1 - \frac{2\gamma - 1}{\gamma}\frac{1+\delta}{1+r_D}\right) \equiv \widehat{q}. \tag{6}$$

Moreover, the IC constraints intersect at $q = \widehat{q}$ and the IC constraint for the bank L is steeper than for the bank H. Thus, in order to preserve the truth-telling incentives, marginal decrease of q requires higher increase in x for the bank L than for the bank H. The reason is that by misreporting the bank L not only saves on capital but is able to appropriate b not available for the bank H. The incentive compatible set $(q; x)$ is depicted by the grey area in Figure 1.

Incentive compatible combinations of $(q; x)$ are feasible if they satisfy $q \in [0; 1]$ and $x \in [\Delta k; 1 - k_H]$. Otherwise, the sensitive capital requirements are not viable, as the available tools (inspection and recapitalization) are not sufficient to eliminate incentives for misreporting. The following Lemma delivers the necessary condition for implementation of the sensitive capital requirements with recapitalization as penalty.

Lemma 2 *The necessary condition for implementation of the sensitive capital requirements with recapitalization as penalty is that the quality of inspection γ is sufficiently high.*

Proof. The proof is in the Appendix. ■

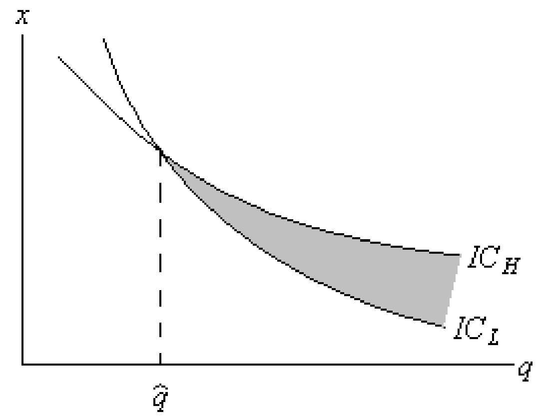

Figure 1: The incentive compatible set of $(q; x)$ is depicted with grey. IC_H and IC_L are the incentive compatibility constraints for the bank H and L.

Quality of inspection has to be high enough in order to make the sensitive capital requirements with recapitalization feasible. Otherwise either 100% equity financing ($x = 1 - k_H$) is not enough to discipline the bank L or the bank H finds misreporting better when it is punished too harsh.

Moreover, the supervisor can be constrained in the choice of q by (6), if for any γ satisfying Lemma 2 the intersection of (4) and (5) lies in the region $q \in [0; 1]$ and $x \in [\Delta k; 1 - k_H]$. The following Lemma establishes necessary and sufficient condition for which the supervisor can ignore (6) while choosing the optimal q, given that the sensitive capital requirements are feasible.

Lemma 3 *The supervisor is not constrained by (6) if and only if the return on the project H or the quality of inspection is high enough.*

Proof. The proof is in the Appendix. ■

The last Lemma is stronger than the previous one, because it guarantees in addition that the bank H does not misreport for all acceptable values of q and x.

The participation constraints can be ignored, because they are implied by the IC constraints.

When Lemma 3 holds the supervisor solves the following program while choosing the optimal supervisory scheme:

$$\max_{q,x} \; W_1, \text{ s.t.: } (5), \, q \in [0; 1], \, x \in [\Delta k; 1 - k_H].$$

As (5) binds at the optimum, it can be inserted into W_1, and after ignoring the terms independent of q and x, yielding an expression to be maximized under the remaining constraints: $-q\,(m-\overline{m})$, where $\overline{m} \equiv (1-\gamma)(r_H - r_L)$. $\overline{m}$ is marginal social cost of increase in capital level needed to preserve incentives to report truthfully when q decreases. When the cost of inspection is higher (lower) than $\overline{m}$, it is optimal to choose the lowest (highest) possible q. The result is summarized in the following Lemma.

Lemma 4 *If the conditions of Lemma 3 are satisfied, the optimal supervisory scheme with recapitalization as penalty is*

$$q_1 = \begin{cases} 1, & \text{if } m \le \overline{m} \\ \frac{1}{\gamma}\frac{\Delta k(1+\delta)}{\Delta k(1+\delta)+(\delta-r_D)(1-k_L)}, & \text{if } m > \overline{m} \end{cases} \quad \text{and } x_1 = \begin{cases} \left[\left(\frac{1}{\gamma}-1\right)\frac{1+\delta}{\delta-r_D}+1\right]\Delta k, & \text{if } m \le \overline{m} \\ 1-k_H, & \text{if } m > \overline{m}. \end{cases}$$

Comparative statics of the optimal solution is intuitive as every change of parameters undermining the bank L's truth-telling incentives (increases in r_H, b and r_D as well as decreases in δ, r_L and γ) requires increase in q_1 for $m > \overline{m}$ and in x for $m \le \overline{m}$. The most interesting comparative statics result concerns the change in δ. Although higher δ increases the incentives to misreport in the first place as the equity financing becomes more expensive, it makes also penalty more expensive. This effect disciplines the bank L willing to overstate its type and allows the supervisor to decrease the scope of his intervention.

4 Downsizing as penalty

The alternative possibility to adjust the capital structure of the bank, after the supervisor has received a signal contrary to report, is to make the bank reduce its size (downsize) to at least s_A by selling part of its project.[22] In order to increase the capital ratio through downsizing the bank has to repay at least part of the deposits using the proceeds from selling. I introduce new agents into the model: Risk-neutral investors interested in buying the bank's project, which has not matured yet. Timing of the moves is modified as follows. First, the supervisor announces q and s_A. Second, nature chooses i. Third, the bank learns i, finances itself and reports i to the

[22] I assume that the project is perfectly divisible.

supervisor. Fourth, the supervisor inspects with probability q upon receiving report of H and orders downsizing to at least s_A when he receives signal contrary to the report. Fifth, the bank chooses how much of the project it sells, $(1-s) \geq (1-s_A)$. Sixth, the investors pay $(1+p)$ for every unit of the project. Seventh, the bank decides whether to operate the project i or earn private benefits. Eighth, the returns are realized.

The investors operate on a competitive market and have the cost of capital δ like the bank's shareholders, but they do not have any access to the insured deposits and finance themselves with their own wealth.[23] The investors are able to observe s_A, q, the bank's initial capital level and the project's size $(1-s)$ the bank wants to sell. They have homogenous prior beliefs about the type of the bank, equal to the probabilities according to which the nature draws the bank's type. After observing the relevant variables, the investors build their beliefs β_i about the type i of the bank that offers to sell $(1-s)$.[24] Given the beliefs, the investors pay a price $(1+p)$ (p is called a premium) for unit of the sold project such that their participation constraint is binding, i.e. the expected cash flow from one unit of the project they buy covers their cost of financing:

$$1 + \beta_H r_H + \beta_L r_L = (1+p)(1+\delta).$$

The premium is then

$$p = \frac{\beta_H r_H + \beta_L r_L - \delta}{1+\delta}.$$

The punished bank raises $(1-s)(1+p)$ from selling of $(1-s)$ of the project. From these proceeds, $(1-s)$ has to be used to repay the deposits at par (as they have not yet matured) if $s \in (k_H; 1]$. If $s \in [0; k_H)$, the bank has to repay all deposits $(1-k_H)$ and return $(k_H - s)$ to the shareholders. The rest, $(1-s)p$, is invested into the alternative project yielding δ. Downsizing can be used to increase the capital ratio in absence of other instruments only if $p \geq 0$, which is

[23] Alternatively, the investors could use external financing and be subject to the moral hazard problem. In such a case their financiers would finance them only when they would supply enough of their own wealth to the financing.

[24] For the ease of exposition, I suppress in the notation the fact that the investors' beliefs are a function of what the investors observe. It is also obvious that the bank's initial capital level is irrelevant for the investors' beliefs, because the investors are concerned about the bank's type only if the bank sells, and this may occur only when the initial capital level is k_H.

guaranteed by (2).[25] When the bank sells $(1-s)$ of the project and operates it, it earns $s(1+r_i)$ on the remaining part of the project and $(1-s)p(1+\delta)$ from investing of the remains of the proceeds in the alternative project. If $s \in [0; k_H)$, the bank is fully equity financed and, moreover, the shareholders invest the returned $(k_H - s)$ in the alternative project too. If $s \in (k_H; 1]$, the bank's profit from operating the project i after downsizing is:

$$\begin{aligned} & s(1+r_i) + (1-s)p(1+\delta) - (s-k_H)(1+r_D) \\ = \; & s\left[r_i - r_D - (\beta_H r_H + \beta_L r_L - \delta)\right] + \beta_H r_H + \beta_L r_L - \delta + (1+r_D)k_H. \end{aligned} \tag{7}$$

If $\beta_H r_H + \beta_L r_L - \delta > r_i - r_D$, the bank would sell the whole project. I assume that this is precluded for any type of the bank and for any beliefs. The sufficient condition for this is

$$r_L \geq \delta > r_D + (r_H - r_L). \tag{8}$$

This condition guarantees that the downsizing ordered by the supervisor constitutes a penalty for the bank if $s \in (k_H; 1]$. Moreover, (8) is not empty if

$$r_H < 2r_L - r_D. \tag{9}$$

This is assumed from that point on. If $s \in [0; k_H]$, the bank's profit after downsizing is

$$\begin{aligned} & s(1+r_i) + (1-s)p(1+\delta) + (k_H - s)(1+\delta) \\ = \; & s(r_i - (\beta_H r_H + \beta_L r_L)) + \beta_H r_H + \beta_L r_L - \delta + (1+\delta)k_H. \end{aligned} \tag{10}$$

The bank H is penalized by downsizing if $\beta_H < 1$, but is indifferent for $\beta_H = 1$. However, the bank L finds it profitable to be downsized if $\beta_L < 1$ or is indifferent if $\beta_L = 1$.

Furthermore, I establish levels of s for which moral hazard does not exist after downsizing. I assume that the private benefits are proportionate to the size of the bank. After downsizing the

[25] See Section 8.4 for the discussion of the case when the bank's assets are specific in the sense that the outside investors cannot generate their full value after having purchased them. This allows for the discussion of the case when $p < 0$.

bank L does not engage in the moral hazard if:

$$s(1+r_L)+(1-s)p(1+\delta)-(1+r_D)(s-k_H) \geq \max[sb; sb+(1-s)p(1+\delta)-(1+r_D)(s-k_H)].^{26} \quad (11)$$

When the proceeds from the investing the premium in the alternative project are not enough to cover the deposit repayments, $(1+r_D)(s-k_H) > (1-s)p(1+\delta)$, then s preventing moral hazard has to fulfill:

$$0 \leq s \leq \frac{p(1+\delta)+k_H(1+r_D)}{p(1+\delta)+k_L(1+r_D)} \equiv s_{MH}(p). \quad (12)$$

$s_{MH}(p)$ depends on the investors' beliefs about the type of the selling bank through p.

The model is solved as follows. After the supervisor's announcement of q and s_A, the bank engages in a game with the investors, in which it chooses a profile of strategies prescribing the report and the amount of project sold, $(1-s) \geq (1-s_A)$.[27] The investors build their beliefs upon observing q, s_A and s, and pay $(1+p)$ consistent with the bank's optimal strategies. The bank's optimal strategy profile has to be consistent with the investors' beliefs. I define a Bayesian Nash Equilibrium of this game as follows[28]:

Definition A Bayes-Nash Equilibrium given q and s_A is characterized by:

- The bank's optimal reporting, $\widetilde{i} = H, L$, and selling strategies, $s \leq s_A$, given the investors' beliefs β_H and β_L, and
- The investors' conditional beliefs β_H and β_L about the bank's type that are consistent with the banks' optimal strategies and the premium $p = \frac{\beta_H r_H + \beta_L r_L - \delta}{1+\delta}$.

This game has plethora of equilibria, which can be categorized according to the bank's reporting strategies: Both types (i) report truthfully, (ii) report L, (iii) misreport, and (iv) report H. In equilibria of the last two types, the bank L fails with some probability. Given the assumption that the cost of bank failure is high enough to make the supervisor prevent this, I do not discuss these equilibria. I concentrate on those of the type (i) and (ii), and use the intuitive criterion to narrow

[26] For $s \in [0; k_H]$ moral hazard problem does not exist.
[27] As the supervisor commits to q and s_A he is not an active player in the game.
[28] I restrict myself only to equilibria in pure strategies.

the set of equilibria. From then on, I call the equilibria of type (i) "truth-telling equilibrium" and of the type (ii) "pooling equilibrium".

In the truth-telling equilibrium, the only type that may sell is H and the amount that it sells is precisely $(1-s_A)$ because it is not profitable to sell more. Then, q and s_A have to be such that the bank L does not misreport. In such a case, the investors observing s_A, q and a bank selling $(1-s_A)$ set $\beta_H = 1$ and $\beta_L = 0$, and offer the premium $p_H = \frac{r_H - \delta}{1+\delta}$. Unlike in the case of recapitalization, the IC constraints have three different forms depending on s_A. If $s_A \in [0; k_H]$, both types are fully equity financed and for $s_A \in (k_H; s_{MH}(p_H)]$ they retain some deposits. In both cases, the bank L would operate the project L if it mimicked H. If $s_A \in (s_{MH}(p_H); 1]$, both types still retain some deposits, but the bank L would appropriate b after downsizing. The IC constraints have familiar form (for the bank H and L respectively):

$$[1 - q(1-\gamma)]\, V_H + q(1-\gamma)V_H(s_A) \geq V_H - (\delta - r_D)\Delta k \tag{13}$$

and

$$V_L \geq (1 - q\gamma)(b - (1+\delta)k_H) + q\gamma V_L(s_A), \tag{14}$$

where

$$V_H(s_A) = \begin{cases} s_A(1+r_H) + (1-s_A)p_H(1+\delta) - (1+\delta)s_A, \text{ for } s_A \in [0; k_H) \\ s_A(1+r_H) + (1-s_A)p_H(1+\delta) - (1+r_D)(s_A - k_H) - (1+\delta)k_H, \text{ for } s_A \in [k_H; 1] \end{cases}$$

and

$$V_L(s_A) = \begin{cases} s_A(1+r_L) + (1-s_A)p_H(1+\delta) - (1+\delta)s_A, \text{ for } s_A \in [0; k_H) \\ s_A(1+r_L) + (1-s_A)p_H(1+\delta) - (1+r_D)(s_A - k_H) - (1+\delta)k_H, \text{ for } s_A \in [k_H; s_{MH}(p_H)] \\ s_A b - (1+\delta)k_H, \text{ for } s_A \in (s_{MH}(p_H); 1] \end{cases}$$

Finding constellations of s_A and q for which the truth-telling equilibrium exists, i.e. constellations satisfying (13) and (14) that are feasible, follows the analog pattern as in Section 3. Hence, I obtain an analogue of Lemma 2.

Lemma 5 *For each interval* $s_A \in [0; k_H]$, $s_A \in (k_H; s_{MH}(p_H)]$ *and* $s_A \in (s_{MH}(p_H); 1]$ *the truth-telling equilibrium exists if the quality of inspection is sufficiently high.*

Proof. Proof of the Lemma can be found in the Appendix. ■

Moreover, for $s_A \in [k_H; s_{MH}(p_H)]$, the regulator may be constrained in the choice of q by the intersection of the IC constraints as for the recapitalization. The following Lemma provides the conditions when this is irrelevant.[29]

Lemma 6 *The supervisor is not constrained in the choice of* q *if and only if the quality of inspection is sufficiently high.*

Proof. Proof of the Lemma can be found in the Appendix. ■

The pooling equilibrium can be supported by the beliefs $\beta_L = 1$, i.e. when the investors observe that a bank sells $1 - s_A$ they attach the type L to it. The following Lemma establishes the conditions under which the pooling equilibrium exists.

Lemma 7 *Pooling equilibrium always exists for* $s_A \in [k_H; 1]$. *There is no pooling equilibrium for* $s_A \in [0; k_H)$.

Proof. Proof of the Lemma can be found in the Appendix.. ■

Furthermore, there are constellations of s_A and q in which the truth-telling and pooling equilibria coexist.[30] The reason is that the pessimistic beliefs make both types report L for higher s_A than for which the truth-telling equilibrium arises, because premium is lower making misreporting less attractive. This leads to overlapping of the regions for which both equilibria exist. However, the pooling equilibrium does not survive the intuitive criterion in the region where both equilibria coexist. The reason is that the bank H can deviate by reporting its type and this is not profitable for the bank L.

When the conditions from Lemmas 5 and 6 hold, the supervisor solves the following problem:

$$\max_{q,s_A} W_2 = \pi\left[(1 - q(1-\gamma))V_H + q(1-\gamma)V_H(s_A) - qm\right] + (1-\pi)V_L.$$

[29] For the case of downsizing it is not easy to combine the conditions from Lemma 5 with the conditions for which the supervisor is not constrained in the choice of q as it is done in the case of recapitalization.

[30] It is easy to verify by simply comparing the IC constraints for both equilibria.

s.t.:

$$(14),\ s \in [0;1] \text{ and } q \in [0;1].$$

The optimal solution is given by the following Lemma.

Lemma 8 *When the conditions from Lemmas 5 and 6 hold, the optimal supervisory scheme with downsizing as penalty is*

$$q_2 = \begin{cases} \frac{1}{\gamma}\frac{1+\delta}{1+r_D}\frac{b+r_D+r_H-r_L-\delta}{b}, & \textit{if } m \le \overline{\overline{m}} \\ \frac{1}{\gamma}\frac{\Delta k(1+\delta)}{(\delta-r_D)-k_H(\delta-r_D+r_L-r_H)}, & \textit{if } m > \overline{\overline{m}} \end{cases} \quad \textit{and } s_A = \begin{cases} s_{MH}(p_H), & \textit{if } m \le \overline{\overline{m}} \\ k_H, & \textit{if } m > \overline{\overline{m}}. \end{cases}$$

The comparative statics of the optimal solution is the same as for the case of recapitalization. Higher δ allows to decrease the scope of the supervisory intervention because the higher cost of financing for the investors is passed onto the bank in the form of a lower premium, increasing the disciplining effect of downsizing.

5 Closure as penalty

An alternative way of punishing the bank for misreporting is to intervene and transfer it to new shareholders. The new shareholders run the bank with the capital level of k_L preventing reoccurrence of the moral hazard problem. I assume the closure and the transfer have social cost of S. The supervisor maximizes

$$W_3 = \pi\left[V_H - q(1-\gamma)(S + (\delta - r_D)\Delta k) - qm\right] + (1-\pi)V_L.$$

Social cost of the penalty amounts to S and the increase in the capital requirements to k_L. Because the penalty is fixed and W_3 is decreasing in q the supervisor chooses the smallest q that is incentive compatible.

The incentive compatibility (IC) constraints read (for the bank H and L respectively)

$$\left[1 - q(1-\gamma)\right]V_H \ge V_H - (\delta - r_D)\Delta k \text{ and } V_L \ge (1 - q\gamma)\left[b - k_H(1+\delta)\right].$$

The constraints differ from (3) only in one detail. The bank H (L) receives nothing with probability $q(1-\gamma)$ when it reports truthfully ($q\gamma$ when it misreports).

As the IC constraint for the bank L is binding the optimal probability of inspection is

$$q_3 = \frac{1}{\gamma}\frac{\Delta k(1+\delta)}{V_H}.$$

q_3 cannot be higher than 1 and has to be incentive compatible for the bank H. Both conditions are fulfilled if

$$\gamma \geq \max\left\{\frac{\Delta k(1+\delta)}{r_H - r_D - (\delta - r_D)k_H}; \frac{1+\delta}{1+2\delta - r_D}\right\}.^{31} \qquad (15)$$

This condition is the analogue of Lemma 3.

There is one difference in the comparative statics results for q_3 with respect to the previous two cases: q_3 is increasing in δ. The reason is that in case of closure the only effect that δ has on the incentives to misreport is the effect on the cost of bank's financing with equity. If δ increases, equity financing becomes more expensive making the bank L more willing to misreport. This requires increase in the probability of inspection.

6 Welfare analysis

This section starts with welfare comparison of the sensitive capital requirements with recapitalization and downsizing as penalties, which leads to the following Lemma.

Proposition 1 *If the conditions from Lemmas 3, 5 and 6 are satisfied, the sensitive capital requirements with recapitalization as penalty deliver strictly higher welfare than those with downsizing as penalty.*

Proof. The proof can be found in the Appendix. ■

The reason why recapitalization as penalty delivers higher welfare is that downsizing is a less severe penalty than recapitalization. As downsizing creates profits in the form of positive premium

[31] The first term comes from the condition $q_2 \leq 1$. The second arises after inserting q_2 into the incentive compatibility constraint of the bank H.

for the bank, the IC constraint for the bank L tightens requiring an increase in the scope of the supervisory intervention.

Next, I consider the insensitive capital requirements of k_L for both banks. Social welfare from this type of regulation is

$$W_0 = \pi V_H + (1-\pi)V_L - \pi(\delta - r_D)\Delta k.$$

The last term is social cost of the insensitive capital requirements: The bank H bears too high equity cost. First, I compare this type of capital requirements with the sensitive ones with recapitalization as penalty. The difference in social welfare between them is

$$\Delta W_1 = W_1 - W_0 = \pi\left[(\delta - r_D)\Delta k - q_1(1-\gamma)(\delta - r_D)x_1 - q_1 m\right].$$

ΔW_1 is the difference between social benefits of lowering the regulatory burden on the bank H and the implementation cost of the sensitive capital requirements with recapitalization. The following Proposition establishes constellations of γ and δ for which $\Delta W_1 > 0$.

Proposition 2 *For each $\delta \in (r_D; r_L)$ there is $\gamma_1(\delta) > 1/2$ such that the sensitive capital requirements with recapitalization yield strictly higher welfare than the insensitive capital requirements for $\gamma > \gamma_1(\delta)$, and strictly lower welfare otherwise. The function $\gamma_1(\delta)$ is strictly decreasing in δ.*

Proof. The proof can be found in the Appendix. ■

The Proposition 2 states that the sensitive capital requirements with recapitalization dominate in welfare terms the insensitive ones when the inspection quality γ and the cost of equity δ are sufficiently high. Higher γ is beneficial because the bank H is punished less frequently and it allows to decrease the scope of the supervisory intervention. Higher δ translates to higher savings for the bank H on equity capital and to a stronger disciplining effect of recapitalization as penalty. The positive effects of γ and δ on ΔW_1 create a trade-off between them, which is reflected in $\gamma_1(\delta)$ being strictly decreasing. The result from Proposition 1 is depicted in Figure **??**. The line $\gamma(\overline{m})$

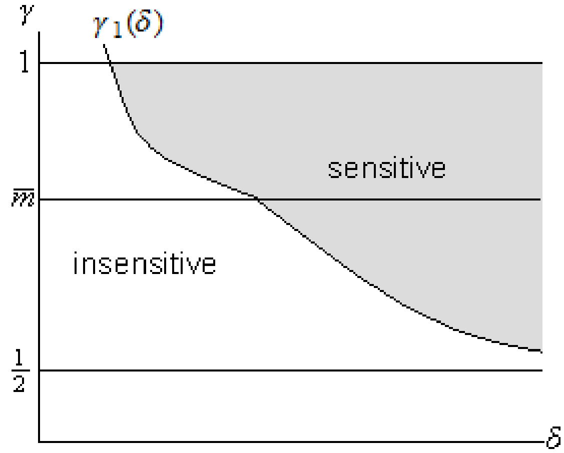

Figure 2: The dominance region of the sensitive capital requirements with recapitalization is depicted in grey. The figure is presented for the case when (16) is not the part of $\gamma_1(\delta)$.

separates the two cases arising in Lemma 3: The case with $m > \overline{m}$ is relevant above this line and $m < \overline{m}$ below. The region above of $\gamma_1(\delta)$ represents constellations of δ and γ, for which the sensitive capital requirements deliver higher social welfare than the insensitive ones. Below $\gamma_1(\delta)$ the opposite holds.

Second, I compare welfare from the insensitive and the sensitive capital requirements with closure as penalty. The difference in social welfare is

$$\Delta W_3 = W_3 - W_0 = \pi \left[(\delta - r_D)\Delta k \left[1 - q_3 \left(1 - \gamma\right)\right] - q_3 \left(m + S(1 - \gamma)\right) \right].$$

The following Proposition summarizes the result of the comparison.

Proposition 3 *For each $\delta \in (r_D; r_L)$ there is $\gamma_2(\delta) > 1/2$ such that the sensitive capital requirements with closure yield strictly higher welfare than the insensitive capital requirements for $\gamma > \gamma_2(\delta)$, and strictly lower welfare otherwise. The function $\gamma_2(\delta)$ is first decreasing and then increasing in δ.*

Proof. The proof can be found in the Appendix. ■

The increasing cost of capital has two countervailing effects on ΔW_3. The first effect leads to higher savings on equity for the bank H. The second effect is increase in q_3 due to higher incentives

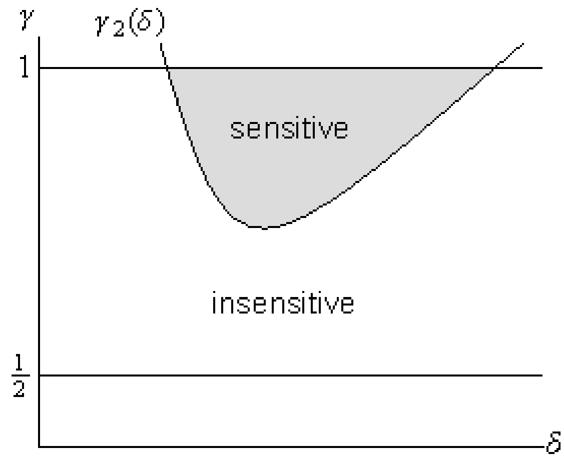

Figure 3: The dominance region of the sensitive capital requirements with closure is depicted in grey.

to misreport. The result may be a non monotonic frontier separating the dominance regions as depicted in Figure 3.

Finally, I compare social welfare for the sensitive capital requirements with recapitalization and closure as penalty.[32] The difference in social welfare is

$$\Delta W_{31} = W_3 - W_1 = \pi \left[(q_1 - q_3)m + (1-\gamma)(\delta - r_D) \left[q_1 x_1 - q_3 \Delta k \right] - (1-\gamma) q_3 S \right].$$

Closure is less socially costly when $S < \overline{S}$, where

$$\overline{S} \equiv \left(\frac{q_1}{q_3} - 1 \right) \frac{m}{1-\gamma} + (\delta - r_D) \left(\frac{q_1}{q_3} x - \Delta k \right).$$

$\overline{S}$ consists of the differences in the expected inspection cost (the first term) and in the social cost of increase in capital requirements (the second term) between these two penalties. The derivation of the last expression with respect to δ delivers the following proposition.

Proposition 4 *For $m > \overline{m}$ $\overline{S}$ is decreasing function of δ. For $m < \overline{m}$ $\overline{S}$ is first increasing in δ and then decreasing in δ.*

[32] I skip the comparison of the sensitive capital requirements with downsizing because they provide lower welfare than those with recapitalization.

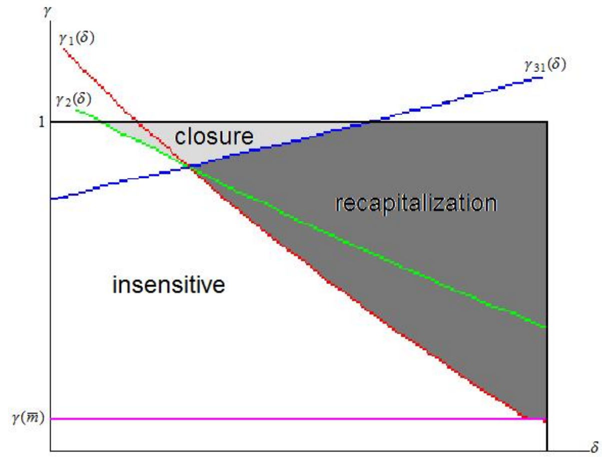

Figure 4: The dominance regions of the three different types of capital requirements. The dominance region of the capital requirements with recapitalization is depicted with dark grey, the ones with closure with light grey and the insensitive ones are without color.

The intuition behind Proposition 4 is the following. First, $\overline{S}$ decreases with δ due to the impact of increase in δ on the truth-telling incentives: q_3 increases, while q_1 decreases (for $m > \overline{m}$) or does not change (for $m \leq \overline{m}$). This affects both terms in $\overline{S}$ negatively. Second, $\overline{S}$ increases with δ due to welfare loss from increased difference between the cost of capital and deposits, $(\delta - r_D)$. It turns out that for sufficiently high m the negative effect on $\overline{S}$ is always stronger leading to $\overline{S}$ decrease with δ. For low m it may be that $\overline{S}$ first increases and then decreases with δ. For very low δ it turns out however that this result is irrelevant as for such δ the higher welfare is delivered by the insensitive capital requirements (see Propositions 2 and 3).

The last three propositions allow for a general conclusion that the sensitive capital requirements with recapitalization as penalty deliver the highest welfare when δ is high, the one with closure for intermediate δ and the insensitive ones for low δ. It is important to note that this result can be obtained analytically for $m > \overline{m}$. It turns out that the frontier in the $(\delta; \gamma)$-diagram is increasing and recapitalization delivers higher welfare for constellations below of this frontier for sufficiently high S. Such an analytical result is not possible for the case $m < \overline{m}$. In such a case the above stated conclusion follows as the frontier separating both regimes is increasing in $(\delta; \gamma)$-diagram and the recapitalization yields higher welfare below this frontier. Figure 4 supports this conclusion.[33]

[33] I do not provide a figure for the case $m < \overline{m}$ as it is similar to Figure 4.

Figure 4 puts together figures 2 and 3 as well as it includes the frontier $\gamma_{31}(\delta)$, which separates the two regimes of the sensitive capital requirements. The figure highlights also the importance of high γ for welfare yielded by the sensitive capital requirements with closure. If γ is too low then, it may not be possible that closure yields the highest welfare for any δ. It is due to the high cost of closure: If the quality of inspection is low and this cost is incurred more often, then recapitalization may turn to be always better.

7 Interpretation of the results and policy implications

Welfare analysis provides the main result of the paper. For given γ, the sensitive capital requirements with recapitalization as penalty deliver the highest welfare when δ is high, with closure when δ is intermediate and the insensitive capital requirements when δ is low. δ could be interpreted as the overall profitability of the projects in the economy,[34] meaning that δ is higher in booms than in downturns. According to that interpretation, recapitalization may help to implement the sensitive capital requirements at low cost during booms, when the banks fear of losing profitable opportunities in case of additional equity capital injection when caught on misreporting. During downturns when the outside opportunities to invest are not so favorable, the solution delivering the highest welfare is either to support the risk-sensitive capital requirements with closures or to introduce the risk-insensitive capital requirements, if closures are not feasible or δ is very low. Making the capital requirements risk-sensitive in booms and -insensitive in downturns stays in opposition to current proposals to increase them in booms and lower in downturns in order to eliminate magnification of the economic cycles.

Next, the necessary condition for the viability of the sensitive capital requirements is sufficiently high γ (see Lemma 2, 5 and (15)). First, if γ represents the degree of banks' opacity and this opacity is high enough, it may be impossible to implement Basel II. If γ is interpreted as the quality of statistical tests used to test the internal risk management models implemented by banks to supply data required for computing the capital requirements,[35] it has been argued that these

[34] For similar interpretation see Parlour and Plantin (forthcoming).

[35] To capture fully the nature of such statistical tests, γ could depend on i. However, it is a minor adjustment and it does not change the results at all. It would come only at a cost of further complication of the model.

tests may not be suitable for the credit risk models (Saidenberg and Schuermann (2003)). Default events are quite rare, especially in booms, hence such tests may fail to deliver conclusive results about risks borne by banks.[36] Hence possibly in downturns, when the defaults tend to cluster, there may be enough data to distinguish banks with low and high risk. A similar situation had occurred in the period prior to the 2007 US sub-prime crisis. The risk management models had failed to reveal what risks the banks had had on their books, before the crisis event hit.

Furthermore, it is interesting to note that the supervisors should encourage banks to recapitalize rather than the downsize as penalty for undercapitalization. The former constitutes a harsher punishment for banks than the latter.

8 Extensions

8.1 Fine as a penalty

Formally, closure equals to taking away the profits from the shareholders. This could also be achieved through a combination of recapitalization, downsizing and a fine f, without involving cost of closure. Theoretically, there are many other ways to decrease the payoff of the owners of the bank (e.g. banning them from the banking business for life-time), but I concentrate on the pecuniary measures that have been used by the supervisors until now. Proposition 2 allows us to disregard downsizing as it is more costly than recapitalization. Given (2), recapitalization cannot lead to taking away all the profits from the shareholders, hence it has to complemented with the fine. The fine has a different disciplining effect than recapitalization. In the latter case the bank looses only the difference between the cost of capital and deposits, $\delta - r_D$, on the additional equity financing. In the former case the bank's shareholders loose their wealth in the amount f and its opportunity cost δ. Moreover, the fine has to be levied at the time of inspection, because it does not harm the bank L, which goes bankrupt a fine collected after the returns have been realized. However, the fine cannot substitute fully recapitalization as a penalty. The reason is that the fine does not eliminate the moral hazard problem as it has to paid before the bank decides whether it

[36] In light of footnote 2, I call in this Section the bank L the high risk bank and the bank H the low risk bank.

operates the project i or appropriates b.

The supervisor solves the following program:[37]

$$\max_{q,x,f}\pi\left[V_H - q(1-\gamma)((\delta - r_D)x + \delta f)) - qm\right] + (1-\pi)V_L$$

s.t.:

$$r_L - r_D - (k_H + x)(\delta - r_D) - f(1+\delta) \geq b - (k_H + x)(1+\delta) - f(1+\delta),$$

$$V_L \geq (1-q\gamma)\left[b - k_H(1+\delta)\right] + q\gamma\left[r_L - r_D - (k_H + x)(\delta - r_D) - f(1+\delta)\right],$$

$$r_L - r_D - (k_H + x)(\delta - r_D) - f(1+\delta) \geq 0,$$

$$0 \leq q \leq 1.$$

The first constraint eliminates the moral hazard. It is obvious the fine is not able to eliminate moral hazard. The second constraint is the truth-telling constraint of the bank L and the third is its participation constraint. The program delivers the following optimal solution:

Lemma 9 *If $m \geq (1-\gamma)r_D\Delta k$, then the optimal solution entails $q = \frac{1}{\gamma}\frac{\Delta k(1+\delta)}{r_H - r_D - (\delta - r_D)k_H}$, $x = \Delta k$ and $f = \frac{V_L}{1+\delta}$. If $m < (1-\gamma)r_D\Delta k$, then the optimal solution entails $q = 1$, $x = \Delta k$ and $f = \frac{1-\gamma}{\gamma}\Delta k$.*

Proof. The proof can be found in the Appendix. ■

The optimal contract implementing the sensitive capital requirements is a combination of recapitalization and fine. Recapitalization eliminates the moral hazard problem and the fine is used to contain the misreporting incentives. Interestingly enough, taking away all profits of the bank is optimal only if the cost of inspection is sufficiently high ($m \geq (1-\gamma)r_D\Delta k$).

8.2 Constrained supervisor

Sometimes the supervisor may be allowed to choose freely only q, given an exogenously prescribed level of penalty. In such a case, it may happen that the penalty may be too low to be incentive compatible for the bank L, even for $q = 1$. Blum (2007) suggests that an increase in the capital

[37] I assume here that the parameters are such that the IC constraint for the bank H is satisfied and the supervisor is not constrained in choice of q (analogue of Lemma 3 holds).

requirement for the bank H could resolve this problem by decreasing gains from misreporting and restoring incentives for truth-telling. However in my setup, it is not clear whether this measure should be better than the insensitive capital requirements, which are optimal when the incentive compatibility of the sensitive ones cannot be reached. Increasing the capital requirements for the bank H can make the sensitive capital requirements viable again, but it still needs penalties that are socially costly, making this solution not necessarily better than the insensitive capital requirements.

8.3 No commitment case

Assumption that the supervisor is able to commit ex ante to a certain probability of inspection may seem sometimes unrealistic. Moreover, ex ante commitment scheme is ex post inefficient, because the bank L behaves prudently in equilibrium and the bank H is punished. Lack of commitment to q requires that the supervisor chooses it after the bank's report. This induces a standard inspection game (see e.g. Khalil (1997)) which may have an equilibrium in mixed strategies in inspection and misreporting of the bank L. The no commitment case is tedious to analyze as there are cases in which equilibria in pure strategies arise.[38] However the qualitative results remain unchanged. Furthermore, in my setup no commitment always delivers lower social welfare than commitment. The reason is that, in addition to the punishment of the bank H, the bank L sometimes goes bankrupt as it cheats with a positive probability, what does not occur in the commitment case.

8.4 Asset-specificity

Acharya and Yorulmazer (2007) argue that the outside investors may be inefficient users of assets purchased from banks for the following reasons. First, the investors may be unable to generate full returns because they lack expertise in the acquired assets. Second, assets' sales may suffer from "fire-sale" discounts especially when many banks fall into distress at the same time. Formally, both possibilities could be modelled by introducing a discount $\lambda > 0$ on the net return earned by the investors purchasing the bank's project. This discount has two effects on welfare. On the

[38] The note with the full analysis of this case can be obtained on request.

one hand, social welfare decreases because the value of the project i is lower. On the other hand, the supervisor can decrease the scope of his intervention because $\lambda > 0$ makes downsizing more harmful for the banks as p decreases. This latter effect makes downsizing more attractive as a penalty relative to recapitalization. Indeed, one can prove the following Proposition.[39]

Proposition 4 *If $\lambda \in (r_H - r_L; r_H - \delta]$, the sensitive capital requirements with downsizing as penalty yield strictly higher welfare than those with recapitalization. If $\lambda \in [0; r_H - r_L)$, the opposite is true. If $\lambda = r_H - r_L$, both yield the same welfare.*

The upper bound on λ, $r_H - \delta$, comes from the fact that selling of the project can be used to reduce the bank's size as long as $p \geq 0$.[40] Hence, sufficiently high λ makes downsizing a viable solution for implementation of the sensitive capital requirements. The question arises how relevant $\lambda > 0$ is in this model. James (1991) provides empirical evidence for significant decrease in the value of sold assets during liquidations of failed banks. However, my model considers the case of selling the assets by banks that are allowed to continue. In reality, such banks have some time to sell their assets, hence the fire-sale discounts may not be so severe and recapitalization may still be better than downsizing. Moreover, during a severe distress when many banks have to sell their assets simultaneously, λ may be so high that downsizing as a measure to recapitalize may not be feasible at all ($p < 0$).

9 Conclusions

The paper has been concerned with the design of the supervisory schemes under the risk-based capital requirements à la Basel II, when bank's risk and actions are its private information. The supervisor punishes the bank, when the signal received during inspection is different from the bank's risk report. Conditions for viability of Basel II and several policy implications have been derived.

The necessary condition to make the banks report their risk truthfully is high quality of inspection. High cost of capital increases incentives for truthful risk reporting under recapitalization

[39] The proof of this result is omitted as it follows the lines of the proof of the Proposition 2.

[40] $\lambda \leq r_H - \delta$ guarantees that $p_H \geq 0$.

and downsizing. This may be surprising as high cost of capital is the reason why the banks may understate their riskiness. In case of closure the opposite is true. Moreover, penalties based on involvement of outside investors such as downsizing lead to lower discipline than injections of inside equity capital.

The main policy implication of the paper is that it may be desirable to make the capital requirements "anti-cyclical": Risk-sensitive in booms supported by a threat of recapitalization, and risk-insensitive in downturns. This conclusion contrasts with the proposals calling for reducing the pro-cyclicality effect of Basel II. This paper with its focus on incentives for reporting the risk highlights the complexity of issues arising due to the introduction of risk-based capital regulation à la Basel II. It also suggests that eliminating risk misreporting incentives and the pro-cyclicality impact in Basel II may not be achievable at the same time. Following this ambiguity of policy implications, coming from the complexity of issues raised by Basel II, an empirical question arises whether and to which extent Basel II will solve the existing problems in the banking industry. This question however can be answered only with a delay.

10 Appendix

Proof of Lemma 2. The incentive compatible set of $(q; x)$ is feasible if and only if the following conditions are satisfied: $\widehat{q} \leq 1$ and the lower bound on x from (5) for $q = 1$ cannot be higher than $1 - k_H$. This is equivalent to:

$$1 \geq \gamma \geq \max \left\{ \frac{(1+\delta)\Delta k}{\Delta k(1+\delta) + (\delta - r_D)(1-k_L)}; \frac{1+\delta}{1+r_D} - \sqrt{\frac{1+\delta}{1+r_D}\left(\frac{1+\delta}{1+r_D} - 1\right)} \right\}. \tag{16}$$

The first term is obtained by inserting $x = 1 - k_H$ and $q = 1$ into (5) and solving for γ. The second term is the smaller solution of the quadratic inequality implied by $\widehat{q} \leq 1$. Both terms are smaller than 1 and the second term is also bigger than 1/2. ■

Proof of Lemma 3. (6) can be ignored if $\widehat{q}$ is not higher than q for which (5) is equal to $1 - k_H$.

This is equivalent to

$$1 \geq \gamma \geq \frac{(1+\delta)(1-k_H)}{(1+\delta)(1-k_H)+\Delta k(1+\delta)+(\delta-r_D)(1-k_L)}.^{41} \tag{17}$$

Comparing three lower bounds from (16) and (17) leads to the conclusion that if $r_H - r_L \geq 1 + r_L - b$, then the first lower bound from (16) is always higher than the other two. When $r_H - r_L < 1 + r_L - b$, then the functions of γ depending on δ implied by these three bounds cross each other at $\delta = \frac{(\Delta k)^2 + r_D(1-k_L)^2}{(1-k_H)(1+k_H-2k_L)} \equiv \widetilde{\delta}$. $\widetilde{\delta}$ is higher than r_D because it holds that $(1-k_L)^2 > (1-k_H)(1+k_H-2k_L)$. However, $\widetilde{\delta}$ is not always smaller than r_L. It is smaller iff $r_H < r_L + (1+r_L-b)\sqrt{\frac{r_L}{1+r_L}}$. If this does not hold, then again the first bound from (16) is always the highest of all three. It is important to note that $r_L + (1+r_L-b)\sqrt{\frac{r_L}{1+r_L}} < 1 + 2r_L - b$. If the last condition holds, then for $r_D \leq \delta < \widetilde{\delta}$ the first of these lower bounds is the highest. When $\widetilde{\delta} < \delta < r_L$, then the lower bound from (17) is the highest and the first lower bound from (16) is the lowest. Hence, (6) is relevant, if γ lies between the second lower bound from (16) and the lower bound from (17). The supervisor is not constrained by (6), iff $r_H \geq r_L + (1+r_L-b)\sqrt{\frac{r_L}{1+r_L}}$ or $r_H < r_L + (1+r_L-b)\sqrt{\frac{r_L}{1+r_L}}$ and

$$1 \geq \gamma \geq \max\left\{\frac{(1+\delta)\Delta k}{\Delta k(1+\delta)+(\delta-r_D)(1-k_L)}; \frac{(1+\delta)(1-k_H)}{(1+\delta)(1-k_H)+\Delta k(1+\delta)+(\delta-r_D)(1-k_L)}\right\}.$$

The first condition, $r_H \geq r_L + (1+r_L-b)\sqrt{\frac{r_L}{1+r_L}}$, is valid if and only if the lower bound is not higher than $b + r_D$. Such an quadratic inequality in b delivers solution that b has to bigger or equal to $(1+r_D)\sqrt{r_L(1+r_L)} - r_D(1+r_L)$, which is always higher than $r_L - r_D$. Hence the first condition for the Lemma 3 holds for b sufficiently high. However, if this is not the case or r_H is sufficiently small, then one needs in addition sufficiently high γ to obtain Lemma 3. ■

Proof of Lemma 5. I start the proof with the case, which is the closest to the case of recapitalization.

(i) $s_A \in [k_H; s_{MH}(p_H)]$. After inserting $V_H(s)$ and $V_L(s)$ into (13) and (14) and rearranging them, they become

$$s \geq 1 - \frac{\Delta k}{q(1-\gamma)} \text{ and } s \leq 1 - \frac{\Delta k}{\delta - r_D + r_L - r_H}\left(\frac{1+\delta}{q\gamma} - (1+r_D)\right). \tag{18}$$

[41] The lower bound lies between $\frac{1}{2}$ and 1.

The procedure to find out for which parameters the incentive compatible set of $(q; s_A)$ is feasible is not empty is the same as in the case of recapitalization. Using again the notation for $q = \widehat{q} = \frac{1}{\gamma}\frac{1+\delta}{1+r_D} - \frac{1}{1-\gamma}\frac{\delta - r_D + r_L - r_H}{1+r_D}$ in which both constraints intersect, this region is not empty if s for which the constraints intersect is not higher than $s_{MH}(p_H)$ and $\widehat{q} \leq 1$. The first condition is equivalent to $1 \geq \gamma \geq \frac{1}{1+\frac{b}{1+\delta}} > 1/2$ (this is guaranteed by the fact that $1 > b > r_H - r_D$) and the second to

$$1 \geq \gamma \geq \frac{2(1+\delta) + r_L - r_H - \sqrt{(2(1+\delta) + r_L - r_H)^2 - 4(1+r_D)(1+\delta)}}{2(1+r_D)} > 1/2.$$ [42]

The region in which s_A and q make the banks report truthfully is not empty for

$$1 \geq \gamma \geq \max\left[\frac{2(1+\delta) + r_L - r_H - \sqrt{(2(1+\delta) + r_L - r_H)^2 - 4(1+r_D)(1+\delta)}}{2(1+r_D)}; \frac{1}{1+\frac{b}{1+\delta}}\right]. \quad (19)$$

(ii) $1 \geq s_A > s_{MH}(p_H)$. The constraint for the bank H remains like the one in the case above. For the bank L after inserting $V_L(s_A)$ into the IC constraint, it gets $s \leq 1 - \frac{\Delta k(1+\delta)}{bq\gamma}$. This time the IC constraints for both types do not cross, hence the region in which the equilibrium may exist is not empty when the IC constraint for L is above of the one for H. This requires that $1 \geq \gamma \geq \frac{1}{1+\frac{b}{1+\delta}}$. Moreover, combinations of $(s_A; q)$ which are incentive compatible for both types are feasible iff the IC constraint for the bank L lies above of $s_{MH}(p_H)$ for $q = 1$. This requires that

$$1 \geq \gamma \geq \max\left[\frac{1+\delta}{1+r_D}\frac{b - (\delta - r_D) + r_H - r_L}{b}; \frac{1}{2}\right].$$

The last condition holds iff the first term in the square brackets is not higher than 1. This holds iff $\min\left[(1+\delta)\left(1 - \frac{r_H - r_L}{\delta - r_D}\right); 1\right] > b > r_H - r_D$. However this interval is not empty if (8) is strengthened to

$$\delta - r_D - r_H + r_L \geq \frac{\delta - r_D}{1+\delta}(r_H - r_D).$$

[42] This is guaranteed by (8).

Hence the incentive compatible $(s_A; q)$ are feasible iff

$$\delta - r_D - r_H + r_L \geq \frac{\delta - r_D}{1+\delta}(r_H - r_D) \text{ and } 1 \geq \gamma \geq \max\left[\frac{1+\delta}{1+r_D}\frac{b-(\delta-r_D)+r_H-r_L}{b}; \frac{1}{1+\frac{b}{1+\delta}}\right]. \tag{20}$$

(iii) $s_A \in [0; k_H]$. This case differs from the previous ones due to the full equity financing. First, the bank H is indifferent between selling or not. Second, the selling is profitable for the bank L when it reports H and does not constitute penalty any more.[43] The IC constraints are equivalent to

$$q \leq \max\left[\frac{\Delta k}{(1-k_H)(1-\gamma)}; 1\right] \text{ and } s \geq \frac{1+\delta}{(1+r_D)q\gamma} - \frac{(\delta - r_D)(1-k_H)}{r_H - r_L}. \tag{21}$$

The combinations of q and s_A are incentive compatible for both banks if the IC condition for the bank L is below of k_H for $q = \max\left[\frac{\Delta k}{(1-k_H)(1-\gamma)}; 1\right]$. This is equivalent to

$$k_H \geq \frac{1+\delta}{(1+r_D)q\gamma} - \frac{(\delta - r_D)(1-k_H)}{r_H - r_L} \text{ and } q = \max\left[\frac{\Delta k}{(1-k_H)(1-\gamma)}; 1\right].$$

If $\gamma \geq \frac{1-k_L}{1-k_H}$, then $q = 1$ and the incentive compatible $(s_A; q)$ are feasible iff $1 \geq \gamma \geq \max\left[\frac{1-k_L}{1-k_H}; \frac{(1+\delta)\Delta k}{(\delta-r_D)(1-k_H)+k_H(r_H-r}\right.$
If $\gamma < \frac{1-k_L}{1-k_H}$, then the incentive compatible $(s_A; q)$ are feasible iff $\gamma \in \left[\frac{(1+\delta)(1-k_H)}{(1+2\delta-r_D)(1-k_H)+k_H(r_H-r_L)}; \frac{1-k_L}{1-k_H}\right]$ and this interval is not empty. It turns out that if $\frac{1-k_L}{1-k_H} \geq \frac{(1+\delta)(1-k_H)}{(1+2\delta-r_D)(1-k_H)+k_H(r_H-r_L)}$, then it holds that $\frac{1-k_L}{1-k_H} \geq \frac{(1+\delta)(1-k_H)}{(1+2\delta-r_D)(1-k_H)+k_H(r_H-r_L)} \geq \frac{(1+\delta)\Delta k}{(\delta-r_D)(1-k_H)+k_H(r_H-r_L)}$. Then the incentive compatible $(s_A; q)$ are feasible iff $1 \geq \gamma \geq \frac{(1+\delta)(1-k_H)}{(1+2\delta-r_D)(1-k_H)+k_H(r_H-r_L)}$. If $\frac{1-k_L}{1-k_H} \leq \frac{(1+\delta)(1-k_H)}{(1+2\delta-r_D)(1-k_H)+k_H(r_H-r_L)}$, then it holds that $\frac{1-k_L}{1-k_H} \leq \frac{(1+\delta)(1-k_H)}{(1+2\delta-r_D)(1-k_H)+k_H(r_H-r_L)} \leq \frac{(1+\delta)\Delta k}{(\delta-r_D)(1-k_H)+k_H(r_H-r_L)}$. The incentive compatible $(s_A; q)$ are feasible iff $1 \geq \gamma \geq \frac{(1+\delta)\Delta k}{(\delta-r_D)(1-k_H)+k_H(r_H-r_L)}$. Summarizing the condition for the truth-telling equilibrium to exist becomes $1 \geq \gamma \geq \max\left[\frac{(1+\delta)\Delta k}{(\delta-r_D)(1-k_H)+k_H(r_H-r_L)}; \frac{(1+\delta)(1-k_H)}{(1+2\delta-r_D)(1-k_H)+k_H(r_H-r_L)}\right]$.

[43] It turns out however that selling everything and revealing itself is worse than mimicking H. The profit from mimicking, $s(r_L - r_H) + r_H - \delta$, is higher for all $s < 1$ than the profit from selling everything and revealing itself as the type L, $r_L - \delta$.

There exist combinations of s_A and q such that the truth-telling equilibria exists iff

$$\begin{cases} 1 \geq \gamma \geq \max\left[\frac{(1+\delta)\Delta k}{(\delta-r_D)(1-k_H)+k_H(r_H-r_L)}; \frac{(1+\delta)(1-k_H)}{(1+2\delta-r_D)(1-k_H)+k_H(r_H-r_L)}; \frac{1}{2}\right] \text{ for } s_A \in [0; k_H] \\ 1 \geq \gamma \geq \max\left[\frac{2(1+\delta)+r_L-r_H-\sqrt{(2(1+\delta)+r_L-r_H)^2-4(1+r_D)(1+\delta)}}{2(1+r_D)}; \frac{1}{1+\frac{b}{1+\delta}}\right] \text{ for } s_A \in [k_H; s_{MH}(p_H)] \\ 1 \geq \gamma \geq \max\left[\frac{1+\delta}{1+r_D}\frac{b-(\delta-r_D)+r_H-r_L}{b}; \frac{1}{1+\frac{b}{1+\delta}}\right] \text{ for } s_A \in [s_{MH}(p_H); 1] \text{ and } \delta - r_D - r_H + r_L \geq \frac{\delta-r_D}{1+\delta}(r_H - r_D) \end{cases}$$

■

Proof of the Lemma 6. $\widehat{q}$ is irrelevant for the supervisor if s, for which the IC constraints intersect, is below or at k_H. This is equivalent to

$$1 \geq \gamma \geq \max\left[\frac{(1+\delta)(1-k_H)}{(1+2\delta-r_D)(1-k_H)+k_H(r_H-r_L)}; \frac{1}{2}\right].$$

The first term in the square brackets is higher than $1/2$ iff $r_H - r_D < b < \min\left[\frac{(1+r_D)^2}{1+r_D+r_H-r_L} + r_H - r_D; 1\right]$.

■

Proof of Lemma 7. The pooling equilibrium when both report L and there is no selling at all can be supported by the out-of-equilibrium beliefs such that $\beta_L = 1$. For the case $s_A \in [k_H; s_{MH}(p_L)]$ the conditions for the pooling equilibrium are

$$[1-q(1-\gamma)]\, V_H + q(1-\gamma)\,[s(r_H - r_D - p_L(1+\delta)) + p_L(1+\delta) - (\delta - r_D)k_H] \leq V_H - (\delta - r_D)\Delta k$$

and

$$V_L \geq (1-q\gamma)(b-(1+\delta)k_H) + q\gamma\,[s(r_L - r_D - p_L(1+\delta)) + p_L(1+\delta) - (\delta - r_D)k_H]\,.$$

The pooling equilibrium exists iff q and s_A belong to the region constructed from the above conditions (appropriately transformed) and $s_A \in [k_H; s_{MH}(p_L)]$

$$\begin{aligned} s &\leq 1 - \frac{\Delta k}{r_H - r_D - p_L(1+\delta)} \frac{\delta - r_D}{q(1-\gamma)}, && (22) \\ s &\leq 1 - \frac{\Delta k}{r_L - r_D - p_L(1+\delta)} \left(\frac{1+\delta}{q\gamma} - (1 + r_D) \right) \text{ and} && (23) \\ k_H &\leq s \leq \frac{p_L(1+\delta) + k_H(1+r_D)}{p_L(1+\delta) + k_L(1+r_D)} && (24) \end{aligned}$$

which is equivalent to

$$k_H \leq s \leq \min \left[1 - \frac{\Delta k}{r_H - r_D - p_L(1+\delta)} \frac{\delta - r_D}{q(1-\gamma)}; 1 - \frac{\Delta k}{r_L - r_D - p_L(1+\delta)} \left(\frac{1+\delta}{q\gamma} - (1 + r_D) \right); \frac{p_L(1+\delta) + }{p_L(1+\delta) + } \right.$$

The region is not empty if the first two conditions for $q = 1$ are not below k_H iff ($p_L = \frac{r_L - \delta}{1+\delta}$)

$$\begin{aligned} k_H &\leq 1 - \frac{\Delta k}{r_H - r_D - p_L(1+\delta)} \frac{\delta - r_D}{(1-\gamma)} \Leftrightarrow \gamma \leq \frac{(1-k_H)(r_H - r_D - r_L + \delta) - (\delta - r_D)\Delta k}{(1-k_H)(r_H - r_D - r_L + \delta))} \\ k_H &\leq 1 - \frac{\Delta k}{r_L - r_D - p_L(1+\delta)} \left(\frac{1+\delta}{\gamma} - (1 + r_D) \right) \Leftrightarrow \gamma \geq \frac{(1+\delta)\Delta k}{(1-k_H)(\delta - r_D) + (1+r_D)\Delta k} \end{aligned}$$

This is possible iff

$$\frac{(1-k_H)(r_H - r_D - r_L + \delta) - (\delta - r_D)\Delta k}{(1-k_H)(r_H - r_D - r_L + \delta))} \geq \frac{(1+\delta)\Delta k}{(1-k_H)(\delta - r_D) + (1+r_D)\Delta k}.$$

After some manipulations, one can conclude that the pooling equilibrium exists iff the condition $r_H < 1 - b + 2r_L$ is satisfied. Then it is equivalent to

$$\delta \geq r_D - (r_H - r_L) \left(1 + \frac{\Delta k k_H}{(1-k_H)(1+k_H - 2k_L)} \right),$$

which is always satisfied given $\delta > r_D$. The condition for s_{MH} is not needed, because even if for $q = 1$ the constraint is above of s_{MH} as for q close to 0 the constraints approach $-\infty$ they have to eventually cross with s_{MH} making the region not empty. When $1 > s > s_{MH}(p_L)$ is satisfied, then the constraint for the bank L is

$$V_L \geq (1 - q\gamma)(b - (1+\delta)k_H) + q\gamma \left[sb - (\delta - r_D)k_H \right].$$

Again the constraints do not cross. The region when the equilibrium is possible is given by the following constraints

$$s \leq 1 - \frac{\Delta k}{r_H - r_D - p_L(1+\delta)} \frac{\delta - r_D}{q(1-\gamma)}, \tag{25}$$

$$s \leq 1 - \frac{(1+\delta)\Delta k}{b\gamma q} \text{ and} \tag{26}$$

$$s \geq \frac{p_L(1+\delta) + k_H(1+r_D)}{p_L(1+\delta) + k_L(1+r_D)} \tag{27}$$

Proceeding as above one can show that the region in which the pooling equilibrium exists is not empty iff $r_H < 1 - b + 2r_L$. Now it turns out that (9) is stronger than the last expression. Hence, given that (9) has to hold, then the pooling equilibrium always exists for $s \in [k_H; 1]$. Analogous proceeding yields the result that for $s \in [0; k_H)$ there is no pooling equilibrium. ■

Proof of Proposition 1. The solution for $s_A \in [0; k_H]$ is obvious: q has to be the lowest and $s_A = k_H$, i.e.

$$q(k_H) = \frac{1}{\gamma} \frac{\Delta k(1+\delta)}{(\delta - r_D) - k_H(\delta - r_D + r_L - r_H)}.$$

For $s_A \in [k_H; 1]$ there are two different incentive compatibility constraints depending whether s_A is below or above of $s_{MH}(p_H)$. When $1 \geq s_A \geq s_{MH}(p_H)$ then after inserting the IC constraint for L in C it becomes

$$qm + \frac{(1+\delta)(1-\gamma)(\delta - r_D)\Delta k}{b\gamma}$$

and the solution is again the lowest q and $s_A = s_{MH}(p_H)$. Hence

$$q(s_{MH}) = \frac{1+\delta}{\gamma(1+r_D)} \frac{b + r_D + r_H - r_L - \delta}{b}.$$

For the case $s_A \in [k_H; s_{MH}]$ the cost becomes

$$\frac{(1+\delta)\Delta k(1-\gamma)}{\gamma} \frac{\delta - r_D}{\delta - r_D + r_L - r_H} + q\left(m - \overline{\overline{m}}\right),$$

where $\overline{\overline{m}} \equiv \frac{\delta - r_D}{\delta - r_D + r_L - r_H}(r_H - r_L)(1-\gamma) > \overline{m}$. Then if $m > \overline{\overline{m}}$, then the supervisor chooses the lowest $q = q(k_H)$ and $s = k_H$ if the conditions of the Lemma 6 are satisfied. If $m < \overline{\overline{m}}$, the supervisor chooses the highest possible $q = q(s_{MH})$ and $s = s_{MH}$ if the conditions of the Lemma 6 are satisfied. It is easy to show that once, $q(k_H) \geq \widehat{q}$ and $q(s_{MH}) \leq 1$, i.e. the conditions of the Lemma 6 are satisfied, then the cost functions are continuous at the boundaries $s_A = k_H$ and $s_A = s_{MH}(p_H)$. The implementation costs of both regimes are

$$C_r = \begin{cases} \frac{1}{\gamma}\frac{\Delta k(1+\delta)}{\Delta k(1+\delta)+(\delta-r_D)(1-k_L)}\left[m+(1-\gamma)(1-k_H)(\delta-r_D)\right] & \text{if } m \geq \overline{m} \\ m+(1-\gamma)\Delta k\left(\frac{1+\delta}{\gamma}-(1+r_D)\right) & \text{if } m < \overline{m} \end{cases}$$

for recapitalization and for downsizing

$$C_s = \begin{cases} \frac{1}{\gamma}\frac{\Delta k(1+\delta)}{(\delta-r_D)-k_H(\delta-r_D+r_L-r_H)}\left[m+(1-\gamma)(1-k_H)(\delta-r_D)\right] & \text{if } m \geq \overline{\overline{m}} \\ \frac{1+\delta}{\gamma(1+r_D)}\frac{b+r_D+r_H-r_L-\delta}{b}\left[m+(1-\gamma)\frac{r_H-r_L}{b+r_D+r_H-r_L-\delta}(\delta-r_D)\right] & \text{if } m < \overline{\overline{m}}. \end{cases}$$

The comparison of welfare for recapitalization and downsizing has to be done for three intervals. The first one is for $m \geq \overline{\overline{m}}$. Here it is sufficient to compare the inspection probabilities. It turns out that $q_s > q_r \Leftrightarrow 1 > k_H$, hence recapitalization is better. Now I turn to the third interval, $m \in [0; \overline{m})$. Comparing of the cost functions delivers that the downsizing delivers higher welfare for $m > \overline{m}\frac{b(\gamma(1+r_D)-(1+\delta))+(\delta-r_D)(1+\delta)}{b(\gamma(1+r_D)-(1+\delta))+(\delta-r_D)(1+\delta)-(r_H-r_L)(1+\delta)} > \overline{m}$. This means that in this interval recapitalization delivers higher welfare too. Then it must be that in the second interval recapitalization is better too. The cost as a function of m for downsizing is $C_s(m) = \frac{(1+\delta)\Delta k(1-\gamma)}{\gamma}\frac{\delta-r_D}{\delta-r_D+r_L-r_H}+q\left(m-\overline{\overline{m}}\right)$, and for recapitalization is $C_r(m) = \frac{(1+\delta)\Delta k(1-\gamma)}{\gamma}+q\left(m-\overline{m}\right)$. First, it holds that for each penalty the cost functions are continuous at $m = \overline{m}$ and $m = \overline{\overline{m}}$. Second, it holds for the optimal q that

$$1 > \frac{1+\delta}{\gamma(1+r_D)}\frac{b+r_D+r_H-r_L-\delta}{b} > \frac{1}{\gamma}\frac{\Delta k(1+\delta)}{(\delta-r_D)-k_H(\delta-r_D+r_L-r_H)} > \frac{1}{\gamma}\frac{\Delta k(1+\delta)}{\Delta k(1+\delta)+(\delta-r_D)(1-k_L)},$$

meaning that the slope of $C_s(m)$ is higher than of $C_r(m)$ for $m > \overline{m}$. These two facts together with the fact that in the first and third interval recapitalization has lower cost, leads to the conclusion that recapitalization always delivers higher welfare. ■

Proof of Proposition 2. When $m > \overline{m}$, rearranging $\Delta W_1 \geq 0$ after plugging q_1 and x_1 yields

$$\gamma \geq \frac{(1+\delta)\left((\delta - r_D)(1-k_H) + m\right)}{(\delta - r_D)[(1+\delta)(1-k_H) + \Delta k(1+\delta) + (\delta - r_D)(1-k_L)]}. \tag{28}$$

The term on the right hand side builds the upper part of the function separating the dominance regions, $\gamma_1(\delta)$. Deriving this term with respect to δ delivers

$$-\frac{\left[\begin{array}{c} m\,[(1+r_D)(\Delta k + (1+2\delta)(1-k_H) - r_D(1-k_L) + 2(1+\delta)(\delta - r_D)(1-k_H)] + \\ (\delta - r_D)^2(1+r_D)(1-k_L)(1-k_H) \end{array}\right]}{[(\delta - r_D)[(1+\delta)(1-k_H) + \Delta k(1+\delta) + (\delta - r_D)(1-k_L)]]^2} < 0,$$

proving that the upper part of $\gamma_1(\delta)$ is decreasing in δ. It is important to observe that for sufficiently low m the function implied by (28) may intersect with the first lower bound from (16), meaning that this bound becomes a part of $\gamma_1(\delta)$. This bound is also strictly decreasing in δ, as its derivative with respect to δ is $-(1+r_D)\Delta k(1-k_L)\left[\Delta k(1+\delta) + (\delta - r_D)(1-k_L)\right]^{-2} < 0$.

If $m < \overline{m}$, the condition for $\Delta W_1 \geq 0$ is

$$\delta \geq \frac{\gamma^2(1+r_D)}{2\gamma - 1} - 1 + \frac{\gamma}{2\gamma - 1}\frac{m}{\Delta k}. \tag{29}$$

The last expression defines implicitly the lower part of $\gamma_1(\delta)$. The derivative of the right hand side term of the last expression with respect to γ is negative for $\gamma \in (1/2; 1)$:

$$\frac{\partial \delta}{\partial \gamma} = -\left(2\gamma - 1\right)^{-2}\left[6\left(1-\gamma\right)\gamma + \frac{2m}{\Delta k} + 2\gamma(1-\gamma)r_D\right] < 0.$$

Because the right hand side term is invertible for positive δ and $\gamma \in [0.5; 1]$, the lower part of $\gamma_1(\delta)$ is also decreasing. This time the function implied by (29) lies above of the second lower bound from (16) (rearranging the latter delivers $\delta \geq \frac{\gamma^2(1+r_D)}{2\gamma-1} - 1$). One has to keep in mind that for $m < \overline{m}$ the function implied by (17) has no bite, because for $m < \overline{m}$ the optimal q_1 is 1.

Rearranging (28) and (29) for $\gamma = 1 - \frac{m}{r_H - r_L}$ shows that they both intersect exactly at $\gamma = 1 - \frac{m}{r_H - r_L}$

(the line $\gamma(\overline{m})$). The function $\gamma_1(\delta)$ after solving for (29) is

$$\gamma_1(\delta) = \begin{cases} \max\left[\frac{\Delta k(1+\delta)}{\Delta k(1+\delta)+(\delta-r_D)(1-k_L)}; \frac{(1+\delta)((\delta-r_D)(1-k_H)+m)}{(\delta-r_D)[(1+\delta)(1-k_H)+\Delta k(1+\delta)+(\delta-r_D)(1-k_L)]}\right] & \text{for } m > \overline{m} \\ \frac{1+\delta}{1+r_D} - \frac{m}{2(1+r_D)\Delta k} - \sqrt{\frac{1+\delta}{1+r_D}\left(\frac{1+\delta}{1+r_D} - 1\right) - \frac{\frac{m}{\Delta k}\left(\frac{m}{\Delta k} - 4(1+\delta)\right)}{4(1+r_D)^2}} & \text{for } m \leq \overline{m}, \end{cases}$$

where the last expression is the smaller solution of the quadratic inequality implied by (29). The other solution of this inequality is always higher than 1 for $m < \overline{m}$. ■

Proof of Proposition 3. After inserting q_3 in ΔW_3 the condition for $\Delta W_3 \geq 0$ is as follows:

$$\gamma \geq \frac{[m + S + \Delta k(\delta - r_D)](1+\delta)}{(r_H - r_D - (\delta - r_D)k_H)(\delta - r_D) + [S + \Delta k(\delta - r_D)](1+\delta)} \equiv \gamma_2(\delta).$$

The derivative of $\gamma_2(\delta)$ has ambiguous sign and reads

$$\frac{\partial \gamma_2(\delta)}{\partial \delta} = [(r_H - r_D - (\delta - r_D)k_H)(\delta - r_D) + [S + \Delta k(\delta - r_D)](1+\delta)]^{-2}(1+r_D) \begin{bmatrix} b(r_H - r_L)(\delta - r_D)^2 \\ -S\left[(r_H - r_D)(1+\delta)^2 - b(\delta - r_D)(2 + \delta - r_D)\right] \\ -m\left[(2r_H - r_D - r_L)(1+\delta)^2 - b(\delta - r_D)(2 + \delta - r_D)\right] \end{bmatrix}.$$

The nominator of this derivative defines a second order polynom of δ. For δ close to r_D the nominator is negative implying that for small δ the function $\gamma_2(\delta)$ is strictly decreasing for $S > 0$ and $m > 0$. It is possible that if S and m are sufficiently small, then the sign of the derivative will turn to positive, implying that $\gamma_2(\delta)$ starts to increase for some δ sufficiently far away from r_D. Moreover, as in the case of recapitalization the part or even the whole $\gamma_2(\delta)$ can be given by (15). This could happen if m and S are sufficiently low, meaning that the expected cost of inspection and closure is negligible, which in the light of $q_3 \leq 1$ means the that insensitive capital requirements deliver lower welfare. In such a case only (15) is the relevant condition. ■

Proof of Proposition 4. For $m > \overline{m}$ the derivative of $\overline{S}(\delta)$ with respect to δ is quite a complicated object. However it can be shown that it has the following properties. Its nominator is a quadratic function of δ with negative term at δ^2. Its maximum is a linear and decreasing function in parameter m and evaluated at $m = \overline{m}$ it is 0. Then because for any $m > \overline{m}$ the maximum is negative the sign of the nominator is always negative, hence $\overline{S}(\delta)$ is decreasing in δ. For $m \in (0;\overline{m}]$ the matters are more complicated. Again one can study the sign of the nominator of the derivative. It turns out that its maximum (-1) is lower than $\delta = r_D$. Hence one can look at the sing of the derivative at this point. It turns out that for m close to $\overline{m}$ it is negative, so $\overline{S}(\delta)$ is decreasing in δ. However, at $m = 0$ the nominator has the value of

$$\begin{aligned} & -\Delta k(1+r_D)\left[k_L(1+r_D)-\gamma(r_H-r_D+k_H(1+r_D))\right] \\ = & -\Delta k(1+r_D)\left[k_L(1+r_D)-\gamma b\right] \\ = & -\Delta k(1+r_D)\left[b(1-\gamma)-(r_L-r_D)\right] \end{aligned}$$

of which sign is not clear cut. This means that $\overline{S}(\delta)$ may have an inverted U-shape. ■

Proof of Lemma 10. The program can be rewritten

$$\min_{(q,x,f)} qm + q(1-\gamma)((\delta - r_D)x + \delta f)$$

s.t.:

$$IC_{ML}\text{: } x \geq \Delta k$$

$$IC_{TT}\text{: } q\gamma\left[(\delta - r_D)x + (1+\delta)f + (1+r_D)\Delta k\right] \geq \Delta k(1+\delta)$$

$$IR\text{: } (\delta - r_D)x + (1+\delta)f \leq r_L - r_D - (\delta - r_D)k_H$$

$$0 \leq q \leq 1$$

The truth-telling constraint is binding, because if it does not bind, then any decrease in q, x or f is still incentive compatible and decreases the implementation cost. Then I can solve it for f and plug it into objective function and the participation constraint. Then the program gets:

$$\min_{(q,x)} q\left[m + (1-\gamma)\left(\frac{\delta - r_D}{1+\delta}x - \frac{\delta(1+r_D)}{1+\delta}\Delta k\right)\right] + \frac{\delta \Delta k(1-\gamma)}{\gamma}$$

s.t.:

$$x \geq \Delta k$$

$$\frac{1}{\gamma}\frac{\Delta k(1+\delta)}{r_H - r_D - (\delta - r_D)k_H} \leq q \leq 1$$

The solution must be such that q and the term in the square brackets are the smallest. There are two solutions, because the term in the square brackets can be negative or positive for $x = \Delta k$. If it positive then q has to be the smallest and the solution is $x = \Delta k$, $q = \frac{1}{\gamma}\frac{\Delta k(1+\delta)}{r_H - r_D - (\delta - r_D)k_H}$ and f such that IC for truth-telling holds with equality for these x and q. If it negative then $q = 1$, $x = \Delta k$ and f such that IC for truth-telling holds with equality for these x and q. The first one occurs when $m \geq (1-\gamma)r_D\Delta k$. Both solution have the property that x is hold at its minimum (just to eliminate moral hazard) and the whole punishment goes through the fine. ■

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