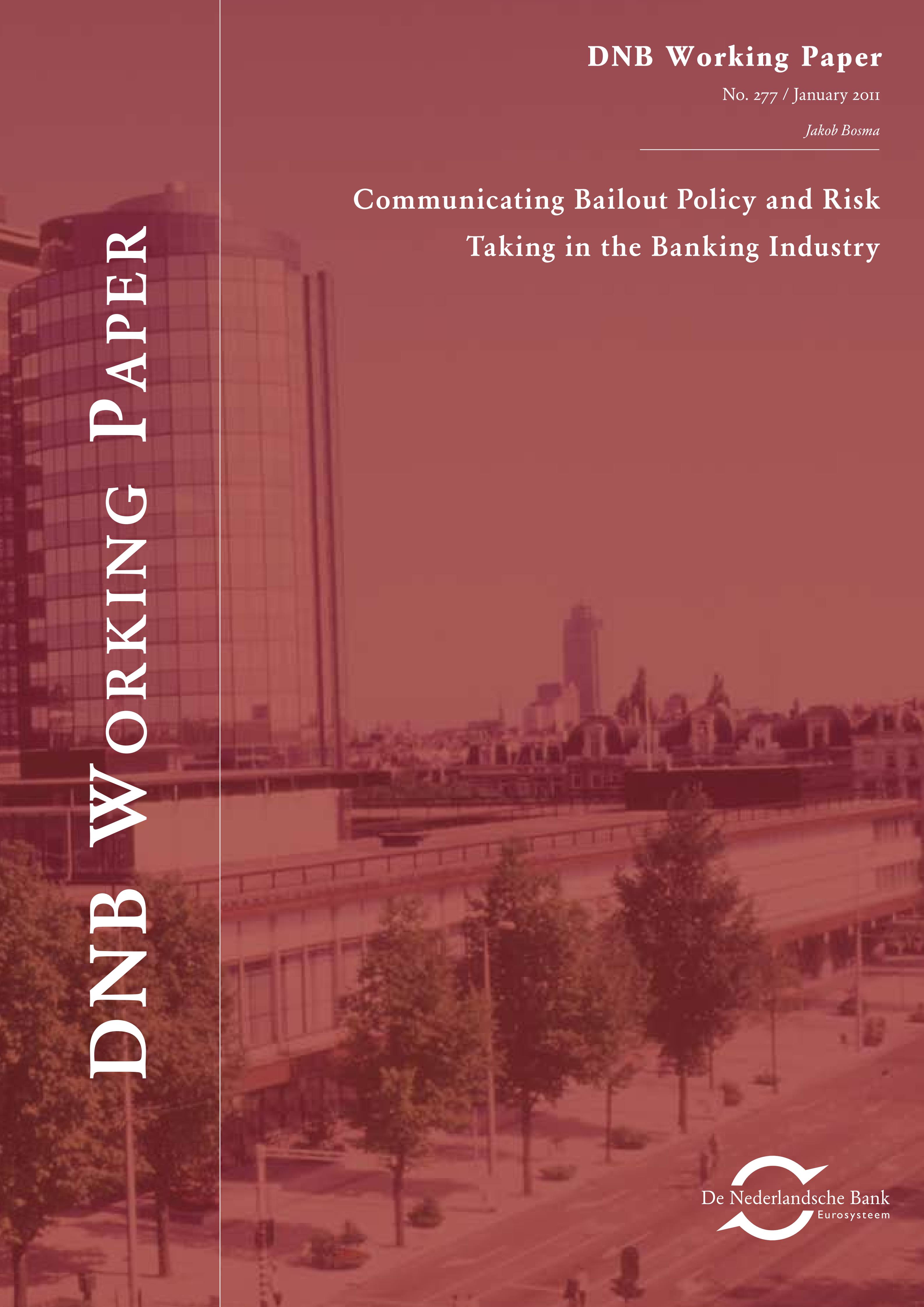

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De Nederlandsche Bank
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* Views expressed are those of the author and do not necessarily reflect official positions of De Nederlandsche Bank.

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Communicating Bailout Policy and Risk Taking in the Banking Industry

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Abstract

This paper considers the effects of imperfectly communicated information about whether a regulator initiates a bailout program for financially distressed banks. The theoretical framework allows for determining whether, and to what extent, it is optimal for a regulator to be imprecise in communicating its bank bailout strategy. Banks do not only rely on their prediction of the regulator's action, but also on their beliefs about other banks' predictions to infer the regulator's strategy. Results indicate that the regulator may substitute higher capital adequacy requirements for being less precise in communicating whether to initiate a bailout program to maintain risk taking by banks.

Key words: bank bailout support, noisy communication, regulation, risk taking
JEL: D82, L51

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1. Introduction

During the recent financial turmoil regulatory authorities, such as central banks, maintained bailout schemes to assist financially distressed banks with capital injections or other forms of support. The main goal of bailouts is to ensure stability in the financial sector by preventing potential negative spillover effects of the failure of banks to the banking sector or to other sectors of the economy. However, a potential side effect is that bailout programs may induce moral hazard in a bank's risk taking. The theoretical model developed in this paper allows for determining whether, and to what extent, it is optimal for a regulator to be imprecise in communicating about bailout strategies. The impact of the degree of imperfection in communication on overall risk taking by banks is evaluated. Additionally, the implication of higher capital requirements on risk taking is assessed for changes in the precision with which the regulator communicates its strategy.

The framework is based on a game played between a regulator and banks. Banks choose their preferred risk level and the regulator weighs the cost associated with bank failure against the cost arising from initiating bailout support. Subsequently, the regulator communicates the probability of initiating a bailout scheme to the banking industry by sending noisy signals about the true cost of bank failure. This ensures that banks face additional uncertainty in taking risk, due to imperfect information on whether they will receive a bailout when financially distressed. Moreover, banks rely on what they believe about other banks' predictions regarding the regulator's action. The analysis uses the global games methodology (Carlsson and Van Damme, 1993; Frankel et al., 2003; and Morris and Shin, 2003).

The model solves for a unique equilibrium that identifies the proportion of banks that engage in risk taking, as a result of banks receiving imperfect information about the strategy of the regulator. Comparative statics reveal that as the regulator communicates planned actions less precise, risk taking in the banking sector can be curtailed. Additionally, the results indicate that higher capital requirements can be substituted for by lowering the precision with which the regulator communicates its strategy. This implies that the structure of communication may be an additional tool to curtail risk taking in banking.

This result is based on the intuition that an increase in capital requirements lowers overall risk taking by banks. Since higher capital requirements increase the expected costs of bankruptcy, which induces banks to take on less risk due to limited liability. It is found that the same result can be achieved by increasing the uncertainty for a bank to receive a possible bailout. This also increases the expected costs of bankruptcy, and can be achieved by lowering the precision with which the regulator communicates its bailout strategy.

The model's implications for strategic communication by regulatory authorities is twofold. First, it allows to investigate the relation between the precision with which the probability of a bailout is communicated and risk taking by banks. Second, it enables to analyze whether the impact of precision in communicating bailout strategies alters the effects of other policy tools on bank risk taking, such as capital requirements.

Risk taking by banks constitutes a strategic complement in the model and bears close resemblance to the model developed by Farhi and Tirole (2009). The complementarity in their approach arises through monetary policy tools of a regulator. When only a marginal fraction of banks take on a risky balance sheet, the regulator is not inclined to conduct a bailout by setting a low interest rate on deposits, since it would be to the detriment of consumer welfare. However, when a significantly large fraction of banks takes on a risky balance sheet, the regulator would not have an option. In contrast, this paper is concerned with the relation between communicating the regulator's strategy in initiating a bailout program and risk taking in banking. Moreover, the implications of changes in the precision with which the regulator communicates its strategy on the effects of other policy tools are evaluated.

Most studies of moral hazard resulting from safety nets for banks are theoretical and focus primarily on the tradeoff between the consequences of bank failure and moral hazard. Goodhart and Huang (1999) model a supervisory authority who faces the tradeoff between the social costs of letting a bank fail versus the moral hazard in bank behavior, induced by the fact that a distressed bank will be saved. Last resort lending would in this case be a result of a regulator's concern about the consequences of adverse contagious effects of individual bank failure, such as financial instability [1] . Similar cost-benefit analyses are adopted by Freixas (1999) and Cordella and Yeyati (2003)

The role of communication has not been explored in the literature on determining optimal bailout strategies for banks by governmental institutions. [2] However, in monetary policy, communication has received considerable attention; see Blinder et al. (2008) for an overview. In their seminal work on the role of communication, Morris and Shin (2002) argue that increasing the precision

[1] See, for instance, Allen and Gale (2000) and Freixas et al. (2000) for more on the negative spillover effects of individual bank failure on the stability of the banking sector.

[2] Since the decision to bail out a bank often involves multiple regulatory institutions, the concepts of 'central bank', 'lender of last resort' ('LLR') and 'government' are used interchangeably in the modeling approach and are commonly denoted as regulator.

with which policies are communicated is not necessarily enhancing social welfare. Notwithstanding that this result is feasible, Svensson (2006) shows in a comment that the necessary conditions for this result are unlikely to hold. In the context of monetary economics, Amata et al. (2003) and Amata and Shin (2003) discuss that increasing central bank transparency, in the form of communicating its inflation target, can be detrimental to social welfare. Following the seminal work of Morris and Shin (2002), the global games methodology is employed to evaluate the implications of communication by a regulatory authority.

The paper is organized as follows. Section 2 presents the model and the equilibrium analysis. Section 3 provides the comparative static exercises, while section 4 presents concluding remarks.

2. The Model

2.1. Actions and payoffs of banks

Consider a continuous set of banks normalized on the unit interval, i.e. this set is defined as $\mathcal{B} = [0, 1]$, where the i^{th} element indexes bank i. Banks are managed by their owners and deposit accounts are fully insured. In the event of bankruptcy, a bank's equity is only preserved when the government decides to bail out the bank. In this game each bank faces the decision to augment its overall loan portfolio with additional earning assets that are more risky than the initial loan portfolio. The intuition of Bolt and Tieman (2004) is followed by interpreting the bank's action as a lowering of the acceptance criteria for granting loans. This is parameterized by a_i, where $a_i = 1$ indicates that a bank lowers its criteria and allows for high risk loans, and $a_i = 0$ indicates no change in acceptance criteria.[3] In functional form, bank i's loans can be expressed as

$$L_i(a_i) \equiv L + a_i\lambda; \quad L > 0,\ \lambda > 0,\ a_i = \{0, 1\}.$$

Where L denotes the market value of the risk-free portfolio, and λ the additional risky loans granted when the acceptance criteria standards have been lowered.

Turning to the payoff of bank i: Let Q_i denote its equity; D_i its deposit holdings; r_D the fixed return on deposits; ρ the premium received by equity holders on top of r_D; $\tilde{r}$ denotes the general random return on the loan portfolio. $\hat{\pi}_i : \mathbb{R}^2 \to (0, 1)$ is the expected probability about the initiation of a bailout scheme, defined by $\hat{\pi}_i = \hat{\pi}(x_i, z)$. The implications of the private signal x_i and public signal z are for now unimportant, but will be discussed in more detail in section 2.4. The randomness in $\tilde{r}$ results in either positive or negative profits for bank i. However, due to limited liability negative profits cannot exceed the amount of equity raised by the bank. Additionally, in the event that a bank enters the state of financial distress, the regulator may decide to bail out the bank and sets its profit equal to zero and allows it to operate. On the other hand, if the regulator decides not to bail out the bank, the bank will go bankrupt and the bank is liquidated. Furthermore, it is assumed that $D_i = (1 - k)L_i(\alpha_i)$, and $Q_i = kL_i(\alpha_i)$, where $k \in (0, 1)$ denotes the capital

[3] Oury (2009) shows that if more than one binary action variable exists in the framework of Frankel et al. (2003), the final results derived by Frankel et al. (2003) remain unchanged. This proposition is used here to argue that the final results are the same as in a model where banks can decide on multiple levels of their risk position. Many different levels of risk adoption would then reflect the case of continuity in a_i between the values zero and one.

adequacy requirement. The profit function of bank i can now be expressed as:

$$U_i(a_i|x_i, z) \equiv \max\{\tilde{r}L_i(a_i) - r_D D_i - (r_D + \rho)Q_i, -(1 - \hat{\pi}_i)(r_D + \rho)Q_i\}$$

Substituting the capital adequacy requirement, this expression can be simplified into:

$$U_i(a_i, x_i, z) \equiv \max\{(\tilde{r} - (r_D + \rho k))L_i(a_i), -(1 - \hat{\pi}_i)(r_D + \rho)kL_i(a_i)\}. \quad (1)$$

The probability of bankruptcy can be denoted by:

$$\text{Prob}[Bankruptcy|x_i, z] \equiv \text{Prob}[\tilde{r} < r_D(1 - k) + \hat{\pi}_i(r_D + \rho)k|x_i, z]. \quad (2)$$

In contrast to the fully insured deposit holders, equity holders face the possibility of bankruptcy. This implies that equity is more risky and equity holders demand a premium, $\rho > 0$, as compensation. Due to this premium a nonlinearity arises in the probability of bankruptcy, (2), in capital requirements k. An increase in capital requirements lowers the probability of bankruptcy, since equity holders' stake in the bankruptcy of the bank increases as well. However, higher capital requirements imply that banks have to recover the additional costs associated with a larger proportion of uninsured equity which is more expensive than holding fully insured deposits. This increases the probability of bankruptcy.

Suppose that $\tilde{r} = \bar{r}\tilde{X}$, where $\tilde{X} \sim Bernoulli(p)$, in which $p \equiv \text{Prob}[\tilde{r} < r_D(1 - k) + (r_D + \rho)k]$. The assumption of independence between the two states of $\tilde{r}$ and the idiosyncratic signals banks perceive ensures tractability, but does not affect the final results as shown in the appendix. Note that $\tilde{r} = \bar{r}$

implies positive profits and $\tilde{r} = 0$ results in financial distress. Furthermore, these distributional properties ensure that the expected utility of bank i is strictly increasing in x_i. This is a necessary condition for identifying a unique equilibrium. The total number of banks investing in additional risky assets can thus be denoted by:

$$\mathcal{A} \equiv \int_{i \in \mathcal{B}} a_i di. \tag{3}$$

2.2. Regulator's incentives and bailout policy

In the event of financial instability, the regulator weighs the cost of a bank bailout program versus the cost arising from not initiating such a program. These costs are denoted by ψ and Ψ, respectively. ψ can be regarded as the necessary effort of the regulator to set up a bailout program combined with the necessary resources to fund it. The cost of not initiating a bailout program Ψ include, for instance, negative spillover effects of the failure of a bank to the banking sector [4]; see, for instance, Allen and Gale (2000) and Freixas et al. (2000). Additionally, loss of depositors' trust in the system may accrue to Ψ. The probability that the regulator attaches to this event is the probability of the banking industry in financial distress. According to (1), banks take into account the expected probability of being bailed out when financially distressed. This implies that their risk taking action is dependent on the probability of receiving bailout support, i.e. $a_i \equiv a(\pi)$, where π denotes the actual probability of a bailout program to be initiated. The assumption that a is increasing in π can be justified by the notion that as it becomes more likely to be bailed out, incentives for risk taking also increase. Based on definition (3), $\mathcal{A}$ is dependent

[4] Only the banking sector is evaluated in a partial equilibrium modeling setting, such that potential negative spillovers to other sectors of the economy are not considered.

on π. Therefore $\mathcal{A} \equiv \mathcal{A}(\pi)$, with $\frac{d\mathcal{A}(\pi)}{d\pi} > 0$. Consequently, the probability of the banking industry in financial distress is denoted by $P \equiv P(\mathcal{A}(\pi))$.

An objective function can be constructed where the regulator maximizes over the probability of initiating a bailout. Such a function $\Omega : [0, 1] \to \mathbb{R}$ is defined by

$$\Omega(\pi) = -P(\mathcal{A}(\pi))(\Psi(1-\pi) + \psi\pi), \tag{4}$$

where Ω reflects the regulator's utility. First the situation is considered where banks have perfect information with regard to Ψ and ψ. Subsequently the case will be considered where banks have imperfect information with regard to their social value. Maximizing (4) with respect to π yields

$$\frac{d\Omega(\pi)}{d\pi} = -\frac{dP(\mathcal{A}(\pi))}{d\pi}(\Psi(1-\pi) + \psi\pi) - P(\mathcal{A}(\pi))(\psi - \Psi). \tag{5}$$

Note that $\frac{dP(\mathcal{A}(\pi))}{d\pi} = \frac{dP(\mathcal{A}(\pi))}{d\mathcal{A}(\pi)}\frac{d\mathcal{A}(\pi)}{d\pi} > 0$. Given that $P(\mathcal{A}(\pi)) > 0$, (5) is negative if and only if (iff) $\psi > \Psi$. This implies that when the costs of bailing out a bank outweigh the costs of letting the bank fail the regulator would set $\pi = 0$ in order to maximize its objective function for possible values of π.

In case $\psi < \Psi$, (5) is negative iff $\frac{dP(\mathcal{A}(\pi))}{d\pi}\frac{1}{P(\mathcal{A}(\pi))} > \frac{\psi-\Psi}{\Psi(1-\pi)+\psi\pi}$. Again, the regulator would set $\pi = 0$ to maximize Ω. However, (5) is positive whenever $\frac{dP(a(\pi))}{d\pi}\frac{1}{P(\mathcal{A}(\pi))} < \frac{\psi-\Psi}{\Psi(1-\pi)+\psi\pi}$, which induces the regulator to set $\pi = 1$. Hence, in the event where $\psi < \Psi$ two possible solutions prevail in maximizing (4), namely $\pi = 1$ or $\pi = 0$. This results in the multiplicity of equilibria that are characterized by either all banks investing in risk bearing assets, when $\pi = 1$, or none, $\pi = 0$.

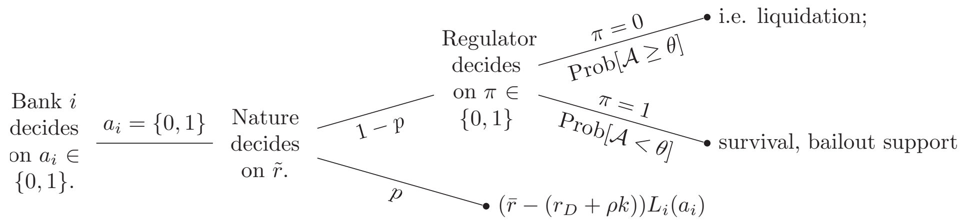
2.3. *Imperfect information about the cost of not bailing out*

In the previous section, where banks have perfect information with regards to Ψ and ψ, the corner solutions $\pi = 1$ and $\pi = 0$ ensure that either all banks engage in risk taking behavior or none. Following up on this, banks are now considered to have imperfect information regarding the two types of costs. First, the social cost Ψ associated with not initiating a bailout program is replaced by θ, and the cost of initiating such a program ψ is replaced by $c_1\mathcal{A} + c_0(1 - \mathcal{A})$. I assume that the costs associated with bailing out banks that have taken on additional risk are higher than the banks that did not, i.e. $c_1 > c_0$. This implies that the condition for the regulator to initiate the bailout policy is altered into $\mathcal{A} < \frac{\theta - c_0}{c_1 - c_0}$. Since banks do not observe θ with complete knowledge, they will not be able to infer with certainty whether $\pi = 1$. Hence, they form a perceived probability about π, that has been introduced above as $\hat{\pi}_i$ and depends on the signals bank i receives. Consequently, $\mathcal{A}$ can not depend on π in the case where banks have incomplete information regarding Ψ and ψ.

2.4. *Timing and information*

The game consists of three stages. In the first stage θ is determined by nature. In stage two each bank forms an expectation about the probability of being bailed out and decides whether to invest in additional risk bearing loans. In determining the expected probability of being bailed out, the bank considers the likelihood that a sufficient portion of banks in the banking sector engages in investing in risky assets. Hence, risk taking constitutes an action that can be regarded as a strategic complement through the probability of being bailed out. In the third stage, the government determines whether to initiate a bailout program. A graphical representation of the staging of the game considered is displayed in figure 1. As stated above, θ is not commonly

Figure 1. Game tree



observed. Rather, banks receive signals that imperfectly reflect this parameter due to a noise component. In the first stage of the game, nature determines θ by means of a random draw from a particular distribution, which is assumed to be unknown to all players. It is assumed that θ is drawn from an improper uniform distribution with the real line as support. However, the complete analysis is conducted conditional on θ, which implies that the underlying improper uniform has no effect on the final outcomes (Morris and Shin, 2003). The signals banks receive, public and private, ensure that information regarding the value of θ is both imperfect and asymmetric. The idiosyncratic signal of θ received by bank i is denoted by $x_i : \mathbb{R}^2 \times \mathbb{R}_+ \to \mathbb{R}$ and defined as

$$x_i(\theta, \xi_i, \alpha_x) = \theta + \frac{\xi_i}{\sqrt{\alpha_x}}, \tag{6}$$

where $\xi_i \sim \mathcal{N}(0,1)$, and is independent of θ as well as across banks. The public signal of θ is denoted by $z : \mathbb{R}^2 \times \mathbb{R}_+ \to \mathbb{R}$ and is defined as

$$z(\theta, \varepsilon, \alpha_z) = \theta + \frac{\varepsilon}{\sqrt{\alpha_z}}, \tag{7}$$

where $\varepsilon \sim \mathcal{N}(0,1)$, and is independent of θ and ξ_i across all banks. The signal z is commonly observed by all banks and may act as their prior distribution for inferring a posterior distribution for θ conditional on their idiosyncratic signal x_i. In addition, since the public signal is equal for all banks, it ensures that the bank's belief about other banks' predictions concerning the regulator's action is included in the bank's decision when deciding on its preferred risk level. Since the distribution of ξ_i and ε follows the standard normal, conventional notation for indicating the associated probability density function (pdf) as well as the cumulative density function (cdf) are adhered to: the pdf is indicated by $\phi(.)$ and the cdf by $\Phi(.)$. Furthermore, it is assumed that the precision by which information is dispersed is known to all players, i.e. α_x and α_z are known. Additionally, the distributional properties associated with z may act as a conjugate prior for inferring a posterior distribution about θ. By letting $\alpha \equiv \alpha_x + \alpha_z$ the posterior is characterized by

$$\theta | x_i, z \sim \mathcal{N}(\frac{\alpha_x x_i + \alpha_z z}{\alpha}, \alpha^{-1}). \tag{8}$$

The cdf associated with this distribution is denoted by $\mu(\theta | x_i, z)$, where $\theta \in \mathbb{R}$.

2.5. Equilibrium analysis

The defining element of the model is the coordination game in which banks coordinate around θ to infer whether risk taking constitutes a profitable action. The resulting equilibrium can be summarized by the following definition, and consists of the necessary conditions defined by Morris and Shin (2003):

Definition An equilibrium consists of a (symmetric) strategy for bank i, $a_i : \mathbb{R}^2 \to \{0,1\}$; a cdf $\mu : \mathbb{R}^3 \to [0,1]$; and solves for equilibrium values

$x^*(z)$ and $\theta^*(z)$ such that:

- $a_i^*(x_i, z) = \arg\max_{a_i \in \{0,1\}}[\mathrm{E}[U(a_i|x_i, z)]]$;
- $\mu(\theta|x_i, z)$ is obtained from Bayes' rule;
- and the resulting banks engaging in additional risk taking $\mathcal{A} : \mathbb{R}^2 \to [0, 1]$ is defined by $\mathcal{A} \equiv \mathcal{A}(\theta, z)$.

The investment decision of bank i can be derived from the expected incremental gain derived from investing in risk bearing assets. Based on (1), the distributional properties of $\tilde{X}$ and the definition of loans, it can be stated that

$$\begin{aligned} a_i^* &= \underset{a_i \in \{0,1\}}{\arg\max}[\mathrm{E}[U(1|x_i, z)] - \mathrm{E}[U(0|x_i, z)]] \\ &= \underset{a_i \in \{0,1\}}{\arg\max}\, a_i[p(\bar{r} - (r_D + \rho k) - (1-p)(1-\hat{\pi}_i)(r_D + \rho)k] \times \lambda \end{aligned} \tag{9}$$

For a given realization of θ and received z it is supposed that there exists a pivotal $x^*(z)$ for which banks who receive a signal $x_i > x^*(z)$ will find it optimal to invest in a risk bearing project [5] . Based on (3) and (6) the entire mass of banks investing in a risk bearing project, $\mathcal{A}$, can be redefined by $\mathcal{A} : \mathbb{R}^2 \to \mathcal{B}$ and takes the functional form of

$$\begin{aligned} \mathcal{A}(\theta, z) &= \int_{i \in \mathcal{B}} \int_{x^*(z)}^{\infty} \sqrt{\alpha_x}\phi(\sqrt{\alpha_x}(x_i - \theta))dx_i di \\ &= 1 - \Phi(\sqrt{\alpha_x}(x^*(z) - \theta)). \end{aligned}$$

The inner integral states the probability that bank i will invest in a risk bearing project and the outer integral sums these probabilities across the

[5] $x^*(.)$ depends on z, since bank i adopts the public signal to infer the distributional properties of θ. Following, (8) is then used to determine $x^*(.)$.

banking sector. Note that $\mathcal{A}$ is strictly increasing in θ. Hence, the condition [6] for initiating a bailout program, $\mathcal{A}(.) < \theta$, can be restated as $\theta > \theta^*(z)$, where $\theta^*(z)$ is obtained through [7]

$$\mathcal{A}(\theta^*(z), z) = \theta^*(z)$$
$$1 - \Phi(\sqrt{\alpha_x}(x^*(z) - \theta^*(z))) = \theta^*(z).$$

Solving for $x^*(z)$ then yields:

$$x^*(z) = \theta^*(z) - \frac{1}{\sqrt{\alpha_x}}\Phi^{-1}(\theta^*(z). \tag{10}$$

Given the new condition for a bailout program to be initiated, $\theta > \theta^*(z)$, it can be stated that $\hat{\pi}_i = \text{Prob}[\theta \geq \theta^*(z)|x_i, z]$. Since each bank forms a different posterior distribution about θ, as indicated by (8), the posterior probability of the event that a bailout program is initiated can be denoted by:

$$\text{Prob}[\theta \geq \theta^*(z)|x_i, z] = 1 - \Phi(\sqrt{\alpha}(\theta^*(z) - \frac{\alpha_x}{\alpha}x_i - \frac{\alpha_z}{\alpha}z)). \tag{11}$$

Since the term $\hat{\pi}_i$ is the only term in (9) that is dependent on x_i and $\text{Prob}[\theta \geq \theta^*(z)|x_i, z]$ is increasing in x_i, it follows that

$$a_i = \begin{cases} 1 & \text{if } x_i \geq x^*(z) \\ 0 & \text{if } x_i < x^*(z). \end{cases}$$

Substituting (11) for $\hat{\pi}_i$ in (9) and equating to zero allows for identifying the bank that has received the private signal rendering the bank indifferent

[6] Without loss of generality, the condition $\mathcal{A} < \frac{\theta - c_0}{c_1 - c_0}$ is normalized by setting $c_0 = 0$ and $c_1 = 1$.

[7] Since $x^*(.)$ depends on z, consequently $\theta^*(.)$ also depends on z.

between lowering its monitoring standards or not. Consequently, the solution yields the threshold value $x^*(z)$.

$$\Phi(\sqrt{\alpha}(\theta^*(z) - \frac{\alpha_x}{\alpha}x^*(z) - \frac{\alpha_z}{\alpha}z)) = \frac{p(\bar{r} - (r_D + \rho k))}{(1-p)(r_D + \rho)k}.$$

Following, substituting (10) and simplifying the new expression yields

$$\Gamma(\theta, z) = \gamma, \tag{12}$$

where $\Gamma(\theta, z) \equiv \frac{\alpha_z}{\sqrt{\alpha_x}}(\theta - z) + \Phi^{-1}(\theta)$, and $\gamma \equiv \sqrt{\frac{\alpha}{\alpha_x}} \frac{p(\bar{r}-(r_D+\rho k))}{(1-p)(r_D+\rho)k}$. Given the equilibrium relationship between $x^*(z)$ and $\theta^*(z)$ in (10), existence of a unique equilibrium can be established by considering the properties of the function Γ. Note that for any value of $z \in \mathbb{R}$, Γ is continuous in θ; with $\Gamma(0, z) = -\infty$, and $\Gamma(1, z) = \infty$. Therefore, to ensure that a unique solution to (12) exists, the following condition must hold:

$$\frac{\partial \Gamma(\theta, z)}{\partial \theta} = \frac{\alpha_z}{\sqrt{\alpha_x}} + \frac{1}{\phi(\Phi^{-1}(1-\theta))} > 0.$$

Since α_z, α_x and $\phi(.)$ are strictly positive, Γ is strictly increasing in θ. This implies that a unique solution, $\theta^*(z)$ can be found that solves (12), provided that $\alpha_x > 0$. This is summarized in the following proposition.

Proposition 2.1 Unique and monotone equilibrium. *Let α_x and α_z denote respectively the precision with which private and public signals are distributed. There always exists a monotone equilibrium and it is unique iff $\alpha_x > 0$ and $\alpha_z \geq 0$. This equilibrium is characterized by identifying a value for θ^* and x^*. It can be shown that θ^* equals the proportion of risk taking banks and x^* identifies the threshold value that renders a bank indifferent in deciding whether to invest in a risk bearing asset.*

Under the conditions imposed on α_x and α_z Morris and Shin (2003) prove that there exists no other equilibrium by iterated deletion of dominated strategies.

3. Imperfect communication about bailouts and risk taking

Proposition 2.1 highlights the multiplicity of equilibria when the private signals are dispersed with zero precision. However, a unique equilibrium prevails when some precision exists in the communication of private signals. This equilibrium is characterized by a unique proportion of banks that engage in risk taking that equals the social costs of not initiating a bailout program. Apart from solving the issue of obtaining multiple equilibria, information plays an additional role. Not only the precision with which the signals reflect the true cost of not initiating a bailout program θ matter. Also the existence of common knowledge among banks about whether the regulator initiates a bailout matters, i.e. whether a bank knows that other banks predict that the social cost of not initiating a bailout program exceed the actual cost of such a program. The public signal plays an important role in the formation of common knowledge among banks, in the sense that all banks receive the same public signal and know that other banks also have received the same signal. In absence of a private signal, all banks would therefore infer an equal posterior probability for the event that a bailout program is initiated. To conduct comparative static exercises condition (12) is simplified, and restated as:

$$\begin{aligned}
&\Gamma(\theta^*(z), z) - \gamma = 0 \\
&\quad \frac{\alpha_z}{\sqrt{\alpha_x}}(\theta^*(z) - z) + \Phi^{-1}(\theta^*(z)) - \sqrt{1 + \frac{\alpha_z}{\alpha_x}}\Phi^{-1}(v) = 0, \qquad (13)
\end{aligned}$$

where $v \equiv \frac{p(\bar{r}-(r_D+\rho k))}{(1-p)(r_D+\rho)k}$ is introduced for ease of exposition. A preliminary evaluation of (13) can be conducted by regarding the limiting results associated with private signals being dispersed with relatively high precision; i.e. $\alpha_x \to \infty$ for given α_z, or $\alpha_z \to 0$ for given α_x. In either of these two cases, $\frac{\alpha_z}{\sqrt{\alpha_x}} \to 0$ and $\sqrt{1+\frac{\alpha_z}{\alpha_x}} \to 1$. This implies that (13) solves for $\theta^*(z) \to v$. Proposition 3.1 summarizes this result.

Proposition 3.1 Limiting results of relatively precise private information:*By taking the limiting cases: $\alpha_x \to \infty$ for given α_z, or $\alpha_z \to 0$ for given α_x, there exists a unique monotone equilibrium in which the regulator would initiate a bail out program for the banking sector iff $\theta > \theta^*(z)$, where $\theta^*(z) = v$.*

Proposition 3.2 summarizes the equilibrium results of precise public information relative to private information.

Proposition 3.2 Limiting result of relatively precise public information: *By taking the limiting cases: $\alpha_z \to \infty$ for given α_x, there exists a unique monotone equilibrium in which the regulator would initiate a bail out program for the banking sector iff $\theta > \theta^*(z)$, where $\theta^*(z) = z$.*

Figure 2. Equilibrium correspondence of α_x and $\theta^*(z)$, for given α_z

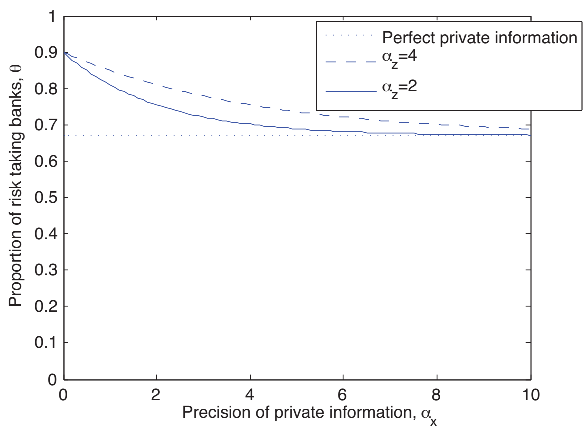


Figure 2 summarizes the equilibrium values of the proportion of banks engaging in risk taking for varying levels of precision with which private information is distributed. The parameter values for figure 2 are summarized in table 1.

Table 1
Baseline parameter values for comparative statics

Parameter	p	$\bar{r}$	r_D	ρ	k	v	α_z
value	0.8	0.051	0.049	0.001	0.050	0.667	4

Figure 2 indicates that equilibrium values of θ^*, and implicitly the group of banks engaging in risk taking behavior, deviate more from the value v the more as public information is dispersed with more precision, for given α_x. This result is dubbed by Morris and Shin (2003) 'overreaction to public information'. By noting that private signals are distributed independently across banks, only the public signal and its distributional properties can be used by banks to infer the predictions of other banks. Banks' posterior about θ is more similar as public information is dispersed more precisely relative to private information. This amplifies banks' common knowledge of each other beliefs whether θ exceeds its critical value for a bail out program to be initiated, regardless of whether the public information accurately reflects the true costs of not initiating a bailout program.

In light of the research question on the impact of the structure of communication, there are two conclusions. Firstly, conditional on the realization of the public signal, overreaction to public information arises by communicating the public signal with more precision relative to private information. This follows from the result that banks place more emphasis on the public signal in deriving the posterior distribution of θ, regardless of whether public information is true or accurate. Secondly, in the event that private information is communicated more precisely relative to public information, v enters the equilibrium value of θ. This implies that the regulator can alter the equilibrium value of the proportion of risk taking banks by setting the policy parameters, such as the capital adequacy requirement. This is considered next.

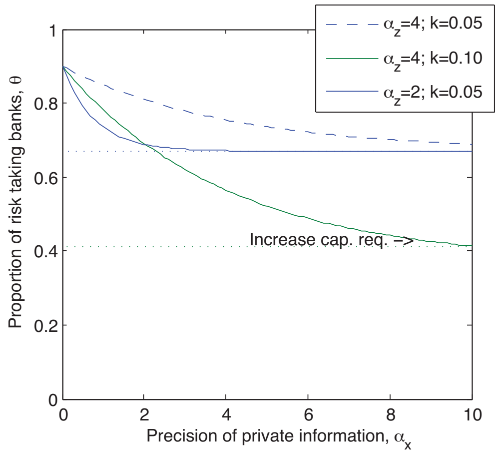
4. Imperfect communication vis-à-vis capital requirements

An initial observation on the implications of changes in capital requirements on risk taking by banks can be inferred from reviewing the bank's objective function (2). Increases in k imply that the cost of bankruptcy of a bank is enhanced. This reduces the incentive for the bank to engage in more risk taking, since in the event of bankruptcy the potential loss is larger due to increase in the obligation to hold more equity.

Figure 3 illustrates the substitution effect between the precision with which public information is communicated α_z and capital adequacy requirements k. The intuition for this result is as follows. Consider an *ex ante* decrease (increase) in the capital requirements. This induces banks to take on more (less) risk, since the potential losses in the event of bankruptcy are reduced (increased). However, by lowering (increasing) the precision with which the public signal is distributed the regulator creates more (less) uncertainty on whether a bailout program will be initiated. In turn, this increased uncertainty lowers (increases) the expected probability of receiving bailout support accross all banks. This offsets the decrease (increase) in bankruptcy costs induced by lower (higher) capital requirements. Effectively, the expected cost of bankruptcy remains unchanged and consequently the risk taking by banks.

Note, however, that the effect of changes in the precision in communicat-

Figure 3. Imposing higher capital adequacy requirements



ing public information on risk taking diminishes as the precision with which the private information is distributed increases. This is due to the result described in propositions 1 and 2. When the precision in communicating private information $\alpha_x \to \infty$ the effect of incremental increases in precision of public information α_z is nullified. Similarly, when $\alpha_z \to \infty$ the equilibrium value of θ equals z, which is independent of capital requirements.

5. Conclusions

In this paper the implications of noisy communication by a regulator are evaluated for its effects on moral hazard in bank behavior, conceptualized by risk taking induced by the perceived likelihood of receiving bailout support. The main findings suggest that the less precise the regulator publicly communicates its strategy, the more the banking sector tends to overreact to the received information; keeping constant the precision with which private information is communicated. This result is due to the fact that banks' beliefs about the regulator's strategy will depend more on what they belief other banks' predictions of the regulator's action are. In case there is no private information at all about the regulator's behavior multiple equilibria prevail. This implies that either all banks engage in excessive risk taking behavior or none, and reflects the concept of 'overreaction to public information'. Hence, the precision with which public information is dispersed through the banking industry is effective in influencing risk taking behavior.

Furthermore, it is found that increasing the capital adequacy requirement ratio lowers overall risk taking behavior by banks, regardless of precision with which the regulator communicates its strategy. Since a lowering of capital requirements results in lower expected costs of bankruptcy, combined with limited liability this would induce banks to take on more risk. For a given level of precision with which private information is distributed, decreasing the precision with which public information is dispersed would create more uncertainty for banks on whether the regulator will initiate a bailout program. This increase in uncertainty offsets the increase in risk taking induced by the lowering of capital adequacy requirements. This result suggests a tradeoff between imposing higher capital requirements or being publicly less precise on whether a bailout will be initiated.

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Appendix: Implications of the return distribution on expected utility

To identify a unique equilibrium it is required that the expected utility of bank i is strictly increasing in x_i. In order to generalize the set up presented in the outline of the model general distribution functions for the return on loans are considered. In what follows it is assumed that $\tilde{r} \sim f(\tilde{r}|a_i)$, and that the cdf is characterized by $F(\tilde{r}|a_i)$. Additionally, it is again assumed that $\frac{\partial \pi_i}{\partial x_i} > 0$. First, the probability of bankruptcy is restated to identify the pivotal value of $\tilde{r}$

$$\begin{aligned}\text{Prob}[Bankruptcy|x_i, z] &\equiv \text{Prob}[\tilde{r} < r_D(1-k) + \pi_i(r_D+\rho)k|x_i, z] \\ &= \text{Prob}[\tilde{r} < r_i^*|x_i, z],\end{aligned}$$

where $r_i^* \equiv r_D(1-k) + \pi_i(r_D+\rho)k$. The expected profits of bank i can now be stated as:

$$\begin{aligned}\text{E}[U(a_i|x_i, z)] &= -\int_{-\infty}^{r_i^*}(1-\pi_i)(r_D+\rho)kL(a_i)f(\tilde{r}|a_i)\text{d}\tilde{r} \\ &\quad + \int_{r_i^*}^{\infty}(\tilde{r}-(r_D+\rho k))L(a_i)f(\tilde{r}|a_i)\text{d}\tilde{r} \\ &= -(1-\pi_i)(r_D+\rho)kL(a_i)F(r_i^*|a_i) + L(a_i)\int_{r_i^*}^{\infty}\tilde{r}f(\tilde{r}|a_i)\text{d}\tilde{r} \\ &\quad - (1-F(r_i^*|a_i))(r_D+\rho k)L(a_i). \qquad (14)\end{aligned}$$

To evaluate the effect of a change in x_i on the expected profits of bank i, the first order derivative of (14) with respect to x_i is evaluated. The term $\frac{\partial}{\partial x_i}\int_{r_i^*}^{\infty}\tilde{r}f(\tilde{r}|a_i)\text{d}\tilde{r}$ will be evaluated with the help of Leibniz's rule. Note that $\frac{\partial r_i^*}{\partial x_i} = (r_D+\rho)k\frac{\partial \pi_i}{\partial x_i}$ This allows for stating the first order derivative of (14) as:

$$\begin{aligned}\frac{\partial \text{E}[U(a_i|x_i, z)]}{\partial x_i} &= (r_D+\rho)kL(a_i)F(r_i^*|a_i)\frac{\partial \pi_i}{\partial x_i} \\ &\quad - (1-\pi_i)(r_D+\rho)kf(r_i^*|a_i)(r_D+\rho)k\frac{\partial \pi_i}{\partial x_i} \\ &\quad - r_i^*f(r_i^*|a_i)L(a_i)(r_D+\rho)k\frac{\partial \pi_i}{\partial x_i} \\ &\quad + f(r_i^*|a_i)(r_D+\rho k)L(a_i)(r_D+\rho)k\frac{\partial \pi_i}{\partial x_i}.\end{aligned}$$

Rearranging terms then yields

$$\begin{aligned}\frac{\partial \text{E}[U(a_i|x_i, z)]}{\partial x_i} &= L(a_i)(r_D+\rho)k\frac{\partial \pi_i}{\partial x_i}[F(r_i^*|a_i) - (1-\pi_i)(r_D+\rho)kf(r_i^*) \\ &\quad - r_i^*f(r_i^*|a_i) + (r_D+\rho k)f(r_i^*|a_i)]. \qquad (15)\end{aligned}$$

For $\frac{\partial}{\partial x_i}\text{E}[U(a_i|x_i, z)] > 0$ to hold, two sufficient conditions are $F(r_i^*|a_i) >$

$r_i^* f(r_i^*|a_i)$ and $(r_D + \rho)k < r_D + \rho k$. The last of these two conditions holds for $k < 1$. Since $k \in (0,1)$, this conditions holds. The former condition can be written as

$$\frac{F(r_i^*|a_i)}{f(r_i^*|a_i)} - r_i^* > 0. \tag{16}$$

Suppose that $\tilde{r} \sim \mathcal{U}[r(a_i), \bar{r}]$, where $r : \{0,1\} \to \mathbb{R}$, defined as $r = r(a_i)$ with $\frac{d}{da_i} r(a_i) < 0$. This distributional form ensures that as bank i decides to take on more risk it allows for a higher variance in its asset's return and for a lower expected return, reflecting the risk enhancing effect associated with lowering monitoring standards. The conditions stated above can now be stated as

$$\begin{aligned}\frac{F(r_i^*|a_i)}{f(r_i^*|a_i)} - r_i &= \frac{r_i^* - r(a_i)}{\bar{r} - r(a_i)}(\bar{r} - r(a_i)) - r_i^* \\ &= r_i^* - r(a_i) - r_i^* > 0\end{aligned}$$

Hence, regardless of the action, a_i, of bank i, its expected utility will be strictly increasing in x_i when $r(a_i) < 0$. Generally, let $h : \mathbb{R} \to \mathbb{R}$ be defined by the left hand side of the condition, i.e. $h(y) = \frac{F(y)}{f(y)} - y$. Where f is a particular density function and F the associated cumulative distribution function. It is explicitly assumed that f represents a distribution that has a single central mass of positive probability weights and has a support that covers the real line. First, the first order derivative is evaluated, yielding $\frac{\mathrm{d}h(y)}{\mathrm{d}y} = \frac{F'(y)f(y) - F(y)f'(y)}{(f(y))^2} - 1 = -\frac{F(y)f'(y)}{(f(y))^2}$. Hence, maximizer or minimizer candidates can be identified by solving $f'(y^*) = 0$. To identify either a maximum or minimum, the second-order derivative is evaluated, yielding:

$$\frac{\mathrm{d}^2 h(y)}{\mathrm{d}y^2} = -\frac{(f(y)f'(y) + F(y)f''(y))(f(y))^2 - 2F(y)(f'(y))^2 f(y)}{(f(y))^4},$$

substituting the candidate solution y^*, for which $f'(y^*) = 0$, then yields:

$$\frac{\mathrm{d}^2 h(y^*)}{\mathrm{d}y^2} = -\frac{F(y^*)f''(y^*)}{(f(y^*))^2}.$$

Since F and f are both strictly positive, y^* denotes a minimizer when $f''(y^*) < 0$. This is commonly the case for distributions with a central mass such as the bell shaped densities, e.g. normal density, or densities that have a central mass with positive probability weight. Assuming that $f''(y^*) < 0$ is indeed the case, the minimizer y^* can be substituted in (16) to verify whether this condition holds[8]. This would then imply that the expected utility of bank i is indeed increasing in its private signal.

[8] In case returns are normally distributed with mean η and standard deviation σ_r, a sufficient condition for (16) to hold is that $\frac{1}{2}\sqrt{2\pi}\sigma_r > \eta$. Since $\sigma_r > 0$, a normalization of $\eta \leq 0$ suffices for (16) to be satisfied.

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