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Bank Regulation Based on Self-Assessment: Extension of an Equilibrium Model

Renlong Miao*, Xinzhu Dai

Law & Finance Research Lab, ZIBS, Hangzhou, China
Email: *renlong.miao@gmail.com

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Abstract

The recent financial crisis revealed that banks, especially these large and complex banks, are opaque to be monitored by regulators. In an ideal world, regulators are hoping all banks to be self-disciplined. That will reduce a lot burdens for regulators. However, in practice, it is not always the case as there will be by nature information asymmetric or information frictions between banks and regulators. We develop a tractable model to study how banks respond to capital requirements that are based on a self-assessment result about banks' riskiness, and derive the policy and wealth implications. We use the model to characterize the optimal requirements, and to study the trade-offs a regulator faces in making efforts to ensure bank's self-assessment more accurate or in disclosing the inspection results to public.

Keywords

Bank Regulation, Self-Assessment, Capital Ratio

1. Introduction

The recent financial crisis (Gorton, 2009; Zéghal & El Aoun, 2016) revealed that banks, especially these large and complex banks, are opaque to be monitored by regulators. As a result, regulators are now increasingly relying on supervisory risk assessment tools to learn about bank-specific risk exposures and capital adequacy. Such tools complement financial reporting and disclosures in informing regulators about banks' riskiness and allow them to better align the baseline capital requirements with individual banks' risk profiles.

In an ideal world, regulators are hoping all banks to be self-disciplined. That will reduce a lot burdens for regulators. However, in practice, it is not always the case as there will be by nature information asymmetric or information frictions between banks and regulators. Most of the banks are to maximize their profits while regulators have broader targets to be considered than banks. Often, the goal of regulator is described as "ensuring the safety and soundness of the banking system". That is, the regulator seeks to reduce the overall risk of the bank sector. This goal is usually motivated by a desire to protect taxpayer liability, reduce failure resolution costs, or prevent systemic risk. Hence, we could always observe the gaps between bank's self-assessment results and regulator's inspection results. Despite empirical evidence (Wu & Zhao, 2016) of such imprecision and gaps of bank's self-assessment, there is lack of a theoretical framework in the literature to study how the self-assessment impacts the behavior of both banks and regulators as the assessment is inherently noisy. We develop a tractable model to study how banks respond to capital requirements that are based on a self-assessment result about banks' riskiness, and derive the policy and wealth implications. We use the model to characterize the optimal requirements, and to study the trade-offs a regulator faces in making efforts to ensure bank's self-assessment more accurate or in disclosing the inspection results to public.

The key players in our model are a banker and a regulator. The banker runs a bank that takes deposits and invests in a risky project. The return on the project can be high or low, depending on the bank's type, which in turn depends on the effort that it exerts ex-ante. A mis-priced deposit insurance combined with limited liability induces the bank to over-borrow relative to the social optimal. Hence, this rationalizes a minimum capital ratio requirement in our model, and allows us to study the welfare implications of counterfactual policies.

A large literature provides several rationales for capital-ratio requirements, such as fire-sale externalization (Kara & Ozsoy, 2020), implicit government guarantees, moral hazard issues (Christiano & Ikeda, 2016; Gertler & Kiyotaki, 2010), and household preference for safe and liquid assets (Begenau, 2020). The approach in this paper is related to that of (Kareken & Wallace, 1978; Van den Heuvel, 2008) who show that over-borrowing, led by mis-priced deposit insurance or otherwise, justifies capital regulation.

In our model, the regulator cannot observe bank risk directly, because the type of the bank is private information. The Basel Committee on Bank Regulation continues to struggle with a practical way of measuring bank's risk in its efforts to implement risk-based capital requirements. In an extreme way by assuming that risk is completely unobservable to the regulator would be possible, however not in line with the reality. Therefore, we assume regulator is able to control Bank's risk indirectly. The main regulatory tools available to do so in our model are bank's self-assessment, onsite inspection and regulatory fines.

To simplify the scenarios considered in the model, we use below key assumptions:

• Regulators are always benevolent and have good-wills to believe that most banks are well disciplined. They define a general framework which banks need to follow during their daily operations. And regulators also set up certain criteria where banks could conduct self-assessments. Bank has a lot support functions as 2nd line of defense which could enhance the self-assessment quality. Then based on banks' self-assessment result, if the bank gives itself good rating, they will be considered as high-type bank, while those banks with self-identified poor rating will be considered as low-type bank.

- The regulator cannot fully observe the bank's type, which means it cannot identify whether bank's self-assessment is genuine or not in date 0. Hence regulator cannot impose bank-specific requirements. We then consider this type of self-assessment as a bank (supervisory) discipline tool that provides an potential imprecise signal about the bank's type. Another key reason we think self-assessment could be imprecise is that sometimes banks may overestimate its performance during stress, although may not be on purpose.
- The regulator will imposes a capital surcharge on top of the baseline capital requirement based on the self-assessment that has done by each bank (*i.e.* the bank being deemed as low or high type). As capital ratio is one of the most important metrics for banks (Gao & Li, 2021), we assume low type bank will have additional capital surcharge from regulator given they are more riskier than high type bank (this is to simplify our model and easy to have analytic analysis below). In doing so, the regulator faces a trade-off. If regulator is purely relying on bank's self-assessment result, it may cause server moral hazard problems. Although self-assessment helps overcome (some) information frictions and align regulatory requirements with individual banks' risk profiles. Yet, inaccuracies can lead to inefficiently low or high requirements for some banks, and at the same time distort certain banks' ex-ante incentives, which lowers welfare.
- In order to mitigate the potential inaccuracy between bank's self-assessment and bank's actual risk profile, regulator will have onsite inspection for banks. The pass or fail results provided by regulators after onsite inspection will be considered as the actual reflection of the bank's type.

Some of the results in our paper are intuitively straight forward. However, we are developing a framework model to systematically explain them. Our main contribution is to show that under less transparent information friction between banks and regulators, a universal higher capital requirement could induce banks to become more risky. Because stricter requirement imposes a higher opportunity cost to a high-type bank, it adversely affects a bank's ex-ante incentives to exert effort towards becoming a high-type bank. The trade-offs faced by the regulator become even more pronounced when the regulator jointly chooses the level of balance between the supervisory burden on both regulators and banks and the optimal capital surcharge.

In an extended version of the model, we study another additional impact for these banks: disclosure the detail of the onsite inspection results to public and potential fines impact for onsite inspection failure banks. From regulator's point of view, disclosures improve market discipline and facilitate the use of capital surcharges. For bank, it may increase its cost of funds and place further limits on the optimal use of capitals.

Please note our model applied here is quite similar as the one used in (Christiano & Ikeda, 2016; Agarwal & Goel, 2021). However, the purpose is different and we think this type of model could be extended for more interests. For example, it could be used to study the wealth management subsidiaries of banks and mutual funds regulation etc. Given in China, FMIs improve the transparency between market participants and regulators, our paper may provide another point to study the FMI impact to Chinese financial market.

2. Equilibrium Model

We target to analyze the welfare and policy implications of a presumed regulatory framework and bank's self risk assessments—which are inherently noisy—and attendant capital requirements.

To this end, we further extended a two period model used by (Marshall & Prescott, 2004) to a three period model with the following main elements. First is a general equilibrium setup that enables us to capture the welfare effect of regulation. Second is a dynamic setup that allows us to assess the effect of regulation on banks' ex-ante behavior. Third is a rationale for capital regulation: an inefficiency that warrants regulatory intervention. Fourth is information frictions: the regulator does not fully observe a bank's type—which justifies the dependence of bank's self-assessment. Accordingly, we consider an economy that lasts three periods (0, 1, and 2), and consists of a representative household, a banker whose decisions are socially inefficient and whose type is stochastic, a regulator that cannot fully observe the bank's type, and a government that runs a deposit insurance program.

The representative household consists of a representative worker and a mass of bankers that are ex-ante identical. The households own all the assets in the economy, consume all the output, and operate all the banks. Each household includes one "banker", who is one of two types, low and high. Low-type bankers are bad at operating a bank while high-type bankers are good at bank operation. (We discuss the consequences of bank type more formally below.)

Household The household is representative, and receives an unconditional income endowment on dates 1 and 2. On date-1, it decides how much to consume, c_1, and how much to deposit, d, in the bank. Deposits are risk-free, and pay a gross return of R on date-2.

Banker We do not model the individual assets of a bank's investment project. Instead, we assume that the bank chooses the distribution of its project return. The banker has a capital of k on date-1. It runs a bank that issues deposits d to invest $k+d$ in a risky project that pays $\phi g(k+d)$ on date-2. $g(.)$ is a decreasing returns to scale (return function. ϕ is an investment shock whose density f_s depends on the banker's self-assessment type s on date-1, which can be high (H) or low (L). Specifically, we assume that while both types face the same standard deviation of ϕ, namely σ, the self-assessed high-type bank has a higher expected return, $\mu_H > \mu_L$, such that a self-assessed high-type bank has a higher risk-adjusted return. The probability p with which the bank is of high-type depends on the effort e the banker exerts on date-0. The cost of exerting effort is $\xi(e)$. The bank learns its self-assessed type on date-1 after its own assessment. Please note a self-assessed high-type bank doesn't mean it could be a regulator assessed high-type bank. And a self-assessed low-type bank is not necessarily a regulatory assessed low-type bank. Regulators have other indicators besides return or profit.

The bank's deposit liabilities on date-2 equal Rd, and thus the net cash-flow n equals $\phi g(k+d)-Rd$. When ϕ is sufficiently high and the bank is solvent, the entire cash-flow is paid as dividends to the banker. However, when ϕ is low enough so that the cash-flow is negative, the bank is in trouble and banker receives null. We assume that the banker only consumes on date-2, and that it has limited liability, so that it cannot be asked for additional capital to rescue a troubling bank. Instead, the government takes the bank into receivership.

Government The government runs the deposit insurance scheme and ensures that depositors are fully protected against bank failure. When a bank insolvent, the government liquidates its assets, and covers any shortfall in the failed bank's liabilities. To fund the scheme, the government imposes a lump-sum tax T on the household. We assume that the insurance scheme is mis-priced—*i.e.* insensitive to the risks banks take—which leads to a social inefficiency. The government runs a balanced budget.

Regulator The regulator is benevolent and also tries to reduce bank systematic risks. On date-0, it announces the minimum capital ratio requirement Ω that the bank must satisfy on date-1. However, we assume that the regulator cannot fully observe the bank's type on date-1. As such, it must announce a requirement that does not depend on banks' type, *i.e.* applies universally to both types of banks on date-1. Next, on top of this baseline setup, banks send self-assessment results/reports to the regulator on their type s. The content of these self-assessment results/reports cannot be verified by the regulator so the bank can say anything. However, we know by the Revelation Principle that as long as we impose the right incentive constraints, we can restrict ourselves to a direct mechanism where a bank directly reports its type. The regulator may or may not have onsite inspections to banks and check the reliability of bank's self-assessment results. The regulator then imposes a surcharge x on the bank deemed to be of low type, effectively imposing a bank-type specific requirement $\Omega_H=\Omega$ and $\Omega_L=\Omega+x$.

Recursive formulation We now formally setup the problem. The household chooses d on date-1 to maximize its expected utility over dates 1 and 2, where D_f is the discount factor:

$$U=\max_{d} c_1+D_f\mathbb{E}(c_2)\ \text{ s.t. } c_1=\overline{Y}-d \ \text{ and } \ c_2=\overline{Y}+Rd-T \tag{1}$$

We first assume regulator will completely trust on bank's self-assessment result, *i.e.* if bank self assesses itself as high-type (low-type) bank, then regulator will consider the same. The banker chooses e on date-0 which determines the probability of being a self-assessed (under the regulator pre-defined framework and rules) high-type (H-type) on date-1:

$$\text{Date 0}: \quad \max_e -\xi(e) + D_f \left(p(e) V_H(\Omega) + (1 - p(e)) V_L(\Omega) \right) \tag{2}$$

where $V_s(\Omega)$ is defined in equation below. The bank of type $s \in \{H, L\}$ chooses d on date-1 to maximize the expected dividend it pays on date-2:

$$\text{Date 1}: \quad V_s(\Omega) = \max_d D_f \int_{\frac{Rd}{g(k+d)}}^{\infty} \left(\phi g(k+d) - Rd \right) f_s(\phi) \mathrm{d}\phi \quad \text{s.t.} \ \frac{k}{\Omega} \geq d \tag{3}$$

The lower limit on the integral is the ϕ cut-off—call it ϕ_c—below which the bank insolvent (and no dividends are paid). Ω is the minimum capital ratio requirement. The government's budget constraint is as follows:

$$T = \begin{cases} Rd - \phi g(k+d) & \text{If the bank insolvent} \\ 0 & \text{Otherwise} \end{cases} \tag{4}$$

3. Analysis

We first assess the equilibrium conditions in the baseline economy where we could have derived some useful results (intuitively). We then characterize—as a benchmark—the optimal regulation in the absence of costly onsite inspection. Later, we analyse the optimal capital surcharge based on the gaps of regulator onsite inspection and bank self-assessment results, including when onsite inspection results are disclosed, and when bank failure is socially costly. Finally, we extend our model to include the potential regulatory fines for a mis-representing self-assessment bank type.

3.1. The Baseline Equilibrium

The first-order condition (FOC) of the bank's problem on date-0 shows that the effort the bank exerts depends on the wedge, say w, between the value of being a high as opposed to low-type on date-1:

$$-\xi'(e) + D_f p'(e) \left(\underbrace{V_H(\Omega) - V_L(\Omega)}_{w} \right) = 0 \tag{5}$$

To see how the effort changes as the wedge increases, we take the total derivative of above equation with respect to w, from where it is straightforward to note Lemma:

$$-\xi''(e) \frac{\mathrm{d}e}{\mathrm{d}w} + D_f p''(e) w \frac{\mathrm{d}e}{\mathrm{d}w} + D_f p'(e) = 0 \tag{6}$$

Lemma 1. If $\xi(.)$ is increasing and convex, and $p(.)$ is increasing and concave, then the bank exerts more effort when the difference in the value of being a high type compared to a low type increases, *i.e.*

$$\frac{\mathrm{d}e}{\mathrm{d}w} > 0$$

Equation (5) provides the intuition for why effort would increase with the wedge w. As the relative value of being a high-type bank increases, the marginal benefit of effort increases while the marginal cost is unaffected. Lemma 1 underscores that the minimum requirement (Ω) affects the wedge w by impacting the value of the bank on date-1. As such, the minimum requirement is a key factor in bank's effort choice on date-0, and will shape the regulator's choice of optimal ex-ante capital requirement as we show later in Section 3.3.

As regards the date-1 FOCs, we have the following:

$$\text{Bank}: \quad D_f \int_{\frac{Rd}{g(k+d)}}^{\infty} \left(\phi g'(k+d) - R\right) f_s(\phi)\,\mathrm{d}\phi - \Lambda_s = 0 \tag{7}$$

$$\text{Household}: \quad R = 1/D_f$$

Note in the bank's FOC that Λ_s is the Lagrange multiplier on the regulatory constraint, and that two of the three terms which arise from a routine application of the Leibniz rule are equal to zero.

3.2. Optimal Ex-Post Regulation

We consider a regulator who maximizes the date-1 and date-2 equally weighted welfare of the household and the banker by choosing the level of deposit funding on behalf of the banker, taking as given the household's first order condition:

$$\max_d c_1 + D_f \mathbb{E}\left(\bar{Y} + \phi g(k+d)\right) \text{ s.t. } R = 1/D_f;\ c_1 = \bar{Y} - d \tag{8}$$

Based on Equation (8), we document a result that will be useful (and intuitive) later. It compares the optimal date-1 regulation for high- and low-type banks. Assume that the regulator can perfectly observe bank type.

Lemma 2. The regulator optimally sets a higher ex-post requirement on the low-type bank as compared to a high-type bank, *i.e.* $\Omega_L^o > \Omega_H^o$.

Proof. Consider the social planner's date-1 FOC, we will have

$$0 = \int_0^{\infty} \left(\phi g'(k+d) - R\right) f_s(\phi)\,\mathrm{d}\phi = \mu_s g'(k+d) - R, \quad s \in \{H, L\} \tag{9}$$

The total derivative of d with respect μ_s implies:

$$g'(k+d) + \mu_s g''(k+d)\frac{\partial d}{\partial \mu_s} = 0 \Rightarrow \frac{\partial d}{\partial \mu_s} > 0,\ s \in \{H, L\} \tag{10}$$

This immediately implies that the optimal d is higher, or equivalently, the optimal Ω^o is lower for a high-type bank.

Intuitively, for a given level of deposits, a low-type bank not only generates lower expected output, but is also more likely to be insolvent. This underpins the stricter regulation for the low-type bank.

3.3. Optimal Ex-Ante Regulation

The bank forms expectations and chooses its date-0 decisions based on date-1 requirements announced by the regulator on date-0. However, because the bank's type on date-1 is unknown information, the regulator must adopt a uniform capital requirement—say Ω —which is applicable on date-1 irrespective of the bank's type. To characterize the optimal Ω , we begin with the following result.

Lemma 3. Assume that regulation capital ratio Ω applies for both bank types on date-1, then the effort the bank chooses to exert on date-0 decreases as Ω rises.

Proof. As shown in Lemma 1, the bank's date-0 effort e depends on $w = V_H(\Omega) - V_L(\Omega)$, *i.e.* the wedge between the value of being a high-versus low-type on date-1. The key then to proving this lemma is to characterize how regulation impacts w.

$$\begin{aligned} w = & D_f \int_{\frac{Rd}{g(k+d)}}^{\infty} \left(\phi g(k+d) - Rd\right) f_H(\phi)\,\mathrm{d}\phi \\ & - D_f \int_{\frac{Rd}{g(k+d)}}^{\infty} \left(\phi g(k+d) - Rd\right) f_L(\phi)\,\mathrm{d}\phi \end{aligned} \tag{11}$$

where $d = k/\Omega$. The derivative of w with respect to Ω gives:

$$\frac{\partial w}{\partial \Omega} = -\frac{k\beta}{\Omega^2}\left(\underbrace{\int_{\frac{Rd}{g(k+d)}}^{\infty} \left(\phi g'(k+d) - R\right) f_H(\phi)\,\mathrm{d}\phi}_{\Lambda_H} - \underbrace{\int_{\frac{Rd}{g(k+d)}}^{\infty} \left(\phi g'(k+d) - R\right) f_L(\phi)\,\mathrm{d}\phi}_{\Lambda_L}\right) \tag{12}$$

where Λ_s is the Lagrange multiplier on the regulatory constraint in the bank's problem.

To sign this expression, we proceed as follows. First note that since the (binding) regulatory requirement is the same for both types of bank, their deposit choices and thus the failure cutoffs ϕ_c are also the same. Then let $\hat{F}_H$ and $\hat{F}_L$ be the distribution functions of ϕ for high- and low-type banks, truncated below at ϕ_c. Since $\mu_H > \mu_L$ (while the variances are the same), $\hat{F}_H$ FOSD $\hat{F}_L$, that is $\hat{F}_H(\psi) \le \hat{F}_L(\psi) \quad \forall \psi$. Finally, since $\left(\phi g'(k+d) - R\right)$ is an increasing function of ϕ, it follows that:

$$\int \left(\phi g'(k+d) - R\right) \mathrm{d}\hat{F}_H - \int \left(\phi g'(k+d) - R\right) \mathrm{d}\hat{F}_L = \Lambda_H - \Lambda_L > 0 \tag{13}$$

In turn, this implies that

$$\frac{\partial w}{\partial \Omega} < 0$$

Then from Lemma 1 we know that

$$\frac{\partial e}{\partial w} > 0$$

which completes the proof since:

$$\frac{\partial e}{\partial \Omega} = \frac{\partial e}{\partial w}\frac{\partial w}{\partial \Omega} < 0. \tag{14}$$

Lemma 3 captures a key insight of this paper. Because a high-type bank's assets are more profitable, the opportunity cost of stricter capital requirements is greater for this bank. As such, an increase from a given level of requirement leads to a greater decline in the expected value of the high-type bank than the low type bank. This, in turn, lowers the returns to exerting more effort. In contrast to the conventional wisdom that more skin-in-the-game (via higher capital requirement) can induce banks to become safer, our finding is that under model assumptions banks might respond to stricter regulation by becoming less willing to perform like a good bank regulator wished (*i.e.* potentially become more riskier).

This insight points to an important trade-off the regulator faces while setting Ω. Compared to no regulation ($\Omega = 0$), a higher Ω can improve welfare ex-post by mitigating some of the inefficiency associated with the bank's choices, especially in case of a low-type bank. Yet, a higher Ω can reduce welfare due to its adverse impact on effort exerted ex-ante.

Proposition 4. The optimal ex-ante requirement Ω^o in the case where the regulator cannot observe the bank's type, lies between by the optimal ex-post requirement for low and high type banks, *i.e.* $\Omega_L^o \geq \Omega^o \geq \Omega_H^o$.

Proof. The problem of a benevolent regulator on date-0 when it cannot impose bank specific requirements, is as follows:

$$\max_{\Omega} D_f p(e) U_H(\Omega) + D_f (1 - p(e)) U_L(\Omega) - \xi(e) \tag{15}$$

Here U_s is the household's and banker's combined expected lifetime consumption utilities when the banker turns out to be of type *s*, while $\xi(e)$ accounts for the banker's effort on date-0. We will prove the proposition via the method of contradiction. Let Ω^o solve the above problem. Then, if $\Omega^o > \Omega_L^o > \Omega_H^o$, it means that the requirement is more strict than the optimal requirement for both bank types, and thus a lower Ω^o would improve welfare in case of each bank type, as well as the total expected welfare. Similarly, if $\Omega_L^o > \Omega_H^o > \Omega^o$, it means that the requirement is more liberal than the optimal requirement for both bank types, and thus a higher Ω^o would improve total welfare.

Intuitively, this proposition 4 shows that when there is information asymmetry or fractions, the regulator chooses a middle-ground relative to the optimal bank-type specific requirements.

3.4. Regulator Onsite Inspection Considered

Now we consider that regulator would like to use onsite inspection to verify bank's self-assessment accuracy. It is desirable as in real world it happens quite often across different regions.

We model bank's self-assessment as a tool that produces a "noisy" signal to the regulator about the bank's type. Based on the bank's self-assessment outcome, one thing is sure that the expected return for high type self-assessed banks are higher than the low type self-assessment banks. We assume that the probability that a self-assessed high-type (low-type) bank is deemed high after regulator's onsite inspection is q_H (q_L). The accuracy of the self-assessment is fully captured by the tuple (q_H, q_L). In this format, $(1 - q_H)$ denotes the "false positive" or Type-I error rate (bank's self-assessed high-type bank fails the regulator's identification), while q_L is the "false negative" or Type-II error rate (self-assessed low-type bank passes the onsite inspection, *i.e.* identified as high-type bank by regulator). A convenient benchmark, which is equivalent to the full-accurate case, is when $q_H = 1$ and $q_L = 0$, *i.e.* a perfect signal that exactly identifies the type of the bank by self-assessment. In all other cases, we refer to bank's self-assessment as imperfect because a self-assessed H-type bank can fail the regulator's identification ($q_H < 1$) or a self-assessed L-type bank can pass the inspection ($q_L > 0$).

The regulator uses the outcome of the onsite inspection to adjust the baseline capital requirement Ω^o. We assume that a bank that passed regulator's onsite inspection is deemed as high-type and is allowed to operate at Ω^o. A failed onsite inspection bank is deemed to be of the low-type, and the regulator strives to align the capital ratio requirement towards $\Omega_L^o \geq \Omega^o$ by imposing a surcharge $x \geq 0$.

The core question of interest then is as follows: what is the welfare maximising level of surcharge x that the regulator must announce on date-0. The choice of x is non-trivial, and is subject to a three-way trade-off.

- In case of the self-assessed low-type bank, the surcharge (upon failing the regulator onsite inspection) increases welfare ceteris paribus as long as $x \leq \Omega_L^o - \Omega^o$. This is because the surcharge brings the requirement ($\Omega^o + x$) closer to the optimal (Ω_L^o).
- In case of the self-assessed high-type bank, the surcharge (upon failing the regulator onsite inspection) decreases welfare ceteris paribus. This is because $\Omega^o + x > \Omega_H^o$, as a result of which the surcharge takes the effective requirement away from the optimal.
- The surcharge affects the wedge between the expected value of being high-versus low-type on date-1, and thus impacts the bank's behaviour on date-0.

Proposition 5. No surcharge shall be imposed by regulator if the error rate of self-assessment results as measured by a (endogenously-defined) linear combination of the Type-I and Type-II error rates is higher than a threshold.

Proof. Welfare as a function of the surcharge x can be written based on the regulator's problem as follows (note that e also depends on x in this expression):

$$\begin{aligned}\max_x W(x) = {} & D_f\, p(e)\big(q_H U_H(\Omega^o) + (1-q_H)U_H(\Omega^o + x)\big) \\ & + D_f(1-p(e))\big(q_L U_L(\Omega^o) + (1-q_L)U_L(\Omega^o + x)\big) - \xi(e)\end{aligned} \tag{16}$$

Our goal is to identify "a" non-trivial set of (q_H, q_L) where $W(0) > W(x)$ $\forall x > 0$, *i.e.* a zero surcharge is optimal. A sufficient condition for this to be the case is $W'(x) < 0 \quad \forall x > 0$. To this end, we consider the first-order condition of the regulator's problem:

$$\begin{aligned}\frac{\mathrm{d}W}{\mathrm{d}x} = {} & p'(e)e'(x)\big(q_H U_H(\Omega^o) + (1-q_H)U_H(\Omega^o + x)\big) \\ & + p(e)(1-q_H)U_H'(\Omega^o + x) \\ & - p'(e)e'(x)\big(q_L U_L(\Omega^o) + (1-q_L)U_L(\Omega^o + x)\big) \\ & + (1-p(e))(1-q_L)U_L'(\Omega^o + x) - \xi'(e)e'(x)\end{aligned} \tag{17}$$

To characterize the sign of this expression, we make a few assumptions, again with the goal to find sufficient conditions under which the optimal surcharge is zero.

First we assume that $x \in \left[0, \Omega_L^o - \Omega^o\right]$. The upper bound corresponds to a surcharge amount that results in a requirement for the low-type banks that is equal to the ex-post optimal requirement Ω_L^o. In principle, the optimal surcharge could be higher (due to its effect on improving ex-ante effort), but that would entail a welfare decreasing effect in case of both high- and low-type banks.

Second, we assume that (q_H, q_L) are such that the effort exerted by the bank decreases as surcharge increases. Intuitively, a higher Type-I (*i.e.* lower q_H) or Type-II error rate (higher q_L) would cause the bank to reduce effort following a higher surcharge. Indeed, if a self-assessed high type bank is sufficiently likely to fail the regulator's onsite inspection (when regulatory requirement is very strict or banks are less disciplined) or the self-assessed low-type bank is sufficiently likely to pass the regulator's onsite inspection (when the additional cost of failing regulator's onsite inspection is too high and hence banks are more disciplined), then the self-assessed high-type bank will often face a surcharge or potential additional high cost, thereby reducing the relative benefit to being a regulator wanted high-type bank. This will induce the bank to exert less effort towards becoming high-type in the first place.

Next, since $U_s\left(\Omega^o + x\right), s \in \{L, H\}$ is a concave function of x, $\Omega_L^o \ge \Omega^o \ge \Omega_H^o$ implies the following: 1) $U_H\left(\Omega^o\right) \ge U_H\left(\Omega^o + x\right)$; 2) $U'_H\left(\Omega^o + x\right) \le 0$; 3) $U_L\left(\Omega^o\right) \le U_L\left(\Omega^o + x\right)$; and 4) $U'_L\left(\Omega^o + x\right) \ge 0$; $\forall x \in \left[0, \Omega_L^o - \Omega^o\right]$. It then follows that:

$$\begin{aligned}\frac{\mathrm{d}W}{\mathrm{d}x} \le\ & p'(e)e'(x)U_H\left(\Omega^o\right) + p(e)(1-q_H)U'_H\left(\Omega^o + x\right) \\ & - p'(e)e'(x)U_L\left(\Omega^o\right) + (1-p(e))(1-q_L)U'_L\left(\Omega^o\right) - \xi'(e)e'(x)\end{aligned} \tag{18}$$

Finally, we re-arrange and set the right-hand-side expression to zero:

$$\begin{aligned}& \underbrace{p'(e)e'(x)\left(U_H\left(\Omega^o\right) - U_L\left(\Omega^o\right)\right)}_{A<0} + p(e)U'_H\left(\Omega^o + x\right) + (1-p(e))U'_L\left(\Omega^o\right) \\ & - p(e)q_H U'_H\left(\Omega^o + x\right) - (1-p(e))q_L U'_L\left(\Omega^o\right) - \xi'(e)e'(x) = 0 \\ & \Rightarrow \underbrace{\frac{A}{p(e)U'_H\left(\Omega^o + x\right)} + 1 + \frac{(1-p(e))U'_L\left(\Omega^o\right) - \xi'(e)e'(x)}{p(e)U'_H\left(\Omega^o + x\right)}}_{\tau_0} \\ & \quad - q_L \underbrace{\frac{(1-p(e))U'_L\left(\Omega^o\right)}{p(e)U'_H\left(\Omega^o + x\right)}}_{\tau_1<0} = q_H \\ & \Rightarrow q_H = \tau_0 - \tau_1 q_L\end{aligned} \tag{19}$$

In Equation (19), while the slope is positive, the intercept can be positive or negative, depending on the underlying parameters. The equation implies that when $q_H < \tau_0 - \tau_1 q_L$ the surcharge should be zero.

Intuitively, the proposition shows that when q_H is low and/or q_L is high—both of which reflect a relatively less accurate self-assessment results—the surcharge shall be zero as the capital requirement shall be insensitive to the self-assessment now.

Now we consider the problem of a regulator that jointly chooses surcharge x and a willingness parameter $y \geq 0$ that maps to the onsite inspection pass probability of the self-assessed high-type bank: $q_H(y) \to 1$ as $y \to \infty$, while keeping q_L fixed. In addition, we assume that to improve accuracy entails a social cost $C(y) = \gamma_c y$. This setup leads to the following result:

Proposition 6. If the regulator tries to increase bank's self-assessment accuracy q_H via more efforts, the capital surcharge for self-assessment failing banks shall increase at the same time.

Proof. The regulator's problem in this case is as follows:

$$\begin{aligned}&\max_{x,y} D_f\, p\left(q_H(y)U_H\left(\Omega^o\right)+\left(1-q_H(y)\right)U_H\left(\Omega^o+x\right)\right)\\&+D_f(1-p)\left(q_L U_L\left(\Omega^o\right)+\left(1-q_L\right)U_L\left(\Omega^o+x\right)\right)-\gamma_c y\end{aligned} \tag{20}$$

The first order conditions are:

$$[x]:\ 0 = p\left(1-q_H(y)\right)U'_H\left(\Omega^o+x\right)+(1-p)\left(1-q_L\right)U'_L\left(\Omega^o+x\right) \tag{21}$$

$$[y]:\ 0 = D_f\, p q'_H(y)\left(UH\left(\Omega^o\right)-U_H\left(\Omega^o+x\right)\right)-\gamma_c \tag{22}$$

Next consider an increase in the cost of accuracy γ_c. A total derivative of the FOCs leads to

$$\begin{aligned}[x]:0 = {}& p\left(\left(1-q_H(y)\right)U''_H\left(\Omega^o+x\right)x'-q'_H(y)y'U'_H\left(\Omega^o+x\right)\right)\\&+(1-p)\left(1-q_L\right)U''_L\left(\Omega^o+x\right)x'\end{aligned} \tag{23}$$

where

$$y' = \frac{\partial y}{\partial \gamma_c}$$

and

$$x' = \frac{\partial x}{\partial \gamma_c}$$

The first total derivative implies that x' and y' are of the same sign since U is concave, $U''_H < 0; U'_H\left(\Omega^o+x\right) < 0$, and $q'_H > 0$. This means that accuracy and surcharge go hand in hand.

Corollary 7. The optimal capital surcharge increases with self-assessment accuracy.

3.5. Extended Model with Additional Fine Costs

We extend our model to include a role for professional uninsured investors that react to onsite inspection results. To create an incentive for the bank to pursue the two types of funding, we assume that deposit based funding is not easily scalable, and thus the unit cost of deposit funding $R(d)$ increases with the funding amount. At the same time, investor funding *w*, even though more costly for smaller amounts, is easily scalable, and is the relatively cheaper source of financing for larger amounts. Yet, when a bank fails the onsite inspection by regulator, while insured depositors do not seek a higher return, uninsured investors raise their required return $Q(w)$ by, say, δ_f. Moreover, regulator may impose financial penalty for these failure banks during the onsite inspection. For our model simplicity, we assume the penalty is a percentage of the bank's uninsured investor's funding, say, δ_p. We denote $\delta = \delta_f + \delta_p$. The date-1 problem of the bank in this case is as follows:

$$V_s(\Omega_s) = \max_{d,w} D_f \int_{\frac{R(d)d+Q(w)w}{g(k+d+w)}}^{\infty} \left(\phi g(k+d+w) - R(d)d - Q(w)w\right) f_s(\phi)\,\mathrm{d}\phi \quad (24)$$

$$\text{s.t. } \frac{k}{\Omega_s} \geq (d+w).$$

Assuming that both forms of financing are used in equilibrium, we assess the implications for banks and for the regulator. We first note that failure in the onsite inspection is now more costly for the bank—not only does it need to satisfy a higher capital ratio, its average cost of funding is higher compared to the case where disclosures have no material impact and regulator has not asked for penalty of the failure (*i.e.* $\delta = 0$). Formally, the FOCs of the bank's problem imply that d and w are determined in the case of passing and failing banks as follows, respectively:

$$\frac{k}{\Omega} = d + w;\ R'(d)d + R(d) = Q'(w)w + Q(w) \quad (25)$$

$$\frac{k}{\Omega + x} = d + w;\ R'(d)d + R(d) = Q'(w)w + Q(w) + \delta \quad (26)$$

To make analytical progress, we assume simple forms of the cost functions: $R(d) = R_0 + R_1 d$ and $Q(w) = Q$ such that they continue to reflect the underlying intuition that investor funding is more elastic than deposit funding. Solving the FOCs explicitly leads to:

$$d_{pass} = \frac{Q - R_0}{2R_1};\ w_{pass} = \frac{k}{\Omega} - \frac{Q - R_0}{2R_1} \quad (27)$$

$$d_{fail} = \frac{Q + \delta - R_0}{2R_1};\ w_{fail} = \frac{k}{\Omega + x} - \frac{Q + \delta - R_0}{2R_1} \quad (28)$$

That is, upon failure during the onsite inspection, the bank reduces its overall balance sheet and funding, and tilts its funding composition towards deposits. At the same time, the total funding cost (TC) of a failing bank is increasing in δ. To see this, consider the total funding cost (TC) of a failing bank as a function of δ: $TC(\delta) = R(d)d + (Q+\delta)\left(k/(\Omega+x) - d\right)$ where $d = (Q + \delta - R_0)/(2R_1)$. Taking the derivative of the above expression with respect to δ immediately leads to the above result: $TC'(\delta) > 0$. Hence the value of a failing bank is decreasing in δ.

To derive the different implications for self-assessed high type and self-assessed low type banks, we study the impact of δ on the expected value function wedge (recall Equation (6)). The value of a self-assessed high- or self-assessed low-type bank that passes the regulatory onsite inspection—*i.e.* $V_H\left(\Omega^o\right)$ and $V_L\left(\Omega^o\right)$—remains unaffected by δ. However, δ leads to a larger decline in the value of a self-assessed high-type bank that fails the onsite inspection, *i.e.* to be considered as low-type bank by regulator. To see this formally, consider the resolved value function of the s-type bank, where we have already solved for the *d*, *w* decisions as a function of δ:

$$V_s\left(\Omega^o + x;\delta\right) = D_f \int_{\frac{TC(\delta)}{g(k+d+w)}}^{\infty} \left(\phi g\left(k+d+w\right) - TC\left(\delta\right)\right) f_s\left(\phi\right) \mathrm{d}\phi \tag{29}$$

The derivative of the value function with respect to δ implies:

$$\frac{\mathrm{d}V_s\left(\Omega^o + x;\delta\right)}{\mathrm{d}\delta} = -D_f TC'\left(\delta\right) \int_{\frac{TC(\delta)}{g(k+d+w)}}^{\infty} f_s\left(\phi\right) \mathrm{d}\phi \tag{30}$$

The above expression proves that the value function of each type of bank is decreasing in δ since $TC'\left(\delta\right) > 0$. Moreover, since the insolvent cutoff and $TC\left(.\right)$ are independent of bank types, the decline in value is greater in case of the self-assessed high-type bank. Intuitively, the probability that the self-assessed high-type bank will give market more surprise if it fails the regulator onsite inspection and potentially receive penalties from regulator, which means that it is more likely to incur the higher funding cost required by market. Therefore, it follows that

$$V_H\left(\Omega^o + x;\delta = 0\right) - V_H\left(\Omega^o + x;\delta > 0\right) > V_L\left(\Omega^o + x;\delta = 0\right) - V_L\left(\Omega^o + x;\delta > 0\right).$$

As such, ceteris paribus, a higher δ depresses the expected value function wedge, *i.e.* gives less incentives for a bank to self identify itself as high-type bank.

4. Conclusion

Use of bank's self-assessments has become an important tool for policymakers and regulators in China. They have helped regulators in gauging banks' idiosyncratic risks and in bolstering financial stability with less effort. Banks and regulators continue to evolve and improve based on lessons learn over the past decades. Despite these enhancements, such self-assessments continue to be noisy, not least due to fundamental difficulties inherent in identifying risks. Given that such self-assessments underpin banks' overall profiles, inaccuracy can lead to misdirected requirements and can have a large impact on banks' capital costs, on their reputations, and on overall economic welfare.

To assess the implications, we build a simple model to analyze the optimal ex-ante and ex-post regulation based on bank's self-assessment and later discuss the inaccuracy impact of self-assessment results with consideration of regulator's onsite inspection, and show that inaccuracy not only reduces overall welfare directly, but may also create adverse ex-ante incentives for banks. Going against the conventional wisdom, we also show that in the presence of information frictions, higher capital requirements may lead to more risky banks. As such, the graduation of capital requirements on the basis of self-assessments shall be inversely related to the accuracy of these self-assessment results. In the extreme case of very low reliability, capital requirements should be insensitive to the self-assessment results. Instead, higher penalty by regulator or cost of funding shall be considered as methods to improve the self-assessment accuracy rate.

In future research, we are considering other regulatory instruments incorporate with market discipline, such as capital stress testing and ad-hoc risk audits when the bank's funding cost increases to above certain threshold, which will have the potential of delivering similar results as those found in this paper while conforming more closely to observed practice.

Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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