The Effects of Capital Regulation on Banks – An Analytical Approach[1]

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Abstract

The effects of capital regulation on a bank are examined in this study. Violating the legal requirements is costly for both the bank manager and the shareholder. Through a stock-based compensation plan, stock prices can be used to evaluate the manager. But stock prices are not always the most accurate measure. The purpose of this compensation plan is to provide incentive to the bank manager. Introducing capital regulation can provide for a more accurate measure. However, this may not work because a moral hazard exists to the extent that the shareholder cannot observe the manager's effort.

I develop a basic agency model and show that when accounting is very flexible, imposing capital regulation is meaningless. I also show that introducing capital regulation is generally good for the shareholder because it reduces monetary compensation to the manager. However, the effectiveness of the capital ratio regulation depends on the relative level of the ratio and accounting flexibility.

I. Introduction

Banks are required to maintain a certain level of capital ratio (Book value of equity / Total risk weighted assets; for example, a required minimum ratio for international-active banks is eight percent in Japan as of 2003) that is required by a local regulatory body. Riskless assets such as government bonds are excluded from the calculation of risk-weighted assets, while commercial loans are treated as risky assets. The capital standard was put into effect internationally in March 1989 by the Basel Committee.[2]

It is costly for banks to violate the minimum capital adequacy ratio because it may trigger

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2 The Bank for International Settlements (BIS) is an international organization that fosters international monetary and financial cooperation and serves as a last resort for central banks. The Basel Committee was established by the central banks of G-10 countries at the end of 1974 within the BIS. The Basel Committee does not possess any formal supervisory authority, though it formulates broad supervisory standards and guidelines and recommends statements.

regulatory intervention, an unwilling merger, or a suspension of operations. Violating the capital adequacy requirements became more costly for Japanese banks after explicit regulation came into effect in 1998 because of the enforcement of "Prompt Corrective Action[3]". Table 1 shows the level of measures that a Japanese regulatory body can take to improve banks' capital adequacy ratio.

There are many studies[4] that focus on banks' behavior when this regulation is enforced. Ito and Sasaki (1998) analyze how Japanese banks responded to the introduction of the capital standards and how the stock market responded at the time. Their focus is to show how banks tried to meet the standards and they found that banks with lower capital ratios tended to issue debts and to reduce their risky assets. Peek and Rosengren (1997) examine Japanese banks' lending behavior overseas when faced with the regulation. Their focus is mainly on banks' "economic" behavior. In this study, my focus is slightly different from that of their study. I develop a simple agency model that describes a bank's "accounting" behavior as well as economic behavior when a bank manager faces the introduction of the capital regulation. Anecdotal evidence suggests that Japanese banks have been using accounting items (such as deferred tax) to help them meet the capital adequacy ratio, when they otherwise would not. Therefore, it is important to know how a bank manager responds to the introduction of capital regulation.

The introduction and enforcement of capital regulation provides an interesting perspective on the roles and effects of the regulation. Also the presence of a moral hazard associated with the unobservability of a manager's effort, provides an interesting perspective on the role of compensation contracts between a bank shareholder and a bank manager.

In order to capture the effects of introduction of the capital regulation, I construct a basic agency model in which a bank shareholder (principal) negotiates a compensation contract with a bank manager (agent), who then chooses effort allocation to achieve the required capital ratio. The basic idea of the study is as follows. A shareholder and a bank manager make a compensation contract that is based on current stock performance. The stock market distinguishes the manager's good effort and bad effort and only appreciates the good effort, but there are some errors. I define "good effort" as effort that produces desirable outcomes for the shareholder, and "bad effort" as effort that produces no desirable outcome for the shareholder. When a stock price is a noisy measure of a manager's effort, the usefulness of a stock price for contract purpose decreases. In this case, a shareholder can benefit from the capital regulation. The problem with the regulation is that it induces both good and bad effort from the manager. Later, I will show how accounting flexibility affects these results.

3 PCA specifies the guidance and potential punishments when the banks violate the minimum capital adequacy ratio.

4 See Ito and Sasaki (1998) for detailed literature review.

Table 1
Level of regulatory intervention by the Prompt Corrective Action (PCA) in Japan.

Level of capital ratios to trigger PCA			
Class	International banks	Non-international banks	Order
Not relevant	$R \geq 8\%$	$R \geq 4\%$	None
First level	$8\% > R \geq 4\%$	$4\% > R \geq 2\%$	Order to prepare and submit improvement plan.
Second level (1)	$4\% > R \geq 2\%$	$2\% > R \geq 1\%$	1. Order to prepare, submit, and execute a plan for sound operation. 2. Restrict or prohibit dividend payment. 3. Restrict or prohibit payment of management compensation. 4. Restrict or compression of total assets. 5. Order to restrict or prohibit "higher-interest deposits." 6. Reduce existing branches. 7. Abolish branches without headquarters. 8. Reduce subsidiaries or affiliates overseas. 9. Sale of stocks in subsidiaries or affiliates overseas. 10. Reduce operations and prohibit new operations.
Second level (2)	$2\% > R \geq 0\%$	$1\% > R \geq 0\%$	Order to choose one of the following plans and implementation of the plan: 1. Improve equity capital. 2. Implement drastic reduction of operations. 3. Implement merger or suspension of operations.
Third level	$0\% > R$	$0\% > R$	Suspension of a part of or a full operations.

Source: The Financial Service Agency web site: http://www.fsa.go.jp

The rest of the paper is organized as follows. The next section introduces the basic analytical models and discusses various assumptions about key parameters in the models. The models that are discussed in this section are (1) the first-best model where the agent's effort is observable, and (2) the second-best model where the manager's compensation rate is based on a stock price. Section III presents the effects of the introduction of capital regulation on the bank. First, I show the effects of regulation on the (1) manager's effort level, (2) compensation contract, (3) stock price, and (4) principal's profit when the (a) accounting flexibility, κ equals zero, and (b) when κ is greater than zero and fixed. Second, I show how changes in accounting flexibility affect the principal's profit and examine the interaction between accounting flexibility and capital regulation. Section IV concludes with a discussion on key results and future extension of the model.

II. Basic Model

In this model, a principal (bank shareholder) is interested in maximizing her profit, and an agent (bank manager) is interested in maximizing her compensation from the principal while minimizing her cost of effort. I assume that the principal is risk-neutral and that the agent is weakly risk- and effort-averse. The manager is assumed to have an exponential utility:[5]

$$u(\omega) = -e^{-r\omega} \tag{2.1}$$

where r denotes a risk parameter and ($r \geq 0$) and ω denotes an income from compensation reduced by the pecuniary equivalent cost of effort involved in the decisions of the manager.

The manager can choose a combination of good and bad effort. For the purposes of my model, I define "good effort" and "bad effort" as follows:

Good effort: Effort such as issuing new equity, reducing risky assets, and increasing safe assets such as government bonds that produces desirable outcomes for the shareholder[6].

Bad effort: Effort such as accounting manipulation that produces no substantial value for the shareholder.

The cost of effort associated with good effort a and bad effort b are determined as follows:

$$C(a, b) = \frac{1}{2}\left(a^2 + \kappa b^2\right) \tag{2.2}$$

and $\kappa \geq 0$. κ implies the degree of accounting flexibility. When $\kappa = 0$, bad effort is costless because accounting is very flexible. As κ increases, bad effort becomes more costly to the manager.

The manager's compensation is described as follows:

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5 The development of the model is based on Hughes and Thevaranjan (1995).

6 In this model, the manager is rewarded as she tries to improve capital ratio. The manager is not rewarded by maximizing profits of the bank in this setting.

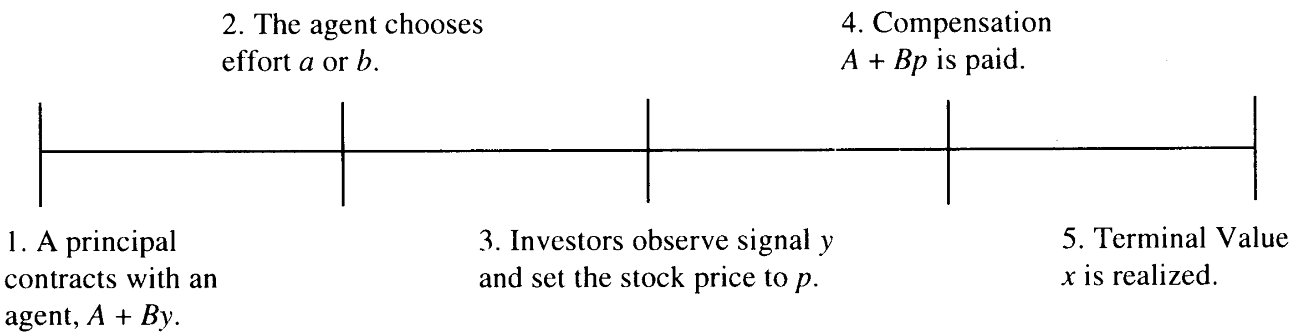
$$c(y) = A + By \tag{2.3}$$

where A is a fixed component of the compensation and By is a variable component based on a fixed compensation rate, B, and a signal, y (or in other words, a filtered stock price). The signal y is set as follows. I assume that a bank's terminal value, x is set by,

$$x = a + \varepsilon_x. \tag{2.4}$$

The bank's terminal value is only increased by the manager's good effort and some normally distributed error, $\varepsilon_x \sim N(0, \sigma_x^2)$. There is a signal y that investors observe after the manager chooses her effort allocation. After observing the signal, the stock market sets a stock price, p. In this paper, the signal y is used for the compensation contract between the manager and the shareholder and $y > 0$[7]. The stock price based contract has its limitations because a stock price is a noisy measure for the manager's effort. The sequence of events is summarized in Figure 1.

Figure 1. Sequence of events



Assumptions:

(1) Linear contract, $A + By$.

(2) Risk neutral principal and weakly risk- and effort-averse agent.

(3) Exponential utility of the agent.

(4) Cost of effort = $C(a, b) = \frac{1}{2}(a^2 + \kappa b^2)$.

(5) $x = a + \varepsilon_z$ and $\varepsilon_x \sim N(0, \sigma_x^2)$ where accounting flexibility $\kappa \geq 0$, and,

$y = a + \varepsilon_y$ and $\varepsilon_y \sim N(0, \sigma_x^2)$ and $p \geq E[x \mid y]$, and,

y = signal = filtered price and $\sigma_{xy} > 0$.

(6) R = capital ratio = $a + b$.

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[7] See the Appendix for the mathematical representations of y and p.

In the following sub-sections, I discuss two models: (1) the first-best contract where the compensation to a manager is fixed, and (2) the second-best contract with an incentive-based compensation, and a utility maximizing manager.

First-best contract

Consider a case with an unrealistic assumption that a manager (agent)'s effort is observable to a principal (shareholder) and the principal pays a fixed compensation to the agent. Note that the risk neutrality of the principal and the risk adversity of the agent are assumed. The principal takes all the associated risk[8]. If the manager's effort were observable to the shareholder, then the shareholder could determine the effort levels corresponding to the most efficient mix of good and bad effort, and write a forcing contract to ensure that the effort level is chosen. This unrealistic case is called the "first-best" case, and I use this as a benchmark. In this setting, the actions are chosen cooperatively with both principal and agent. In the first-best solution, both principal and agent choose the contract that maximizes the principal's expected utility subject to meeting the agent's acceptable level of utility[9]. The principal's problem is given by:

$$\underset{a,b}{Maximize} \quad E[y] - E[c(y)]$$

$$\text{Subject to} \quad Eu\left[-\exp\left\{r\left(A - \frac{1}{2}(a^2 + \kappa b^2)\right)\right\}\right] \geq 0. \tag{2.5}$$

Paying a flat compensation A equivalent to the cost of effort ensures that the agent will accept the contract. In this case, the principal's problem is simply to find the effort that maximize the expected payoff, $E(y) - \frac{1}{2}\left(a^2 + \kappa b^2\right)$ and the principal's first-best problem reduces to:

$$\underset{a,b}{Maximize} \quad a - \frac{1}{2}\left(a^2 + \kappa b^2\right). \tag{2.6}$$

It follows immediately that the solutions for the first-best are $a_{FB} = 1$, $b_{FB} = 0$, $E[y_{FB}] = 1$, principal's profit = $\pi_{FB} = \frac{1}{2}$, and cost of agent = $c_{FB} = \frac{1}{2}$ [10]. The subscript FB denotes that they are the first-best results. The results are summarized in Table 2.

Second-best contract

Next, consider the more realistic case when the manager's effort is not observable to the principal. Instead, now signal, y is observable to both principal and agent, and they can

8 Later, I will consider the case where the agent is also risk-neutral.

9 See Lambert (2001).

10 Proofs are shown in the Appendix.

Table 2
Summary for first-best results, second-best results and results for capital regulation.

Variables	First best results	IC on price and IR (But no capital ratio regulation)	IC, IR, and capital ratio regulation, R = a + b
B = Compensation	N/A	$B_{SB} = \frac{1}{1 + r\sigma^2{}_y}$	$B_R = \frac{1}{1 + (1 + \kappa) r\sigma^2{}_y}$
a = Good effort	$a_{FB} = 1$	$a_{SB} = \frac{1}{1 + r\sigma^2{}_y}$	$a_R = \left(\frac{1}{1+\kappa}\right)\left[\kappa R + \frac{1}{1 + (1 + \kappa) r\sigma^2{}_y}\right]$
b = Bad effort	$b_{FB} = 0$	$b_{SB} = 0$	$b_R = \left(\frac{1}{1+\kappa}\right)\left[R - \frac{1}{1 + (1 + \kappa) r\sigma^2{}_y}\right]$
P = Stock price, y = Filtered price, E[y] = Expected filter price	$E[y_{FB}] = 1$	$E[y_{SB}] = \frac{1}{1 + r\sigma^2{}_y}$	$E[y_R] = \left(\frac{1}{1+\kappa}\right)\left[\kappa R + \frac{1}{1 + (1 + \kappa) r\sigma^2{}_y}\right]$
π = Principal's profit	$\pi_{FB} = \frac{1}{2}$	$\pi_{SB} = \frac{1}{2}\left(\frac{1}{1 + r\sigma^2{}_y}\right)$	$\pi_R = \left(\frac{1}{2}\right)\left(\frac{1}{1+\kappa}\right)\left[\kappa(2R - R^2) + \frac{1}{1 + (1 + \kappa) r\sigma^2{}_y}\right]$
$C(a,b) = \frac{1}{2}(a^2 + \kappa b^2)$ Cost of effort	$C_{FB} = \frac{1}{2}$	$C_{SB} = \frac{1}{2}\left(\frac{1}{1 + r\sigma^2{}_y}\right)^2$	$C_R = \frac{1}{2}(a_R^2 + \kappa b_R^2)$

contract upon the signal y. The sequence of events and basic assumptions of the model are summarized in Figure 1. As described in the Appendix, the signal y is affected by random factors, $\varepsilon_y \sim N(0, \sigma_y^2)$, which are beyond the control of the agent.

Following Holmström and Milgrom (1987), Feltham and Xie (1994), and Banker and Thevaranjan (2000), I assume that the compensation plan is linear in the performance measure, signal, and the manager's compensation.

Now the principal's problem is to choose a compensation plan and the agent's effort to maximize her expected profit subject to compliance with the individual rationality (IR) constraint and the incentive compatibility (IC) constraint[11]. Specifically, the principal's problem is:

$$\underset{A,B}{Maximize} \quad E(y) - E(A + By)$$

$$\text{Subject to} \quad E\left[-\exp\left\{r\left((A + By) - \frac{1}{2}\left(a^2 + \kappa b^2\right)\right)\right\}\right] \geq 0 \qquad \text{(IR constraint)}$$

$$(a, b) \in \underset{(a,b)}{\arg\max}\ E\left[-\exp\left\{r\left((A + By) - \frac{1}{2}\left(a^2 + \kappa b^2\right)\right)\right\}\right] \qquad \text{(IC constraint).} \quad (2.7)$$

I can combine a linear contract with a normal distribution and exponential utility. The agent's expected utility is described as:

$$Eu = -\exp\left[-r\left(A + Ba - \frac{1}{2}\left(a^2 + \kappa b^2\right) - \frac{r}{2}B^2\sigma^2{}_y\right)\right]. \qquad (2.8)$$

If the expected compensation, $E(A + By)$ is set equal to the cost of effort of the agent plus the risk premium, the IR constraint can be simplified and the agent's objective function also simplified to:

$$\underset{a,b}{Maximize} \quad A + Ba - \frac{1}{2}\left(a^2 + \kappa b^2\right) - \frac{r}{2}B^2\sigma^2{}_y\,. \qquad (2.9)$$

The agent's expected utility in (2.7) is strictly concave in the agent's efforts a and b and the two first-order-conditions (FOCs) with respect to both efforts a and b imply that: $a_{SB} = B_{SB}$ and $b_{SB} = 0$. The principal's reduced problem can be expressed as we substitute these optimal efforts that satisfy the IC constraint into (2.9) and the IR constraint. The IR constraint is satisfied if the expected compensation is set equal to the cost of effort and the risk

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11 The individual rationality constraint (also refers to as participation constraint) defines that in order for an agent to accept contract, a principal has to offer more than zero benefit to the agent. The incentive compatible constraint is defined that it is the best action that an agent take is al so the best action for a principal.

premium. These substitutions result in an unconstrained maximization problem in B. The reduced principal's problem is:

$$\underset{B}{Maximize}\ \ B - \frac{1}{2}B^2 - \frac{r}{2}B^2\sigma^2{}_y. \tag{2.10}$$

This maximization problem is strictly concave in B and the FOC with respect to B is necessary and sufficient to characterize the optimal B_{SB}: $B_{SB} = \dfrac{1}{1 + r\sigma^2{}_y} = a_{SB}$. It is also clear that $E[y_{SB}] = \dfrac{1}{1 + r\sigma^2{}_y}$, and $\pi_{SB} = \dfrac{1}{2}\left(\dfrac{1}{1 + r\sigma^2{}_y}\right)$ [12]. The subscript SB denotes that they are the second-best results. When a manager's risk aversion, r and noise in a stock price, $\sigma^2{}_y$ are high, the good effort induced is very low. A stock price can be a very noisy measure of a manager's effort because it is affected by macroeconomic factors and industry wide factors that are beyond the control of the manager.

In the second-best setting, no capital regulation is imposed. Let us set a required capital adequacy ratio as $R = a + b$. Representing R with a combination of good and bad effort is reasonable because the capital adequacy ratio is achieved by both the good effort and bad effort of the bank manager. Then, in this case without capital regulation, the capital ratio, R, can be represented as $R_{SB} = \dfrac{1}{1 + r\sigma^2{}_y}$. This level of the capital ratio is achieved even if there is no explicit capital regulation. I use this as a minimum level of capital ratio. The results are summarized in Table 2. In the next section, I investigate the impact of capital regulation in addition to the stock price based compensation contract.

III. Introduction of capital regulation

In this section, I first model the effects of capital regulation on the (1) manager's effort level, (2) compensation contract, (3) stock price, and (4) principal's profit when accounting flexibility, κ is fixed. Second, I model the effects of changes in accounting flexibility on the principal's profit. Finally, I examine the interaction between accounting flexibility and capital regulation.

Effects of capital regulation when κ is fixed

Assume that regulators are concerned with the current low level of capital ratio and impose a certain capital ratio that is higher than the current level of capital ratio. The manager can achieve the required capital ratio by a combination of good effort and bad effort. As discussed in the previous section, the capital ratio, R can be defined as

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[12] Proofs are shown in the Appendix.

$$R = a + b. \tag{3.1}$$

In this setting, R is observable, but effort allocation is not observable to the principal. After observing R, the stock market observes a signal y, and sets a stock price p.

It is more realistic to assume that the bank manager cares for both meeting a certain capital ratio and maximizing her personal wealth. Now assume that contractible information consists of R before compensation. Since the future benefit component of gross profits depends on random factors as well as the manager's effort, the principal must now deal with the ability of the manager to obscure lower effort by claiming that low outcomes are the results of unfavorable factor realizations that are beyond the manager's control. Now the principal has to design a compensation contract with this in mind. Now R is observable, but individual effort a and b is not observable. To further develop the model, I also require the linear compensation contract (2.3). I also assume that the manager has an exponential utility function, $Eu = -\exp\left[-r\left(A + Ba - \frac{1}{2}(a^2 + \kappa b^2) - \frac{r}{2}B^2\sigma^2{}_y\right)\right]$, and stock prices are normally distributed. Then, the manager's objective function for a given set of compensation weights A and B may be stated as (2.7), but now I can substitute $b = R - a$ in the equations.

$$\underset{A,B}{Maximize} \quad E[y] - E[A + By] = a - E[A + By]$$

$$\text{Subject to} \quad E\left[-\exp\left\{r\left((A + By) - \frac{1}{2}(a^2 + \kappa(R - a)^2)\right)\right\}\right] \geq 0 \quad \text{(IR constraint)}$$

$$(a) \in \underset{(a)}{\arg\max}\ E\left[-\exp\left\{r\left((A + By) - \frac{1}{2}(a^2 + \kappa(R - a)^2)\right)\right\}\right] \quad \text{(IC constraint)}. \tag{3.2}$$

I can combine a linear contract with a normal distribution and exponential utility, and the agent's expected utility is described as:

$$Eu = -\exp\left[-r\left(A + Ba - \frac{1}{2}(a^2 + \kappa(R - a)^2) - \frac{r}{2}B^2\sigma^2{}_y\right)\right]. \tag{3.3}$$

If the expected compensation, $E[A + By]$, is set equal to the cost of effort of the agent plus the risk premium, the IR constraint can be simplified and the agent's objective function also simplified to:

$$\underset{a,b}{Maximize} \quad A + Ba - \frac{1}{2}(a^2 + \kappa(R - a)^2) - \frac{r}{2}B^2\sigma^2{}_y\,. \tag{3.4}$$

The agent's expected utility in (3.4) is strictly concave in the agent's efforts a and b and the FOC with respect to effort a implies that: $a^* = \dfrac{B + \kappa R}{1 + \kappa}$ and $b^* = \dfrac{R - B}{1 + \kappa}$ because $b = R - a$[13].

[13] Proofs are shown in the Appendix.

The principal's reduced problem can be expressed as we substitute these optimal efforts that satisfy the IC constraint into (2.9) and the IR constraint. The IR constraint is satisfied if the expected compensation is set equal to the cost of effort and risk premium. These substitutions result in an unconstrained maximization problem. The reduced principal's problem can be represented as:

$$\underset{B}{Maximize}\ \frac{B+\kappa R}{1+\kappa}-\frac{1}{2}\left(\frac{B+\kappa R}{1+\kappa}\right)^2-\frac{\kappa}{2}\left(\frac{R-B}{1+\kappa}\right)^2-\frac{r}{2}B^2\sigma^2{}_y. \tag{3.5}$$

This maximization problem is strictly concave in B, and the FOC with respect to B is necessary and sufficient to characterize the optimal B_R: $B_R = \dfrac{1}{1+(1+\kappa)r\sigma^2{}_y} \leq B_{SB}$. The subscript R denotes the results after the introduction of regulation. Substituting $B_R = \dfrac{1}{1+(1+\kappa)r\sigma^2{}_y}$ into optimal efforts $a*$ and $b*$ described above will yield:

$$a_R = \frac{1}{1+\kappa}\left(\kappa R+\frac{1}{1+(1+\kappa)r\sigma^2{}_y}\right) \geq a_{SB} \text{ if } R \geq R_C \text{ and } < a_{SB} \text{ if } R < R_C$$

$$\text{where } R_C = \frac{1}{1+r\sigma^2{}_y}\left(1+\frac{r\sigma^2 y}{1+(1+\kappa)r\sigma^2{}_y}\right) > \frac{1}{1+r\sigma^2{}_y} \text{ and}$$

$$b_R = \frac{1}{1+\kappa}\left(R-\frac{1}{1+(1+\kappa)r\sigma^2{}_y}\right) > 0. \tag{3.6}$$

It is also clear that:

$$E[y_R] = a_R = \frac{1}{1+\kappa}\left(\kappa R+\frac{1}{1+(1+\kappa)r\sigma^2{}_y}\right), \text{ and}$$

$E[y_R] \geq E[y_{SB}]$ if $R \geq R_C$ and $< E[y_{SB}]$ if $R \geq R_C$. Also,

$$\pi_R = \frac{1}{2}\left(\frac{1}{1+\kappa}\right)\left\{\kappa(2R-R^2)+\frac{1}{1+(1+\kappa)r\sigma^2{}_y}\right\} \geq \pi_{SB} \tag{3.7}$$

$$\text{where } k \in [0,\infty) \text{ and } R \in \left(\frac{1}{1+r\sigma^2{}_y}, 1\right]^{14}.$$

The results are summarized in Table 2. The implications for introducing capital regulation can be stated in words as follows. First, when accounting is very flexible ($\kappa = 0$), then the

[14] Proofs are shown in the Appendix. Also, it is easy to verify that π_R is maximized at $R = 1$ for any $\kappa > 0$. Therefore, it is reasonable to analyze a case with the upper bound $R = 1$, since the capital ratio higher than 1 only reduces the shareholder's profit.

regulation only induces bad effort. Under this environment, it is easy to show that the compensation contract, stock price, principal's profit, and good effort are the same level as those cases with no regulation since $B_R^{\kappa=0} = \frac{1}{1+r\sigma^2_y}$, $a_R^{\kappa=0} = \frac{1}{1+r\sigma^2_y}$, $E[y_R^{\kappa=0}] = \frac{1}{1+r\sigma^2_y}$, and $\pi_R^{\kappa=0} = \frac{1}{2}\left(\frac{1}{1+r\sigma^2_y}\right)$[15]. The results are the same as the results of the second-best contract. However, in this case with the regulation, bad effort exists because $b_R^{\kappa=0} = R - \frac{1}{1+r\sigma^2_y} > b_{SB} = 0$ where $\frac{1}{1+r\sigma^2_y} < R \leq 1$. The results can be summarized in the following proposition.

Proposition 1: *If accounting manipulation is costless (κ = 0), then the regulation only induces bad effort. There are no changes in the compensation contract, stock price, principal's profit, and good effort. However, bad effort, or accounting manipulation, increases by introducing capital regulation.*

Second, consider the case where accounting is not perfectly flexible and κ is fixed at any $\kappa > 0$. Introducing the regulation affects the (1) manager's effort level, (2) compensation contract, (3) stock price, and (4) principal' profit[16]. Under this environment, it can be shown that the principal's profit increases and the agent's compensation decreases. The effects on the manager's effort level and a stock price differ depending on the level of the required capital ratio. If the required ratio is lower than the critical capital ratio, R_c shown in (3.6), then the introduction of the regulation *decreases* the manager's good effort, and the stock market reacts negatively to the regulation. The manager's bad effort also decreases. This means that there is less accounting manipulation. If the required ratio is higher than R_c, then the introduction of the regulation increases the manager's good effort, and the stock market reacts positively to the regulation. However, the manager's bad effort also *increases*. This means that there is more accounting manipulation. The overall effect to the principal's profit increases from the second-best results for any R where $\frac{1}{1+r\sigma^2_y} < R \leq 1$. It is clear that[17]:

$$\pi_R - \pi_{SB} = \frac{\kappa^2(r\sigma^2_y)^2}{2(1+r\sigma^2_y)^2(1+\kappa)(1+r\sigma^2_y+\kappa r\sigma^2_y)} \geq 0. \tag{3.8}$$

15 We can obtain these results by substituting $\kappa = 0$ to (3.6) and (3.7).
16 Proofs are shown in the Appendix.
17 Proofs are shown in the Appendix.

We can draw an inference on agent's risk adversity and the noise in stock price from the above equation. If the agent is risk neutral ($r = 0$) or the noise in stock price is zero ($\sigma^2 = 0$), then accounting flexibility does not matter and the principal's profit equals that of the second-best results. The results can be summarized in the following propositions.

Proposition 2: *When accounting manipulation is costly and κ is fixed at any $\kappa > 0$, then the regulation benefits the principal because it decreases the monetary compensation and increases the principal's profit. However, the regulation triggers some accounting manipulation depending on the required level of capital ratio. The regulation affects the stock market, and the direction of the reaction depends on the required level of capital ratio. If the required level of ratio is not high enough, then the expected stock price decreases. If the required level of capital ratio is high enough, then the expected stock price increases.*

Proposition 3: *If an agent is risk neutral ($r = 0$), then accounting flexibility does not matter and the principal's profit equals that of second-best results. Similarly, when the noise in a stock price is zero ($\sigma^2 = 0$), accounting flexibility does not matter and the principal's profit equals that of the second-best results.*

In the following sub-section, I show how the changes in accounting flexibility affect the principal's profit and examine the interaction between accounting flexibility and the capital regulation on the principal's profit.

Effects of changes in accounting flexibility

My prediction for changes in accounting flexibility on the principal's profit is that as accounting becomes more rigorous, accounting manipulation becomes more costly to the manager and thus the principal's profit increases. I show that for any $\kappa > 0$, $\dfrac{\partial \pi_R}{\partial k} \geq 0$. The less flexible the accounting, the higher the shareholder's profit[18]. The results can be stated in the following proposition.

Proposition 4: *As the accounting becomes more rigorous, (i.e. as κ increases), the higher the principal's profit.*

Next, I show the interaction between accounting flexibility and the capital regulation. I show that $\dfrac{\partial^2 \pi_R}{\partial \kappa \partial R} = \left(\dfrac{\kappa}{1+\kappa}\right)(1 - R) \geq 0$. There is a complimentary relationship between the

[18] Proofs are shown in the Appendix.

capital ratio regulation and the accounting regulation[19]. The results can be stated in the following proposition.

Proposition 5: *The higher the required capital ratio, the stronger the effects of the accounting regulation on the principal's profit. Similarly, the more rigorous the accounting regulation (i.e. the less accounting flexibility), the stronger the effects capital regulation has on the principal's profit.*

IV. Conclusion and future extensions

The analytical model presented in this study sheds light on the impact of capital regulation. Capital regulation is a major issue for both regulators and banks that are struggling to maintain the required ratio. I develop a simple agency model to address this problem and obtain five key results.

First, I find that a manager maintains some level of capital ratio even if there is no explicit regulation on the capital ratio. When the manager's compensation plan is tied to a stock price, then only the manager's good effort induced is distorted by noise in a stock price. However, when the manager's risk aversion, r and noise in a stock price, σ^2 are high, it is very hard to induce the manager's good effort. A stock price can be a very noisy measure for the manager's effort because it is affected by macroeconomic factors and industry wide factors that are beyond the control of the manager. So contracts solely on a stock price do not always work.

Second, in an environment where accounting is very flexible, or in other words, accounting manipulation is costless, introducing capital regulation does not work. Under such an environment, the regulation only induces accounting manipulation. It may indicate that capital regulation may not be effective in a country where accounting is too flexible.

Third, I show that when manipulation of accounting numbers is costly, introducing the regulation benefits the principal because it decreases the monetary compensation and increases the principal's profit. However, the regulation also triggers some accounting manipulation depending on the required level of capital ratio. The regulation affects the stock price and the direction of the reaction depends on the required capital ratio. If the required ratio is not high enough, the expected stock price decreases. If the required ratio is high enough, then the expected stock price increases.

Fourth, I show that as accounting becomes more rigorous, the principal's profit increases because accounting manipulation becomes more costly for managers.

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19 Proofs are shown in the Appendix.

Finally, I show that there is a complimentary relationship between capital regulation and accounting regulation.

Overall, the model developed in this study shows that capital regulation affects a manager's effort level, compensation contract, stock price, and principal's profit. However, the effects on these variables differ depending on the level of required capital ratio and the degree of accounting flexibility. Possible extension of the study can be summarized as follows.

(1) Analyze a case when the stock market does not immediately distinguish good effort and bad effort of an agent. The agent can fool the market in order to obtain more reward in the short-term (e.g., consider a case that an agent has a stock option), but there is a certain possibility that the market could discover the agent's effort.

(2) Analyze a case where there are multiple banks, managers and shareholders, and the banks compete with each other.

(3) Analyze a case where an agent has multiple tasks to achieve.

(4) Analyze a case from a regulator's point of view. What are the most efficient κ and R to maximize social welfare?

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Appendix

Mathematical representation of a stock price (*p*) and a filtered price (or signal *y*)

Let y and p be the filtered price and the stock price, respectively. Both prices can be expressed as follows:

$$y = a + \varepsilon_y ,$$

$$p = E[x|y] = \hat{a} + \frac{\sigma_{xy}}{\sigma_y^2}(y - \hat{a}) = \left(\frac{\sigma_y^2 - \sigma_{xy}}{\sigma_y^2}\right)\hat{a} + \left(\frac{\sigma_{xy}}{\sigma_y^2}\right)y,$$

where $\varepsilon_y \sim N(0, \sigma_y^2)$ and $\hat{a} \equiv E[a]$.

The noise to signal ratio can be described as

$$\frac{Noise}{Signal} = \frac{\frac{\sigma_{xy}^2}{\sigma_y^4} \bullet \sigma_y^2}{\frac{\sigma_{xy}^2}{\sigma_y^4}} = \sigma_y^2.$$

Using the above equations, a filtered price (FP) can be computed as

$$FP = \frac{p - \left(\frac{\sigma_y^2 - \sigma_{xy}}{\sigma_y^2}\right)a}{\frac{\sigma_{xy}}{\sigma_y^2}} = y = signal\ .$$

Therefore, the filtered price is identical to the signal y that investors can observe.

First-best contract

It is easy to compute the first-order-conditions (FOCs) for (2.6) with respect to a and b,

$$a_{FB} = 1,$$
$$b_{FB} = 0.$$

The expected filtered price is given by

$$E[y_{FB}] = a_{FB} = 1.$$

The principal's profit and the agent's cost can be seen that

$$\pi_{FB} = a - \frac{1}{2}\left(a^2 + \kappa b^2\right) = 1 - \frac{1}{2} = \frac{1}{2},$$

$$c(a,b) = \frac{1}{2}\left(a^2 + \kappa b^2\right) = \frac{1}{2}\ .$$

Q. E. D.

Second-best contract (IC and IR constraints are binding and incentive contract *A+By* is presented)

It is easy to compute the FOCs for (2.9) with respect to a and b,

$$a_{SB} = B,$$
$$b_{SB} = 0.$$

Substituting these optimal efforts into (2.9) and the IR constraint, we get the principal's reduced problem (2.10). Computing the FOC for (2.10) with respect to B yield

$$1 - B - rB\sigma^2{}_y = 0$$

implies that

$$B_{SB} = \frac{1}{1 + r\sigma^2{}_y}.$$

Furthermore, the expected filtered price and the principal's profit can be derived as follows:

$$E[y_{SB}] = a_{SB} = B_{SB} = \frac{1}{1 + r\sigma^2{}_y},$$

$$\pi_{SB} = \frac{1}{2}\left(\frac{1}{1 + r\sigma^2{}_y}\right).$$

Q. E. D.

Introduction of capital regulation (IC and IR constraints are binding, the incentive contract is presented as *A+By*, and the capital ratio requirement is *R = a + b*)

The value of a that maximizes (3.4) must satisfy the FOC, therefore,

$$B - a + \kappa(R - a) = 0.$$

The above equation reduces to

$$a_R^* = \frac{B + \kappa R}{1 + \kappa}.$$

Substituting $a_R^* = \dfrac{B + \kappa R}{1 + \kappa}$ into $b = R - a$, b_R^* can be calculated as follows:

$$b_R^* = \frac{R - B}{1 + \kappa}.$$

Furthermore, substituting these efforts a and b into (2.9) and IR and IC constraints, we get the principal's reduced problem (3.5). Computing the FOC for (3.5) with respect to B yields

$$\frac{1}{1 + \kappa} - \left(\frac{B + \kappa R}{1 + \kappa}\right) + \kappa\left(\frac{R - B}{1 + \kappa}\right) - rB\sigma^2{}_y = 0,$$

or

$$B_R = \frac{1}{1 + (1 + \kappa)r\sigma^2{}_y}.$$

Substituting $B_R = \dfrac{1}{1+(1+\kappa)r\sigma^2{}_y}$ in a_R^* and b_R^* gives the optimal contract

$$a_R = \frac{1}{1+\kappa}\left(\kappa R + \frac{1}{1+(1+\kappa)r\sigma^2{}_y}\right) \gtreqless a_{SB} \quad if\ R \gtreqless RC$$

$$b_R = \frac{1}{1+\kappa}\left(R - \frac{1}{1+(1+\kappa)r\sigma^2{}_y}\right) > 0$$

where $R_C \equiv \dfrac{1}{1+r\sigma^2{}_y}\left(1+\dfrac{r\sigma^2{}_y}{1+(1+\kappa)r\sigma^2{}_y}\right) > \dfrac{1}{1+r\sigma^2{}_y}$.

In this case, the expected filtered price and the principal's profit are

$$E[y_R] = a_R = \frac{1}{1+(1+\kappa)r\sigma^2{}_y},$$

$$\pi_R = \frac{1}{2}\left(\frac{1}{1+\kappa}\right)\left\{\kappa(2R-R^2) + \frac{1}{1+(1+\kappa)r\sigma^2{}_y}\right\}.$$

Q. E. D.

The relevant range of capital regulation

First, consider a case where $\kappa = 0$. Substituting $\kappa = 0$ into (3.7), it can be proved easily that $\pi_R = \pi_{SB}$ for any R.

Next, consider a case where $\kappa > 0$. The FOC for π_R with respect to R is

$$\frac{\partial \pi_R}{\partial R} = \left\{\frac{2\kappa}{2(1+\kappa)}\right\}(1-R) \geq 0. \tag{A.1}$$

It is clear that π_R is a monotone nondecreasing function in R. If (3.7) is rewritten as $f \equiv \pi_R - \pi_{SB} \geq 0$, the lowest f realizes when $R = \dfrac{1}{1+r\sigma^2{}_y}$. So it is sufficient to prove that $f \geq 0$ at $R = \dfrac{1}{1+r\sigma^2{}_y}$. Thus, substituting $R = \dfrac{1}{1+r\sigma^2{}_y}$ into f, we obtain

$$f = \frac{\kappa^2(r\sigma^2{}_y)^2}{2(1+r\sigma^2{}_y)(1+\kappa)(1+r\sigma^2{}_y+\kappa r\sigma^2{}_y)}. \tag{A.2}$$

Hence, it is clear that $f \geq 0$ for any $\kappa > 0$.

Q. E. D.

The effects on the principal's profit (π_R) with changes in accounting flexibility (κ)

In order to verify the effects of changes in accounting flexibility, differentiating (3.7) with respect to κ,

$$\frac{\partial \pi_R}{\partial R} = \frac{-\dfrac{1+2r\sigma^2_y(1+\kappa)}{(1+r\sigma^2_y+r\sigma^2_y\kappa)^2}+2R-R^2}{2(1+\kappa)^2} \tag{A.3}$$

It is clear that $2R - R^2$ in (A.3) is a monotone nondecreasing function in the range of $R \in \left(\frac{1}{1+r\sigma^2_y}, 1\right]$. Therefore, $\frac{\partial \pi_R}{\partial R}$ is minimized at $R = \frac{1}{1+r\sigma^2_y}$. So it is sufficient to prove that $\frac{\partial \pi_R}{\partial R} \geq 0$ at $R = \frac{1}{1+r\sigma^2_y}$. If we evaluate (A.3) at $R = \frac{1}{1+r\sigma^2_y}$, we obtain

$$\left.\frac{\partial \pi_R}{\partial R}\right|_{R=\frac{1}{1+r\sigma^2_y}} = \frac{1}{2}(r\sigma^2_y)^2 \left\{\frac{\kappa(2+\kappa+2r\sigma^2_y(1+\kappa))}{(1+r\sigma^2_y)^2(1+\kappa)^2(1+r\sigma^2_y+r\sigma^2_y\kappa)^2}\right\}.$$

It is readily verified that $\frac{\partial \pi_R}{\partial R} \geq 0$ for any $\kappa > 0$.

Q. E. D.

The interaction between accounting flexibility (κ) and the capital ratio requirement (R)

We already showed that $\frac{\partial \pi_R}{\partial R} = \left\{\frac{2\kappa}{2(1+\kappa)}\right\}(1-R)$. Therefore, it is easy to show the following:

$$\frac{\partial^2 \pi_R}{\partial k \partial R} = \left(\frac{\kappa}{1+\kappa}\right)(1-R) \geq 0.$$

Q. E. D.