



# Managerial compensation contract and bank bailout policy <sup>☆</sup>

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## Abstract

Under the incomplete contract framework, we consider an optimal regulatory policy for motivating bank equity owners and bank managers to restructure the bad loans of their banks in the presence of managerial compensation contracts with stock options. The regulatory policy studied in this paper is mainly concerned with the design of repayment schedules in the scheme of injection of cash funds into insolvent banks by the regulator. We show that the regulator cannot necessarily attain the social optimal allocation by injecting cash funds into insolvent banks through the purchase of subordinated bonds with the risk-free interest rate. However, even in that case, we also suggest that, if the regulator injects cash funds into active restructuring banks through the purchase of subordinated bonds or preferred stocks with less stringent repayment conditions and nationalizes passive restructuring banks, the regulator can attain the social optimal allocation by performing such a non-linear injection scheme under certain conditions. © 2002 Elsevier Science B.V. All rights reserved.

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## **1. Introduction**

Since the end of 1980s, many countries including not only emerging countries but also developed countries such as Japan, Northern European countries, and the United States have suffered the fragility of the banking system. In the banking crises, one of the serious problems is that banks are likely to rollover loans in default or to take more risky activities in order to hide their poor financial conditions and gamble for resurrection. To overcome the banking crises, the regulator can choose a variety of policies such as bank closures or bank rescues. These policies are likely to demand that insolvent banks dismiss their bank managers. This is so because a soft bailout policy that the bank managers of insolvent banks continue to retain their management positions causes formidable political disputes or future moral hazard action by bank managers in taking risky investment. As a result, the bank managers of insolvent banks are afraid of a tough bailout policy and may be induced to rollover loans in default or to take more risky activities in order to hide the extent of their banks' loan losses and gamble for resurrection. Thus, understanding how a banking policy in banking crises affects an incentive for the bank managers of failing banks to restructure the banks' assets is important in understanding the effectiveness of the banking policy in banking crises.

Stock option plans for bank managers may be useful for dealing with such a problem of the adverse incentive for bank managers. The reason is that bank managers can still retain their equity positions of their banks even after they are dismissed. Unless bank managers are required to compensate some portion of the loan losses of their banks after their dismissal, stock option plans may prevent the moral hazard behavior by bank managers. However, since this function of stock option plans depends on the future residual value of the bank that is affected by a policy done by the regulator at the financial crisis, the regulator needs to design an ingenious regulatory policy at the financial crisis to handle the moral hazard problem of bank managers.

In this paper, under stock option plans for bank managers, we consider an optimal regulatory policy for motivating the bank managers of failing banks to restructure bad loans and not to take more risky activities in order to hide the poor financial conditions of their banks and gamble for resurrection. This consideration is done with the restriction that the regulator cannot be committed to the soft bailout policy. The regulatory policy studied in this paper is mainly concerned with the scheme of injection of cash funds into insolvent banks by the regulator, which includes the design of the schedule of repayments from insolvent banks to the regulator after the financial crisis. The purpose of this paper, therefore, is to find an optimal design of the schedule of repayments that can prevent bank managers from taking more risky activities and can attain the constrained social optimal allocation under managerial compensation contracts with stock options.

To address these problems, we model the decision of a bank manager for restructuring the assets of his failing bank as a game between bank equity owners, the bank manager, and the regulator under the incomplete contract framework. Because of the lack of managerial ability, the bank equity owners delegate the control of their bank to the bank manager. The bank manager then manages the bank and derives private benefits from the continued operation. The bank manager also has private information on the quality of the loan portfolio of the bank. On the other hand, the bank equity owners and the regulator only know a probability distribution over the fraction of bad loans in default across banks in the economy unless the regulator succeeds in monitoring the bank.

If the bank manager faces bad loans in default, he can choose two options. In one choice, the bank manager takes risky action in which the probability of the bank recovering current losses increases whereas the probability of the bank suffering substantial future losses also increases. In the other choice, the bank manager takes safety action in which the expected future losses are smaller than those of the risky action although the probability of the bank recovering current losses is small.

As a result of the above two actions, the bank may become insolvent at the interim period. Then, the insufficient amount of bank capital must be recapitalized by the injection of capital funds at the interim period to protect the insolvent bank from the liquidity needs.<sup>1</sup> This cash injection often needs to be made by the regulator under our incomplete contract setting because neither interbank loans nor new equity and bond finance is likely to be feasible. In fact, since the regulator is not assumed to be committed to the soft bailout policy, the recapitalization of the insolvent bank forces the bank manager to lose his management position. Hence, even though the safety action is assumed to bring smaller expected future losses than the risky action, the bank manager has a potential incentive to take the risky action, which raises the possibility that the bank manager can retain his management position in the bank by hiding the bank's poor financial condition and gambling through the exploitation of a deposit insurance put option. If the action choice done by the bank manager is unverified without monitoring by the regulator and if the verification by the regulator is imperfect, the regulator needs to design a well-suited scheme of recapitalization for avoiding the moral hazard action by the bank manager.

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<sup>1</sup> We assume that depositors must be compensated for their deposit claims if the bank is insolvent, and that the regulator is committed to recapitalizing the insufficient amount of capital funds of the insolvent bank in the interim period if it is ex post optimal for the regulator to do so. Thus, we do not discuss the forbearance question of whether the regulator should be committed to rescuing or closing the insolvent bank according to a rule prespecified in the ex ante period.

The soft bailout policy is a possible policy for giving discipline on the bank manager. In this policy, the bank manager can retain his management position in the bank even after the regulator injects cash funds into the bank. Since the bank manager need not be afraid of losing his management position, he has a less incentive to take the risky action in order to hide the bank's poor financial condition and gamble for resurrection. Indeed, because the soft bailout policy causes formidable political disputes or future moral hazard action by bank managers in taking risky investment, it would be difficult for the regulator to be committed to executing the soft bailout policy. Hence, the bank manager of the failing bank is afraid that the regulator is forced to choose the tough bailout policy in which the regulator dismisses the bank manager when recapitalizing the bank. Then, the possibility of the tough bailout policy may induce the bank manager to take the risky action in order to retain his management position.

To get around this problem, we consider a situation in which the bank equity owners offer the bank manager a managerial compensation contract based on stock option plans. Then, the bank manager will be able to receive his compensation in the form of equity claims even after his dismissal if the failing bank is well restructured. Thus, it would be possible that the bank manager is given enough incentive to take the safety action if the bank equity owners are afforded a proper incentive to offer a well-suited managerial compensation schedule. Indeed, whether this possibility really occurs or not depends on the scheme of injection of public funds such as the design of the schedule of repayments from the bank to the regulator after the financial crisis because the repayments affect the future residual value of the bank. Hence, the regulator needs to organize a repayment schedule of injected cash funds in order to build the main source of discipline on the bank manager.

Our main results are summarized as follows: (i) Under the setting described above, the regulator cannot necessarily attain the social optimal allocation by injecting cash funds into the insolvent bank through the purchase of subordinated bonds with the risk-free interest rate. (ii) Even then, the regulator can attain the social optimal allocation by performing the following non-linear injection scheme under certain conditions: as long as the bank needs to be recapitalized, the regulator injects cash funds into the safety action bank through the purchase of subordinated bonds or preferred stocks with less stringent repayment conditions, while nationalizing the risky action bank.

We may consider that the non-linear injection scheme stated above corresponds to the public injection scheme of Japan in November, 1998. In this scheme, relatively "good" banks received the injection of public funds through the purchase of subordinated bonds or preferred stocks with less stringent repayment conditions, while bad banks that had seriously damaged assets were forced to be transformed into government-owned banks.

In addition to the main results, the incomplete contract approach in the scheme of injection of cash funds into the insolvent bank by the regulator

clarifies several points on this issue although it does not change the equilibrium allocation.<sup>2</sup> In the financial crisis, this approach indicates (i) that it may be infeasible for the insolvent bank to be recapitalized by new equity or bond finance in the private sector alone even though the insolvent bank has positive net present value, and (ii) that it may be impossible for the insolvent bank to utilize interbank loans in a similar situation. Thus, the incomplete contract approach provides one rationale for the policy of injection of cash funds into the insolvent bank by the regulator.<sup>3</sup>

There are several studies of the adverse effect of the tough recapitalization policy on managerial incentive for bank managers. Aghion et al. (1999, 2001) designed a bailout scheme by examining the effect of the soft or tough recapitalization policy on managerial incentive for bank managers. Their main result suggests that, combined with a non-linear transfer pricing mechanism for bad loans, the soft recapitalization policy in which the bank managers of insolvent banks continue to have management control can achieve the socially efficient outcome under certain conditions. Mitchell (1998) modeled two aspects of banking crises that are concerned with not only the bank's decision between the procedures of the passive rollover and active bankruptcy of bad loans but also the regulator's decision between the soft and tough recapitalization policies. The principal result is that the regulator chooses the soft recapitalization policy when reacting to the threat of banks triggering "too-many-to-fail", whereby it is less costly to rescue than to close a large number of banks.

The public policy of injection of cash funds into insolvent banks is also investigated in the context of deposit insurance under asymmetric information. Dreyfus et al. (1994) and Nagarajan and Sealey (1995) developed a rigorous model of forbearance in the context of optimal bank regulation and examine the endogenous determination of an optimal closure policy. Dreyfus et al. studied the role of coverage caps on the scope of insured deposits as an alternative to a regulatory forbearance policy backed by cash infusions, and showed that the optimal level of the ceiling for insured deposit coverage is beyond a minimum level consistent with the existence of a feasible financing

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<sup>2</sup> Rajan (1998) studied the role of the regulator in the banking industry using the incomplete contract approach in another context. Maskin and Tirole (1999) showed that the incomplete contract situation in which contracting parties face the inability to describe the nature of trade in advance does not matter if they can be committed not to renegotiate (also see Hart and Moore, 1999). Although this result holds in our framework, the incomplete contract approach is still useful because it enables us to avoid imposing some annoyed ad hoc assumptions such as the exclusion of the new equity or interbank loan market 'directly'.

<sup>3</sup> Applying the agency model to the market liquidity demand and supply, Holmström and Tirole (1998) gave another reason why the private sector cannot satisfy its own liquidity needs in the presence of aggregate uncertainty.

plan. Nagarajan and Sealey also suggested that regulatory forbearance is optimal under moral hazard when the bank's insolvency is due to factors beyond its control.

John et al. (2000) discussed how the incentive features of management compensation structures, together with a bank's capital ratio, determined the investment policy implemented by the bank's management in its own interest under a fairly priced deposit insurance premium. They showed that, if the fairly priced deposit insurance premium reflects the structure of managerial compensation along with the level of bank capitalization, it can motivate bank equity holders to pick optimal compensation contracts that ensure first-best investment risk choices.

What distinguishes our model from those mentioned above is that we explicitly consider not only the managerial compensation contract to the bank manager but also the repayment schedule of the amount of recapitalization from the bank to the regulator, given that formidable political disputes or the possibility of future moral hazard action by the bank manager in taking risky investment prevents the regulator from choosing the soft bailout policy.<sup>4</sup>

The paper is organized as follows: Section 2 presents the basic model in which the regulator injects cash funds into an insolvent bank through the purchase of subordinated bonds with the risk-free interest rate under a managerial compensation contract with stock options to the bank manager. Section 3 discusses the equilibrium. Section 4 extends the basic model by introducing a non-linear injection scheme, and compares the equilibrium allocation of the extended model with that of the basic model. The final section summarizes our conclusions.

## **2. Basic model**

There are four agents in this economy: the regulator, bank equity owners, bank managers, and depositors. All agents are risk neutral. Since the equilibrium risk-free interest rate is normalized to zero, all cash flows are discounted at this rate. We consider a representative bank in which bank equity owners delegate managerial tasks to a bank manager. The representative bank issues deposit accounts to depositors under the auspices of the regulator offering deposit insurance covering all deposits.

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<sup>4</sup> Osano (1998, 2001), using the security design framework such as Townsend (1979), Diamond (1984), Gale and Hellwig (1985), and Hart and Moore (1998), investigated an optimal scheme of injection of cash funds into insolvent banks together with a bank closure policy under deposit insurance. On the other hand, in the present paper, we not only consider the managerial compensation contract but also the moral hazard problem of the bank manager under the incomplete contract framework.

2.1. Timing of events

The timing of the decision process of each agent is illustrated in Fig. 1.

In period 0, the bank takes initial equity capital  $K - D_0$  and deposit funds  $D_0$ . The bank also has outstanding investment in the amount of  $K$ . For the simplification of the analysis,  $D_0$  and  $K$  are assumed to be fixed. The bank equity owners offer the bank manager a managerial compensation contract.

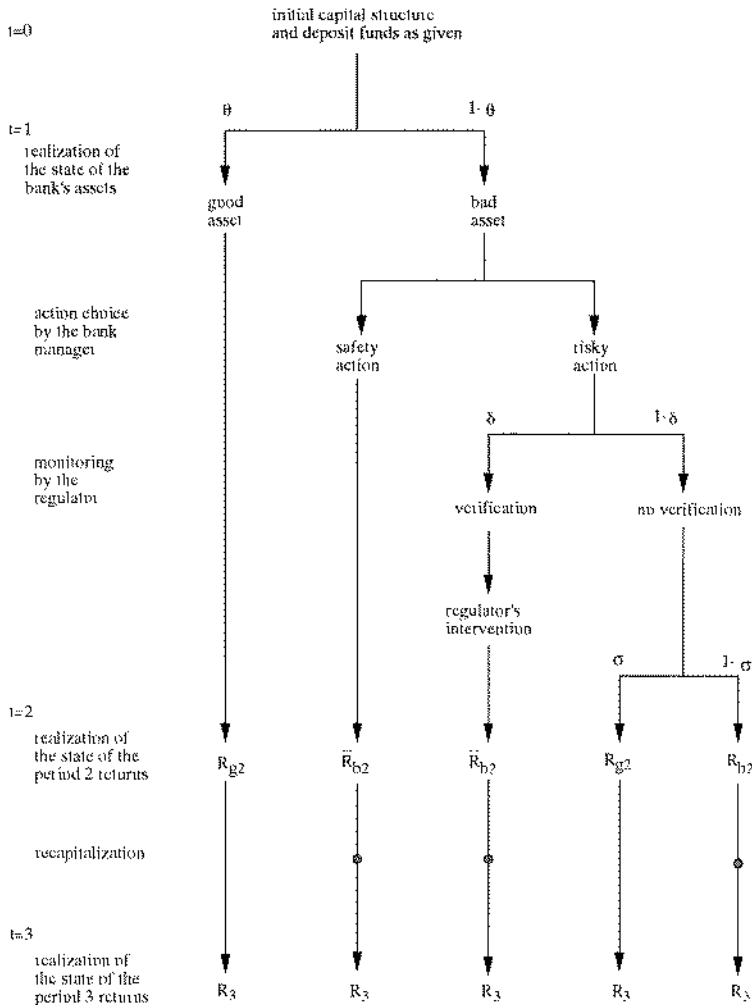


Fig. 1. Timing of events.

In period 1, the bank's assets are good or bad. The probability that the bank's assets are good is given by  $\theta$ . The bank manager can privately observe the state of the bank's assets. On the other hand, the regulator cannot verify the state of the bank's assets until period 3 unless it succeeds in verifying the action of the bank manager by monitoring in period 1. None of the other agents know the state of the bank's assets until period 3 unless the regulator can verify the action of the bank manager in period 1.

If the bank's assets are good, the bank manager does not take any moral hazard action. Although this assumption limits the scope of our paper, we will retain it to focus on the action of a financially depressed economy.

If the bank's assets are bad, the bank manager can choose between two actions: "risky" action or "safety" action. If the bank manager chooses the risky action, the probability of the bank recovering current losses increases whereas the probability of the bank suffering substantial future losses also increases. In contrast, if the bank manager chooses the safety action, the expected future revenues are larger than those realized by the risky action even though the bank cannot recover current losses.

Although the state of the bank's assets is generally unobservable, the regulator monitors the bank and will be able to verify with probability  $\delta$  the choice of the risky action on the part of the bank.<sup>5</sup> If the regulator can verify that the bank chooses the risky action, then all the agents know the information. In this case, we assume that the regulator replaces the incumbent bank manager with a new one in period 1 and forces the new bank manager to choose the safety action.<sup>6</sup>

In period 2, the interim period returns from the bank's assets are realized but are observable to only the bank manager and the regulator. Indeed, unless the regulator injects public funds into the bank, the regulator cannot verify the period 2 bank returns until period 3 begins. This assumption can be justified by supposing that the financial crisis occurs in period 2. This is so because most of the other agents are likely to suspect that information on the bank returns at the financial crisis is not trustworthy; as a result, at the financial crisis, most of the other agents doubt that information on the bank's balance sheet given by the regulator is true unless the regulator injects public funds into the bank.

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<sup>5</sup> In Mitchell (1998), the regulator could choose a monitoring capability that would determine a probability with which the regulator would be able to detect passivity on the part of banks. However, to clarify the effect of the injection policy through the managerial compensation contract, we assume in this paper that the probability of the verification of the risky action  $\delta$  is exogenous.

<sup>6</sup> In Mitchell (1998), the regulator had two options. One option was to intervene the detected bank and replace the bank manager. The other option was to rescue the detected bank and allow the bank manager to remain in the current position. Again, to focus on the effect of the injection policy through the managerial compensation contract, we assume here that the regulator always intervenes the bank once it verifies the risky action of the bank manager.



There are four cases to be considered with regard to the bank returns in period 2. First, if the bank's assets are good, the returns are assumed to be  $R_{g2}$  with probability 1. Second, if the bank's assets are bad and if the bank chooses the safety action, the returns are assumed to be  $\tilde{R}_{b2}$  with probability 1. Third, if the bank's assets are bad, if the bank chooses the risky action, and if the risky action is unverified, the returns are assumed to be  $R_{g2}$  with probability  $\sigma$  and  $R_{b2}$  with probability  $1 - \sigma$ . Finally, if the risky action is verified, the regulator replaces the incumbent bank manager and forces a new bank manager to choose the safety action. Thus, the bank returns are the same as those in the second case.

For the size of the returns realized in period 2, we put the following assumption:

**Assumption 1.**  $R_{g2} > 0 > \tilde{R}_{b2} > \sigma R_{g2} + (1 - \sigma)R_{b2} > R_{b2}$ .

The inequality  $\tilde{R}_{b2} > \sigma R_{g2} + (1 - \sigma)R_{b2}$  implies that the safety action yields the higher expected period 2 returns than the risky action if the bank's assets are bad. This reflects the fact that the safety action allows the bank to take the reorganization or liquidation of the debtors in default, thereby yielding the highest expected value of the assets of the debtors in default. Under Assumption 1, the risky action of the bank manager causes inefficient results.

The bank facing the negative period 2 returns must finance an additional amount of its liquidity needs to cover operating expenditures and other cash needs. Unless the bank can obtain the additional amount of financing, the bank becomes insolvent in period 2. We assume that new deposit funds are not provided to the bank in period 2. We also assume that the bank cannot utilize interbank loans or new equity and bond finance. The former assumption can be justified if depositors do not necessarily trust the protection of their deposit claims by the regulator at the financial crisis.<sup>7</sup> Such a belief of depositors is realistic, since it was very often observed in many actual banking crises. The latter assumption can be justified by the unverifiability of both the period 2 bank returns and the action choice by the bank manager facing the bad assets, together with Assumptions 3 and 4 introduced below.<sup>8</sup>

The above two financing assumptions with Assumption 1 indicate that, if the period 2 bank returns are  $R_{b2}$  or  $\tilde{R}_{b2}$ , the regulator forces the bank to be

<sup>7</sup> In contrast, Osano (1998, 2001) assumed that banks can obtain new deposit funds to finance their liquidity needs in the interim period although those banks may be insolvent in the final period. The differences of these assumptions, however, do not modify our main results.

<sup>8</sup> In fact, once the risky action has been verified, the bank is forced to choose the safety action. This type of bank may utilize interbank loans or new equity and bond finance. However, if this type of bank issues the same kind of subordinated bonds purchased by the regulator in recapitalization, the subsequent analysis still holds.

closed unless the regulator offers the bank at least the minimum level of recapitalization that will render the bank solvent. To simplify the analysis, we assume that the liquidation value of the bank's assets in period 2 or 3 is zero if the bank is closed. Then, it is ex post optimal for the regulator to recapitalize the insolvent bank as long as the period 3 bank returns are positive. This is because the regulator must compensate depositors for their deposit claims under the deposit insurance system irrespective of whether the bank is closed in period 2 or 3. If the regulator recapitalizes the insolvent bank, we also assume that the regulator will be forced to offer the insolvent bank at least the minimum level of recapitalization that will render the bank solvent.<sup>9</sup>

The regulator recapitalizes the insolvent bank by injecting cash funds  $I$  into the bank through the purchase of securities. In the subsequent sections, we discuss how and to what extent the design of the managerial compensation contract can control the moral hazard action by the bank manager if the injection policy is executed through the purchase of subordinated bonds by setting the interest rate equal to zero.<sup>10</sup> In this policy, the injection amount  $I$  is equal to the minimum level of recapitalization that will render the insolvent bank solvent; and the bank must repay  $I$  from the bank's net revenues in period 3. Note that  $I$  is verifiable by all the agents after the recapitalization of the insolvent bank. We also assume that the regulator replaces the bank manager in period 2 if the regulator injects cash funds into the insolvent bank. This implies that the regulator must replace the bank manager even though he takes the safety action if the bank's assets are bad.

In period 3, if the bank is allowed to remain open, the final returns of the bank are realized and verified by all the agents. To simplify the analysis, we assume that the period 3 bank returns are  $R_3 > 0$  irrespective of the net financial position of the bank in period 2. The regulator, bank equity owners, and depositors receive their financial claims; and the original bank manager is compensated according to the managerial compensation contract if he still retains his position in period 3.<sup>11</sup>

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<sup>9</sup> It may be ex ante optimal for the regulator to close the insolvent bank if the regulator can properly control the moral hazard action by the bank manager using the threat of bank closure. However, we assume in the subsequent analysis that the regulator will be forced to offer the insolvent bank at least the minimum level of recapitalization that will render the bank solvent. Although it is important to discuss which bank should be closed from the viewpoint of the ex ante optimality, we do not investigate the forbearance problem because it is better to address the forbearance question separately.

<sup>10</sup> Since the risk-free interest rate is normalized to zero in our model, this assumption implies that the regulator injects cash funds into the insolvent bank through the purchase of subordinated bonds with the risk-free interest rate.

<sup>11</sup> We need not consider the managerial compensation contract to the new bank manager appointed after the dismissal of the original bank manager. The reason is that the new bank manager is assumed not to be concerned with any moral hazard action in our setting.

In addition to the assumptions that have been already described, we further assume:

**Assumption 2.**  $D_0 - R_{b2} > R_3 > D_0 - \tilde{R}_{b2}$ .

**Assumption 3.** Outside investors suppose that the bank has taken the risky action in period 1 if the bank tries to finance its liquidity needs in the interbank loan or new equity and bond markets at the financial crisis.

**Assumption 4.**  $\sigma(R_{g2} + R_3 - D_0) + (1 - \sigma)(R_{b2} + R_3 - D_0) < 0$ .

The first (second) inequality of Assumption 2 implies that the sum of the periods 2 and 3 bank returns  $R_{b2} + R_3$  ( $\tilde{R}_{b2} + R_3$ ) are smaller (larger) than the initial deposit funds  $D_0$  if the period 2 bank returns are  $R_{b2}$  ( $\tilde{R}_{b2}$ ). Given Assumption 1, we also have  $R_{g2} + R_3 - D_0 > 0$ . Thus, the sum of the periods 2 and 3 bank returns are larger than the initial deposit funds if the period 2 bank returns are  $R_{g2}$ .

Assumption 3 restricts the out-of-equilibrium belief of outside investors if the bank tries to finance its liquidity needs in the interbank loan or new equity and bond markets in period 2. This assumption may be justified from the setting that neither the period 2 bank returns nor the action choice by the bank manager facing the bad assets are verifiable until the beginning of period 3.

Assumption 4 shows that the expected total net revenues of the bank in periods 2 and 3 are negative if the risky action of the bank manager is unverified. Assumptions 3 and 4 together ensure that the bank cannot utilize interbank loans or new equity and bond finance to satisfy its liquidity needs in period 2 because the expected revenues of interbank loan lenders or newly issued equity and bond holders are negative under the incomplete contract framework of the model.

Depositors are repaid from the funds retained by the bank in period 3. Since bank deposits are fully insured, depositors are compensated for their deposit claims by deposit insurance even if the funds retained by the bank in period 3 are insufficient to meet their deposit claims. If depositors are compensated fully, the promised payments of subordinated bonds  $I$  must be repaid to the regulator. After these payments are completed, the bank equity owners and the bank manager receive their dividends from the residual value of the bank according to their equity claims.

## 2.2. The objective and strategies of the bank equity owners

The objective of the bank equity owners is to maximize their dividends from the bank by offering the bank manager a managerial compensation contract in period 0.

Since the bank equity owners can observe only the residual value of the bank in period 3, they make the managerial compensation contract contingent on the residual value of the bank in period 3 if the bank manager retains his management position until period 3. Indeed, the bank equity owners may pay the bank manager his compensation irrespective of whether he retains or loses the management position.<sup>12</sup> In practice, it would be difficult for the bank manager to receive his compensation after he loses the management position. However, if the compensation is paid by stocks, the bank manager can receive his compensation from his equity claims even after he loses the management position. In the case of stock options, this assumption can be justified if the bank manager executes his stock options at the end of period 0. In addition, if the sales of stocks by the bank manager are restricted to avert his insider trading, this incentive scheme is further enhanced. Thus, in the rest of this paper, we assume that the bank manager can be compensated in the form of equity claims.

Although a large variety of compensation structures can be considered as candidates for managerial compensation contracts, we focus on a simple class of contracts that can capture some important incentive features. The compensation structure is characterized as follows: the bank manager receives a fixed cash salary (which is normalized to zero), and a fraction  $\alpha \in [0, 1]$  of the equity of the bank with an exercise price  $p_e \in [0, \bar{p}_e]$  if he executes his stock options at the end of period 0.<sup>13</sup> Note that there exists an upper limit  $\bar{p}_e$  because the bank manager usually faces the liquidity constraint. To simplify the analysis, we also put the following assumption.

**Assumption 5.**  $\bar{p}_e < \min[-\tilde{R}_{b2}, -(R_3 - D_0 + R_{b2})]$ .

This assumption together with Assumption 1 implies that the bank facing the bad assets is still insolvent in period 2 even though  $p_e$  is added to the period 2 bank returns. Furthermore,  $R_{b2} + R_3 + p_e < D_0$  for all  $p_e \in [0, \bar{p}_e]$  if the period 2 bank returns are  $R_{b2}$ .<sup>14</sup>

<sup>12</sup> If the bank manager loses the management position, he might also receive severance payments although his risky action is verified by the regulator or his bank is insolvent. However, due to political reasons, the regulator would have trouble designing such a managerial compensation schedule with severance payments. As a result, we do not consider severance payments to the bank manager in this paper.

<sup>13</sup> Since the bank equity owners cannot observe the bank returns in period 2, we need not discuss the renegotiation of the managerial compensation contract in period 2. Indeed, after the monitoring by the regulator, the bank equity owners may offer an additional stock option plan to the bank manager who has chosen the safety action or who has chosen the risky action but has not been verified. However, the relaxation of this assumption does not modify our main results.

<sup>14</sup> At the end of the next section, we will discuss how the relaxation of the restrictions imposed here on the compensation structure modifies our results.

Now, if the bank manager executes his stock options at the end of period 0, he receives the compensation  $\pi_M(\alpha, p_e) = \alpha\Pi_B(p_e) - p_e$ , where  $\Pi_B(p_e)$  represents the residual value of the bank in period 3. The dividends received by the bank equity owners  $\pi_E(\alpha, p_e)$  are then  $\pi_E(\alpha, p_e) = (1 - \alpha)\Pi_B(p_e)$ .

For expositional convenience, we assume that the bank manager executes his stock options at the end of period 0 unless  $\alpha \neq 0$ :  $\alpha E_0\Pi_B(p_e) \geq p_e$ .<sup>15</sup>

For fixed  $(\alpha, p_e)$ , we proceed to check whether the bank equity owners prefer the safety or the risky action of the bank manager if the bank's assets are bad. First, suppose that the bank manager facing the bad assets chooses the safety action in period 1. Since the probability that the bank's assets are good is  $\theta$ , the expected residual value of the bank in period 0,  $E_0\Pi_B^s(p_e)$ , is then

$$E_0\Pi_B^s(p_e) = \theta(R_{g2} + R_3 - D_0 + p_e) + (1 - \theta)(R_3 - D_0 + \tilde{R}_{b2} + p_e) > 0. \tag{1}$$

Here, the first term represents the residual value of the bank if the bank's assets are good. In this case, the regulator need not inject any cash funds. The second term indicates the residual value of the bank if the bank's assets are bad. Since the injection amount in period 2 is equal to  $-\tilde{R}_{b2} - p_e$ , the repayments of subordinated bonds in period 3 are also equal to  $-\tilde{R}_{b2} - p_e$ . Under Assumptions 1 and 2, each of these two terms is positive.

We next suppose that the bank manager facing the bad assets chooses the risky action in period 1. The expected residual value of the bank  $E_0\Pi_B^r(p_e)$  is then

$$\begin{aligned} E_0\Pi_B^r(p_e) &= \theta(R_{g2} + R_3 - D_0 + p_e) + (1 - \theta)\delta(R_3 - D_0 + \tilde{R}_{b2} + p_e) \\ &\quad + (1 - \theta)(1 - \delta)\sigma(R_{g2} + R_3 - D_0 + p_e) + (1 - \theta)(1 - \delta) \\ &\quad \times (1 - \sigma)\max(R_3 - D_0 + R_{b2} + p_e, 0). \end{aligned} \tag{2}$$

Here, the first term again corresponds to the residual value of the bank if the bank's assets are good. However, the remaining three terms are different. The second term indicates the residual value of the bank if the bank's assets are bad and if the risky action is verified. The third term expresses the residual value of the bank if the bank's assets are bad, if the risky action is unverified, and if the period 2 bank returns are  $R_{g2}$ . Since the bank is solvent in this case, the regulator need not inject any cash funds into the bank. The final term is the residual value of the bank if the bank's assets are bad, if the risky action is unverified, and if the period 2 bank returns are  $R_{b2}$ . Since the injection amount in period 2 is equal to  $-R_{b2} - p_e$  in this case, the repayments of subordinated

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<sup>15</sup> This assumption can be more likely to be justified if  $\bar{p}_e$  is small enough. The relaxation of this assumption will again be studied at the end of the next section.

bonds in period 3 are  $\max(-R_{b2} - p_e, R_3 - D_0)$ . Under Assumptions 1, 2 and 5, the first three terms are positive, whereas the final term is zero. Thus, Eq. (2) is rearranged so that

$$E_0 \Pi_B^r(p_e) = \theta(R_{g2} + R_3 - D_0 + p_e) + (1 - \theta)\delta(R_3 - D_0 + \tilde{R}_{b2} + p_e) + (1 - \theta)(1 - \delta)\sigma(R_{g2} + R_3 - D_0 + p_e) > 0. \quad (3)$$

To simplify the analysis, we put the following assumption:

**Assumption 6.**  $(1 - \sigma)(R_3 - D_0) > -\tilde{R}_{b2} + \sigma R_{g2}$ .

Then, we obtain the following lemma. The proofs of all the propositions and lemmas derived below are available upon request from the author.

**Lemma 1.** *Under Assumption 6, the bank equity owners always prefer to motivate the bank manager to take the safety action rather than the risky action for fixed  $(\alpha, p_e)$  in the basic model.*

However, if  $(\alpha, p_e)$  is adjusted according as the bank manager is expected to take the safety or the risky action, Assumption 6 does not necessarily imply that the bank equity owners always prefer to motivate the bank manager to take the safety action. Thus, even under Assumption 6, we do not neglect the case in which the interests of the bank equity owners and the regulator differ.<sup>16</sup>

### 2.3. The objective and strategies of the bank manager

The objective of the bank manager is to maximize the expected managerial compensation plus the expected private benefit of keeping the management position in the bank by selecting the safety or the risky action in period 1. The ex post payoff of the bank manager is given by  $\hat{\pi}_M(\alpha, p_e) = \max(\pi_M(\alpha, p_e), 0) - p_e + \gamma\chi_2 + \gamma\chi_3$ , where  $\pi_M(\alpha, p_e)$  denotes the managerial compensation,  $\gamma(> 0)$  the private benefit from retaining the management position, and  $\chi_i = 1$  ( $\chi_i = 0$ ) if the bank manager retains (loses) his management position until the beginning of period  $i$  ( $i = 2, 3$ ). As has been discussed in

<sup>16</sup> Alternatively, we may assume that the bank equity owners prefer to induce the bank manager to take the risky action for fixed  $(\alpha, p_e)$  if the bank's assets are bad. Since our later discussion will show that the regulator always prefers to motivate the bank manager to take the safety action, this alternative assumption implies that the interests of the bank equity owners and the regulator differ for fixed  $(\alpha, p_e)$ . However, in the next section, we can explicitly allow for the situation in which the interests of the bank equity owners and the regulator differ even under Assumption 6 if  $(\alpha, p_e)$  is adjusted according as the bank manager is expected to take the safety action or the risky action.

Section 2.1, the bank manager loses his position in period 1 ( $\chi_2 = \chi_3 = 0$ ) if his risky action is verified by the regulator; and he also loses his position in period 2 ( $\chi_3 = 0$ ) if the bank is insolvent in period 2.

In order to discuss the action choice of the bank manager, we need to specify the expected payoff of the bank manager in period 1 according as he chooses the safety or the risky action if the bank's assets are bad.

We first determine the expected payoff of the bank manager in period 1 if he faces the bad assets and chooses the safety action. The residual value of the bank in period 3 in this case is  $R_3 - D_0 + \tilde{R}_{b2} + p_e$ . Thus, the expected payoff of the bank manager in period 1,  $E_1 \hat{\pi}_M^s(\alpha, p_e)$ , is represented by

$$E_1 \hat{\pi}_M^s(\alpha, p_e) = \alpha(R_3 - D_0 + \tilde{R}_{b2} + p_e) - p_e + \gamma. \quad (4)$$

Note that the bank manager who faces the bad assets and chooses the safety action is replaced by a new one in period 2.

We next specify the expected payoff of the bank manager if he faces the bad assets and chooses the risky action. The residual value of the bank in period 3 in this case is  $R_3 - D_0 + \tilde{R}_{b2} + p_e$  if the risky action is verified;  $R_{g2} + R_3 - D_0 + p_e$  if the risky action is unverified and if the period 2 bank returns are  $R_{g2}$ ; and 0 if the risky action is unverified and if the period 2 bank returns are  $R_{b2}$ . The expected payoff of the bank manager in period 1,  $E_1 \hat{\pi}_M^r(\alpha, p_e)$ , is then expressed by

$$E_1 \hat{\pi}_M^r(\alpha, p_e) = \delta[\alpha(R_3 - D_0 + \tilde{R}_{b2} + p_e) - p_e] + (1 - \delta)\sigma[\alpha(R_{g2} + R_3 - D_0 + p_e) - p_e + 2\gamma] + (1 - \delta)(1 - \sigma)[-p_e + \gamma]. \quad (5)$$

The first term of Eq. (5) indicates the case in which the risky action is verified; then, the bank manager is replaced in period 1. The second term of Eq. (5) corresponds to the case where the risky action is unverified and the period 2 bank returns are  $R_{g2}$ . In this case, the bank manager keeps his position until period 3 because the bank is solvent in period 2. The final term of Eq. (5) represents the case in which the risky action is unverified but the period 2 bank returns are  $R_{b2}$ . Then, the bank manager is replaced in period 2 because the bank is insolvent in period 2.

Comparing Eqs. (4) and (5), we see that the bank manager chooses the safety action if and only if

$$\alpha[(1 - \sigma)(R_3 - D_0 + p_e) + \tilde{R}_{b2} - \sigma R_{g2}] \geq \left(\sigma - \frac{\delta}{1 - \delta}\right)\gamma. \quad (6)$$

#### 2.4. The objective of the regulator

The objective of the regulator is to attain the social optimal allocation that is defined as an allocation which maximizes the social surplus. The social

surplus is equal to the sum of the expected net residual value of the bank in period 0 ( $\Pi(p_e) - p_e$ ) and the expected private benefits of the incumbent and new bank managers in period 0 from their retaining the control of the firm minus the expected total costs in period 0 associated with default on bank debt.<sup>17</sup>

To define the social surplus, we need to specify the ex ante expected total costs in period 0 associated with default on bank debt. We first discuss the case in which the bank manager facing the bad assets chooses the safety action in period 1. If the bank's assets are good, then the regulator need not inject any cash funds into the bank in period 2 nor compensate any depositors for their deposit funds in period 3. On the other hand, if the bank's assets are bad, then the regulator needs to inject cash funds in period 2. However, the regulator can receive the full repayments of subordinated bonds and need not compensate any depositors for their deposit funds in period 3 because the safety action bank becomes solvent in period 3 under Assumption 2. Thus, in this case, the ex ante expected total costs in period 0 associated with default on bank debt  $E_0C^s$  are equal to 0.

We next suppose that the bank manager facing the bad assets chooses the risky action. Again, if the bank's assets are good, the regulator need not inject any cash funds into the bank in period 2 nor compensate any depositors for their deposit funds in period 3. In contrast, if the bank's assets are bad, the situation is quite different. If the regulator can verify the risky action, it replaces the incumbent bank manager and forces the new bank manager to take the safety action. Then, the regulator can receive the full repayments of subordinated bonds and need not compensate any depositors for their deposit funds in period 3. Even though the regulator cannot verify the risky action, it need not do anything if the period 2 bank returns are  $R_{g2}$ . The only case in which the regulator needs to inject cash funds into the bank in period 2 and compensate depositors for their deposit funds in period 3 is that the regulator cannot verify the risky action and that the period 2 bank returns are  $R_{b2}$ . Since the risky action bank is insolvent in period 3 in this case, the costs associated with default on bank debt are  $D_0 - R_{b2} - R_3 - p_e > 0$ , where the sign of the inequality is derived from Assumption 5. The ex ante expected total costs in period 0 associated with default on bank debt  $E_0C^r(p_e)$  are equal to  $(1 - \theta)(1 - \delta)(1 - \sigma)(D_0 - R_{b2} - R_3 - p_e) > 0$ .

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<sup>17</sup> The ex ante expected total costs associated with default on bank debt may include not only deposit insurance payments but also default losses to bank debt holders other than depositors if  $R_3 + R_{b2} < 0$ .



The level of the social surplus is now defined as follows. If the bank manager facing the bad assets selects the safety action, then it is found from Eq. (1) that<sup>18</sup>

$$\begin{aligned} S^s &= E_0 \Pi_B^s(p_e) - p_e + 2\gamma - E_0 C^s \\ &= \theta(R_{g2} + R_3 - D_0) + (1 - \theta)(R_3 - D_0 + \tilde{R}_{b2}) + 2\gamma. \end{aligned} \quad (7)$$

If the bank manager facing the bad assets takes the risky action, then it is seen from Eq. (3) that

$$\begin{aligned} S^r &= E_0 \Pi_B^r(p_e) - p_e + 2\gamma - E_0 C^r(p_e) \\ &= \theta(R_{g2} + R_3 - D_0) + (1 - \theta)\delta(R_3 - D_0 + \tilde{R}_{b2}) \\ &\quad + (1 - \theta)(1 - \delta)\sigma(R_{g2} + R_3 - D_0) - (1 - \theta)(1 - \delta)(1 - \sigma) \\ &\quad \times (D_0 - R_{b2} - R_3) + 2\gamma. \end{aligned} \quad (8)$$

Comparing Eqs. (7) and (8), we show  $S^s \geq S^r$  if and only if  $(1 - \theta) \times (1 - \delta)[\tilde{R}_{b2} - \sigma R_{g2} - (1 - \sigma)R_{b2}] \geq 0$ . Under Assumption 1, this inequality is always satisfied. Thus, the social optimal allocation is achieved only if the bank manager always chooses the safety action in the event that the bank's assets are bad.

### 3. Equilibrium managerial compensation contract

#### 3.1. Definition of equilibrium

We can define the subgame perfect equilibrium of the basic model as follows:

(i) In period 0, the bank equity owners choose  $(\alpha, p_e)$  to maximize their expected dividends from the bank, taking as given the response function (6) of the bank manager who chooses between the safety and risky actions if the bank's assets are bad.

(ii) In period 1, if the bank's assets are bad, the bank manager chooses the safety or the risky action to maximize his expected managerial compensation plus his expected private benefit from keeping the management position in the bank, taking as given  $(\alpha, p_e)$  chosen by the bank equity owners.

<sup>18</sup> Note that the sum of the private benefits of the incumbent and new bank managers from their retaining the control of the firm is  $2\gamma$ .

### 3.2. Characterization of equilibrium managerial compensation contract

We solve the subgame perfect equilibrium of the model by backward induction, and obtain the following proposition.

**Proposition 1.** *Suppose that Assumptions 1–6 hold.*

(i) (a) *If  $\sigma \leq \delta/(1 - \delta)$ , then the optimal compensation structure is given by  $(\alpha^*, p_e^*) = (0, 0)$ . The bank manager chooses the safety action if the bank's assets are bad. (b) If  $\sigma > \delta/(1 - \delta)$ ,  $(1 - \sigma)(R_3 - D_0 + \bar{p}_e) + \tilde{R}_{b2} - \sigma R_{g2} \geq (\sigma - (\delta/(1 - \delta)))\gamma$ , and  $(1 - \theta)(1 - \delta)[(1 - \sigma)(R_3 - D_0) + \tilde{R}_{b2} - \sigma R_{g2}] + \bar{p}_e \geq \Xi[R_3 - D_0 + \bar{p}_e + \theta R_{g2} + (1 - \theta)\tilde{R}_{b2}]$ , then  $(\alpha^*, p_e^*) = (\Xi, \bar{p}_e)$ , where*

$$\Xi \equiv \frac{(\sigma - \frac{\delta}{1-\delta})\gamma}{(1 - \sigma)(R_3 - D_0 + \bar{p}_e) + \tilde{R}_{b2} - \sigma R_{g2}}.$$

*The bank manager chooses the safety action if the bank's assets are bad.*

(ii) *Otherwise,  $(\alpha^*, p_e^*) = (0, 0)$ . The bank manager chooses the risky action if the bank's assets are bad.*

Proposition 1 shows that the conditions of Proposition 1(i) are required to motivate the bank manager to choose the safety action if the bank's assets are bad. Since the social surplus is maximized only if the safety action is taken, this proposition implies that the equilibrium is efficient only if this parametric configuration holds. We therefore conclude that the social optimum cannot be necessarily attained in the basic model.

The intuition behind Proposition 1 can be explained as follows. Under Assumption 6, Lemma 1 indicates that the bank equity owners always prefer to motivate the bank manager to take the safety action rather than the risky action if  $(\alpha, p_e)$  is not adjusted according to the expectation of the action chosen by the bank manager. Furthermore, the incentive compatibility condition for the bank manager, Eq. (6), suggests that the bank manager is more likely to be motivated to choose the safety action as  $\alpha$  and  $p_e$  are larger. The positive incentive effect of an increase in  $p_e$  comes out of the setting that some part of the exercise price paid by the bank manager returns to him as dividend payments if the bank is solvent in period 3.

Now, suppose that  $\sigma \leq \delta/(1 - \delta)$ . Then, given Eq. (6), the bank manager prefers to take the safety action even though  $\alpha = 0$ . Thus, the bank equity owners naturally choose  $(\alpha, p_e) = (0, 0)$  to maximize their expected dividend claims.

On the other hand, suppose that  $\sigma > \delta/(1 - \delta)$ . If  $(1 - \sigma)(R_3 - D_0 + \bar{p}_e) + \tilde{R}_{b2} - \sigma R_{g2} < (\sigma - (\delta/(1 - \delta)))\gamma$ , then Eq. (6) implies that the bank manager never chooses the safety action even though  $(\alpha, p_e) = (1, \bar{p}_e)$ . Hence, the bank

equity owners must make do with the situation in which the bank manager takes the risky action. The bank equity owners set  $(\alpha, p_e) = (0, 0)$  to maximize their expected dividend claims.

However, if  $(1 - \sigma)(R_3 - D_0 + \bar{p}_e) + \tilde{R}_{b2} - \sigma R_{g2} \geq (\sigma - (\delta/(1 - \delta)))\gamma$ , then Eq. (6) shows that the bank manager takes the safety action if and only if  $\alpha \geq \Xi$ . Thus, the bank equity owners need to design  $(\alpha, p_e) = (\Xi, \bar{p}_e)$  in order to maximize their expected dividend claims as long as they desire the bank manager to take the safety action. If  $\sigma > \delta/(1 - \delta)$  and  $(1 - \theta)(1 - \delta) \times [(1 - \sigma)(R_3 - D_0) + \tilde{R}_{b2} - \sigma R_{g2}] + \bar{p}_e \geq \Xi[R_3 - D_0 + \bar{p}_e + \theta R_{g2} + (1 - \theta)\tilde{R}_{b2}]$ , the expected payoff of the bank equity owners in period 0 is larger under the safety action than under the risky action even though  $(\alpha, p_e)$  is adjusted according as the bank manager is expected to take the safety or the risky action. The bank equity owners thus have an incentive to motivate the bank manager to take the safety action, and offer him  $(\alpha, p_e) = (\Xi, \bar{p}_e)$ . In contrast, if  $\sigma > \delta/(1 - \delta)$  and  $(1 - \theta)(1 - \delta)[(1 - \sigma)(R_3 - D_0) + \tilde{R}_{b2} - \sigma R_{g2}] + \bar{p}_e < \Xi[R_3 - D_0 + \bar{p}_e + \theta R_{g2} + (1 - \theta)\tilde{R}_{b2}]$ , the expected payoff of the bank equity owners in period 0 under the safety action does not compensate for their loss of equity claims. Hence, the bank equity owners have an incentive to induce the bank manager to take the risky action; as a result, the bank equity owners offer him only  $(\alpha, p_e) = (0, 0)$ .

### 3.3. Relaxation of the restrictions on the compensation structure

In this subsection, we consider how the relaxation of the restrictions on the managerial compensation structure modifies the results of this section.

We begin with examining the effect of the upper limit constraint on  $p_e$ . Since the incentive constraint for the bank manager is given by Eq. (6), one might suppose that the bank equity owners can always motivate the bank manager to take the safety action by setting  $p_e$  large enough. Indeed, if the bank equity owners set  $p_e$  large enough, the bank manager has no incentive to execute his stock options unless  $\alpha$  is large enough. Thus, a high level of  $p_e$  reduces the expected payoff of the bank equity owners, or contradicts the assumption that the bank manager has an incentive to execute his stock options. Furthermore, if  $p_e$  can be extremely large, the bank facing the bad assets would become always solvent because the bank receives  $p_e$  large enough prior to period 1. Since this setting is not only unrealistic but also makes our analysis trivial, it is reasonable to impose the liquidity constraint on the bank manager.

We next discuss the assumption that the bank manager always has an incentive to execute his stock options under the constraint  $p_e \in [0, \bar{p}_e]$  unless  $\alpha \neq 0$ . In the absence of this assumption, the bank equity owners can construct  $(\alpha, p_e)$  so that the bank manager executes his stock options only if he prefers to choose the safety action when facing the bad assets. Hence, the bank equity owners have another instrument for motivating the bank manager to take the

safety action even though they cannot completely delete the moral hazard incentive of the bank manager. In this sense, the bank manager is more likely to choose the safety action if the bank's assets are bad.

Finally, we have assumed that a fixed cash salary is normalized to zero. If a fixed cash salary is positive and paid in period 0, then we need not modify our main results. However, if a fixed cash salary is positive and paid in period 3, then the bank manager receives the fixed cash salary only if he retains his management position in the bank until period 3. This effect gives the manager more incentive to take the risky action because it is more probable that the bank manager retains his management position until period 3 if he chooses the risky action. Thus, this modification induces the bank manager to be more likely to choose the risky action if the bank's assets are bad.

#### 4. Non-linear injection scheme toward the improvement in social efficiency

Since we are interested in the case in which the equilibrium is inefficient, we will focus on the following parametric configuration:

**Assumption 7.**  $\sigma > \delta/(1 - \delta)$ .

##### 4.1. Non-linear injection scheme and managerial compensation contract

Let  $S(I, V)$  be the amount of repayments from the bank to the regulator in period 3, where  $I$  denotes the amount of injection of cash funds and  $V$  the gross residual value of the bank in period 3 prior to the repayment to the regulator. These two variables are verifiable by all the agents after the execution of the public scheme of injection of cash funds into the insolvent bank. We assume the limited liability of both the bank equity owners and the bank manager so that  $S(I, V) = 0$  for any  $V \leq 0$  and  $0 \leq S(I, V) \leq V$  for any  $V \geq 0$ .

Let us introduce the following conditions for any  $p_e \in [0, \bar{p}_e]$ :

$$(1 - \sigma)S(-R_{b2} - p_e, R_3 - D_0) \geq S(-\tilde{R}_{b2} - p_e, R_3 - D_0) + \sigma(R_{g2} + p_e) + \left( \sigma - \frac{\delta}{1 - \delta} \right) \gamma, \quad (9a)$$

$$(1 - \theta)[\delta S(-\tilde{R}_{b2}, R_3 - D_0) + (1 - \delta)(1 - \sigma)S(-R_{b2}, R_3 - D_0) - S(-\tilde{R}_{b2} - p_e, R_3 - D_0) - (1 - \delta)\sigma R_{g2}] + \theta p_e \geq \frac{(\sigma - \frac{\delta}{1 - \delta})\gamma[R_3 - D_0 + \theta(R_{g2} + p_e) - (1 - \theta)S(-\tilde{R}_{b2} - p_e, R_3 - D_0)]}{(1 - \sigma)S(-R_{b2} - p_e, R_3 - D_0) - \sigma(R_{g2} + p_e) - S(-\tilde{R}_{b2} - p_e, R_3 - D_0)}, \quad (9b)$$

$$0 \leq S(I, R_3 - D_0) \leq R_3 - D_0,$$

$$\text{for } I \in \{-\tilde{R}_{b2}, -\tilde{R}_{b2} - p_e, -R_{b2}, -R_{b2} - p_e\}. \tag{9c}$$

Then, we obtain the following proposition.

**Proposition 2.** *Suppose that Assumptions 1–7 hold. If there exists a repayment schedule that satisfies Eqs. (9a)–(9c), the social optimal allocation can be attained by the repayment schedule. The optimal equity claim ratio of the bank manager  $\alpha^*$  is equal to*

$$\Xi_S^*(p_e^*) \equiv \frac{(\sigma - \frac{\delta}{1-\delta})\gamma}{(1 - \sigma)S^*(-R_{b2} - p_e^*, R_3 - D_0) - \sigma(R_{g2} + p_e^*) - S^*(-\tilde{R}_{b2} - p_e^*, R_3 - D_0)}.$$

The optimal exercise price  $p_e^*$  is determined as an optimal solution for  $\alpha^* = \Xi_S^*(p_e^*)$ .

Proposition 2 suggests that under certain conditions, the social optimal allocation is achieved by the injection of cash funds into the insolvent bank through the purchase of securities with a non-linear repayment schedule even though the social optimum cannot be attained by the injection of cash funds into the insolvent bank through the purchase of subordinated bonds with the risk-free interest rate.

The intuition behind Proposition 2 can be explained as follows. The inequality (9a) is derived from the incentive compatibility condition for the bank manager in order to ensure  $\alpha \leq 1$ , while the inequality (9b) is obtained from the incentive compatibility condition for the bank equity owners. The first inequalities of Eq. (9c) represent the limited liability conditions for the regulator that need not subsidize the bank beyond the injection amount. The second inequalities of Eq. (9c) express the limited liability conditions for the bank equity owners that need not repay any amount which is larger than the gross residual value of the bank in period 3. If these conditions are satisfied, all of the agents prefer the safety action rather than the risky action. Thus, the moral hazard problem can be resolved. Since the social optimum is attained only if the bank manager facing the bad assets chooses the safety action, the social optimal allocation can be attained by any repayment schedule that satisfies Eqs. (9a)–(9c).

#### 4.2. More specific characterization of the optimal injection scheme

Given in Eqs. (9a), (9c),  $R_{g2} > 0$ ,  $0 < \sigma < 1$ , and Assumption 7, we provide the following corollary of Proposition 2.

**Corollary 1.** *Suppose that Assumptions 1–7 hold. If there exists a feasible repayment schedule that satisfies Eqs. (9a)–(9c), then  $0 \leq S^*(-\tilde{R}_{b2} - p_e, R_3 - D_0) < S^*(-R_{b2} - p_e, R_3 - D_0) \leq R_3 - D_0$ .*

This corollary implies that the repayments from the safety action bank to the regulator are smaller than those from the risky action bank to the regulator if there exists a feasible repayment schedule set to satisfy Eqs. (9a)–(9c) and if the bank manager executes his stock options for the exercise price  $p_e$ . The corollary also suggests that the regulator does not take away all equity claims from the safety action bank in period 3 even if the bank is insolvent in period 2. The intuition behind this result is that if the regulator takes away all equity claims from the insolvent bank regardless of the bank's action, then the bank manager facing the bad assets has more incentive to choose the risky action because of gamble for resurrection.

The next corollary shows that under certain conditions, there exists a feasible repayment schedule that satisfies Eqs. (9a)–(9c); furthermore, the social optimal allocation can be attained by the injection policy such that the risky action bank must repay all of the gross residual value of the bank.

**Corollary 2.** *Suppose that Assumptions 1–7 hold.*

(i) *If  $(1 - \sigma)(R_3 - D_0) - \sigma R_{g2} - (\sigma - \frac{\delta}{1-\delta})\gamma \geq 0$  and*

$$\frac{[(1 - \sigma)(R_3 - D_0) - \sigma R_{g2}][ (1 - \sigma)(R_3 - D_0) - \sigma(R_{g2} + \bar{p}_e) ]}{R_3 - D_0 + \theta(R_{g2} + \bar{p}_e)} \geq \frac{\sigma(1 - \delta) - \delta}{(1 - \theta)(1 - \delta)^2} \gamma,$$

*the social optimum allocation can be attained by setting  $S(I, V)$  to satisfy  $S^*(-\tilde{R}_{b2}, R_3 - D_0) = S^*(-\tilde{R}_{b2} - p_e, R_3 - D_0) = 0$  and  $S^*(-R_{b2}, R_3 - D_0) = S^*(-R_{b2} - p_e, R_3 - D_0) = R_3 - D_0$ . The optimal stock option plan is then*

$$\alpha^* = \frac{(\sigma - \frac{\delta}{1-\delta})\gamma}{(1 - \sigma)(R_3 - D_0) - \sigma(R_{g2} + p_e^*)} \quad \text{and}$$

$$p_e^* = \min \left\{ \sigma^{-1} \left[ (1 - \sigma)(R_3 - D_0) - \sigma R_{g2} - \left( \sigma - \frac{\delta}{1 - \delta} \right) \gamma \right], \bar{p}_e \right\}.$$

(ii) *The above repayment schedule is more likely to achieve the social optimal allocation as (a) the period 2 good state returns  $R_{g2}$  are smaller; (b) the period 3 gross residual value of the bank  $R_3 - D_0$  is larger; (c) the probability of the risky action being verified  $\delta$  is larger; (d) the probability of the bank's assets being good  $\theta$  is smaller; (e) the private benefit of the bank manager from keeping the management position in the bank  $\gamma$  is smaller; and (f) the upper limit of the amount paid by the bank manager in the execution of stock options  $\bar{p}_e$  is smaller.*

Corollary 2(i) suggests that there exists a repayment schedule which achieves the social optimal allocation under certain conditions: the insolvent bank that has taken the safety action need not make any repayments despite receiving injected cash funds, while the insolvent bank that has taken the risky action must make repayments equal to all the gross residual value of the bank in period 3. More realistically, the former class of contract (security) can be viewed as subordinated bonds or preferred stocks with less stringent repayment conditions, whereas the latter class of contract (security) can be interpreted as the nationalization of the insolvent bank.

The intuition behind Corollary 2(ii) can be explained as follows. Suppose that the regulator sets the repayment schedule specified in Corollary 2(i). Then, as  $R_{g2}$  is smaller, the expected residual values of the bank in periods 0 and 1 decrease more under the risky action than under the safety action because the probability of  $R_{g2}$  being realized is higher under the risky action than under the safety action. Thus, a decline in  $R_{g2}$  reduces the expected payoffs of both the bank equity owners in period 0 and the bank manager in period 1 more under the risky action than under the safety action unless  $(\alpha^*, p_e^*)$  is adjusted. In fact, the bank equity owners can reduce  $\alpha^*$  although they may raise  $p_e^*$ . The total effect of a decline in  $R_{g2}$  is more likely to cause the bank equity owners to prefer the safety action rather than the risky action. This change, therefore, is more likely to attain the social optimum allocation. The effect of a rise in  $R_3 - D_0$  is also similar to that of a decline in  $R_{g2}$ .

An increase in  $\delta$  reduces the expected residual values of the bank in periods 0 and 1 under the risky action. It also reduces  $\alpha^*$  although it may raise  $p_e^*$ . Since an increase in  $\delta$  does not change the expected residual value of the bank under the safety action, such a change is more likely to lead the equilibrium to be socially optimal.

A decline in  $\theta$  has no effects on the expected residual value of the bank in period 1 if the bank's assets are bad. This implies that such a change does not affect the incentive for the bank manager to take the safety action. Thus, a decline in  $\theta$  need not alter  $(\alpha^*, p_e^*) = (\bar{\alpha}_S^*(p_e^*), p_e^*)$ . However, a decline in  $\theta$  strengthens the incentive for the bank equity owners to prefer  $(\alpha, p_e) = (\bar{\alpha}_S^*(p_e^*), p_e^*)$  rather than  $(\alpha, p_e) = (0, 0)$  because it reduces the expected residual value of the bank in period 0 more under the risky action than under the safety action in the presence of Assumption 1. This makes the social optimal allocation more likely to be attainable.

Finally, a decrease in  $\gamma$  or  $\bar{p}_e$  causes the equilibrium to be more likely to be socially optimal because it provides the less incentive for the bank equity owners and the bank manager to prefer the risky action. However, a decrease in  $\gamma$  leads the bank equity owners to offer the lower  $\alpha^*$  and the higher  $p_e^*$ , whereas a decrease in  $\bar{p}_e$  results in the opposite effect on  $\alpha^*$  and  $p_e^*$ .

We may consider that the regulatory scheme given by Corollary 2 corresponds to the injection scheme of Japan in 1998, where most of the major

banks announced to accept the injection of public funds through the purchase of subordinated bonds or preferred stocks with less stringent repayment conditions while two major private banks (Long-Term Credit Bank of Japan and Nippon Credit Bank) were forced to be transformed into government-owned banks. Corollary 2 suggests that this kind of regulatory scheme can attain the social optimal allocation if the conditions of Corollary 2 are satisfied. Indeed, the problem in the Japanese case is that several banks with seriously damaged assets were also able to receive the injection of cash funds; and it took long time to privatize the two nationalized banks again.

Our result is also reminiscent of the optimal repayment schedule derived by Innes (1990) in the standard model of the lender–borrower relationship with limited liability: he shows that, under the monotone likelihood ratio property, the best way to provide correct incentive for the borrower's effort is to give the borrower maximal reward if the borrower's returns are good, and maximal penalty if the borrower's returns are bad. The difficulty in interpreting his result is that this type of contract (security) is not observed in practice in the usual lender–borrower relationship. However, in our regulatory framework, this kind of contract (security) can be interpreted as the nationalization of the insolvent bank that has chosen the risky action.

## **5. Conclusion**

Under the incomplete contract framework, we have considered an optimal regulatory policy for motivating bank equity owners and bank managers to restructure the bad loans of their banks. We have also supposed that bank equity owners can freely control a managerial compensation contract with stock options for bank managers. The regulatory policy studied in this paper is mainly concerned with the design of the repayment schedule in the scheme of injection of cash funds into insolvent banks by the regulator. We have shown that the regulator cannot necessarily attain the social optimal allocation by injecting cash funds into insolvent banks through the purchase of subordinated bonds with the risk-free interest rate. However, even in that case, we have indicated that, if the regulator injects cash funds into active restructuring banks through the purchase of subordinated bonds or preferred stocks with less stringent repayment conditions and nationalizes passive restructuring banks, then the regulator can attain the social optimal allocation under certain conditions.

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