Incentive-based capital requirements*

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Abstract

This paper proposes a new regulatory approach that implements capital requirements contingent on executive incentive schemes. We argue that excessive risk-taking in the financial sector originates from the shareholder moral hazard created by government guarantees rather than from corporate governance failures within banks. The idea behind the proposed regulatory approach is thus that the more the compensation structure decouples the interests of bank managers from those of shareholders by curbing risk-taking incentives, the higher the leverage the bank is permitted to take on. Consequently, the risk-shifting incentives caused by government guarantees and the risk-mitigating incentives created by the compensation structure offset each other such that the manager chooses the socially efficient investment policy.

Keywords: capital regulation, compensation, leverage, risk

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1 Introduction

In response to the 2008–2009 financial crisis that exposed the excessive risk-taking of banks, legislators have sought to curb risk-taking incentives in the financial sector. Since the risky investment behavior of many financial institutions can often be directly linked to the compensation schemes of their managers (e.g., Bear Stearns, Lehman, UBS, Citigroup, Merrill Lynch, and AIG)[1], it has been argued that corporate governance failures within banks were a primary cause of the financial crisis. Following this line of argument, aligning executive pay arrangements with the interests of banks' shareholders may limit excessive risk-taking (e.g., by introducing say-on-pay rules).

However, shareholders of financial institutions may have strong risk-shifting incentives due to explicit and implicit government guarantees. Hence, shareholder empowerment aggravates the excessive risk problem because shareholders will simply pass on their risk-shifting incentives to bank managers. The regulatory solution to this problem thus far has been the implementation of risk-weighted capital requirements. In this paper, we propose a new regulatory approach that involves capital requirements that are contingent on managerial compensation. This approach utilizes the compensation scheme to drive a wedge between the interests of top management and shareholders, counteracting shareholder risk-shifting incentives.

Risk-shifting incentives have been widely studied since the seminal work of Jensen and Meckling (1976). The classical risk-shifting problem between debtholders and shareholders arises when debtholders are unable to obtain adequate adjustments of risk premiums in case the investment risk increases. This problem is particularly relevant for banks because of their high leverage and the relative ease with which they can change the degree of risk of their business activities. This risk-shifting problem between debtholders and shareholders can be mitigated to some extent by including loan covenants in the debt contract (Berlin and Mester, 1992; Chava and Roberts, 2008) or by using short-term debt (Calomiris and Kahn, 1991).

In the case of financial institutions, however, an even more severe risk-shifting problem arises when governments implicitly or explicitly guarantee part of the banks' deposits or borrowed funds. Targeted at preventing panic-based bank runs and interbank contagion, these guarantees limit the downside risk of debt and, in turn, increase the expected repayment to debtholders. As a result, the incentive of insured debtholders to monitor bank risk is weakened, and they do not appropriately adjust debt costs for risk. Consequently, insured debt is comparatively inexpensive, and banks are incentivized to increase their leverage. The resulting high amount of debt financing, with interest rates that are not appropriately adjusted for risk, incentivizes banks to invest in very risky assets. Ultimately, this behavior resulting

[1] For details see Kashyap, Rajan, and Stein (2008), Acharya and Richardson (2009), and Bebchuk, Cohen, and Spamann (2010).

from the presence of government guarantees increases banks' default probability. Whereas equityholders do not bear the expected costs of a bank failure in the form of a higher cost of debt funding ex-ante, taxpayers have to bear all the costs of bank failures ex-post. Wealth is thereby transferred from society to equityholders.

This problem justifies regulatory intervention, which so far has been characterized by the implementation of risk-weighted capital requirements. However, the 2008–2009 financial crisis revealed that measuring bank asset risk is a difficult task because risk modeling per se has strong limitations (Danielsson, 2002, 2008; Hellwig, 2010; Rajan, Seru, and Vig, 2015). In addition, with risk-weighted capital requirements, banks have an incentive to understate their asset risk (Behn, Haselmann, and Vig, 2014) and to engage in regulatory capital arbitrage (e.g., Cochrane, 2014).

Hence, various academics have advocated for substantially higher and non-risk-weighted capital requirements in banking (e.g., Admati, Allen, Brealey, Brennan, Boot, Brunnermeier, Cochrane, De Marzo, Fama, Fishman, et al., 2010; Cochrane, 2014; Admati and Hellwig, 2014), which could potentially reduce banks' default probability. However, as long as banks are still allowed to take on debt that is protected by some sort of government guarantee, these risk-shifting incentives prevail.[2] Hence, even with higher and non-risk-weighted capital requirements, shareholders still have an incentive to put incentive schemes in place that encourage the bank management to take on excessive risk.

To prevent bank shareholders from just passing on their risk-shifting incentives to bank managers, Bebchuk and Spamann (2010) advocate that monitoring compensation structures should play an important role in determining the capital requirements that are appropriate for each financial institution. The authors argue that this approach improves the overall effectiveness of banking regulation because information about pay structures can be used to produce a better fit between capital requirements and the investment risks posed by individual banks. We present a model that provides a theoretical justification for this approach. In particular, we show how the excessive risk-taking problem, given explicit or implicit government guarantees, can be solved by incentive-based capital requirements. Our proposed regulation stipulates a higher minimum capital requirement for banks that remunerate their management using a relatively high performance-based wage component and a relatively low fixed payment. Therefore, when a bank implements a conservative compensation structure, the regulator can allow a (potentially) riskier capital structure because the risk-shifting incentives induced by government guarantees and high leverage are offset by the remuneration structure. Banks thus face a trade-off between leverage and the risk-taking incentives embedded in their executive compensation contract. Hence, a bank that pays its management only with a fixed wage can be allowed to finance itself mostly with debt. Conversely, a bank

[2] Since bank debt does provide benefits beyond providing funding for banks (e.g., the information-insensitivity of banks' debt is valuable for liquidity provision), it is arguably not socially optimal to prohibit banks from taking on at least a moderate level of debt. See, for example, Gorton, Lewellen, and Metrick (2012), Krishnamurthy and Vissing-Jorgensen (2013), Myerson (2014), and Admati and Hellwig (2015).

that pays management solely performance-based has to be purely equity financed, which corresponds to the regulatory approach proposed by Cochrane (2014).

2 Related Literature

Designing CEO contracts to establish optimal investment risk decisions is a subject that has gained an increased amount of attention since the 2008–2009 financial crisis. Early work by John and John (1993) shows that compensation schemes can be used to correct distorted risk-taking incentives. The theoretical analysis provided by John, Saunders, and Senbet (2000) proposes a regulatory approach in which the deposit insurance premium scheme incorporates incentive features of top management compensation. Edmans and Liu (2011) show that a wage scheme that is also based on debt components can improve effort as well as deter risk-shifting. A recent paper by Bolton, Mehran, and Shapiro (2015) proposes the inclusion of CDS spreads in the incentive scheme to mitigate the risk-shifting problem. Thanassoulis (2012) and Hakenes and Schnabel (2014) develop theoretical arguments for caps on bankers' bonuses. Similar to our paper, Thanassoulis and Tanaka (2015) acknowledge the importance of the excessive risk-taking incentives of bank shareholders that are due to the moral hazard created by government guarantees. The authors conclude that with existing regulatory approaches, bank shareholders are still able to pass on their risk-shifting incentives to bank management. Therefore, to eliminate the moral hazard problem created by government guarantees, the authors argue for malus and clawback clauses in manager compensation.

Various papers have empirically investigated the relations between shareholder power, CEO compensation, insured debt, and banks' risk-taking decisions. Chesney, Stromberg, and Wagner (2010) find evidence suggesting that higher risk-taking incentives for managers of U.S. financial institutions were significantly positively associated with write-downs during the crisis. Cheng, Hong, and Scheinkman (2015) also show that there is a correlation between compensation structures and risk-taking. Furthermore, Fahlenbrach and Stulz (2011) find evidence that banks with CEOs whose incentives were better aligned with shareholder interests performed worse during the crisis, on average. Laeven and Levine (2009) show that high shareholder power within a bank's corporate governance structure translates into greater risk-taking by the bank. Moreover, the authors show that an increase in shareholder power is associated with a rise in risk in response to tougher regulation and more access to deposit insurance. Westman (2010) confirms these results. An empirical study by Gropp and Koehler (2010) finds that shareholder-controlled banks behave in a riskier fashion and obtain more government assistance than manager-controlled banks. The results of Adams (2012) suggest the same: The study shows that banks that had higher performance pay for CEOs prior to the 2008-2009 financial crisis were more likely to receive government support. Likewise, using a new management insulation index, Ferreira, Kershaw, Kirchmaier, and Schuster (2016) show that banks in which managers were more insulated from shareholders before the recent financial crisis were less likely to be bailed out during the crisis. Taken together, the empirical evidence confirms our paper's conjectures by showing that insured debt induces excessive risk-taking by banks and that close alignment of shareholder and manager interests aggravates the risk-shifting problem.

3 Model setup

To study risk-shifting incentives in a model with an endogenous capital structure choice, we build on Inderst and Mueller (2008) and consider an economy that consists of three dates, $t = 0, 1, 2$, and three risk-neutral parties: bank shareholders, creditors, and the bank manager. The bank is protected by limited liability and has access to two investment possibilities, a risky investment opportunity and a safe one. Both investments require a fixed capital outlay of k. The bank manager decides on the bank's investments as well as its capital structure and acts on her own behalf. The timing of the model is depicted in Fig. 1.

At $t = 0$, the external claims are issued. The bank's sources of capital are equity (e) provided by the shareholders and debt (d) that is at least partially insured by the government, yielding total funds of $K = e+d$. We assume that all investors have the opportunity cost of capital r.[3] The debt claims mature at $t = 2$. The face value of debt is denoted by $D = d(1 + r_d)$, with r_d being the respective interest rate. Since all of the bank's investment opportunities require a capital outlay k, we specify that $K = k$.

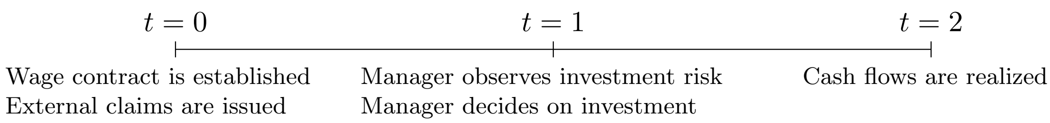

Figure 1: Timing of the model

The bank's investment possibilities materialize at $t = 1$. The success probability of the risky investment opportunity depends on the investment's quality, which is given by $q \in Q = [0, 1]$. With probability q, the risky investment generates a positive return of R_H, and with probability $(1 - q)$, the risky investment fails, in which case its return is zero. Instead of investing in the risky investment, the bank can choose a safe investment opportunity that always yields the return $R_L < R_H$.[4] At $t = 2$, the cash flows from the investment made at $t = 1$ are realized.

In the case where the bank invested in the risky investment and it turns out to be a failure, we assume that the government steps in with probability $I_D\beta \in [0, 1]$ and repays the bank's creditors, where I_D is an

[3] We relax this assumption in the online appendix, where we analyze the case in which equity has a higher opportunity cost than debt financing.

[4] R_L is assumed to be sufficiently high that the bank is able to repay its debt liabilities when it invests in the safe asset.

indicator function that is equal to one if $D \leq \overline{D}$ and zero otherwise. That is, to limit the bank's incentive to increase its leverage, we assume that if the bank increases its debt liabilities beyond the threshold $\overline{D}$, it becomes "too-big-to-save" (i.e., the government does not have the financial means to bail out the bank if it defaults) and is thus no longer protected by government guarantees.[5] We assume that $\overline{D} < k$, such that the bank cannot finance its investments solely with debt without becoming "too-big-to-save". The parameter $\beta \in [0, 1]$ can be thought of as the agents' belief about the extent of the government insurance coverage (i.e., bailout probability).

Before deciding between the two investment possibilities, the manager receives a signal $s \in \Sigma = [0, 1]$ about the quality of the risky investment opportunity through a screening procedure. For the screening procedure, we follow Inderst and Mueller (2006) and assume that the investment opportunity with quality q generates a signal s according to the distribution function $F_q(s)$, which is assumed to be absolutely continuous in s. The family of density functions $f_q(s)$ is positive and continuous in s, and it satisfies the Monotone Likelihood Ratio Property (MLRP); that is, the ratio $f_{q_1}(s)/f_{q_2}(s)$ is strictly increasing in s for all $q_1 > q_2$.

The prior that the investment quality is of type q is denoted by $\pi(q)$. Therefore, it follows from Bayes' theorem that the posterior beliefs about the investment quality given the signal s are

$$\pi(q'|s) = \frac{\pi(q')f_{q'}(s)}{\int \pi(q)f_q(s)dq}, \tag{1}$$

which, due to the properties of $f_q(s)$, also satisfy the MLRP. Therefore, a high s is good news because in this case, more probability mass is on the quality of the risky investment being high. Furthermore, to ensure that there exists a signal $s \in (0, 1)$ for which the expected returns of the risky and the safe investments are the same, we assume that for $s = 1$ the risky asset's expected return is higher than the safe asset's expected return and vice versa for $s = 0$.

The manager then decides between the risky and riskless asset based on her private observation of s at $t = 1$ and her wage contract. Since the signal about the investment quality is the manager's private information, it is not possible to write a contract contingent on the quality signal s. However, the relevant parties know the distribution of s and observe the realized investment return at $t = 2$. Therefore, the bank can offer the manager a state-contingent wage contract, but the contract cannot be made contingent on the signal about the quality of the risky investment. The state-contingent wage payments at $t = 2$ are denoted as follows. In the case where the manager chooses the risky investment and it is successful, the wage payment is denoted by S_H, and the payment if the risky investment fails is S_F. Furthermore, the payment in the case where the manager decides to invest in the safe asset is denoted by S_L. Finally,

[5]This assumption can be motivated with the findings of Demirgüç-Kunt and Huizinga (2013), who provide empirical evidence that banks can become "too-big-to-save". In particular, the authors show that a country's public finances impose limits on the generosity of the financial safety net and that these limits are reflected in bank valuation and CDS spreads.

any payment at $t = 0$ is denoted by S_0.

We start by determining the socially efficient investment decision, which we then use as a reference point for our analysis. From a social welfare perspective, it is efficient to always invest in the risky asset when, after having received the signal about the asset's quality, its expected return is higher than the safe asset's return. Therefore, we must determine the range of the signal s about the investment quality for which the risky investment has a higher expected return than the safe investment and should hence be selected over the safe investment opportunity. Thus, it is socially efficient to invest in the risky investment opportunity when $s \geq s_{se}$ and to reject it if $s < s_{se}$, where s_{se} is the investment quality at which the two investments have the same expected return:

$$\int \pi(q|s_{se}) q R_H dq = R_L, \tag{2}$$

which, by using Eq. (1), can also be written as

$$\int \pi(q) f_q(s_{se}) \left[q R_H - R_L \right] dq = 0. \tag{3}$$

As in John and John (1993), we define an investment policy of investing in the risky investment opportunity for all $s \geq \widetilde{s}$ as investment policy $\widetilde{s}$. As expected, the range of the signal s for which it is optimal to choose the risky investment increases with the high return of the risky asset R_H and decreases with the return of the safe asset R_L. This yields the following lemma.

Lemma 1 *The critical threshold s_{se} depends positively on the return of the safe asset R_L and negatively on the high return of the risky asset R_H.*

Proof. Proof See the Appendix. ■With the socially efficient investment policy s_{se}, the expected return from the two investment opportunities at $t = 0$ is:

$$\begin{aligned} V_{se} &= \int \pi(q) \int_{s_{se}}^{1} f_q(s) q R_H ds dq + \int \pi(q) \int_{0}^{s_{se}} f_q(s) R_L ds dq - k(1+r) \\ &= \int \pi(q) \left(1 - F_q(s_{se})\right) q R_H dq + \int \pi(q) F_q(s_{se}) R_L dq - k(1+r). \end{aligned} \tag{4}$$

The first term of Eq. (4) consists of the probability that the risky investment is chosen at $t = 1$, which is the case if $s \geq s_{se}$, multiplied by the expected cash flow for the risky investment. The second term is the probability that the safe investment is chosen times the safe asset's cash flow. The last term represents the opportunity cost of capital.

4 Capital structure and investment decisions without regulation

In this section, we characterize the optimal capital structure and investment choices for the case where the government does not introduce any regulation. We solve the shareholders' optimization problem using backward induction. That is, we first determine the manager's optimal investment policy at $t = 1$ and then solve for the optimal wage contract at $t = 0$. Regarding the investment decision at $t = 1$, the manager optimally invests in the risky investment opportunity whenever $s \geq s_m$, where the cut-off investment policy s_m solves

$$\int \pi(q|s_m)\,[qS_H + (1-q)S_F]\,dq = S_L. \tag{5}$$

The left-hand side of Eq. (5) represents the expected wage payment in the case where the manager chooses the risky investment, and the right-hand side is the remuneration for the case where the safe investment is chosen. Using Eq. (1), Eq. (5) can be rearranged to

$$\int \pi(q)f_q(s_m)\,[qS_H + (1-q)S_F - S_L]\,dq = 0. \tag{6}$$

Using the same argument as in the proof of Lemma 1, we can infer from Eq. (6) that the investment policy s_m decreases with S_H and S_F and increases with S_L. Naturally, if the remuneration in states where the risky (safe) assets was chosen is increased, the investment policy becomes riskier (safer) because it is more likely that the manager will choose the risky (safe) investment opportunity.

Next, we have to determine the wage contract that maximizes the shareholders' expected return on equity at $t = 0$, which, after incorporating the manager's wage and her investment policy, becomes

$$\begin{aligned} V_e &= \int \pi(q)\,(1 - F_q(s_m))\,q\,[R_H - D - S_H]\,dq \\ &+ \int \pi(q)F_q(s_m)\,[R_L - D - S_L]\,dq - e(1+r) - S_0. \end{aligned} \tag{7}$$

The first term represents the cash flow in the case where the risky investment was chosen and is successful. The second term represents the cash flow for the case where the manager invests in the safe asset, and the third term is the opportunity cost of equity.

The manager is free to accept or reject the wage contract offered by the bank. Therefore, to attract a manager, the bank must promise the manager an expected payment equal to or above her reservation value $\underline{V}_m$. We assume that $V_{se} > \underline{V}_m > 0$, such that it is always possible for the bank to hire a manager.

The participation constraint of the manager thus becomes

$$\int \pi(q)\left(1-F_q(s_m)\right)\left[qS_H+(1-q)S_F\right]dq+\int \pi(q)F_q(s_m)S_L dq+S_0\geq \underline{V}_m. \tag{8}$$

Furthermore, to attract debt from creditors, their participation constraint must be satisfied:

$$\int \pi(q)\left(1-F_q(s_m)\right)\left[qD+(1-q)I_D\beta D\right]dq+\int \pi(q)F_q(s_m)D dq\geq d(1+r). \tag{9}$$

Again, the first term is the value of the debt claim in the case where the risky investment was chosen, successfully or not. If the risky investment fails and the bank's liabilities are below or equal to $\overline{D}$, the government bails out the bank and repays the creditors with probability β. The second term states the creditors' claims for the case where the manager invests in the safe asset. Solving Eq. (9) for r_d yields

$$r_d=\frac{(1+r)}{\int \pi(q)\left(1-F_q(s_m)\right)\left[q+(1-q)I_D\beta\right]dq+\int \pi(q)F_q(s_m)dq}-1>r, \tag{10}$$

as $D=d(1+r_d)$. Because the denominator on the right-hand side is smaller than one, it directly follows that $r_d>r$. Eq. (10) implies that the creditors' interest rate r_d decreases with the repayment probability (which is in the denominator) and the bank's bailout probability β. Constraint (9) needs to be binding in the optimum since the shareholders have the bargaining power and they could otherwise extract more profits by lowering the interest rate r_d. Plugging the binding constraints from Eq. (8) and Eq. (9) into Eq. (7) yields for the shareholders' expected return on equity at $t=0$, after rearranging,

$$\begin{aligned} V_e=&\int \pi(q)\left(1-F_q(s_m)\right)\left[qR_H+(1-q)I_D\beta D\right]dq \\ &+\int \pi(q)F_q(s_m)R_L dq-k(1+r)-\underline{V}_m. \end{aligned} \tag{11}$$

Since the shareholders are the residual claimants, they maximize their expected return by maximizing the sum of the expected investment returns and the value of the implicit government bailout guarantee. This also directly follows from the expression in Eq. (11). As shown by Eq. (6), when optimizing the compensation structure at $t=0$, the shareholders have to take into account that the compensation scheme influences the investment policy at $t=1$ and, in turn, their expected return on equity. It is straightforward to show that the shareholders can maximize their expected return on equity by aligning the manager's incentives with their own incentives, that is, by paying the manager a stake α^* of their expected investment returns. This yields the following proposition.

Proposition 2 *Without regulation, the bank shareholders can maximize their expected return by offering* *the manager the compensation scheme* $W^* = [S_H^*, S_F^*, S_L^*, S_0^*]$ *with*

$$S_H^* = \alpha^*(R_H - I_D\beta D),\ S_F^* = 0,\ S_L^* = \alpha^*(R_L - I_D\beta D),\ S_0^* = -\alpha^*\left(k(1+r) - I_D\beta D\right), \tag{12}$$

where α^* *is given by*

$$\alpha^* = \frac{\underline{V}_m}{V_e^* + \underline{V}_m}, \tag{13}$$

With the compensation scheme W^**, the manager's expected compensation becomes* $V_m^* = \alpha^*(V_e^* + \underline{V}_m)$ *and she chooses* $D^* = \overline{D}$*. Moreover, the contract implements the shareholders' optimal investment policy at* $t = 1$*,* s^**, which is given by*

$$\int \pi(q) f_q(s^*) \left[qR_H + (1-q)\beta\overline{D} - R_L\right] dq = 0. \tag{14}$$

Hence, the compensation scheme W^* *maximizes the shareholders' expected return on equity to*

$$V_e^* \;=\; \int \pi(q)\left(1 - F_q(s^*)\right)\left[qR_H + (1-q)\beta\overline{D}\right] dq + \int \pi(q) F_q(s^*) R_L dq - k(1+r) - \underline{V}_m. \tag{15}$$

Proof. Proof See the Appendix. ■Hence, without any regulation, the bank shareholders offer the manager a stake α^* of their expected investment returns, and thus, the manager's remuneration is performance-based. With this compensation scheme, the manager implements the investment policy s^*. By comparing Eq. (3) and Eq. (14) and because $\pi(q|s)$ satisfies the MLRP, it immediately follows that $s^* < s_{se}$. Therefore, the shareholders incentivize the manager to choose a riskier investment policy than the socially efficient one. Furthermore, it follows that the threshold s^* decreases with the face value of debt, and thus, the investment policy becomes riskier if the leverage increases (due to the same argument as in the proof of Lemma 1). This behavior can be explained by the classical risk-shifting problem. Due to public bailout guarantees, the creditors do not demand an interest rate that fully reflects the risk of their investment. Hence, by choosing a riskier investment policy than the socially efficient one, the shareholders can increase their expected return on equity to the detriment of society. Therefore, as expected, the shareholders simply pass on their risk-shifting incentives to the bank management.

5 Incentive-based capital requirements

In this section, we show that incentive-based capital requirements are able to avert the risk-shifting problem and thus are able to implement the socially efficient investment policy. The proposed regulation stipulates that the bank can decrease its minimum capital requirement by adding a fixed wage payment

S to the manager's compensation in all success states in addition to the performance-based stake α that the bank offers the manager in the case without regulation (i.e., adding S to S_H and S_L).

In the following, we first analyze the manager's behavior in the case where the bank decides to add the payment S to the manager's wage scheme. In a second step, we then show that the socially efficient investment policy can be implemented with a capital requirement that is contingent on the composition of the compensation. We solve the manager's optimization problem by backward induction, given the compensation scheme (α, S) in place. At $t = 1$, the manager decides to invest in the risky investment opportunity whenever the success probability s is greater than or equal to s_m, where s_m solves

$$\int \pi(q|s_m)q\left[S + \alpha(R_H - I_D\beta D)\right]dq = S + \alpha(R_L - I_D\beta D). \tag{16}$$

The left-hand side of the equation represents the expected wage payment in the case where the manager chooses the risky investment, and the right-hand side is the remuneration in the case where the safe investment is chosen. Using Eq. (1), Eq. (16) can be rearranged to

$$\int \pi(q)f_q(s_m)\left[q\alpha R_H + (1-q)\alpha I_D\beta D - \alpha R_L - (1-q)S\right]dq = 0. \tag{17}$$

As shown in Eq. (17), the investment decision at $t = 1$ is influenced by the capital structure decision at $t = 0$ and by the compensation structure (α, S). In particular, by using the same argument as in the proof of Lemma 1, Eq. (17) shows that an increase in S leads to an increase in s_m, whereas an increase in the performance-based wage component α leads to a decrease in s_m. Therefore, a higher performance-based remuneration (i.e., higher α) incentivizes the manager to choose a riskier investment policy, and raising S reduces the manager's risk-taking incentives so that the manager chooses a less risky investment policy. Furthermore, the threshold s_m decreases with the face value of debt, and thus, the investment policy becomes riskier if the leverage increases.

Based on this mechanism, the underlying idea behind the new regulatory approach proposed in this paper is that the manager's compensation scheme can be used by the regulator to counteract the risk-shifting incentives caused by government guarantees. In particular, the more the compensation structure decouples bank managers' interests from those of shareholders by curbing risk-taking incentives (i.e., the higher S relative to α), the higher the leverage a bank is permitted to take on.

Next, we show that by making capital requirements contingent on the pay structure, the socially efficient investment policy can be implemented. To implement this investment policy, the regulator has to ensure that the manager's investment policy in Eq. (17) equals the socially efficient policy from Eq.

(3). A comparison of Eq. (17) and Eq. (3) shows that the regulatory requirement

$$D \leq D^r = \frac{S}{\alpha\beta} \;\Leftrightarrow\; e \geq e^r = k - \frac{S}{\alpha\beta(1+r_d)}. \tag{18}$$

ensures that the bank's investment policy can never be riskier than the socially efficient investment policy. Note that the right-hand expression (i.e., the incentive-based equity requirements) follows from the left-hand expression due to $k = e + d$. If this regulation binds (i.e., $D = D^r$), the manager's investment policy and the socially efficient investment policy coincide. From Condition (18), it follows that the compulsory level of equity decreases with the fixed wage S and increases with the performance-based component α and the bailout probability β.

In the following, we show that the bank will always set the wage structure such that the incentive-based capital requirements bind, implying that the regulation always implements the socially efficient investment policy s_{se}. With the proposed regulation, the manager's expected wage becomes

$$\begin{aligned} V_m &= \int \pi(q)\,(1-F_q(s_m))q\,[S+\alpha(R_H - I_D\beta D)]\,dq \\ &+ \int \pi(q)F_q(s_m)\,[S+\alpha(R_L - I_D\beta D)]\,dq - \alpha\,(k(1+r) - I_D\beta D)\,. \\ &= \int \pi(q)\,(1-F_q(s_m))\,[qS+\alpha(qR_H + (1-q)I_D\beta D)]\,dq \\ &+ \int \pi(q)F_q(s_m)\,[S+\alpha R_L]\,dq - \alpha k(1+r). \end{aligned} \tag{19}$$

Taking the derivative of V_m with respect to D yields

$$\begin{aligned} \frac{\partial V_m}{\partial D}(D \leq \overline{D}) &= \int \pi(q)\,(1-F_q(s_m))\,(1-q)\alpha\beta dq \\ &- \int \pi(q)f_q(s_m)\alpha\,[q\alpha R_H + (1-q)\alpha\beta D - \alpha R_L - (1-q)S]\,dq \cdot \frac{\partial s_m}{\partial D} > 0 \qquad (20) \\ \frac{\partial V_m}{\partial D}(D > \overline{D}) &= 0. \qquad (21) \end{aligned}$$

Hence, because $V_m(D = \overline{D}) > V_m(D > \overline{D})$, the manager always chooses $D^* = \min\{\overline{D}, D^r\}$. At $t = 0$, the bank shareholders choose the compensation structure (α, S) that maximizes their expected return on equity. With the proposed regulation and the manager's capital structure choice (i.e., $D^* = \min\{\overline{D}, D^r\}$), the shareholders' expected return on equity becomes[6]

$$\begin{aligned} V_e = &\int \pi(q)\,(1-F_q(s_m))\,\left[qR_H + (1-q)\beta\min\{\overline{D}, D^r\}\right]\,dq \\ + &\int \pi(q)F_q(s_m)R_L dq - k(1+r) - \underline{V}_m. \end{aligned} \tag{22}$$

[6]In this expression, we have also already incorporated the manager's and the creditor's binding participation constraints.

It is straightforward to show that it cannot be optimal to set the compensation scheme such that $D^r = S/(\alpha\beta) > \overline{D}$ because this does not increase the value of the implicit bailout guarantee but incentivizes the manager to implement a too conservative investment policy, that is, $s_m > s_{se}$.[7]

Hence, the optimal wage scheme always requires $D^r = S/(\alpha\beta) \leq \overline{D}$, in which case the manager chooses $D^* = D^r = S/(\alpha\beta)$, implying that the regulatory requirement from Eq. (18) is binding. Plugging the binding constraint from Eq. (18) into Eq. (17) shows that, with this regulatory requirement, the investment policy of the manager at $t = 0$ indeed coincides with the socially efficient investment policy:

$$\int \pi(q) f_q(s_m)\alpha \left[qR_H - R_L\right] dq = 0 \Rightarrow s_m = s_{se}. \tag{23}$$

These findings yield the following proposition.

Proposition 3 *The implementation of the incentive-based capital requirements from Eq. (18) induces the manager to choose the socially efficient investment policy.*

Proof. Proof See the Appendix. ■With the incentive-based capital requirements in place, the bank can alter the permitted leverage level (and, conversely, the minimum equity stake) by setting the compensation components accordingly. Hence, this regulatory approach allows all kinds of business models. The economic intuition is as follows. Banks that pay their manager very conservatively (i.e., relatively high S and relatively low α) and that have a relatively low bailout probability can choose a higher leverage (i.e., higher amount of insured debt). On the other hand, banks that implement very steep incentives (i.e., relatively low S and relatively high α) and that have a relatively high bailout probability can only choose a rather low leverage. Therefore, even in the extreme case where banks choose $S = 0$, the bank can still invest in risky projects. However, with $S = 0$, it has to be purely equity financed, which would correspond to the approach proposed by Cochrane (2014).

This result is quite intuitive. Implementing a conservative compensation structure (low risk on the managerial side) enables a (potentially) riskier capital structure because the risk-shifting incentives induced by government guarantees and high leverage are offset by a remuneration structure that mitigates risk-taking incentives. On the other hand, in the case where the bank implements a compensation structure that provides incentives for risky investment behavior, the bank is forced to choose a low-risk capital structure. However, for the proposed approach to be effective, the regulator must be able to gather information about the manager's compensation structure, which, of course, implies certain transparency requirements. We discuss these transparency requirements in more detail in Section 6.

A special feature of the proposed incentive-based capital requirements is that the regulator does not need to be able to measure the bank's investment risk to implement the socially efficient investment policy.

[7]See the proof of Proposition 2.

Instead, the approach utilizes information about the manager's incentives to draw conclusions about bank risk and adjust the capital requirements accordingly. Consequently, compared to traditional approaches such as risk-weighted capital requirements, the need to monitor the adequacy of risk assessments for the assets of banks is greatly reduced. Incentive-based capital requirements have this feature because they are a state-contingent regulation; that is, they are able to ex-post state-wise offset the benefits from the government insurance subsidy. This is in contrast to traditional regulatory approaches, which are not contingent on the investment outcome and thus rely on determining the investment policy of the bank ex-ante to adjust the regulatory requirement accordingly (e.g., risk-weighted capital requirements and deposit insurance premiums). However, as discussed in Section 6, determining the investment policy ex-ante requires detailed information about the bank's investment opportunities.

Next, we characterize the optimal manager compensation scheme from the bank shareholders' perspective, given that the incentive-based capital requirements are in place. As shown by Eq. (22), for all $D^r < \overline{D}$, V_e can be increased by raising S and lowering α (such that the manager's participation constraint is still binding), which increases D^r until either the constraint (i) $D^r \leq \overline{D}$ or (ii) $S \leq R_L - D^r$ becomes binding. The first constraint is because $D^r > \overline{D}$ cannot be optimal (see the proof of Proposition 2), while the second constraint states that the bank has to choose the fixed wage S low enough such that it is able to pay the manager the amount S when she chooses the safe asset. This yields the following lemma.

Lemma 4 *If constraint (i) is tighter than (ii), the shareholders implement the compensation scheme*

$$\alpha_1^* = \frac{\underline{V}_m}{V_{se} + \beta\overline{D}}, \; S_1^* = \frac{\underline{V}_m \beta \overline{D}}{V_{se} + \beta\overline{D}}, \tag{24}$$

such that the $D^r = \overline{D}$*; if constraint (ii) is tighter, they implement*

$$\alpha_2^* = \frac{\underline{V}_m}{V_{se} + \beta\frac{R_L}{\alpha_2^* + \frac{1}{\beta}}}, \; S_2^* = \frac{R_L}{1 + \frac{1}{\alpha_2^* \beta}}. \tag{25}$$

In this case, it holds that $D^r < \overline{D}$.

Proof. Proof See the Appendix. ■

6 Discussion and policy implications

To successfully avoid risk-shifting behavior caused by government guarantees, a regulatory measure has to meet at least three requirements: (i) effectiveness; it must be able to implement the socially efficient investment policy, (ii) transparency; the regulator must be able to observe all factors necessary to determine the appropriate bank-specific regulatory requirement, and (iii) flexibility; the regulatory approach must be flexible with regard to changes in these factors. In this section, we first analyze whether the proposed regulation meets these requirements and then discuss implementation-related issues.

6.1 Effectiveness

Given that the regulator is unable to observe the management's private information about the investment opportunities, he has two options to avoid risk-shifting: (i) try to directly impose the socially efficient incentives or (ii) introduce regulatory benefits/costs to reduce the risk-shifting incentives.

An example for directly implementing the socially efficient incentives is banning insured debt altogether. However, as discussed in the online appendix, this incurs the risk of bank runs and/or interbank contagion. Furthermore, the regulator could simply impose a compensation scheme that induces the efficient investment incentives. In this case, the regulator must first determine the socially efficient investment policy, for which he needs to know investment-related details, that is, R_H and R_L (please see the online appendix for a detailed analysis).

An example for mitigating the risk-shifting incentives by introducing regulatory benefits/costs is the implementation of an insurance premium (e.g., deposit insurance premium, systemic risk tax). As shown in the online appendix, this option also requires that the regulator be able to quantify investment-specific parameters (that is, R_H and R_L) because with an insurance fee, the regulator must impose regulatory costs on the bank ex-ante at $t = 0$. Therefore, the insurance fee has to be adjusted ex-ante such that it exactly offsets the bank's benefits from the government insurance subsidy ex-post. However, the value of the insurance subsidy depends on the bank's investment policy, which, in turn, depends on investment specific parameters.

In contrast, the proposed incentive-based capital requirements have an ex-post effect on the management's investment incentives through the wage payment, which is state-contingent. In particular, the proposed regulation creates an ex-post "cost" for the manager in the event that the bank defaults because the manager receives her wage payment S only if the bank is successful. This creates an incentive to act prudently. Since the compensation is state-contingent, the regulator is able to adjust the incentive-based capital requirements such that the risk-taking incentives caused by the insurance subsidy are exactly offset. Therefore, compared to approaches that impose the regulatory benefits/costs ex-ante, the regulator does not need to predict the investment policy ex-ante and hence does not need to know investment-specific information. Instead, the regulator must be able to observe the banks' pay scheme.

6.2 Transparency

To successfully implement the proposed incentive-based capital requirements, the regulator must ensure transparency with regard to the compensation policies. Otherwise, secret arrangements could be made between the bank and the management to circumvent the regulation. According to O'Donnell and Rodda (2015), performance-based compensation in large U.S. banks consists of long-term incentives (e.g., shares and options), which make up 63% of the top management's total pay, and annual incentives (e.g., cash bonuses), which make up 22% of total compensation.

The incentives created by existing share and option holdings are easily observable and thus transparent. The incentives created by a CEO's annual pay can be determined by the regulator if its level is mainly based on a transparent formulaic approach. O'Donnell and Rodda (2015) report that 50% of banks use a formulaic approach to determine the annual performance-based payment, while 40% use a combination of formula and discretion, and only 10% of banks use a fully discretionary approach. Since 90% of banks are using a formulaic approach anyway, it does not seem overly restrictive to introduce a regulation requiring all banks to base a high fraction of the performance-based compensation on a transparent formulaic approach. This transparency requirement would allow regulators to appropriately adjust the incentive-based capital requirements. Arguably, there can also be a discretionary component, as long as the compensation arising from the formulaic approach dominates.

In response to the 2008-2009 financial crisis, regulators around the world are pushing for exactly these types of transparency requirements with regard to the compensation arrangements for bank managers. These efforts are highly complementary to the proposed incentive-based capital requirements. According to the "Principles for Sound Compensation Practices" published by the Financial Stability Board (FSB), banks should be required to disclose the process used to determine the bank's compensation policy, the criteria used for performance and risk measurement, the pay-performance link, and the parameters used to allocate cash versus other forms of compensation. Many financial services regulators have taken steps to implement regulations based on the FSB Principles. For example, the U.S. passed the Dodd Frank Act, and the European Union introduced the "Compensation Capital Requirements Directive" (CRD)[8], which are both largely consistent with the principles proposed by the FSB. Similar regulatory requirements were also introduced in the main financial centers in Asia.[9]

Furthermore, the regulator has to ensure that the management compensation is appropriately adjusted for the actual investment outcome, which takes some time to become apparent. One way to

[8]The CRD disclosure regulations go even beyond the FSB principles. They include the metrics used for performance assessment and risk adjustments, a description of the different forms in which variable and fixed remuneration is paid (cash, equity, etc.), the respective amounts, and the categorization of the components as variable versus fixed remuneration.

[9]Recently, Singapore introduced the "Code of Corporate Governance", Hong Kong introduced "The Hong Kong Stock Exchange Rules and Guidance on Listing Matters", Japan recently revised "The Japan Cabinet Office Ordinance on Disclosure of Corporate Affairs", and South Korea introduced "The Financial Investment Services and Capital Markets Act". All these regulations significantly increased the disclosure requirements for compensation policies.

address this problem is to ensure that a portion of the managers' pay is deferred. For example, the CRD requires that at least 40 to 60% of variable remuneration be deferred with a minimum deferral period of three to five years. The Prudential Regulation Authority and the Financial Conduct Authority introduced similar rules on remuneration in the U.K. in January 2016.

6.3 Flexibility

To always maintain a balance between risk-shifting and risk-reducing incentives, incentive-based capital requirements have to be adjusted as soon as the compensation structure changes and, in turn, the risk-taking incentives change. The proposed regulation meets this requirement, as compensation structures are altered infrequently[10], changes in the compensation scheme are readily identified, and the incentive-based capital requirements can easily be changed.

6.4 Scope and implementation

Since the cause of the risk-shifting problem is access to public guaranteed debt, the proposed regulatory approach needs to be applied only to the subset of deposit-taking banks, as well as financial institutions that are considered systemically important. The other institutions do not need to be subject to regulation. Furthermore, linking only the top management's compensation and not the remuneration of lower-level management to the requirements seems to be sufficient. Since the board of directors, especially the CEO, is responsible for setting the compensation structure and incentives of all other bank employees as well as monitoring them, it seems likely that top management will pass on its incentives to its subordinates by either implementing the right compensation schemes and/or closely monitoring the employees (see also Ang, Lauterbach, and Schreiber (2002) for more details).

The new regulatory approach effectively eliminates the risk-shifting problem created by government guarantees. However, banks could be run with very high leverage in cases where an extremely low performance-based compensation component and a high fixed component S is chosen. Then, when the risk management of the bank fails, a default of the bank becomes very likely, as the bank might not have an adequate equity cushion to absorb such an error. Therefore, in addition to the incentive-based capital requirements, a safeguard is needed to preclude excessive leverage levels. As described in the introduction, a suitable regulatory response to this problem is the imposition of non-risk-weighted capital requirements (see, for example, Admati, Allen, Brealey, Brennan, Boot, Brunnermeier, Cochrane, De Marzo, Fama, Fishman, et al., 2010; Cochrane, 2014; Admati and Hellwig, 2014), usually referred to as a leverage ratio, as a complement to the proposed approach. Hence, banks would have to meet two independent measures

[10]Requirements such as the so-called "say-on-pay" rules prohibit frequent changes to the wage scheme. These rules require a shareholder vote to approve the remuneration packages of executives. Because banks' general meetings are often held only annually, the wage scheme can not be altered that frequently with such requirements in place.

of capital adequacy: incentive-based capital requirements to mitigate the risk-shifting problem and the fixed leverage ratio to prohibit the bank from becoming too highly leveraged.

7 Conclusion

Without regulatory interference, bank shareholders have an incentive to take on excessive risks due to public guarantees that are granted to bank depositors and creditors. Therefore, without regulation, shareholders design the compensation contracts of the top management such that the managers' incentives are aligned with their own risk-taking incentives. Hence, the recently discussed say-on-pay requirements for banks are at best ineffective and at worst counterproductive.

The traditional approaches to mitigate this risk-shifting problem, such as risk-adjusted capital requirements, rely on determining the riskiness of bank assets and thus require detailed knowledge of the banks' asset portfolios as well as an extremely sophisticated understanding of risk modeling. The difficulty of making this risk assessment was highlighted during the 2008–2009 financial crisis.

This paper shows that the fit between bank risk and capital regulation can be improved by taking into account the banks' compensation structures. We argue that the incentive features of the managerial compensation scheme provide valuable information about shareholder objectives, which can help the regulator reduce the information disadvantages vis-a-vis bank managers. In particular, the proposed regulatory approach stipulates that the more the compensation structure decouples bank managers' interests from those of shareholders by curbing risk-taking incentives, the higher the leverage the bank is permitted to take on. Implementing incentive-based capital requirements can thus curtail bank incentives for risk-shifting and, in turn, lead to welfare improvements.

Appendix

Proof of Lemma 1

Eq. (2) can be simplified to

$$E(q|s_{se}) = \frac{R_L}{R_H}. \tag{26}$$

Since $\pi(q|s)$ satisfies the MLRP, $E(q|s_{se})$ increases with s_{se}. Therefore, if the right-hand side of the Eq. (26) increases, s_{se} has to be increased to balance the equation and vice versa. ■

Proof of Proposition 1

An optimal wage contract maximizes the shareholder's expected return on equity given in Eq. (11). First, we determine the optimal investment policy and the optimal amount of debt. In a second step, we then show that the wage contract W^* from Eq. (12) implements these optimal choices. We start by showing that for any given level of debt liabilities, the optimal investment policy for the shareholder is given by $\widehat{s}$, which solves

$$\int \pi(q) f_q(\widehat{s}) \left[qR_H + (1-q)I_D\beta D - R_L\right] dq = 0. \tag{27}$$

We prove this conjecture by contradiction and assume that some different investment policy $\widetilde{s} \neq \widehat{s}$ is optimal. We then show that this choice is always dominated by $\widehat{s}$. First, we consider the case where $\widetilde{s} < \widehat{s}$ and, second, the case where $\widetilde{s} > \widehat{s}$. Therefore, we have to compare the expected return on equity at $t = 0$ under the two regimes, that is, compare $\widetilde{V}_e$ and $\widehat{V}_e$. When implementing $\widetilde{s} < \widehat{s}$, the expected return on equity becomes

$$\begin{aligned} \widetilde{V}_e &= \int \pi(q) \left(1 - F_q(\widetilde{s})\right) \left[qR_H + (1-q)I_D\beta D\right] dq + \int \pi(q) F_q(\widetilde{s}) R_L dq - k(1+r) - \underline{V}_m \\ &= \int \pi(q) \int_{\widetilde{s}}^1 f_q(s) \left[qR_H + (1-q)I_D\beta D\right] ds dq + \int \pi(q) \int_0^{\widetilde{s}} f_q(s) R_L ds dq - k(1+r) - \underline{V}_m. \end{aligned} \tag{28}$$

When implementing $\widehat{s}$ from Eq. (27), the expected return on equity is

$$\begin{aligned} \widehat{V}_e &= \int \pi(q) \left(1 - F_q(\widehat{s})\right) \left[qR_H + (1-q)I_D\beta D\right] dq + \int \pi(q) F_q(\widehat{s}) R_L dq - k(1+r) - \underline{V}_m \\ &= \int \pi(q) \int_{\widehat{s}}^1 f_q(s) \left[qR_H + (1-q)I_D\beta D\right] ds dq + \int \pi(q) \int_0^{\widehat{s}} f_q(s) R_L ds dq - k(1+r) - \underline{V}_m. \end{aligned} \tag{29}$$

By changing the integration limits, the expression from Eq. (28) can be transformed to

$$\begin{aligned}\widetilde{V}_e &= \int \pi(q) \int_{\widehat{s}}^{1} f_q(s) \left[qR_H + (1-q) I_D \beta D \right] dsdq + \int \pi(q) \int_{0}^{\widehat{s}} f_q(s) R_L dsdq \\ &+ \int \pi(q) \int_{\widetilde{s}}^{\widehat{s}} f_q(s) \left[qR_H + (1-q) I_D \beta D \right] dsdq - \int \pi(q) \int_{\widetilde{s}}^{\widehat{s}} f_q(s) R_L dsdq - k(1+r) - \underline{V}_m. \end{aligned} \tag{30}$$

Subtracting $\widehat{V}_e$ from $\widetilde{V}_e$ and simplifying yields

$$\widetilde{V}_e - \widehat{V}_e = \int \pi(q) \int_{\widetilde{s}}^{\widehat{s}} f_q(s) \left[qR_H + (1-q) I_D \beta D - R_L \right] dsdq. \tag{31}$$

Furthermore, Eq. (27) implies that

$$\int \pi(q) f_q(s) \left[qR_H + (1-q) I_D \beta D - R_L \right] dq < 0 \ \ \forall s < \widehat{s}, \tag{32}$$

and, thus, $\widetilde{V}_e - \widehat{V}_e < 0$, which contradicts the initial claim that $\widetilde{s}$ is the optimal investment policy.

Next, we consider the case where $\widetilde{s} > \widehat{s}$, and we again compare the expected returns on equity under the two regimes, $\widehat{V}_e$ and $\widetilde{V}_e$. For this case, by changing the integration limits, $\widetilde{V}_e$ can be transformed to

$$\begin{aligned}\widetilde{V}_e &= \int \pi(q) \int_{\widehat{s}}^{1} f_q(s) \left[qR_H + (1-q) I_D \beta D \right] dsdq + \int \pi(q) \int_{0}^{\widehat{s}} f_q(s) R_L dsdq \\ &- \int \pi(q) \int_{\widehat{s}}^{\widetilde{s}} f_q(s) \left[qR_H + (1-q) I_D \beta D \right] dsdq + \int \pi(q) \int_{\widehat{s}}^{\widetilde{s}} f_q(s) R_L dsdq - k(1+r) - \underline{V}_m. \end{aligned} \tag{33}$$

Subtracting $\widehat{V}_e$ from $\widetilde{V}_e$ and simplifying yields

$$\widetilde{V}_e - \widehat{V}_e = - \int \pi(q) \int_{\widehat{s}}^{\widetilde{s}} f_q(s) \left[qR_H + (1-q) I_D \beta D - R_L \right] dsdq < 0, \tag{34}$$

which is smaller than zero due to the same argument as in the case in which $\widetilde{s} < \widehat{s}$. This finding again contradicts the claim that $\widetilde{s}$ is an optimal investment policy, implying that $\widehat{s}$ is optimal.

Next, we show that the shareholders can maximize their expected return on equity by implementing $D^* = \overline{D}$. Taking the derivative of Eq. (29) with respect to D yields

$$\begin{aligned}\frac{\partial \widehat{V}_e}{\partial D}(D \leq \overline{D}) &= \int \pi(q) \left(1 - F_q(\widehat{s})\right) (1-q) \beta dq \\ &- \int \pi(q) f_q(\widehat{s}) \left[qR_H + (1-q) \beta D - R_L \right] dq \cdot \frac{\partial \widehat{s}}{\partial D} > 0 \end{aligned} \tag{35}$$

$$\frac{\partial \widehat{V}_e}{\partial D}(D > \overline{D}) = 0. \tag{36}$$

The expression in Eq. (35) is greater than zero because the second term is equal to zero (due to Eq. (27)), and the first term is positive. Furthermore, it holds that $\widehat{V}_e(D = \overline{D}) > \widehat{V}_e(D > \overline{D})$. Hence, it is optimal for the shareholders to implement $D^* = \overline{D}$. Therefore, the optimal investment policy for the shareholders is s^*, which solves

$$\int \pi(q) f_q(s^*) \left[qR_H + (1-q)\beta\overline{D} - R_L \right] dq = 0. \tag{37}$$

Finally, we have to show that the compensation scheme W^* from Eq. (12) implements the investment policy s^* from Eq. (37) and the debt level $\overline{D}$. Plugging W^* into Eq. (6) yields

$$\int \pi(q) f_q(s_m) \left[qR_H + (1-q) I_D \beta D - R_L \right] dq = 0, \tag{38}$$

for the manager's investment policy. Moreover, with the wage contract W^*, the expected pay for the manager at $t = 0$ becomes

$$\begin{aligned} V_m &= \int \pi(q) \left(1 - F_q(s_m)\right) \alpha \left[qR_H + (1-q) I_D \beta D \right] dq + \int \pi(q) F_q(s_m) \alpha R_L dq - \alpha k(1+r) \\ &= \alpha(\widehat{V}_e + \underline{V}_m). \end{aligned} \tag{39}$$

Comparing Eqs. (27) and (38) as well as Eqs. (29) and (39) shows that the manager's optimal capital structure choice and investment policy coincide with the shareholders' optimal choice. Moreover, with the wage contract W^*, the participation constraint of the manager becomes binding, which can be seen by solving the binding creditors' participation constraint (i.e., V_m from Eq. (39) has to equal $\underline{V}_m$) for α and plugging in $D^* = \overline{D}$. ■

Proof of Proposition 2

Shareholders can set the pay scheme such that $D^r = S/(\alpha\beta) \leq \overline{D}$ or $D^r = S/(\alpha\beta) > \overline{D}$. In the following, we show that the latter can never be optimal. If the wage structure is set such that $D^r > \overline{D}$, the manager chooses $D^* = \overline{D}$ (see Eqs. (20) and (21)). Hence, the shareholders' expected return on equity from Eq. (22) becomes

$$V_e = \int \pi(q) \left(1 - F_q(s_m)\right) \left[qR_H + (1-q)\beta\overline{D} \right] dq + \int \pi(q) F_q(s_m) R_L dq - k(1+r) - \underline{V}_m. \tag{40}$$

Moreover, the manager's investment policy from Eq. (17) is now given by

$$\int \pi(q) f_q(s_m) \left[q\alpha R_H + (1-q)\alpha\beta\overline{D} - \alpha R_L - (1-q)S \right] dq = 0. \tag{41}$$

Furthermore, $D^r = S/(\alpha\beta) > \overline{D}$ requires that $S > \alpha\beta\overline{D}$, which implies that $s_m > s_{se}$ due to Eq. (41). As shown in the proof of Proposition 1, the investment policy $s^* < s_{se}$ maximizes Eq. (40). Therefore, due to the MLRP of $f_q(s)$, the shareholders can increase their expected return on equity by lowering S and increasing α (such that the manager's participation constraint is still binding), thereby lowering s_m (see Eq. (41)). This increases V_e as long as $S > \alpha\beta\overline{D}$. Hence, setting the compensation scheme such that $D^r = S/(\alpha\beta) > \overline{D}$ cannot be optimal, implying that the shareholders always implement a wage structure such that $D^r = S/(\alpha\beta) \leq \overline{D}$.

If $D^r \leq \overline{D}$, the manager chooses $D^* = D^r$ (see again Eqs. (20) and (21)), implying that the incentive-based capital requirements from Eq. (18) bind. Inserting $D^* = D^r = S/(\alpha\beta)$ into Eq. (17) and comparing it to Eq. (3) shows that with the regulation from Eq. (18), it holds that $s_m = s_{se}$. ■

Proof of Lemma 2

For $D^r \leq \overline{D}$, the manager chooses $D^* = D^r$ (see Eqs. (20) and (21)), and her participation constraint becomes

$$\begin{aligned} V_m &= \int \pi(q)\left(1 - F_q(s_m)\right)\left[qS + q\alpha R_H + (1-q)\alpha\beta\frac{S}{\alpha\beta}\right]dq + \int \pi(q)F_q(s_m)\left[S + \alpha R_L\right]dq - \alpha k(1+r) \\ &= \alpha V_{se} + S \geq \underline{V}_m. \end{aligned} \tag{42}$$

Solving the manager's binding participation constraint from Eq. (42) for S yields

$$S = \underline{V}_m - \alpha V_{se} \tag{43}$$

Using $D^r = S/(\alpha\beta)$ and plugging this expression into the shareholders' expected return on equity from Eq. (22) yields

$$\begin{aligned} V_e = &\int \pi(q)\left(1 - F_q(s_m)\right)\left[qR_H + (1-q)\left(\frac{\underline{V}_m}{\alpha} - V_{se}\right)\right]dq \\ &+ \int \pi(q)F_q(s_m)R_L dq - k(1+r) - \underline{V}_m. \end{aligned} \tag{44}$$

Furthermore, with $D^* = D^r = S/(\alpha\beta)$, the manager's investment policy becomes $s_m = s_{se}$ (see proof of Proposition 2). Because $\partial V_e/\partial\alpha < 0$, the shareholders have an incentive to decrease α until either constraint (i) $D^r \leq \overline{D}$ or (ii) $S \leq R_L - D^r$ becomes binding. If constraint (i) becomes binding first, it holds that $\overline{D} = D^r = S/(\alpha\beta)$ and, hence,

$$\alpha_1^* = \frac{\underline{V}_m}{V_{se} + \beta\overline{D}}. \tag{45}$$

The corresponding optimal level for S follows from Eq. (43):

$$S_1^* = \frac{\underline{V}_m \beta \overline{D}}{V_{se} + \beta \overline{D}}. \tag{46}$$

Therefore, if constraint (i) becomes binding first, the optimal compensation structure from the bank shareholders' perspective is given by (α_1^*, S_1^*). From Eq. (45) and Eq. (46), it follows that in this case the optimal performance-based component and the fixed wage increase with the manager's reservation value $\underline{V}_m$; as the reservation value increases, the total expected wage payment has to be increased to satisfy the manager's participation constraint. Furthermore, α_1^* and S_1^* decrease with the expected socially efficient investment return V_{se} because in this case, the manager's participation constraint becomes slack; thus, the total expected wage payment can be reduced. Finally, as expected, α_1^* decreases and S_1^* increases with the bailout limit $\overline{D}$ and the bailout probability β.

If constraint (ii) becomes binding first, the optimal fixed wage becomes

$$S_2^* = R_L - D^r = R_L - \frac{S_2^*}{\alpha\beta} \Rightarrow S_2^* = \frac{R_L}{1 + \frac{1}{\alpha\beta}}. \tag{47}$$

The corresponding optimal α_2^* follows from plugging S_2^* and $D = S/(\alpha\beta)$ into Eq. (43) and solving for α. Therefore, α_2^* is implicitly given by

$$\alpha_2^* = \frac{\underline{V}_m}{V_{se} + \beta \frac{R_L}{\alpha_2^* + \frac{1}{\beta}}}. \tag{48}$$

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8 Online Appendix

8.1 Robustness and Extensions

In the following, we consider two extensions to our model and determine the implications for the proposed regulation. First, we analyze the case where the manager needs to be incentivized to exert effort. Second, we relax the assumption that the opportunity costs of equity and debt are the same.

8.1.1 Effort

To determine the implications for the proposed incentive-based capital requirements in the case where the manager needs to be incentivized to exert a certain effort level, we assume that the manager has two possible effort levels, $\eta \in \{0, 1\}$, and incurs the private effort costs $c(\eta) = \tau\eta$. If the manager decides to exert the high effort level ($\eta = 1$) at $t = 0$, the risky investment yields the high outcome R_H in the success state, while it only yields the low outcome R_L in the success state if the manager chooses the low effort level ($\eta = 0$) at $t = 0$. Furthermore, we assume that

$$\int \pi(q)\,(1 - F_q(s_{se}))q\,[R_H - R_L]\,dq > \tau, \tag{49}$$

such that it is always socially efficient if the manager exerts the high effort level at $t = 0$. Consequently, the shareholders have to ensure that the manager benefits sufficiently from a potentially higher return in the success state such that she has the incentive to exert the high effort level. With the proposed regulation in place, the incentive compatibility constraint of the manager becomes

$$\int \pi(q)\,(1 - F_q(s_{se}))q\alpha R_H dq + \int \pi(q)F_q(s_{se})\alpha R_L dq - \tau \geq \alpha R_L, \tag{50}$$

where we have already incorporated the fact that the regulation will implement the socially efficient investment policy. Note that if the manager chooses the low effort level at $t = 0$, investing in the safe investment always dominates investing in the risky investment at $t = 1$. Isolating α in Condition (50) yields

$$\alpha \geq \frac{\tau}{\int \pi(q)\,(1 - F_q(s_{se}))\,[qR_H - R_L]\,dq}. \tag{51}$$

Therefore, if α is high enough that Condition (51) holds, the manager is sufficiently incentivized to exert the high effort level. Hence, in the case where the manager needs to be incentivized to exert a certain effort level, it is still possible to implement the socially efficient investment policy by introducing the proposed incentive-based capital requirements. However, there will be an additional lower bound on the performance-based wage component α in addition to the previously determined constraints (i) $D^r \leq \overline{D}$ and (ii) $S \leq R_L - D^r$ from Section 5. Hence, if Condition (51) is the tightest of the three constraints, the optimal performance-based component becomes

$$\alpha_3^* = \frac{\tau}{\int \pi(q)\,(1 - F_q(s_{se}))\,[qR_H - R_L]\,dq}. \tag{52}$$

Note that it is in the shareholders' own interest not to lower the performance-based wage component α below the threshold α_3^*. Lowering α below α_3^* would not only worsen the outcome from a social welfare perspective but also lower the shareholders' expected return on equity. Hence, no regulatory adjustment of the incentive-based capital requirements is needed in the case where the manager needs to be incentivized to exert a certain effort level. In the case where Condition (51) binds first, the optimal performance-based wage component increases with the effort costs τ and with the low return R_L, and it decreases with the high return of the risky project R_H.

8.1.2 Heterogeneous financing costs

A common assumption in the banking literature is that equity financing is more costly for banks than debt financing. Possible reasons for a divergence between the costs of equity and debt are, for example, the debt tax shield, adverse selection costs, and transaction costs.[11] In this section, we therefore relax the assumption that equity and debt have the same opportunity costs, and we analyze whether the incentive-based capital requirements are still able to implement the socially efficient investment policy. To capture the idea that equity is a more expensive form of financing than debt, we now assume that the costs of equity are $r_e = r + \Delta_e$ with $\Delta_e > 0$. Hence, the expected value of equity from Eq. (11) now becomes

$$\begin{aligned} V_e &= \int \pi(q)\,(1 - F_q(s_m))\,[qR_H + (1-q)I_D\beta D]\,dq \\ &+ \int \pi(q)F_q(s_m)R_L dq - k(1+r) - e\Delta_e - \underline{V}_m. \end{aligned} \tag{53}$$

Therefore, the shareholders have an incentive to change the manager's wage payment at $t = 0$ to $S_0 = -\alpha\,(k(1+r) + e\Delta_e - I_D\beta D)$, in which case their incentives would again be perfectly aligned.

However, the proposed incentive-based capital requirements are still able to implement the socially efficient investment policy as long as the regulator adjusts the wage contract between the bank and the

[11] Under a majority of taxation systems, the cost of debt (interest) is deductible from corporate tax, while the cost of equity (dividends) is not. Furthermore, when managers have significant private information, new equity issuance may sell at a discount. Finally, the transaction costs of issuing equity can be quite substantial (costs of preparing the prospectus, registration fees, underwriting fees, etc.). For more details, see, for example, Berger, Herring, and Szegö (1995), Gorton and Winton (2003), Hellmann, Murdock, and Stiglitz (2000), Repullo (2004), Allen, Carletti, and Marquez (2011), and Mehran and Thakor (2011).

manager for the gap between the costs of debt and equity. That is, the regulator only has to ensure that $S_0 = S_0^* = -\alpha\,(k(1+r) - I_D\beta D)$. In this case, the expected payment to the manager at $t = 0$ is still the same as in Eq. (19). Therefore, with the regulation from Eq. (18), the manager still chooses $s_m = s_{se}$. Hence, the incentive-based capital requirements are still able to implement the socially efficient investment policy.

8.2 Alternative regulatory measures

In the following, we analyze traditional and alternative regulatory responses to the risk-shifting problem described in Section 4, and we discuss their benefits and drawbacks. In particular, we analyze the regulatory approaches of banning insured debt, directly regulating compensation schemes, introducing an insurance premium, and implementing traditional capital requirements.

8.2.1 Banning insured debt

From Eq. (11), it follows that banning insured debt would eliminate the shareholder's incentive to engage in risk-shifting. However, it is not reasonable to remove government guarantees entirely due to the risk of bank runs and/or interbank market disruptions (e.g., Diamond and Dybvig, 1983; Blanchard, 2009). Banning bank debt altogether (i.e., requiring 100% equity financing) would also eliminate the moral hazard problem. However, this is arguably not socially optimal either because the information-insensitivity of banks' debt is valuable for liquidity provision (e.g., see Admati and Hellwig (2015)).

8.2.2 Regulating compensation schemes

By directly imposing a regulation on the manager's compensation scheme, the regulator can ensure that the manager has the incentive to implement the socially efficient investment policy. Comparing the manager's investment policy from Eq. (6) and the socially efficient one from Eq. (3) shows that by setting the compensation structure such that $S_H^r = \alpha R_H$ and $S_L^r = \alpha R_L$, the regulator can induce the socially efficient investment policy. However, to successfully implement this compensation regulation, the regulator needs to know the investment-related parameters, that is, R_H and R_L. To quantify these parameters, the regulator must be able to evaluate the risks of the bank's investments. However, the 2008-2009 financial crisis revealed that risk modeling in the financial sector has strong limits (e.g., Danielsson (2002), Danielsson (2008), Hellwig (2010), Behn, Haselmann, and Vig (2014), and Rajan, Seru, and Vig (2015)).

Finally, to implement this approach effectively, the mandatory compensation structure must be changed as soon as the bank's investment parameters change (i.e., R_H and R_L). This issue is especially problematic for financial institutions because their investment opportunities change very frequently, which would require a corresponding adjustment to the compensation structure.

8.2.3 Insurance premium

Another way the regulator can implement the socially efficient incentives at $t = 0$ is to introduce an insurance premium that the bank must pay when it takes on debt. This premium has to increase with the riskiness of the bank's investment policy, as well as with the amount of the bank's insured debt, such that it offsets the risk-shifting incentives that arise from taking on insured debt. Hence, the appropriate debt insurance premium that has to be imposed on the bank at $t = 0$ is given by

$$\phi = \int \pi(q)\,(1 - F_q(s))\,(1 - q) I_D \beta D dq. \tag{54}$$

This result can be verified by subtracting the fee ϕ from the expected return on equity given in Eq. (11), which yields

$$\begin{aligned} V_e &= \int \pi(q)\,(1 - F_q(s))\,[qR_H + (1 - q) I_D \beta D]\,dq + \int \pi(q) F_q(s) R_L dq - k(1 + r) - \underline{V}_m \\ &- \int \pi(q)\,(1 - F_q(s))\,(1 - q) I_D \beta D dq. \end{aligned} \tag{55}$$

Simplifying this expression and comparing it to Eq. (4) shows that with an insurance premium, the bank's shareholders have the incentive to implement the socially efficient investment policy s_{se}. However, the appropriate debt insurance premium ϕ depends on the investment policy s, which, in turn, depends on investment-related parameters, that is, R_H and R_L. Therefore, as explained before, this regulatory approach is very difficult to implement. Furthermore, the necessary insurance premium ϕ also depends on the bank's leverage. Hence, due to the continual variation in the banks' capital structure, the insurance premiums need to be adjusted very frequently.

8.2.4 Traditional capital requirements

Eq. (11) shows that the shareholders have risk-shifting incentives as soon as the bank takes on debt. Hence, introducing a regulation on the ratio between debt and equity reduces, but does not eliminate, their risk-shifting incentives. Therefore, even after introducing such a regulation, the investment policy that maximizes the shareholders' expected return is still s^*. Hence, by implementing the compensation structure W^* from Eq. (12), the bank shareholders can still implement the riskier investment policy s^* from Eq. (14), even if traditional capital requirements are in place.