Online Appendix

EC.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.

EC.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

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

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

$$\int \pi(q)\,(1 - F_q(s_{se}))q\alpha R_H dq + \int \pi(q)F_q(s_{se})\alpha R_L dq - \tau \geq \alpha R_L, \tag{EC.2}$$

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 (EC.2) yields

$$\alpha \geq \frac{\tau}{\int \pi(q)\,(1 - F_q(s_{se}))\,[qR_H - R_L]\,dq}. \tag{EC.3}$$

Therefore, if α is high enough that Condition (EC.3) 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 (EC.3) is the tightest of the three constraints, the optimal performance-based component becomes

$$\alpha_3^* = \frac{\tau}{\int \pi(q)\,(1-F_q(s_{se}))\,[qR_H - R_L]\,dq}. \tag{EC.4}$$

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 (EC.3) 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.

EC.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

$$\begin{aligned} V_e = &\int \pi(q)\,(1-F_q(s_m))\,[qR_H + (1-q)I_D\beta D]\,dq \\ &+ \int \pi(q)F_q(s_m)R_L dq - k(1+r) - e\Delta_e - \underline{V}_m. \end{aligned} \tag{EC.5}$$

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 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.

[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 et al. (1995), Gorton and Winton (2003), Hellmann et al. (2000), Repullo (2004), Allen et al. (2011), and Mehran and Thakor (2011).

EC.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.

EC.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)).

EC.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 et al. (2014), and Rajan et al. (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.

EC.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

$$\phi = \int \pi(q)\,(1-F_q(s))\,(1-q)I_D\beta D dq. \tag{EC.6}$$

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

$$\begin{aligned} V_e = &\int \pi(q)\,(1-F_q(s))\,[qR_H + (1-q)I_D\beta D]\,dq + \int \pi(q)F_q(s)R_L dq - k(1+r) - \underline{V}_m \\ &- \int \pi(q)\,(1-F_q(s))\,(1-q)I_D\beta D dq. \end{aligned} \tag{EC.7}$$

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.

EC.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.

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