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Bank capital requirements and managerial self-interest

Arturo Bris[a,*], Salvatore Cantale[b]

[a] Yale School of Management, 135 Prospect Street, New Haven, CT 06520-8200, USA
[b] Tulane University, New Orleans, LA, USA

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Abstract

Is there an interaction between bank capital requirements and agency problems? To which extent is the assumption of perfectly aligned bank manager–shareholders harmless? To address these questions, we consider a bank in which both a regulator–bank conflict and a shareholders–manager agency problem coexist. We analyze the effect of capital adequacy requirements on bank risk policy when managers and shareholders have different information about the quality of the loan portfolio. Taking as given optimal regulation on capital requirements and deposit insurance, we show that the separation of ownership and control in banks leads to an excessive reduction in the banks' loan portfolio risk (underinvestment) and an increase in the managerial effort in loan supervision. We find, in fact, that only high-quality loans are taken on by banks, and some profitable investments are bypassed. Additionally, we show how bank debt and reserve requirements can help restore efficiency. Our results are related to the theoretical and empirical literature that deals with the effects of the Basle Accords on the banks' credit policy.

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The role of regulation of banks and financial institutions has been widely discussed in the finance literature. In a seminal paper, Diamond and Dybvig (1983) offer an explanation of deposit insurance that considered the real economic damages caused by the financial distress of a depository institution. However, if deposit insurance helps prevent bank runs on one side, it does encourage risk-taking by bank managers on the other side (see Merton, 1977, among others). Many authors addressed this issue concentrating on the potential *external* agency problem

* Corresponding author. Tel.: +1-203-432-5079; fax: +1-203-432-3003.
E-mail address: arturo.bris@yale.edu (A. Bris).

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between the regulator and the bank as a whole[1] (often represented by a perfectly aligned manager). The general conclusion of all this stream of thought is that with information asymmetry between managers and regulator, the effort level proffered by managers drives away from the first best level and it is inefficient[2] (see also Gorton & Winton, 1995). Regulation is thus needed to restore efficiency. Some have, therefore, suggested that a regulatory scheme constraining the feasible set of investment choices and fund sources may partially solve such a problem. In fact, it is said, a regulation scheme comprising deposit insurance and capital requirements[3] (and possibly forbearance systems) is able to enforce the socially optimal level of risk (see Bensaid, Pages, & Rochet, 1993; Chan, Greenbaum, & Thakor, 1992; Dewatripont & Tirole, 1994; Rochet, 1991, for the joint effect of deposit insurance plus capital requirements, and Nagarajan & Sealey, 1995, for an analysis of forbearance systems).

Although the conflict of interests between managers and shareholders is very much considered in corporate finance and the empirical results by Hughes and Mester (1994) explicitly inform us that bank's managers are *not* maximizing shareholders value, implying the existence of a relevant *internal* agency problem, only recently scholars in banking considered alternative explanations, and namely corporate control, to help explain bank risk behavior. Gorton and Rosen (1995) present a model of banking based on a conflict of interest between shareholders and managers (internal agency problem). The main finding of the paper is that in an environment where managers enjoy private benefits of control, the aggregate risk-taking drives away from the first best and may be excessive. Additionally, they find empirical support for their hypotheses and show that corporate control rather than standard moral hazard considerations were responsible for the risk-taking behavior in banking during the 1980s. Note, however, that Gorton and Rosen focus their attention to an environment that is only *partially* regulated, that is to an economy where deposit are insured and capital requirements are easily satisfied (this particular feature of the model allows them to neglect the regulator–bank conflict of interests).

In this paper, we link the two layers of agency conflicts, namely the standard moral hazard regulator–bank owners problem and the corporate control literature based on the conflict between bank owners and managers. In particular, we shed some light on the effect of capital requirements scheme on the risk and volume of the bank loan portfolio when managers' actions are not observable. Is there an interaction between capital requirements (or more generally, between regulation) and agency problems? Do capital requirements have an impact on the lending and on the risk-taking activities of banks? How? To which extent is the assumption of perfectly aligned managers–shareholders harmless? We believe that these are not just empirically relevant matters. Recall in fact that much public policy draws from the empirical predictions of the literature and we know how much bank regulation is important.

To address these questions, we consider a bank that is publicly owned in a two-period setting. Bank managers choose the structure of the balance sheet, affecting the risk of insolvency by the choice of the debt-to-equity ratio, and determine the quality of the loan book by exerting effort. Two orders of countervailing incentives are considered in this paper. Firstly, the regulator–shareholders *external* agency problem, centered around the assumption that there are some costs associated with financial distress that are borne by the society and not by shareholders. Secondly, and more importantly, the shareholders–manager *internal* agency problem arising in a framework where managers have to perform costly actions. When we analyze the case in which the only conflict of interest is between outsiders (bank–regulator) and *the bank as a whole* (i.e., the interests of shareholders and bank managers are perfectly aligned), we show, in line with most part of the previous literature, that capital requirements help reduce the excess risk-taking problem created by deposit insurance. Additionally, we are able to fully characterize the optimal capital adequacy scheme in a closed form solution and the optimal level of effort put forth by the manager. Then, we introduce the other level of conflict *within the firm*. We assume that effort is not observable, and therefore not contractible: shareholders can only induce the management to choose the right action through the compensation package. To directly test if the assumption of perfectly aligned managers–shareholders is indeed irrelevant and not driving the results, we take as given the *optimal regulation on capital requirements derived before*, and we solve once again the model. What we find is that the separation of ownership and control in the banking industry can induce levels of risk that are suboptimally low when compared to those that would be chosen in an ideal framework (with no conflict of interest between managers and shareholders), and therefore the internal agency problem must be acknowledged and cannot be passed by. The inefficiency arises because, with self-interested managers, banks will only take on safe loans, and the risk level in the economy will be too low with respect to what would be socially desirable. In other words, while it is possible to design a regulatory system with deposit insurance and capital requirements that provides the right incentives to achieve the optimal level of risk in an economy with asymmetric information between the bank as a whole and the regulator, the same scheme becomes suboptimal when it is applied to banks with internal agency problems: managers will exert a high level of effort, some good loans will be passed by, and the bank will become too safe. This result can help understand the empirical findings of Saunders, Strock, and Travlos (1990). They document in fact that “stockholder controlled” banks took on more risk than their “managerial controlled” counterpart, implying that the second layer of agency problems is important in explaining risk-taking behavior.

The model presented in this paper is also closely related to John, Saunders, and Senbet (2000). Both papers investigate economies with self-interested managers. The focus of John et al. (2000) is to derive a compensation package that could restore the Pareto-optimal investment policy, even in the absence of capital requirements. That is, in their model, regulation does not play any role and it is, therefore, irrelevant. The focus of the present paper is different. Firstly, we derive an optimal capital requirements regulation scheme (at least in presence of external agency problem). Then, we explore the implications for risk taking an lending behavior. We are, therefore, able to study the relation between regulation and managerial behavior.

Through the introduction of a conflict of interests between managers and shareholders, our model helps explain some stylized facts. Firstly, we find that bank debt is a potential device to circumvent the inefficiencies induced by capital requirements. Debt disciplines managers because it makes capital requirements more difficult to comply with. With leverage the risk that equity capital becomes insufficient, and consequently that the regulator takes over the bank, is higher. Secondly, this model helps clarify the relationship between loan portfolio and managerial compensation.

The model is introduced in the next section. In Section 1.1, we set up the model. We solve for the first best risk level in Section 1.2. In Section 2, we show that the first best is not achievable in the presence of an external agency conflict, and we solve for the optimal equity capital regulation. Section 3 introduces a second, internal agency conflict, and presents the main results of the paper. Section 4 presents a discussion of the main results and concludes the paper. Proofs are in the Appendix A.

1. A model with deposit insurance and capital requirements

1.1. Basic model

We consider a bank which is publicly owned and lives for two periods. Shareholders are disperse and risk neutral.

At $t = 1$, the bank manager chooses the structure of the balance sheet. The bank's assets consist of the loan portfolio, L, and riskless reserves R. Investments are financed with deposits D or by raising equity K_1 from the market. To lend L, the bank must spend cL as cost of credit, which can be interpreted as inspection, advertising, and transaction costs which are entirely paid for by the bank. Without loss of generality, we assume $c = 0$. Moreover, the supply of loans is downward sloping, i.e., $L = L(r)$, and $L'(r) < 0$, where r denotes the average lending rate. Therefore, r can be interpreted as the average quality of the loan portfolio, that is endogenously determined in the model. The lower the loan quality, the higher the risk of default.

Loans contractual repayment at $t = 2$ is $(1 + r)L$. Loans are risky and only a random proportion $\tilde{\theta}$ is paid back. For simplicity, we assume that reserves and deposits pay zero interest rate. The bank chooses the lending rate, and indirectly the size of the loan portfolio, so as to maximize the bank's profits.

Deposits are insured in the sense that depositors will receive the amount D at $t = 2$ even if the bank cannot meet its obligations. When this happens, the regulator (either Central Bank or Deposit Insurance Corporation) takes over the bank, collects outstanding debtors and repays deposits through an injection of additional liquidity. However, there is a social cost of providing liquidity in financial distress, and for any dollar contributed by the regulatory institution, the cost to society is $1 + \delta$.

At $t = 1$, the budget constraint for the bank is as follows:

$$D + K_1 = R + L(r) \tag{1}$$

Bank managers can affect the bank performance by exerting a level of effort $e \in [0, \infty)$. The final level of effort affects the distribution of $\tilde{\theta}$ since e denotes the quality of the managerial screening in the credit market. Intuitively, when more resources are spent in investigating potential borrowers, the quality of the loans, in terms of probability of repayment, increases. In particular, it is assumed that $\tilde{\theta}$ can take two possible values:

$$\tilde{\theta} = \begin{cases} 1 & \text{with probability } \dfrac{e}{1+e} \\ 0 & \text{with probability } \dfrac{1}{1+e} \end{cases}$$

Note that the characterization of $\tilde{\theta}$ is such that $\tilde{\theta}$ can take the value of zero for any effort level e. That amounts to say that loans are risky. The expected value of the proportion of loans that are paid back is thus a concave function of effort, and the probability of default, that is decreasing in effort, is then known if managerial effort is observed. In equilibrium, loans will be serviced as long as its expected repayment exceeds the borrowing costs, $(1+r)\tilde{\theta} \geq 0$. Hence, the riskiness of the bank's loans has two components. The observable component r is chosen by the bank's shareholders. Any value of r can be imposed by regulation. However, only if the effort choice is publicly observable, can the riskiness of the loan portfolio be controlled by the Central Bank.[4]

At $t = 1$ shareholders, who are risk neutral, calculate the expected value of their stake in the bank given its credit policy, the deposit insurance scheme and the probability of repayment:

$$E[K_2] = E[\max\{(1+r)\tilde{\theta}L(r) + R - D, 0\}]$$

Bank regulation is designed at $t = 0$. We assume that the Central Bank requires a minimum level of reserves R that the bank must hold.[5] In order to ensure that the bank is in financial distress whenever loans are not paid back, first we have to show that it is optimal for equityholders to finance deposit with equity rather than reserves. Every dollar of deposits that is invested in reserves yields a net return of 0 at $t = 2$, because both deposits and reserves are riskless. However, for every dollar of deposits that becomes a loan, equityholders get an expected repayment of $(1 + r)E(\tilde{\theta}) = (1 + r)(e/(1 + e)) \geq 0$. Hence, shareholders prefer loans to reserves. We further assume that the Central Bank requires a minimum level of reserves R. Shareholders optimally choose D such that $R < D$, as stated.

Defining θ_0 as the level of repayment that guarantees an expected positive value for the equity, we can write the last expression as:

$$E[K_2|\tilde{\theta} \geq \theta_0] = E[(1+r)\tilde{\theta}L(r) + R - D|\tilde{\theta} \geq \theta_0], \quad \text{for } \tilde{\theta} \geq \theta_0 \tag{2}$$

Substituting R in (2) from (1), we get:

$$E[K_2|\tilde{\theta} \geq \theta_0] = E[[(1+r)\tilde{\theta} - 1]L(r) + K_1|\tilde{\theta} \geq \theta_0], \quad \text{for } \tilde{\theta} \geq \theta_0 \tag{3}$$

with $\theta_0 = (1 - (K_1/L))/(1 + r)$.

Finally, using Assumption 2, the expected value of equity becomes:

$$E[K_2] = [rL(r) + K_1]\frac{e}{1+e} \tag{4}$$

Managerial effort is costly and $W(e) = we$, with $w > 0$, denotes such a cost. The linearity of the cost function is allowed since e is not bounded to the right, and thus it is never possible to achieve the maximum level of effort even with w very low. The parameter w is the cost per unit of effort.

Managers are risk neutral, and their compensation consists of a proportion α of the firm value that is paid at $t = 2$ and contracted upon at $t = 1$. The salary α can be interpreted as a bonus that is determined based upon some measure of performance. The optimal contract is designed so as to achieve the desired level of effort. The percentage α is paid by shareholders and dilutes their holdings in the firm.[6]

Managers are able to raise money from the market as long as investors' discounted expectations about the firm value equal their investment:

$$K_1 = (1 - \alpha)E[K_2] \tag{5}$$

where we assume for simplicity that the required return to equity equals zero.[7]

The financial constraint together with the expression for the firm value in (4) defines $E[K_2]$ as a function of α and e only:

$$E[K_2] = \frac{e}{1+\alpha e} rL(r) \tag{6}$$

By choosing the effort level e, bank managers directly determine the value of the equity claim at $t = 2$, and therefore the amount of equity capital to be raised at $t = 1$. Such a formulation eliminates the theoretical potential for regulatory capital arbitrage. However, our main insights remain unchanged.[8]

To summarize, the timing of events is as follows: at $t = 0$ the regulator enforces r, that determines the loan base size, together with other pieces of regulation—capital and reserve requirements when needed. At $t = 1$, bank managers choose their effort level, and bank shareholders provide financing. At $t = 2$, loans mature, and their repayment rate determines the equity value.

Shareholders maximize the value of the equity at $t = 2$, net of managerial compensation, i.e., $(1 - \alpha)E[K_2]$, which is equivalent to maximizing their stake in the firm at $t = 1$ because $(1 - \alpha)E[K_2] = K_1$ from (5). Managers maximize their stake in the firm $\alpha E[K_2]$.

1.2. The socially optimal risk policy

Throughout this section, we will assume that managers' actions are public information. We will first describe the socially optimal risk and effort choices. In the next section, we show that because of the external agency problem, the first best is not attainable.

The socially optimal solution can be described as follows:

$$\max_{\alpha,e,r} E[K_2] \left\{ - \frac{(1+\delta)dL(r)}{1+e} \right\} \tag{F1}$$

$$\text{s.t. } \alpha E[K_2] \geq we$$

That is, in the case where the regulator can enforce any effort level, its objective function consists of the expected value of the bank's equity (observe that since deposits are insured, the regulator is not concerned about their expected value) minus the social cost of its involvement in the banking activity. With probability $1/(1 + e)$ loans repay zero and the bank is in financial distress.[9] In such a situation, the regulator must repay deposits $D = dL(r)$, where $d = D/L(r)$ represents the deposit ratio, the social cost being $1 + \delta$. We assume that the society spends $1 + \delta$ dollars for every dollar of public money that is spent to finance the deposit insurance. Giammarino, Lewis, and Sappington (1993) interpret such a cost as the social losses that occur when distortionary taxes are imposed in one sector to finance other sectors of the economy. Moreover, Ballard, Shoven, and Whalley (1985) estimate δ and obtain values in the range $[0.17, 0.56]$. Intuitively, the social welfare function has three components: $E(K_2)$ represents the expected return on the loan portfolio minus the cost of the manager's effort; the last component is the social cost of financial distress. The risk subsidy embedded into the deposit insurance benefits bank shareholders, but it is only a transfer payment from the social point of view.

The second equation is a participation constraint for the manager: she will accept the contract as long as her expected compensation exceeds the cost of exerting a level of effort e.

In equilibrium, the constraint will be binding. The reason why the participation constraint is binding is that $E(K_2)$ is maximized when α is minimum. Therefore, the regulator only needs to guarantee that managers receive a compensation $\alpha E(K_2) = we$. Using Eq. (6), it is easy to show that the optimal compensation package α^{FB} offered to the managers satisfies:

$$\alpha^{\mathrm{FB}} = \frac{w}{L(r)r - we^{\mathrm{FB}}}$$

Plugging this value in (F1), the maximization problem becomes equivalent to the following:

$$\max_{e,r} e[rL(r) - we] - \frac{1+\delta}{1+e} dL(r) \tag{7}$$

Solving the above program, we get the first best solution $(e^{\mathrm{FB}}, r^{\mathrm{FB}})$, that is characterized in the next proposition.

Proposition 1. *The socially optimal effort level and the optimal lending rate are given by*:

$$(r-c)L(r^{\mathrm{FB}}) = 2we^{\mathrm{FB}} - \frac{(1+\delta)dL(r^{\mathrm{FB}})}{(1+e^{\mathrm{FB}})^2} \tag{8}$$

$$e(L(r^{\mathrm{FB}}) + (r^{\mathrm{FB}} - c)L_r) - \frac{(1+\delta)dL_r}{1+e^{\mathrm{FB}}} = 0 \tag{9}$$

where L_r is the partial derivative of $L(r)$ with respect to r.

The above problem characterizes the first best and informs us on the optimal compensation package, the socially optimal lending rate, and the first best managerial effort. In equilibrium, some loans with positive expected profits $(E(\tilde{\theta})(1+r) > 0)$ are not granted, because more loans require more deposits, which entail a deadweight loss. Note that e^{FB} and r^{FB} are negatively related, which implies that, as more effort is put forth, the loan base increases. Intuitively, higher effort makes the average loan more profitable, and hence the range of acceptable loans widens.

2. External agency conflicts: regulators vs. banks

2.1. The unregulated optimum

Suppose regulators cannot contract on the effort level e. In a sense, the regulator cannot directly regulate loan quality but can regulate the initial capital level. We will show next that the first best is generally not attainable in a unregulated economy. To see this, consider shareholders' point of view. Their objective is to maximize their residual claim, subject to managers' participation. The problem can be formalized as follows:

$$\max_{\alpha,e,r} (1-\alpha)E[K_2] \tag{10}$$

$$\text{s.t.}\ \alpha E[K_2] \geq we \tag{11}$$

Note the difference between (F1) and (10). The regulator is concerned about the social cost of insurance (the last term in the maximization program (F1)), shareholders are not. While the optimal compensation package is given by the same expression as α^{FB}, the optimal effort level is given by $e^{\mathrm{S}} = ((rL(r) - w)/2w)$. A simple comparison between the effort levels in the two solutions would suggest us that the socially optimal effort level is always greater than the shareholders', implying that the first best level is not attainable in a unregulated economy and that banks (and therefore, the banking system) would be riskier than it would socially optimal. We can summarize the above results in the following proposition:

Proposition 2. *The socially desirable effort level is not attainable and is always higher than the level of effort that is optimal from shareholders' point of view. That is,* $e^{\mathrm{S}} < e^{\mathrm{FB}}$*. Moreover, in the presence of agency conflicts, the loan base size reduces and the optimal lending rate is higher*: $r^{\mathrm{S}} > r^{\mathrm{FB}}$.

That is, because of a external agency conflict, banks become riskier. In this simple setup, the need for banking regulation arises endogenously. As the next section shows, requirements on equity capital can restore the first best solution.

2.2. Optimal bank regulation in presence of external agency problems

The last section pointed out that banks left alone do not have enough incentives to attain the first best level of risk and to provide the necessary stability to the economic system. What we will show in this section is that, in presence of an external agency situation, a regulatory scheme consisting of (deposit insurance and) capital requirements can help to enforce the desirable level of effort.

The regulator can easily implement the socially optimal lending rate r^{FB}, and therefore the size of the loan base. This is so because the lending rate is verifiable, hence the Central Bank, by means of the monetary policy, can indirectly decide on the prevailing lending rate. In what follows, we assume that this is the case. Alternatively, we interpret the riskiness of the loan portfolio as having two components. Regulation can control the observable component (r), but not the unobservable component (e).

As we know them, capital requirements dictate that, for any amount $L(r)$ that is lent to the market at $t = 1$, $B(\tilde{\theta})$ must be—at least, raised as equity:

$$K_1 \geq B(\tilde{\theta}) \tag{12}$$

Therefore, capital requirements guarantee that the bank cannot assume any additional loan without communicating it to the market through a demand of extra funds. In this situation, shareholders will choose a compensation scheme α, and a level of effort e to maximize the value of their residual claim, given the constraint imposed by the regulator (capital requirements + lending rate). Formally, the problem, that we denote (F2) can be described as follows:

$$\max_{\alpha,e} (1-\alpha)E[K_2] \tag{F2}$$

$$\text{s.t. } K_1 \geq B(\tilde{\theta}) \qquad \alpha E[K_2] \geq we \qquad e \geq 0,\ 0 \leq \alpha \leq 1$$

Shareholders choose the values for α and e that optimize the diluted value of equity.[10] The first constraint is a liquidity constraint for the bank and imposes a minimum on the amount of equity raised by the bank (capital requirements). The second is the usual participation constraint, and the others are some regularity conditions.

However, and since the risk of the loan portfolio cannot be observed by bank regulators, an optimal regulation scheme must be designed so as to make bank's shareholders and managers choose the social optimum level of risk. We assume that the regulatory institution (e.g., FDIC) sets a capital requirement scheme $B(\tilde{\theta}) = B[\widetilde{E(\theta)}] = B(e/(1+e)) = B(e)$ that assigns a level of required reserves to every choice of portfolio risk. Furthermore, we assume that the objective of the regulator is to maximize the expected value of the bank, less the deadweight loss incurred by deposit insurance. Hence, bank regulators choose $B(\tilde{\theta})$, so as to solve:

$$\max_{B(\tilde{\theta})} E[K_2]\left\{-\frac{(1+\delta)dL(r)}{1+e}\right\} \tag{F3}$$

$$\text{s.t. } e \in \arg\max_{\hat{e}} \text{(F2)}$$

Therefore, (F2) becomes now:

$$\max_{\alpha,e} (1-\alpha)E[K_2]$$

$$\text{s.t. } K_1 \geq B(\tilde{\theta}) \qquad \alpha E[K_2] \geq we \qquad e \geq 0,\ 0 \leq \alpha \leq 1$$

The solution to (F2) together with (F3) is stated in the following proposition:

Proposition 3. *When managerial effort is observable, the capital requirement level that maximizes the regulator's objective function is given by the following expression (optimal regulation)*:

$$B^* = (r^* - c)e^* - \frac{1+e^*}{L(r^*)}we^* \tag{13}$$

Consistent with B^*, *the optimal compensation package offered to, and the optimal effort level exerted by the manager are socially optimal, i.e.* $\alpha^* = \alpha^{FB}$, $e^* = e^{FB}$.

Also, at the optimum, capital requirements are binding and the bank is financed with equity equal to $K_1 = B^*$.

In line with the banking literature, we find that capital requirements help alleviate the excess risk taking caused by deposit insurance. A positive relation between capital requirements and risk has been formalized in the theoretical work by Blair and Heggestad (1978) and Kim and Santomero (1988). Blair and Heggestad (1978) suggest that regulation, by reducing the viable opportunity set, may adversely increase the probability of default. Kim and Santomero (1988), in a mean–variance framework, examine the effect of capital regulation for an optimizing bank. They show that the traditional uniform capital ratio is ineffective to reduce risk. They also show that a risk-related capital regulation is more effective only when the weights are calculated optimally. In Rochet (1991), the adoption of capital requirements may paradoxically entail an increase of the banks' risk of default, unless the weights used in the computation of the capital ratio are proportional to the systematic risk of the assets. Also risk-based standards are not without criticism. Some institutions claim that the capital standards are too severe and affect their ability to compete with unregulated, nonbanking financial institutions. Additionally, another potential problem is that big and small institutions are evaluated using the same scale even though their credit risks may not be the same.[11] In the same line, it is argued that the Bank for International Settlements regulation, "which offers few incentives, has left many banks complaining that they will be lumbered with a capital charge so heavy that their trading operations will struggle to earn a decent return" (The Economist, 1995).

The agency problem between the regulator and the bank is in fact resolved by the intelligent use of a minimum requirement of equity financing. Capital requirements force managers to proffer a level of effort (and thus to choose the riskiness of the portfolio) that is socially optimal. In this sense, capital requirements are an optimal mechanism: they eliminate completely any distortion created by the asymmetry of information and by the partially conflicting objectives. Note also that, as intuition suggests, α is increasing in effort. Additionally, it is always the case that $B^*(e) > 0$, a direct implication of the fact that $0 \leq \alpha^* \leq 1$.

The next result describes the shape of the capital requirements scheme:

Corollary 1. *If $rL > 4w$, then $B^*(e)/L(r)$ is increasing in the riskiness of the loan portfolio e.*

The ratio $B(\tilde{\theta})/L(r)$ represents in our model the proportion of equity financing relative to the total loan base. We show that, as loans (or investments in broader sense) get riskier, the probability of a bank failure gets higher, and the regulator will require a larger proportion of the assets financed via equity to reestablish efficiency. Note that this result is in line with the basic principles contained in the Basle Accords. That is, depositary institutions must hold a level of equity financing that is increasing in the riskiness of their assets.[12]

3. Internal and external agency problems: regulators–banks–managers

In this section, we formalize the idea of the separation of ownership and control by assuming that the effort level (and therefore the loan quality) is not observable, and therefore not contractible. When this is the case, shareholders must design a compensation package that ensures the implementation of their desired effort level. We denote this contract $\alpha(e)$.

To test if the assumption of perfectly aligned managers–shareholders is indeed irrelevant, we take as given the *optimal regulation on capital requirements derived before*. For what follows, in fact, we will assume that the regulator is not aware of the internal agency problem and bank owners will be, therefore, required to maintain a level of equity financing equal to at least $B^*(e) = B^*$. We could alternatively assume that the regulator is aware of the internal conflict, solve for the resulting capital requirements, and compare them to the first best level. However, we take the current approach because our objective in the paper is to make a claim concerning the choice of the loan portfolio risk by self-interested managers. The objective of this section is that of illustrate the effect of neglecting the internal agency problem on managerial performance, compensation, as well as on the bank's risk policy.

Define $\pi(e, \hat{e})$ as the manager's net compensation when effort e is undertaken and managerial compensation is $\alpha(\hat{e})$. From (6):

$$\pi(e, \hat{e}) = \frac{\alpha(\hat{e})e}{1 + \alpha(\hat{e})e}(r^*)L(r^*) - we \tag{14}$$

That is, managerial net compensation equals the expected value of the performance-based compensation minus the costs of exerting effort e.

In this situation, the shareholders' problem[13] can be reformulated as follows:

$$\max_{\alpha(e)} (1-\alpha(e))E[K_2] \tag{P1}$$

$$\text{s.t. } e \in \arg\max_{\hat{e}} \pi(e,\hat{e}) \qquad e \geq 0,\ 0 \leq \alpha \leq 1$$

The solution to (P1) characterizes the conditions that any function $\alpha(e)$ should satisfy under moral hazard. Call $\alpha^*(e) = \arg\max_{\alpha(e)}$ (P1). Now the bank managers' optimal strategy solves:

$$\max_{e} \alpha^*(e)E[K_2] - we \tag{P2}$$

$$\text{s.t. } K_1 \geq B^*$$

where B^* and e^* come from (13) and (8) respectively.

In the next lemma, we describe the solution to (P1), (P2).

Lemma 1. *When managerial effort is not observable, the maximization problem* (P1) *and* (P2) *has a unique solution. Taken as given the parameter B^*, the optimal effort level e^*_{MH} is given by the minimum positive value satisfying the following expression*:

$$we^*_{\text{MH}}(1+e^*_{\text{MH}})^2 = \frac{B^*}{L(r)} + r\left[\frac{B^*/L(r)}{r} + e^*_{\text{MH}}\right]L(r)$$

The optimal compensation package $\alpha^*(e^*_{\text{MH}})$ will be given by:

$$\alpha^*(e^*_{\text{MH}}) = \frac{r - ((B^*/L(r^*_{\text{MH}}))/e^*_{\text{MH}})}{r + B^*/L(r^*_{\text{MH}})} \tag{15}$$

At the optimum, capital requirements bind and the bank is financed with equity $K_1 = B^*$. Additionally, the effort level e^*_{MH} exerted in equilibrium is increasing in B^*, and decreasing in w.

When effort (and therefore the risk of the loan portfolio) is neither contractible nor observable not only by the regulator but also by shareholders, the latter sets a compensation scheme by granting managers a stake in the firm so to align their interests with those of shareholders'. Bank managers' effort will thus be bounded above by their participation constraint and below by the capital requirements constraint. However, note that managers bear all the cost of exerting effort, but, as usual in a moral hazard environment, get only a fraction of the benefits. This in turn implies that the level of effort (and hence risk) that managers are going to choose may be different from the first best level of effort e^{FB}, and therefore not optimal from the claimholders' point of view. We tackle the issue whether the optimal capital requirements B^* are able to restore the social level of effort in the next proposition.

Proposition 4. *There exists $w^{\text{c}} > 0$ such that, for $w > w^{\text{c}}$, the effort level exerted by managers is higher in presence of external agency problems. That is, $e^*_{\text{MH}} > e^*$.*

The reason why shareholders prefer less equity in the presence of an internal agency conflict is that capital requirements are specified in terms of $t = 0$ equity value, $B(\tilde{\theta}) < K_1$. But K_1

equals the diluted equity value at $t = 2$, i.e., $K_1 = (1 - \alpha)E(K_2)$. The more costly effort is, the higher α, and then the larger the portion of the bank's assets that are financed with debt. The reason why the result only holds for high values of w is that the inefficiency is driven by the need for managerial compensation. If effort is costly, then $\alpha = 0$, and given that the size of the bank is given (can be enforced by the regulator), shareholders have no choice on the effort level, and they have to exert the socially optimal level in order to satisfy capital requirements.

We can interpret the positive difference $w - w^c$ as a measure of internal agency costs. When managerial actions are costly enough (exacerbating therefore the internal agency problem), managers will surprisingly tend to profuse more effort in the lending activity. The intuition of the result goes as follows. From Proposition 2, we know that in equilibrium both the capital requirements constraint and the participation constraint are binding at the optimum. In this case, the compensation package and the effort level are given by the duplet (α^{FB}, e^{FB}). Additionally, because of the second set of agency problems, shareholders have to promise a higher stake of the firm α^{MH} with respect to the first best compensation level α^{FB}. This is where capital requirements enter into the picture. Since the stake of the firm attributed to the managers is higher, managers, to ensure that capital requirements be satisfied, must exert a level of effort that is higher than the first best level e^{FB}. The cut-off point w^c characterizes the *inefficient regulation* region in our model. Whenever $e^*_{MH} > e^{FB}$, banks will reduce the average risk of the loan portfolio—which is assumed fixed at its socially optimal level. Extant literature (Bensaid et al., 1993; Chan et al., 1992; Dewatripont & Tirole, 1994; Nagarajan & Sealey, 1995; Rochet, 1991) assumes that managers maximize shareholders' value and uses this argument to formalize the problem of a regulator that chooses the optimal B function. The previous proposition indicates that, when we include another level of countervailing incentives, namely the one between managers and shareholders, the optimal regulation scheme B, derived in an economy with only external agency problems, induces a level of risk that is suboptimally low in a richer agency environment. Note in fact that, when $w - w^c > 0$, the *ex ante* probability of bank failure, $P[\tilde{\theta} < \theta_0] = 1/(1 + e)$ is lower in the moral hazard case, implying an excessive reduction in the risk taken by the bank.

As we prove below, there are several factors that determine the cut-off point w^c. In the following corollary, we show how bank's shareholders and regulators can influence and manoeuvre those instruments in order to restore credit risk to its socially optimal level and, even though managerial activities cannot be perfectly monitored, to make internal agency problems completely vanish.

Corollary 2. *The threshold value w^c is*:

1. *Increasing in the deposit ratio d and in the bank's debt-to-equity ratio*.
2. *Decreasing in the social cost of financial distress δ*.

The intuition of the corollary goes as follows.

1. The minimum wage w^c is increasing in the deposit ratio d. This result illustrates the role of leverage in disciplining bank managers. Intuitively, bank debt reduces the willingness of managers to reduce effort (the violation of capital adequacy ratios becomes more likely) and, at the very same time, increases its costs (financial distress and therefore loss of compensation). Hence, the set of parameters for which the loan portfolio risk is too low shrinks. On the same line, and the intuition is analogous, we further show that agency problems

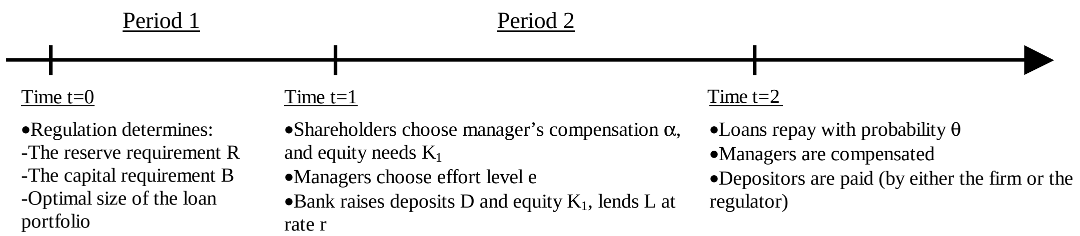

Fig. 1. Timing of the model. This is a model with three dates and two time periods. At $t = 0$, regulation (in case it is needed) determinates the reserve requirement R, the level of capital requirements B, and the optimal loan portfolio size. At $t = 1$, shareholders choose managerial compensation, and managers choose effort. Financing is raised, and investment is made. At $t = 2$, payoffs are realized.

are less likely to exist in banks whose bank's debt-to-equity ratio is high. This in turn implies that undercapitalized banks tend to suffer less from the agency conflict between bank managers and shareholders in the presence of capital requirements. This result is in line with the empirical evidence in Wagster (1996). His paper addresses the Basle Accords' effect on the competitiveness of international banks, and examines the effect of a series of events leading up to the Basle Accords in 1988 (when capital requirements were established) on returns to stockholders of international banks from Canada, Germany, Japan, the Netherlands, Switzerland, U.K., and U.S.A. While his results show that shareholders of banks from Canada, Switzerland, U.K., and U.S. (countries in which the average capital ratios were well above the new requirement) did experience non-negative wealth effects, the paper also documents that shareholders of banks from Germany, the Netherlands, and Japan (with significantly undercapitalized banks) did not experience wealth losses upon the introduction of the new capital adequacy ratios, as it would have been intuitively expected.

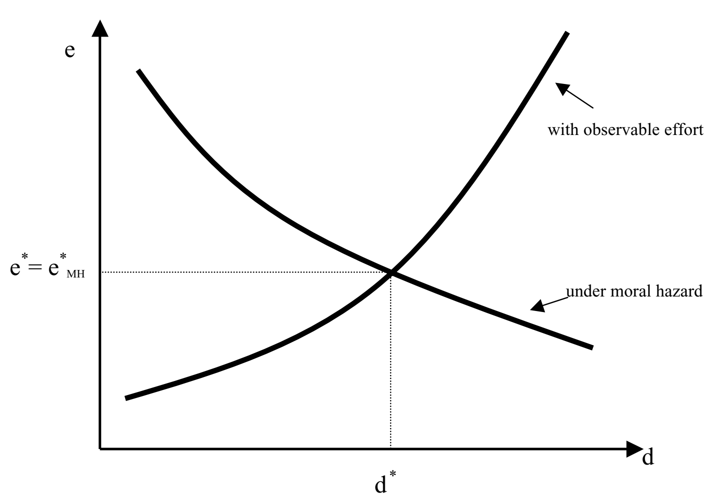

Fig. 2. Deposit rate and excess risk-taking. Effect of deposit rate on optimal portfolio risk both under perfect information and moral hazard. At d^*, the optimal credit risk levels in both cases equal, eliminated the pervasive effect of the agency conflict between managers and shareholders.

Fig. 1 shows how regulation on the deposit ratio d could be used to lessen the effects of the internal agency problem. First note that in our model regulation on deposits is similar to reserve requirements,[14] given the fix size of the bank. It is straightforward to prove that e^* and e^*_{MH} are respectively increasing and decreasing in the deposit ratio d. It is then possible to set a value for $d = d^*$, such that the credit risk level is restored to the first best case ($w = w^{\text{c}}$, $e^*_{\text{MH}} = e^{\text{FB}}$), even in the presence of severe internal agency problems. John et al. (2000) demonstrate how efficiency could be restored by the optimal choice of a compensation scheme alone. In a more regulated environment, we show that it is possible to achieve the same result with a combination of capital adequacy requirements and a lower bound on bank deposits (reserve requirements) (Fig. 2).

2. There exists a negative relationship between w^{c} and the costs of financial distress. Whenever bankruptcy is very costly, the socially optimal level of credit risk is relatively low. Therefore, bank regulation needs be more severe in order to induce bankers to use external financing, and hence to undertake safer investments.

4. Discussion and conclusions

Our model helps clarify some unexplored aspects of capital adequacy regulations related to managerial incentives and to the conflicts with the bank's owners. The banking literature has primarily analyzed the effects and problems of capital regulation under the assumption that the only relevant agency problem was the one between the regulator and the bank as a whole. In this paper, we claim that the assumption of the absence of an internal agency problem is not harmless. Whenever an internal agency problem is present, it has to be addressed otherwise models' outcomes and policy implications may result seriously biased. In fact, we have shown that the separation of ownership and control in the banking industry induces levels of risk that can be lower when compared to those that would be chosen in an ideal framework (perfect information, no conflict of interest between managers and shareholders). That is, while it is possible to design a regulatory system with deposit insurance and capital requirements that provides the right incentives for managers to achieve the optimal level of risk, the same scheme becomes suboptimal when it is applied to banks with imperfect monitoring. Note that our paper states that the inefficiency induced by capital requirements depends on idiosyncratic parameters, such as the debt-to-equity ratio, and the bank's profit margin. Therefore, a (socially) optimal bank regulation should allow for some degree of flexibility, and requirements on bank's equity capital should be determined on the basis of firm-specific measures of credit risk. This indeed seems to be the trend in bank regulation: since 1996 regulators allow financial institutions to monitor and evaluate themselves using the institution's proprietary internal risk model.

Additionally, we can motivate theoretically some empirical regularities observed in the literature since the Basle Accord imposed risk-based capital requirements in 1988. Firstly, the relationship between bank performance and managerial compensation. The result that pay and performance should be closely related does not seem to hold for banks and financial institutions. Houston and James (1993) document that bank CEOs have lower pay-performance sensitivity than that of non-bank CEOs. Additionally, Thomson and Yan (1997) find that bank managers total compensation is not closely tied to market performance after the enactment of FDICIA in 1991. Our model seems to indicate that, when we consider a richer agency environment, performance-driven compensation alone can have pervasive effects on bank's risk policy,[15] and more generally that shareholders should respond optimally to the external shock caused by capital requirements to incentive managers. A possible way of testing if the second layer of internal agency problems is relevant in explaining bank regulation and behavior would be to look at the change, if any, in the relation between bank performance and managerial compensation before and after the 1988 Basle Accords.

Secondly, the relation between capital adequacy regulations and risk taking by banks. Our paper contributes to the literature on bank regulation and risk policy by showing that minimum requirements on equity capital can be counterproductive. Bank regulation that does not consider specific bank characteristics, such as ownership concentration, scale, and charter value, can induce self-interested managers to choose suboptimally low risk levels. Our paper argues for flexibility: different banks should be allow to hold different capital levels. Therefore, we provide a theoretical motivation for the recent trend taken by the Bank for International Settlements. The new 2001 Basel Capital Accord recognizes the need for flexibility and market discipline, and puts more emphasis on banks' own internal methodologies.

Some useful extensions are possible in our framework. The inclusion of a second layer of agency problem, and namely the conflict of interests between shareholedrs and managers, creates a richer agengy environment and puts the theoretical foundations for a deeper analysis of the complicated web of interelationship between risk-taking behavior, incentives, and regulations. Many questions, therefore, arise and are possible in such an environment that are not possible in a model where managers' interests are perfectly aligned with shareholders'. We addressed one of the possible issues in risk taking behavior, and we did not tackle others. Other relevant questions have been in fact ignored and are left for future research. Notably, what are the relationships between growth opportunities, bank's regulation, and managerial discretion (i.e., internal agency problems)? Addressing this feature would in fact help us to understand better banks's risk-taking behavior, and would put also an interesting link between the literature in banking and in corporate finance.

We assumed that the size of the loan portfolio is optimally determined by the regulator. However, it would be useful to assume that banks have discretion on the loan base. In this way, we believe that internal agency conflicts can explain the so-called credit crunch. The underinvestment problem has been the focus of much research in the corporate finance literature starting with Myers and Majluf (1984). It is easy to argue that the impact on the real economic activity of such a problem is accentuated for banks. Many explanations have been put forward to explain this phenomenon. Among others, Stanton (1998) argues that only banks with many profitable loans or growth opportunities (i.e., high chart value) have a relatively more severe underinvestment problem. However, Peek and Rosengren (1995) study empirically the extent to which bank shrinkage is directly tied to the enforcement action of federal regulators. Their sample includes all large insured institutions in New England between 1989 and 1992, and they find that the capital crunch reported in previous work has indeed an explicit regulatory link (see also Berger & Udell, 1994; Hancock, Laing, & Wilcox, 1995).

We assumed for simplicity that all agents in our model are risk neutral, and thus the distribution of loan repayment depends on effort in the sense of first-order stochastic dominance. The introduction of risk-averse managers could avoid the undesirable linearities in our model and contribute to the study of the optimal risk weights in solvency ratios (as in Rochet, 1991). Additionally, it would allow for more complicated distributions and would show how the effect of managerial effort on loans' risk is directly related to regulation. An analysis with that perspective would complete ours.

Notes

1. Giammarino et al. (1993) assume that bank managers know more about the riskiness of their loan portfolio than do regulators. In Bensaid et al. (1993), bankers have some information on their investments' quality and have to monitor their implementation. The regulator, however, has only access to accounting information. Sometimes, bank–regulator may even pursue self-interest rather than social welfare (Boot & Thakor, 1993).
2. Another class of incentives problem between managers and claimholders has been also analyzed. Dewatripont and Tirole (1994) focus on the incentive problem between bank managers and all the creditors of the bank (depositors and stockholders). This problem motivates capital requirements in a competitive environment. However, the effect of such a regulation on risk policy is not analyzed. In Daltung (1994), the moral hazard problem between managers and claimholders arises because the latter cannot observe the bank's portfolio choice. Thus, the uninsured bank takes too much risk (undertakes projects with negative NPV). To mitigate this problem, a fairly priced deposit insurance scheme would induce the bank to take less risk. Miles (1995) considers information asymmetry between managers and depositors.
3. Capital adequacy requirements force institutions to have sufficient capital to cover the estimated credit risks inherent in their balance- and off-balance-sheet activities. In 1996, market risk was added to the standards. Market-risk standards apply to large banks.
4. This is equivalent to assuming that the probability of loan repayment depend on the effort and the supply of loans, $\tilde{\theta} = \tilde{\theta}(e, L)$, with $\tilde{\theta}_e > 0$, $\tilde{\theta}_L < 0$.
5. All depository institutions—commercial banks and thrifts—in the United States are subject to reserve requirements on customer deposits. The required reserve ratio depends on the amount of checkable deposits a bank holds. The first \$42.8 million of deposits are subject to a 3% reserve requirement. Above \$42.8 million they are subject to 10% reserve requirement. These breakpoints were effective in 12/28/2000, and are adjusted annually in accordance with money supply growth. No reserves are required against time deposits or savings accounts.
6. Our results do not change if we assume a linear compensation of the form $A + \alpha e$. However, the calculations become far more complicated and it does not contribute to the basic argument of the paper.
7. We could assume any positive required return $\rho > 0$ without any change in our results.
8. That is, by allowing the managers to choose only the effort level, we ignore the possibility that the managers use equity capital strategically in order to extract rents from less-informed equityholders.
9. Giammarino et al. (1993) consider a very similar net payoff function for the government. However, they state that the actual formulation chosen to model the bankruptcy costs does not affect the qualitative nature of the results.

10. It is easy to see that even a different assumption on the required rate of return on the bank's activity would lead to the same results. Assume in fact that $\rho \geq 0$ is the required return of equity in Eq. (6) (see also footnote 6). Then problem (F2) becomes exactly equivalent to the following:

$$\max_{\alpha,e,r} (1-\alpha)[E[K_2]-K_1]$$

$$\text{s.t. } K_1 \geq bL(r) \qquad \alpha[E[K_2]-K_1] \geq we \qquad e \geq 0,\ 0 \leq \alpha \leq 1$$

i.e., the managerial compensation consists of a proportion of the *incremental* value of equity, where the expected value of equity at $t=2$ becomes:

$$E[K_2] = r\frac{e(1+\rho)}{(1+e)(\alpha+\rho)}L(r)$$

It is straightforward to see that the optimal solution involves $\rho = 0$, which leads to the original problem (F2).

11. Federal Reserve Bank of Atlanta, Financial Update, Volume 11, Number 3, July–September 1998.
12. Finally, it is worth noting here that, although our model predicts that in any situation, capital requirements are a binding constraint for banks, the empirical evidence shows that capital ratios of the largest banks in the U.S., Britain, Italy, Germany, Japan, and France all exceed the Basle requirements. However, in an easy extension of our model, we can show that if we consider a dynamic framework, when the bank is subject to liquidity shocks or when outside capital is scarce, it may be optimal for the bank to maintain a level of equity financing well above the legal requirement.
13. We make use of the revelation principle to solve the principal-agent problem. The revelation principle guarantees that, in equilibrium, $\hat{e} = e$.
14. Since 1980 and the enactment of the Depository Institutions Deregulation and Monetary Control Act (DIDMCA), all depository institutions have been required to observe reserve requirements. Currently, these reserve requirements are levied against net 'transaction accounts,' 'non-personal time deposits' and 'eurocurrency liabilities.' Additionally, the Federal Reserve Board may, after consultation with the Board of Directors of the FDIC, impose a supplementary reserve requirement of up to 4% of transaction accounts if this is deemed 'essential for the conduct of monetary policy.'
15. In an unregulated economy, John et al. (2000) derive a compensation package comprising a fixed salary plus a bonus that depends on the bank's equity value that would be enough to restore the social level of risk.

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Association 1997 Meetings (Vienna), the European Economic Association 1997 Meetings (Toulouse), and the Southern Finance Association 1997 Meetings (Baltimore). All errors are ours.

Appendix A.

A.1. *Proof of Proposition 1*

The optimum e^{FB} results from the first-order condition on e. The second-order derivative are negative, which guarantees a maximum.

A.2. *Proof of Proposition 2*

First note that, since r^{S} satisfies $e(L(r^{\mathrm{S}} + rL_r) = 0 \Rightarrow r^{\mathrm{S}} > r^{\mathrm{FB}}$. To see that, suppose instead that $r^{\mathrm{FB}} > r^{\mathrm{S}}$. Then, $e(L(r^{\mathrm{S}} + rL_r) < 0$ because $rL(r)$ is decreasing in r. However, this implies $e(L(r^{\mathrm{FB}}) + (r^{\mathrm{FB}})L_r) - ((1+\delta)dL_r/(1+e^{\mathrm{FB}})) < 0$, which is absurd. Now, From the definition of e^{S}, $2we^{\mathrm{S}} = rL(r^{\mathrm{S}}) - w$. Besides, from (8), $2we^{\mathrm{FB}} = rL(r^{\mathrm{FB}}) + ((1+\delta)dL(r^{\mathrm{FB}})/((1+e^{\mathrm{FB}})^2))$, hence $e^{\mathrm{S}} < e^{\mathrm{FB}}$.

A.3. *Proof of Proposition 3*

Let us define $b(e, r) = B/L(r)$.

First use (4) together with (5). Solving for $E[K_2]$ results:

$$E[K_2] = \frac{e}{1+\alpha e} rL(r) \tag{A.1}$$

(F2) is equivalent to:

$$\max_{e,\alpha} \frac{(1-\alpha)e}{1+\alpha e} rL(r) \tag{A.2}$$

$$\text{s.t. } \frac{(1-\alpha)e}{1+\alpha e} r \geq b(e, r) \qquad \frac{\alpha e}{1+\alpha e} rL(r) \geq we$$

given that $e \geq 0$, $0 \leq \alpha \leq 1$ is satisfied.

The Lagrangian is:

$$\mathcal{L}(e, \alpha, r) = \frac{(1-\alpha)e}{1+\alpha e} rL(r) + \lambda_1 \left[\frac{(1-\alpha)e}{1+\alpha e} r - b(e, r) \right] + \lambda_2 \left[\frac{\alpha e}{1+\alpha e} rL(r) - we \right] \tag{A.3}$$

Conditions for optimality are:

$$\text{(i) } \frac{\partial \mathcal{L}}{\partial e} = \frac{1-\alpha}{(1+\alpha e)^2} rL(r) + \lambda_1 \left[\frac{1-\alpha}{(1+\alpha e)^2} r - b_e(e, r) \right] + \lambda_2 \left[\frac{\alpha}{(1+\alpha e)^2} rL(r) - w \right] = 0$$

(ii) $\dfrac{\partial \mathcal{L}}{\partial \alpha} = -(1+e)L(r) - \lambda_1(1+e) + \lambda_2 L(r) = 0$

(iii) $\lambda_1 \left[\dfrac{(1-\alpha)e}{1+\alpha e} r - b(e,r) \right] = 0$

(iv) $\lambda_2 \left[\dfrac{\alpha e}{1+\alpha e} rL(r) - we \right] = 0$

Let's consider the possible solutions:

1. $\lambda_1 = \lambda_2 = 0$, which implies $(rL(r)/(1+\alpha e)^2) = 0$ and $(1+e)L(r) = 0$, or $e = -1$: impossible.
2. $\lambda_1 = 0, \lambda_2 < 0$, which implies $(\alpha e/(1+\alpha e))rL(r) = we$, and $\lambda_2 = 1+e > 0$: contradiction.
3. $\lambda_1 < 0, \lambda_2 = 0$. In this case, $-(1+e)L(r) - \lambda_1(1+e) = 0 \Rightarrow \lambda_1 = -L(r) < 0$. Additionally, $b(e,r) = ((1-\alpha)e/(1+\alpha e))r$, so $b_e(e,r) = (1-\alpha/(1+\alpha e)^2)r$. Since $\lambda_1 < 0$, from (iii):

$$(1-\alpha)\frac{rL(r)}{(1+\alpha e)^2} - L(r)\left[\frac{1-\alpha}{(1+\alpha e)^2} r - b_e(e,r)\right] = b_e(e,r)L(r) = \frac{(1-\alpha)e}{1+\alpha e} rL(r) = 0$$

which implies $\alpha = 1$: a minimum.
4. $\lambda_1 < 0, \lambda_2 < 0$. Hence,

$$\frac{(1-\alpha)e}{1+\alpha e} r = b(e,r)$$
$$\frac{\alpha e}{1+\alpha e} rL(r) = we \tag{A.4}$$

which is equivalent to:

$$\alpha^* = \frac{w}{rL(r) - we^*}$$
$$b^*(e,r)L(r) = re^*L(r) - (1+e^*)we^* \tag{A.5}$$

Therefore, solving (i) and (ii), yields:

$$\lambda_2 = \frac{L(r)[(1-\alpha/(1+\alpha e^*)^2)r - b(e,r)] - ((1-e^*)/(1+\alpha e^*)^2)rL(r)}{(L(r)/(1+e^*))[((1-\alpha)/(1+\alpha e^*)^2)r - b(e,r)] + (\alpha/(1+\alpha e^*)^2)rL(r) - w} \tag{A.6}$$

$$\lambda_1 = L(r)\frac{\lambda_2 - 1 - e^*}{1+e^*} \tag{A.7}$$

Moreover, $\lim_{\alpha\to\alpha^*}\lambda_1 = \lim_{\alpha\to\alpha^*}\lambda_2 = -\infty$. Finally, let's check that (iii) and (iv) are satisfied:

$$\lim_{\alpha\to\alpha^*}\left(\lambda_2\left[\frac{\alpha e^*}{1+\alpha e^*}rL(r) - we^*\right]\right)\lim_{\alpha\to\alpha^*}\frac{\lambda_2}{(1/(\alpha e^*/(1+\alpha e^*))rL(r) - we^*)}$$
$$= \lim_{\alpha\to\alpha^*}\frac{(\partial\lambda_2/\partial\alpha)}{(\partial/\partial\alpha)(1/[(\alpha e^*/(1+\alpha e^*))rL(r) - we^*]}$$
$$= \lim_{\alpha\to\alpha^*}\left[\frac{(\partial\lambda_2/\partial\alpha)}{-e^{*-1}r(L(r)/(\alpha L(r)r - \alpha L(r) - w - w\alpha e^*)^2)}\right] = 0$$

Additionally,

$$\lim_{\alpha\to\alpha^*}\left(\lambda_1\left[\frac{(1-\alpha)e^*}{1+\alpha e^*}r - b(e,r)\right]\right)$$
$$= \lim_{\alpha\to\alpha^*}\frac{(\partial\lambda_2/\partial\alpha)}{(\partial/\partial\alpha)[(1/(1-\alpha)e^*/(1+\alpha e^*))r - b(e,r)]}$$
$$= \lim_{\alpha\to\alpha^*}\frac{(\partial\lambda_2/\partial\alpha)}{e^*[(r+e^*r)/(-e^*r + e^*\alpha r + [re^* + ((-1-e^*)/L(r))we^*] + [re^* + ((-1-e^*)/L(r))we^*]\alpha e^*)^2]} = 0$$

We solve now (F2) using the solution to (F3) obtained above.
(F2) is equivalent to:

$$\max_{b(e,r)} \frac{e^*}{1 + (w/(rL(r) - we^*))e^*}rL(r) - \frac{(1+\delta)dL(r)}{1+e^*} \tag{A.8}$$
$$\text{s.t. } b(e^*, r) = re^* - \frac{1+e^*}{L(r)}we^*$$

Or,

$$\max_{b} e^*rL(r) - 2we^* - \frac{(1+\delta)dL(r)}{1+e^*} \tag{A.9}$$
$$\text{s.t. } b(e^*, r) = re^* - \frac{1+e^*}{L(r)}we^*$$

Therefore,

$$B^* = re^*L - (1+e^*)we^*$$

Finally, from (A.4), $we^* < rL(r)$, hence $\alpha^* > 0$. Besides, for $\alpha^* \le 1$, it has to be $w \le (L(r)r/(1+e^*))$, and from (A.5):

$$\frac{L(r^*)r^*}{1+e^*} = w + \frac{b^*L(r^*)}{e^*(1+e^*)} > w \tag{A.10}$$

And $e^* > 0$ since, the right hand side in (A.10) is negative for $e^* = 0$ and increasing in e^*.

A.4. Proof of Corollary 1

First note that $\mathrm{Var}(\tilde{\theta}) = (1/(1+e)^2)$ is decreasing in e.

Second, from (13),

$$\frac{\partial B^*}{\partial e} = rL - w - 2we$$

which is positive (negative) if $e^* < (>)((rL - w)/2w)$

From (A.5), e^* satisfies:

$$2we^{*3} + e^{*2}[4w - rL] + 2e^*[w - rL] - [(1+\delta)d + r]L = P(e^*) = 0 \tag{A.11}$$

Note that $P(0) < 0$, $P'(0) < 0$, and under the assumption that $rL > 4w$, $P(e)$ only reaches a minimum at some $e > 0$. Therefore, to prove the statement, it suffices to show that $P((rL - w)/2w)$ is negative.

Plugging $(rL - w)/2w$ into $P(\cdot)$ and after some algebra, we get:

$$P\left(\frac{rL - w}{2w}\right) = \left[\frac{rL - 2}{2w}\right]^2 \left[\frac{3w - rL}{2}\right] - [(1+\delta)d + r)]L < 0$$

because $rL > 3w$.

Thus, $e^* > ((rL - w)/2w) \Rightarrow (\partial B^*/\partial e) < 0$.

A.5. Proof of Lemma 1

Let us first solve for (P1). From (14):

$$\left.\frac{\partial \pi(e, \hat{e})}{\partial \hat{e}}\right|_{\hat{e}=e} = \frac{\alpha'(e)}{[1 + \alpha(e)e]^2} r^* L(r^*) = 0 \tag{A.12}$$

Hence, $\alpha'(e) = 0$.

Additionally, constructing the Lagrangian for (P2), results:

$$\mathcal{L}(e, \alpha) = \alpha(e)E[K_2] - we + \lambda[B^* - (1 - \alpha(e))E[K_2]]$$

with partial derivative:

$$\frac{\partial \mathcal{L}(e, \alpha)}{\partial e} = \alpha'(e)E[K_2] + \alpha \frac{\partial E[K_2]}{\partial e} - w + \lambda \left[\alpha'(e)E[K_2] - (1 - \alpha(e))\frac{\partial E[K_2]}{\partial e}\right]$$

which yields two possible solutions, which are analyzed independently:

(i) $\lambda = 0$, $\alpha'(e) = 0$, which implies $\alpha(\partial E[K_2]/\partial e) = w$.
(ii) $\lambda \neq 0$, $\alpha'(e) = 0$. Solving for λ we obtain:

$$\lambda = \frac{\alpha(e)(\partial E[K_2]/\partial e) - w}{(1 - \alpha(e))(\partial E[K_2]/\partial e)} \tag{A.13}$$

Then, the solution to (P1) is equivalent to

$$\max_{\alpha(e)} (1-\alpha(e))E[K_2]$$

$$\text{s.t.}\ \alpha E[K_2] \geq we$$

plus the conditions stated in either one of the two solutions to the manager's problem.

Only solution (ii) leads to a maximum. To see that, note that, if the constraint is not binding, it is always profitable for the bank to increase the value of the equity, until $(1-\alpha(e))E[K_2] = B^*$. Therefore, the shareholders' problem becomes:

$$\max_{\alpha(e)} (1-\alpha(e))E[K_2] \qquad (1-\alpha(e))E[K_2] = B^* \qquad \alpha\frac{\partial E[K_2]}{\partial e} \leq w$$

It is easy to verify that the optimum is achieved when the last inequality is binding.

Solving the system defined by the two constrains, it turns out that e^*_{MH} solves:

$$we^{*3}_{\mathrm{MH}} + 2we^{*2}_{\mathrm{MH}} - e^*_{\mathrm{MH}}[(B^*/L(r)+r^*)L(r^*) - w] - B^*\frac{B^*/L(r)+r^*}{r^*} = \mathrm{MH}(e^*_{\mathrm{MH}}) = 0 \qquad \text{(A.14)}$$

with α^*_{MH} as stated in the proposition.

And, since $\mathrm{MH}(0) < 0$ from Proposition 1, $\mathrm{MH}(\cdot)$ is continuous and $\lim_{x\to+\infty}\mathrm{MH}(x) = +\infty$, there exists $e^*_{\mathrm{MH}} > 0$, such that $\mathrm{MH}(e^*_{\mathrm{MH}}) = 0$.

Second-order conditions are verified because of the convexity of the maximand.

Finally, from (15), it is immediate that $\alpha^* < 1$. Besides, since $(1-\alpha^*(e^*_{\mathrm{MH}}))(e^*_{\mathrm{MH}}/(1+\alpha^*(e^*_{\mathrm{MH}})e^*_{\mathrm{MH}}))rL(r^*) = B^*$, $\alpha^*(e^*_{\mathrm{MH}}) < 0 \Rightarrow e^*_{\mathrm{MH}} < 0$, which is absurd. Hence, $\alpha^*(e^*_{\mathrm{MH}}) \geq 0$.

And $e^* > 0$ since, the right hand side in (A.10) is negative for $e^* = 0$ and increasing in e^*.

To show that e^*_{MH} exerted in equilibrium is increasing in B^*, just notice that $\mathrm{MH}(e)$ is increasing at $e = e^*_{\mathrm{MH}}$ and MH is decreasing in B^*. Therefore, $(\partial e^*_{\mathrm{MH}}/\partial B)|_{B=B^*} > 0$. Moreover, e^*_{MH} is decreasing in w because $\mathrm{MH}(e)$ is increasing in w.

A.6. *Proof of Proposition 4*

From the definition of e^*_{MH}, we can write:

$$we^{*3}_{\mathrm{MH}} + 2we^{*2}_{\mathrm{MH}} - e^*_{\mathrm{MH}}\left[\left(\frac{B^*}{L(r)+r}\right)L(r) - w\right] - B^*\frac{B^*/L(r)+r}{r} = \mathrm{MH}(e^*_{\mathrm{MH}}, r) = 0$$

From the definition of e^*:

$$rL(r)e^* - (1+e^*)we^* - B^* = 0$$

which is equivalent to:

$$we^{*2} + e^*[w - rL(r)] + B^* = N(e^*, r) = 0$$

where B^* is a constant independent of e^* (and e^*_{MH}).

Hence,

$$\mathrm{MH}(e,r) - N(e,r) = we^3 + we^2 - B^*e - B^*\frac{B^*/L(r) + 2r}{r} \tag{A.15}$$

First notice that $\mathrm{MH}(0,r) < 0$ and $N(0,r) > 0$, $\mathrm{MH}''(\cdot,r) > 0$, $N''(\cdot,r) > 0$. Also note that $N(\cdot,r)$ and $\mathrm{MH}(\cdot,r)$ are continuous functions.

Define w^c as the value of w such that $\mathrm{MH}[e(w^c),r] = N[e(w^c),r] = 0$.

From the definition of e^*, and defining $Z = rL(r) - w^c$, w^c satisfies the following expression:

$$e^*(w^c,r) = \frac{Z + \sqrt{Z^2 - 4Bw^c}}{2w^c}$$

From the participation constraint in (A.2), $(\alpha e/(1+\alpha e))rL(r) \geq we \Rightarrow rL(r) > w\ \ ,\forall w$. Hence, $Z > 0$.

Plugging e^* into (A.15) results:

$$\begin{aligned}\mathrm{MH}(e^*,r) - N(e^*,r) &\\ = \frac{1}{4w^2}[2Z^3 - 8wB^*Z + 2Z^2w - 4w^2B^*] &+ \frac{1}{4w^2}[2Z^2 - 4wB^* + 2Zw]\sqrt{Z^2 - 4B^*w}\\ - B^*\frac{B^*/L(r)+2r}{r}&\end{aligned} \tag{A.16}$$

$$\begin{aligned}\mathrm{MH}[e^*(w^c),r] &- N[e^*(w^c),r]\\ = \frac{1}{4(w^c)^2}&[2Z^3 - 8w^cB^*Z + 2Z^2w^c - 4(w^c)^2B^*]\\ + \frac{1}{4(w^c)^2}&[2Z^2 - 4w^cB^* + 2Zw^c]\sqrt{Z^2 - 4B^*w^c} - B^*\frac{B^*/L(r)+2r}{r} = 0\end{aligned} \tag{A.17}$$

It is clear that $\mathrm{MH}(e^*,r) - N(e^*,r)$ is decreasing in w since both terms in brackets are decreasing in w. Therefore, $\mathrm{MH}(e^*,r) - N(e^*,r) > 0$ for $w < w^c$, $\mathrm{MH}(e^*,r) - N(e^*,r) < 0$ for $w > w^c$. Additionally, $\mathrm{MH}[e^*(w),r] - N[e^*(w),r]$ is continuous for $w > 0$ and $\mathrm{MH}[e^*(w),r] - N[e^*(w),r] < 0$ for $w = rL(r)$, so $w^c < rL(r)$.

Hence, for $w > w^c$, it must be $e^*_{\mathrm{MH}} > e^*$.

A.7. Proof of Corollary 2

First notice that w^c is implicitly defined from $\mathrm{MH}[e^*(w^c)] - N[e^*(w^c)] = 0$, which is decreasing in w^c. Clearly, it is also decreasing in B^*. Therefore, $(\partial w^c/\partial B^*) < 0$ and:

$$\frac{\partial w^c}{\partial d} = \frac{\partial w^c}{\partial B^*}\frac{\partial B^*}{\partial d}$$

Using (13):

$$\frac{\partial B^*}{\partial d} = \frac{\partial B^*}{\partial e^*}\frac{\partial e^*}{\partial d} = [rL(r) - (1+2e)w]\frac{\partial e^*}{\partial d}$$

The first term in brackets is negative from (A.14). Deriving (A.14) as an implicit function of e^* and d, yields $(\partial e^*/\partial d) > 0$. Therefore, $(\partial B^*/\partial d) < 0$, which proves the first statement.

In the same way:

$$\frac{\partial w^c}{\partial \delta} = \frac{\partial w^c}{\partial B^*}\frac{\partial B^*}{\partial \delta} = \frac{\partial w^c}{\partial B^*}\frac{\partial B^*}{\partial e^*}\frac{\partial e^*}{\partial \delta}$$

And $(\partial e^*/\partial \delta) > 0$ from (A.14), which proves the second statement.

And finally, the debt-to-equity ratio equals:

$$\frac{D}{K_1} = \frac{dL(r)}{B^*}$$

Since w^c increases with d and decreases with B^*, the fourth statement holds.

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