Optimal Regulation, Executive Compensation and Risk Taking of Financial Institutions

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Abstract
The paper analyzes the effects of two regulatory tools, cap on banker’s equity based compensation and upper bound on a bank asset risk through supervision and regulation of its activity. The analysis is based on an equilibrium which is the result of strategic interactions of three stakeholders: (1) regulators (e.g. FDIC, OCC), (2) shareholders of financial institutions, and (3) management. Regulators put into place cap either on executive compensation or on asset risk; shareholder chooses levels of compensation; and management chooses the level of asset risk. We show that it can be possible to achieve the socially ‘optimal’ level of financial risk taking, which trades off the benefit of a well-functioning financial sector with the expected social cost of financial distress, by either setting upper bound on asset risk or on equity based compensation. However, if the regulator is limited in its ability to enforce such limits, capping equity based compensation is less efficient tool than setting an upper limit on asset risk. Moreover, if information about management’s preferences is incomplete, employing more than one policy tool may be optimal.

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1. Introduction

Excessive risk taking by financial institutions is considered one of the major causes of the 2008 financial crisis. The increase in asset risk was clearly identified by regulators, market participants and policymakers (Brunnermeier, 2009). There are two main approaches regarding the factors that brought about the observed increase in asset risk and resulting impairment of financial stability. The first is the increase in executive pay with a dominant component of equity-based compensation (Bebchuk, and Spamann, 2010; Bebchuk et al., 2010; Bolton, Mehran and Shapiro, 2011). The second focuses on supervisory inertia: there may have been inadequate supervisory review processes and low enforcement of existing laws and regulations (Blanchard, 2008; Caprio, Demirgüç-Kunt and Kane, 2010; Delis and Staikouras, 2011).

As a response to the crisis and to its potential causes policymakers initiated reforms that aimed to strengthen the resilience of financial institutions and markets. The Basel III accord adopted more stringent regulation regarding capital and bank activities. The Dodd-Frank Wall Street Reform and Consumer Protection Act (2010)\(^1\), prohibits financial institutions from adopting any incentive plan that regulators determine encourages inappropriate risks by covered financial institutions. However, no stringent regulation on executive pay package were adopted till recently, where the European Union adopted, in 2013, a provision which limits the amount of bankers’ bonuses to the amount of fixed remuneration.

Still, the issues of the social optimal level of asset risk and executive compensation structures as well different policy measures need to be further examined. First, what is the risk taking motivation of bank management under (a) different structures of compensation, (b) capital structure, and (c) limits set by regulators on asset risk and/or on executive compensation.

\(^1\) See the Consumer Protection Act (2010), in Part (b) of Section 956.
Second, what are the tools regulators can and should use to induce owners and executives of financial firms to achieve the public optimal level of asset risk? Should regulation focus on executive pay packages or on more traditional regulatory policy tools such as direct control of bank risk taking? More generally, are these two policy tools complements or substitutes? In this context it is important to note that the public optimal level of risk (represented by a benevolent regulator) may differ from the private optimal (bank owner and executive).

To address these questions, we present a simple equilibrium model of financial regulation and stability using an option based approach. The market imperfection in our model steams from the limited ability of regulators to enforce the optimal level of asset risk of financial institutions. Thus the regulator is using imperfect instruments to affect the level of asset risk, which is the outcome of choices made by stockholders and management. Management chooses the level of asset risk, stockholders determines the executive’s pay in the form of ownership share in the bank, and, given these choices, the benevolent regulator, who tries to maximize social welfare, limits asset risk and/or executive ownership. Using our model we find the equilibrium levels of asset risk, executive ownership, and the regulatory limits on asset risk or on executive compensation.

The equilibrium results of our model provide a setting to understand and interpret recent developments in the behavior of the financial sector: pre-crisis excessive risk-taking, and low levels of lending (credit freeze) during and after the 2008 crisis. In addition to these positive aspects of our model, we also derive normative policy implications. We find the optimal design of prudential regulation under different scenarios, deriving the appropriate mix of policy tools as well as their interactions.
In our model there are three claimholders that can affect asset risk. The stockholder is a residual claimholder, where the value of her position increases with asset value and asset risk (Jensen and Meckling, 1976; Galai and Masulis, 1976). The public, as represented by a benevolent regulator, has a position made up of two components. The first is a positive payoff from *tax payments* by banks. A possible broader interpretation of this component is the social welfare created by a well-functioning banking system (Demirgüç-Kunt and Maksimovic, 1998; Wurgler, 1999; Gertler, 1988; and Levine, 1997). The value of this position increases with bank asset value. The second component is a negative payoff in the form of *deposit insurance*. In a broader sense, this can be interpreted as the social cost of financial distress (Merton 1977, Ronn and Verma, 1986). We show that the value of the public’s position may have a global maximum with respect to asset risk. This provides a motivation for the regulator to avoid both excessive risk-taking as well as risk avoidance (“credit freeze”).

Management’s position is also composed of two components. The first is *equity-based compensation*, where its value increases with bank assets. The second component is a *loss due to bank failure*. This component may include “inside debt” i.e., an executive’s uninsured pension benefits that would be foregone (Edmans and Liu, 2011; Gerakos, 2007; Sundaram and Yermack, 2007; Bolton, Mehran and Shapiro, 2010), reputation costs (Fama, 1980; Hirshleifer and Thakor, 1992), and loss of specific human capital (Gilson, 1989; Graham et al., 2013). Since these two components have opposite signs with respect to asset value, the relationship between the executive’s position and asset risk may be humped shaped with a single global maximum. However, the relationship may also be upward sloping so that the position is maximized by
choosing the highest possible level of asset risk. Furthermore, as leverage increases the level of asset risk which maximizes the value of the position decreases.\textsuperscript{2}

We analyze the strategic interaction between the different claimholders. First, we consider the case where the regulator can enforce any limit on asset risk and find that in equilibrium the chosen level of asset risk maximizes social welfare. Next, we examine the more realistic case where the regulator has limited ability to enforce the maximum level of asset risk.\textsuperscript{3} In this case we obtain an equilibrium solution with both excessive risk taking and a greater equity base compensation. That is consistent with the excessive risk taking in financial institutions observed prior to the 2008 financial crisis. The analysis demonstrates that excessive risk taking is a result of both regulatory inertia and the structure of executive pay package. We further demonstrate the need to adjust regulations of financial institutions to changes in the leverage ratio – as leverage increases, as was the case during the crisis, the limit on asset risk should be reduced.

Because of the evidence of limited regulatory ability to enforce limits on asset risk, we consider an alternative regulatory tool - a limit on equity based compensation (ownership), and initially we assume that the regulator can enforce this limit. We show that resulting equilibrium solution is identical to the case of a regulatory limit on asset risk. Thus, the policymaker should consider the cost and benefits of the two measures.

The drawback of using limit on executive ownership as a tool to control asset risk is demonstrated regarding the potential loss of the executive due to bank failure. The regulator and

\textsuperscript{2} In our analysis we generalize the analysis by Sundaram and Yermack (2007), who consider the special case where executive compensation includes only stock and leverage has no effect on risk taking.

\textsuperscript{3} Since over the past decades, as the size and complexity of financial firms have increased, the ability of regulator to control banks asset risk became more difficult (Berger, Davies, and Flannery, 2000; DeYoung et al., 2001; and Evanoff and Wall, 2000).
the executive may have different estimate of the loss due to bank failure, which is composed of intangible components that are difficult to estimate. In the case of heterogeneous beliefs the effectiveness of this tool may be impaired. The regulatory limit on executive ownership would motivate the executive to choose too low or too high levels of asset risk. This may be an additional explanation for the excessive risk taking prior to the crisis and to the observed risk avoidance during the crisis (Ivashina and Scharfstein, 2010).

As a conclusion of the above discussion we finally analyze the case where the two policy tools are used simultaneously, i.e., where the regulator has a limited ability to enforce both tools. We show that applying the two policy tools will increase social welfare in the case of heterogeneous beliefs.\(^4\)

The rest of this paper is organized as follows: Section 2 briefly discuss the most related literature. Section 3 presents the analysis of the risk taking motivation of all claimholders and derives the valuation of their positions. An equilibrium solution for the chosen level of asset risk, executive ownership and regulatory limits on the level of asset risk is presented in Section 4. The equilibrium solution is calculated on Section 5, where now the regulator limits executive ownership. The analysis is also extended to relax the assumption of homogenous beliefs regarding the potential loss of the executive due to bank failure. Section 6 concludes.

2. Related Literature

The presented work relates to both the literature on micro prudential and macro prudential regulation, since we explore the optimal mix of two traditional microrudential policy tools: limit on assets risk and limit on executive ownership and analyze their effect on the welfare of the

\(^4\) Using the two policy tools simultaneously has an added cost which may offset the benefit of using more than one policy tools. However, such analysis is beyond the scope of our paper.
financial system as a whole. While the literature on these two general fields is very broad, the effect of regulating banker pay and its interaction with more traditional regulatory measures is smaller, but developing quickly.

The earlier literature focuses on the agency problem between shareholders and managers, rather than on that between shareholders and regulators. Therefore, many policy suggestions aim at aligning the interests of shareholders and managers, which may come at the price of raising risk shifting incentives. Jensen and Meckling (1976) and Galai and Masulis (1976) show that equity-linked pay fails to deliver optimal risk choice when the debt market cannot observe the riskiness of the chosen project. Sundaram and Yermack (2007) consider the risk taking motivation of an executive given both the equity based compensation and inside debt, which is part of the wealth that an executive can loss in a financial distress. In an empirical paper, Anderson and Core (2013) use a similar method to estimate executive risk taking. As in our paper, the equity based compensation is represented by a call option and the potential loss in default by a put option. In this paper, we expand this framework for equity based compensation other than stock, and thus in our work leverage affects the level of risk. Moreover, we relate specifically to banks, by introducing a benevolent regulator who tries to maximize social welfare and executive ownership is not exogenous in our work.

The implications of agency problems, management compensation and risk-taking in banking received a close attention after the 2008 financial crisis where most papers focused on explaining excessive risk taking chosen by managers as a result of competition between risk neutral banks on talented bankers which are risk averse (Acharya et al., 2011; Acharya and Volpin, 2010; and Bannier, Feess and Packham, 2012). In line with this literature, Thanassoulis (2012) suggests that competition for bankers induces negative externality driving up bankers'
compensation and implicitly also the default risk of rival banks. Our paper differs from this strand of literature since the main economic imperfection that leads to excessive risk taking in our paper is the limited ability of the regulator to control either assets risk or executive pay package. Moreover, these papers assume that risk-neutral banks compete for risk-averse manager, while our model is “preference free” and the risk is determined at equilibrium according to the positions and decisions of the claimholders.

A different approach is presented by Hakenes and Schnabel (2014) who relates executive pay to corporate governance problems and the weakness of shareholder rights. They suggest that a sufficiently large increase in bailout perceptions makes it optimal for a welfare-maximizing regulator to impose caps on bank bonuses. Not like in our paper, social welfare is measured in terms of the value of deposits only and not as in our work, where the value of a well-functioning financial system is considered as well as suggested by Korinek and Kreamer (2014).

This paper also belongs to the general literature that studies how the design of executive compensation affects risk taking decisions in banking and how the design of such rules and instruments can enhance social welfare. John, Saunders and Senbet (2000) argue that banks’ risk taking can be improved by making the insurance premiums that a bank pays a direct function of the parameters of the compensation contract. Bolton, Mehran, and Shapiro (2010) specifically model financial firm CEOs’ risk taking incentives, showing that tying CEO compensation to a measure of the firm’s default risk could reduce firm risk taking. While the usage of inside debt can reduce asset risk, the analysis in our paper is broader and the aim of the regulator is to maximize social welfare, a target which is different from maximizing the value of deposits or minimizing risk. Besley and Ghatak (2011) study the effect of bonus taxation and find that the
optimal bonus structure can be achieved by a combination of a regulation on the structure of bonuses and a tax on their level.

3. Decision makers: their positions and sensitivities to changes in asset risk

In this section we derive the value of the claimholder’s position. For each of the claimholders (the public, stockholders, and executives) we specify their claims to bank assets and then analyze how their payoffs depend on asset risk. We discuss how the decisions of any claimholder can affect the value of the position of the other claimholders. To demonstrate the theoretical results, we calibrate the model to data that are typical to US banks over the period before and during the 2008 crisis. The base case parameters are described in Table 1 and justified in Appendix 3.

We consider a financial institution that is financed by an equity $S$, secured deposits, maturing at time $T$, with face value $F^D$, and subordinated debt with face value of $F^S$ with the same maturity. We assume that asset value follows a geometric Brownian motion and calculate the values of the various claims (discussed below) using the standard Black and Scholes (1973) and Merton (1974) pricing equations (see Appendix 1).

3.1. The Public

An essential market imperfection introduce to our model is incomplete insurance market between bankers and the rest of the society (Korinek and Kreamer, 2014). More generally, a sufficient condition is that the holdings of bank equity are not proportionally distributed across the financial elite and the rest of society. Thus, the position of the public has two components. The first component is a positive payoff from tax collected from the residual assets of the firm if debt is fully paid. A possible broader interpretation of this payoff is the welfare effect which is
created by a well-functioning banking system. We assume that at debt maturity, if asset value exceeds the total face value of debt ($F^D + F^S$), a fraction $\tau$ ($0 \leq \tau \leq 1$) of the residual value, the difference between the value of the financial institution’s assets and the total value of debt, is paid to the public.

The second component is a negative payoff that is paid in the event of default to the secured depositors. This deposit insurance is held by the depositors. It is paid if at maturity the value of the financial institution’s assets lies below the face value of deposits. In such an event, the deposit insurer pays the difference between the face value of deposit and the value of assets. The total position of the public at maturity is expressed as:

$$G_T = \tau \max(V_T - F^D - F^S, 0) - \max(F^D - V_T, 0).$$

(1)

The position of the public can be replicated by two options. The first is $\tau$ units of a long call position on the value of the bank’s assets with a strike price equal to the total face value of debt, and the second is a short put option with a strike price equal to the face value of the insured deposit, $F^D$. The value of the position can be written as:

$$G = \tau \text{Call}(V, F^D + F^S, \sigma) - \text{Put}(V, F^D, \sigma)$$

(2)

If we define the leverage ratio of the financial institution, as in Merton (1974) being equal to $LR = ((F^D + F^S)e^{-\rho T})/V$, then we can normalize the total face value of debt to one and express asset value in terms of leverage: $V = 1/(LR e^{-\rho T})$. Thus, we can relate in our analysis to leverage and asset value as inverse.

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The pricing of the different options and position is presented in Appendix 1.
Figure 1 Panel A plots the payoff of debt at maturity for different asset values. The position is known as a “risk – reversal” position, which is composed of a short put option and a long call option with a higher strike price.

**Theorem 1:** The public’s position may have a global maximum with respect to asset risk if the tax rate is positive and the size of subordinated debt is positive. All else equal, the level of asset risk that maximizes the public position increases with the size of subordinated debt and the tax rate and decreases with total leverage.

**Proof:** See appendix 2.

The two components of the public position have opposite effects to asset risk. As asset volatility increases, both the expected value generated from tax collection as well as the cost of deposit insurance increase. What we show is that, for certain parameter combinations, there can be levels of volatility for which these two effects exactly offset. This level of bank asset volatility is what we refer to as the ‘optimal’ level of risk (from the perspective of social welfare).

Panel A of Figure 2 presents the value of the public position with respect to asset risk for different levels of leverage. In our example, the quasi leverage ratio between debt and assets is equal to 0.92, the subordinated debt is 6% of the total face value of debt, all debt instruments mature in one year and the risk-free rate is equal to 3.5%. All other parameters are at their base case values as listed in Table 1, unless stated otherwise. The motivation for choosing these specific levels is explained in Appendix 3.

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6 All other parameters are at their base case values as listed in Table 1, unless stated otherwise. The motivation for choosing these specific levels is explained in Appendix 3.
incentive and the leverage of financial institutions (Kim and Santomero, 1994). Furthermore, the results are in line with the financial literature which points out that bank depositors are indifferent to their banks’ risk taking since deposits are insured by the government, and regulators are left with the task of constraining risk taking by banks (Houston and James, 1995).

Furthermore, if leverage is increased to 0.95 the level of risk which maximizes the payoff of the public decreases to 7.1% (See Figure 2 and Table 2) and thus social welfare is maximized at a lower level of leverage. This relationship highlights the fact that one rule does not fit all and a benevolent regulator should consider a bank capital structure while limiting its level of risk as discussed at Sections (4) and (5).

3.2. Management

The executive’s position also has two different components which are sensitive to the value of the financial institution’s assets: equity-based compensation and loss due to bank failure.\(^7\) We assume that the executive holds \(\alpha\) units of equity-based compensation, which has a positive payoff at maturity equal to the difference between the value of assets and a strike price of \(H\), which is equal to or greater than the total face value of debt, \(H \geq (F^D + F^S)\). In the special case where the equity-based compensation includes only stock the strike price is equal to the total face value of debt.\(^8\) The second component is composed of \(\beta\) (0 ≤ \(\beta\) ≤ 1) units of loss due to bank failure, that may include “inside debt,” an executive’s uninsured pension benefits that would be forgone in the event of failure, loss of future employment opportunities, and loss of reputation. Since these losses tend to be subordinated to the secured deposits in financial

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\(^7\) We do not consider other components of executive pay that are not sensitive to asset risk.

\(^8\) We assume that, in the case of executive stock options, the dilution effect is relatively small and has only a secondary effect on the other liabilities that were issued by the financial institution.
institutions, we assume that the payoff at maturity is equal to $\beta$ times the difference between the total face value of debt ($F^D + F^S$) and firm assets. The executive payoff at maturity can be expressed as:

$$E_t = \alpha \max(V_t - H, 0) - \beta \max(F^D + F^S - V_t, 0). \tag{3}$$

The value of this position can be replicated by two options: a long position in $\alpha$ units of a plain vanilla call option with a strike price of $H$ and a short position in $\beta$ units of a put option with a strike price equal to the total face value of the bank’s debt:

$$E = \alpha \text{Call}(V, H, \sigma) - \beta \text{Put}(V, F^D + F^S, \sigma) \tag{4}$$

Figure 1 Panel C plots the payoff of the position as a function of asset value. Once again we have a “risk – reversal” position where the components have opposing effects when volatility changes. When risk increases the value of equity-based compensation increases while the value of inside debt decreases, resulting in larger expected losses for the executive.\(^9\) Therefore, it is again possible for a global maximum to exist.

**Theorem 2:** The executive’s position has a global maximum with respect to asset risk if the units of equity based compensation, $\alpha$, is larger (smaller) than the number of units of loss due to bank failure, $\beta$, and the total face value of debt, $F^D + F^S$, is larger (smaller) than the strike price of the equity based compensation, $H$. Otherwise, there is no internal maximum to the position value.

**Proof:** See Appendix 2.

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\(^9\) The pricing of the different options and position is presented in Appendix 1.
All else equal, the level of asset risk which maximizes the value of the executive’s position increases with the value of equity based compensation and decreases with the value of loss due to bank failure. The results of the calibrated model are shown in Figure 3 where the value of the executive position is shown with respect to asset risk for leverage ratio of 0.92, as in our base case. For relatively low and medium levels of equity based compensation we consider the case where the executive hold 0.15%, 0.30% of the financial institution stocks, the relationship between the value of the position and asset risk is hump shaped with a single global maximum.\textsuperscript{10} The maximum value of the executive’s position increases with the units of equity based compensation. The maximum is achieved at asset risk of 4.59% and 6.54% for executive ownership of 0.15% and 0.30% respectively. When executive ownership increases to 0.6% the relationship between the value of the executive’s position value and asset risk becomes upward sloping and there is no global maximum for the value of the position. Panel C of Figure 2 presents the effect of leverage on the value of asset risk. When leverage increases to 0.95 the maximum is achieved at level of asset risk of 4.43%, more than 2.12% below the maximum level when leverage is equal to 0.92.

A special case is when the strike price of the equity based compensation is set to equal the financial institution leverage ratio, as in Sundaram and Yermack (2007). In this case, the executive has only compensation in the form of common stocks and leverage has no effect on the risk taking motivation of the executive. The relationship between the value of the executive’s position and asset risk would become either linearly increasing or decreasing. If the number of

\textsuperscript{10} John, Mehran and Qian (2010) calculate the median value of CEO ownership in financial institution as being equal to 0.29%.
units of equity based compensation is greater (smaller) than the number of units of loss due to default (α>β) the value of the position would always increase (decrease) with asset risk. The value of the position is insensitive to asset risk when the number of units of equity based compensation is equal to the number of units of loss due to bank failure.

3.3. Stockholders

The stockholder position includes the residual value of the financial institution after paying taxes and allocating equity based compensation to the executive. Therefore, the value of the stockholder is decreasing in the tax rate and in the units of equity based compensation. The stockholder payoff at maturity \( T \) is equal to

\[
S_T = (1 - \tau) \max(V_T - F^D - F^S,0) - \alpha \max(V_T - H,0) .
\]

The value of this position can be replicated by two options. The first is a long position of \((1-\tau)\) units of a plain vanilla call option with a strike price equal to the total face value of debt. The second is a short position of \(\alpha\) units of a plain vanilla call option with a strike price equal to \(H\), i.e., the strike price of the equity based compensation. The executive’s payoff at debt maturity with respect to the financial institution’s asset value is presented in Panel B of Figure 1. The current value of the executive position can be written in options term as follow:

\[
S = (1 - \tau) \text{Call}(V, F^D + F^S, \sigma) - \alpha \text{Call}(V, H, \sigma) .
\]

In the special case, where the executive has only equity compensation the stockholder position can be replicated by a single option:

\[
S = (1 - \alpha - \tau) \text{Call}(V, F^D + F^S, \sigma)
\]
The value of the stockholder position always increases with asset volatility and decreases with the tax rate and the percentage of executive ownership and leverage as presented in Panel B of Figure 2.

4. Risk-taking and executive compensation with regulatory limits on asset risk

In this section we analyze the effect of an upper bound on asset risk set by the regulator on the optimal decisions and the derived payoff of each of the claimholders. First, we assume that the regulator sets limit on the maximum level of asset risk and there is a full compliance by the different claimholders. Furthermore, we show the equilibrium solution under different bank’s leverage ratios. Finally, we analyze the equilibrium solution in case where the ability of the regulator to impose maximum level on asset risk is limited.

The equilibrium solution for the decision variables and the stakeholders’ positions is determined in three steps. First, the executive chooses the level of asset risk that maximizes the value of her position, $\sigma^*$. This decision is taken after receiving information about the limit on asset risk set by the regulator, and the units of equity based compensation (managerial ownership), determined by the stockholder. Next, stockholders maximize their holding by determining the number of units of equity based compensation which is awarded to the executive, $\alpha^*$, given the regulatory maximum limit on asset risk. Lastly, after analyzing the decisions of the stockholders and the executive, the regulator chooses the limit that maximizes the value of the public holding, $\sigma_{UBound}^*$. If each claimholder has chosen a strategy and no other claimholders can benefit by changing its strategy, while the other claimholders keep theirs unchanged, then the current set of strategy choices and the corresponding payoffs constitute a
Nash equilibrium. We define the set of parameters and payoffs in such an equilibrium as:
\[
(\sigma^*, \alpha^*, \sigma_{\text{UBound}}^*, (E^*, S^*, G^*))^{11}.
\]

We use a framework of a non-cooperative game and thus one claimholder cannot bail out the other and vice versa. Moreover, since we assume a complete information environment, where each claimholder is fully familiar with the payoff function and the possible strategies of all other claimholders, the equilibrium results of a sequential game would be identical to the results of simultaneous game. Thus, the starting point of the game has no effect on the results in equilibrium and we solve the equilibrium problem by a backward induction that start with any of the players.

4.1 Unrestricted ability of regulator to set maximum asset risk

In this baseline case all claimholders have full control of their chosen strategy and can immediately respond to changing market conditions. Moreover, the stakeholders’ domain of choice is unbounded. Therefore, the stockholders can choose any level of executive’s ownership where \( \alpha \in [0,1] \), the regulator can impose any upper bound on asset risk and thus \( \sigma_{\text{UBound}} \in [0, \infty) \) and the executive can decide about any level of asset risk between zero and the upper bound on asset risk which is set and enforced by the regulator, \( \sigma \in [0, \sigma_{\text{UBound}}] \).

**Result 1.** Assuming internal solutions to the public and management maximization problems (see Theorems 1 and 2), if claimholders have full control of their decisions, in equilibrium, the upper limit of asset risk set by the regulator would be the level that maximizes its position, and

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11 If each claimholder has chosen a strategy and no other claimholders can benefit by changing its strategy while the other claimholders keep theirs unchanged, then the current set of strategy choices and the corresponding payoffs.
the chosen level of asset risk by the executive would be equal to that level as well:

\[ \sigma^* = \sigma^*_{U\text{Bound}} = \sigma^*_{G\text{ovMax}}. \]

We outline the proof this result in three steps. First, we find the risk level that maximizes the value of the public position:

\[ \sigma_{G\text{ovMax}} = \arg \max G(\sigma, V, F^D, F^S). \quad (8) \]

In the case that the government position has a global maximum with respect to assets risk, as described in **Theorem 1**, the solution of Equation (8) can be calculated by setting the derivative of the government position with respect to assets risk to zero:

\[ \frac{\partial G}{\partial \sigma} \bigg|_{\sigma = \sigma_{G\text{ovMax}}} = 0 \quad (9) \]

Relying on the standard option valuation model as presented at Appendix 1, the derivative at Equation (9) can be derived as follow:

\[ \frac{\partial G}{\partial \sigma} = \frac{\tau S \sqrt{T}}{\sqrt{2\pi}} e^{-\frac{d(F^D + F^S)^2}{2}} - \frac{S \sqrt{T}}{\sqrt{2\pi}} e^{-\frac{d(F^S)^2}{2}} = 0 \quad (10) \]

where:

\[ d(K) = \frac{\ln(S/K) + (r + \frac{\sigma^2}{2})T}{\sigma \sqrt{T}} \]

The benevolent regulator would limit asset risk to this level and thus at the second step, after deriving the equilibrium level for the upper bound of asset risk, we calculate the units of equity.
compensation that maximize the value of the stockholder position at this level of risk. The value of the stock increases with asset risk. However, the level of asset risk is bounded at the level of $\sigma_{Ubound}^*$. Moreover, as the units of executive ownership increase, the value of the stockholder’s position decreases. Therefore, stockholder will award the minimum ownership to management that still motivates them to take a level of risk which is equal to the regulatory upper bound of asset risk. Technically, this is done by equalizing to zero the derivative of the executive position with respect to asset risk, while fixing the level of asset risk to the regulatory upper bound of asset risk, $\sigma_{Ubound}^*$:

$$\frac{\partial E(\sigma = \sigma_{Ubound}^*)}{\partial \sigma} \bigg|_{\sigma = \sigma_{Ubound}^*} = 0$$

(11)

The derivative of Equation (11) can be calculated as follow:

$$\frac{\partial E(\sigma = \sigma_{Ubound}^*)}{\partial \sigma} = \frac{\alpha^* \sqrt{T} e^{\frac{d(H)^2}{2}}}{\sqrt{2\pi}} - \frac{\beta \sqrt{T} e^{\frac{d(F^0 + F^3)^2}{2}}}{\sqrt{2\pi}} = 0$$

(12)

We refer to the optimal level of ownership as $\alpha^*$. Third, the executive, given its ownership of $\alpha^*$ and a limit on the maximum level of asset risk equal to $\sigma_{GovMax} = \sigma_{Ubound}^*$ would choose the maximum level of asset risk $\sigma^* = \sigma_{Ubound}^*$ since the value of her position is maximized at that level of asset risk.

The calibration of the model to the base case parameters yields a level of asset risk of 8.33%, where the chosen level of asset risk is equal to the regulatory upper bound of asset risk (See Panel-A of Figure 2). The equityholder would compensate the executive with 0.388% of the firm’s stock (See Table 2). It should be noted, that if the regulator’s efforts to impose the upper
bound of asset risk are effective then the executive would be motivated to take this level of risk with any ownership which equal or greater than $\alpha^*$. For example, for the base case parameter, an executive ownership of 0.6% of the bank’s stock, as described in Panel C of Figure 3, would motivate the executive to take a risk which is equal to the limit on asset risk. However, such a choice would decrease the value of the stockholder position, since the same level of asset risk can be achieved by a lower level of ownership (0.388% as in Panel A of Figure 2).

The level of executive ownership which is awarded by the stockholder for different upper bounds of asset risk, $\sigma_{UBound}$ set by the regulator is studied at Panel-B of Figure 4. For relatively low levels of upper boundary of asset risk (between 0% and 3%) the stockholder prefers not to pay any equity based compensation, since the increase in stock value due to the higher level of risk is smaller than the decrease in value due to dilution. However, for any regulatory limit above 3%, it is optimal for the stockholders to award the executive the minimum level of ownership which would motivate them to take the maximum possible level of asset risk allowed by the regulator. The regulator, which is aware of this information, would set the upper bound of asset risk to be equal to the level that maximizes its holding, and in equilibrium, all the three would be equal: the regulatory upper bound of asset risk, $\sigma_{UBound}^*$, the chosen level of risk by the executive, $\sigma^*$ and the level of risk that maximizes social welfare, $\sigma_{GovMax}$.

4.2 The effect of leverage

The leverage of the financial sector in the period 2000 to 2008 remained almost constant (Kalemli-Ozcan, Sorensen and Yesiltas, 2012). However, during the 2008 financial crisis the leverage of many financial institutions increased as result of sizable declines in assets value and due to mainly to illiquidity of the financial markets. In this section we analyze the effect of a
change in leverage under complete claimholders’ control of the decision variables. As will be demonstrated here the effect of leverage on asset risk and executive ownership may be non-trivial.

**Result 2. If all claimholders have a full control of their decisions, in equilibrium, a financial institution’s asset risk would decrease with leverage and executive ownership would increase.**

The effect of leverage under this setting is presented in Figure 5. When leverage increases the public position is maximized with a lower level of asset risk and the limit on asset risk is thus reduced. However, in order to motivate the executive to take this level of asset risk, the stockholder has to increase the size of the equity based compensation, since the executive position is even more sensitive to asset risk than the position of the public. The public and the executive hold a risk reversal position, which becomes more sensitive to asset risk as its moneyness increases. The strike price of the loss in default component, held by the executive, is higher than the strike price of the deposit insurance, held by the public, and therefore it is closer to the forward value of the institutions’ asset and more sensitive to asset risk.

In the numerical example, leverage increases from 0.92 to 0.95, as a result of a decline of the value of assets. Under a leverage ratio of 0.95 the value of the public position is maximized at a lower level of 7.07% compare to a level of 8.33% before (Panel A of Figure 2 and Table 2). However, the executive, with a position that is more sensitive to changes in leverage than the public position, reduces asset risk from 8.33% to 5.64%, as presented in Panel-A of Figure 5. In order to maximize the value of the public position the regulator sets a new upper bound on the level of asset risk of 7.07%. The stockholder in response increases executive ownership to 0.45%, under such compensation the executive is motivated to take the maximum level of asset risk, which in turn maximizes the stockholder position (Panel B of Figure 5). Our results are
consistent with the Dot.com crisis of 2001. As a result of a decrease in the value of assets and increase in leverage of financial institutions, stockholders reacted by increasing the executives’ equity based compensation, either awarding them with more units of ownership or changing the strike of their stock options.

4.3 Restricted ability of regulator to set maximum asset risk

The ability of regulators to enforce an effective upper limit of asset risk on financial institutions may be restricted, especially for large and complex financial institutions. This may be due to “regulatory inertia,” caused either by inadequate supervisory review processes and/or leniency of law and regulation enforcement. In the following analysis we assume that the regulator is aware of its restricted power and the reactions of the other agents. Therefore, the regulator can only attain an upper bound of asset risk that is greater than the level of risk that maximizes the value of its position, i.e. \( \sigma_{UBound} \in [\sigma_{MinReg}, \infty) \), where: \( \sigma_{MinReg} > \sigma_{GovMax} \).

In such case, stockholder would increase the equity based compensation up to the point where the executive position reaches its maximum level at a level of asset risk, \( \sigma_{UBound} = \sigma_{MinReg} \).

As presented in Panel B of Figure 4, all else equal an increase of the upper bound of asset risk would lead to an increase of executive ownership. Moreover, as presented in Panel C of Figure 4, as the upper bound of asset risk increases the positions’ value of the executive and the stockholder would increase, while the value of the public position decreases below its global maximum value.

**Result 3.** If the minimum level that the regulator can set as an upper bound of asset risk is greater than the level which maximizes the position of the public, \( \sigma_{MinGov} > \sigma_{MaxGov} \), then at
equilibrium the executive would choose this level of asset risk: \( \sigma^* = \sigma_{\text{UBound}} = \sigma_{\text{MinReg}} \).

Consequently, executive ownership is greater than in the case where the regulatory limit on asset risk is equal to the level which maximizes the public position.

The stockholder, who is aware of the actual limit on asset risk \( \sigma_{\text{UBound}} = \sigma_{\text{MinReg}} \), and as in Section (4.1), finds the amount of equity based compensation, \( \alpha \), which maximizes the value of the executive position at that level of risk. Technically, this is done by equalizing to zero the derivative of the executive position with respect to asset risk, while adjusting the level of asset risk to the new higher regulatory maximum level. Since all else is equal, the executive would be willing to shift to a higher level of asset risk only for a greater equity compensation, thus in equilibrium executive ownership would be increased.

Result 3 is consistent with the excessive risk taking by financial institutions as observed prior to the 2008 financial crisis and with the increase in executive’s pay. The result shows that there are two necessary conditions for the executive to increase risk taking: an increase in executive equity based compensation and supervisory inertia.

We demonstrate these results numerically by the following example. Suppose all the data are identical to the base case parameters and the share of executive ownership is equal to 0.388% of the firm’s stock as in Section (4.1). However, in the current case, we assume that the regulator can only restrict asset risk to 11% or more, \( \sigma_{\text{UBound}} = \sigma_{\text{MinReg}} = 11\% \). At this level of risk stockholder would increase executive ownership from 0.388% to 0.462% and the executive, in response, would increase the level of asset risk to 11% (as compared to the level that maximizes social welfare - 8.33%). The value of the executive position would increase from 0.1726 to 0.217 and the stock value would increase from 58.90 to 63.58. However, this happen at the cost of
social welfare as the value of the public position would decline from 30.49 to 29.72 (See Table 2).

5. Equilibrium with a regulatory cap on equity-based compensation

The difficulties to control bank risk with traditional measures can lead to excessive risk taking by financial institutions, as described in Section (4.3). In this section, we show how regulatory limits on executive equity pay can replace (or augment) limits on risk taking to maximize social welfare.

5.1 Unrestricted ability of regulator to cap executive ownership

In this baseline scenario, as in Section (4.1), all claimholders have full control of their chosen strategy and they can immediately respond to changing market conditions. Since the regulator can impose any level of executive’s ownership maximum executive ownership can get any value where $\alpha_{UBound} \in [0,1]$.

**Result 4.** If claimholders have a complete control over their decisions, then in equilibrium, the cap on executive ownership, set by the regulator, would motivate the executive to choose a level of asset risk which equals the level that maximizes the position of the public, $\sigma_{MaxGov} = \sigma^*$. The amount of ownership awarded by the stockholders to the executive would be equal to the regulatory cap on executive ownership. $\alpha^* = \alpha_{MaxGov}^*$.

The equilibrium solution is calculated in three steps. As in Section (3.1), first the risk level that maximizes the value of the public position is found, $\sigma_{MaxGov}$. The regulator cap executive ownership, $\alpha_{UBound}^*$, at the level that maximizes the value of the executive position at the level of
risk which maximizes the public position and consequently social welfare. Next, the stockholder chooses to award this quantity of equity based compensation, since the increase in the value of the stock due to the higher level of asset risk more than offsets the decrease in value due to dilution and as a result: $\alpha^* = \alpha_{\text{Bound}}^*$. Note that the value of $\alpha_{\text{Bound}}^*$ equals to the value chosen by the stockholder in the case of complete regulatory control over asset risk (Section 4.1). Thus, the equilibrium results of an upper bound on asset risk and capping executive ownership are identical. However, capping executive ownership may be preferable over a limit on asset risk, since it usually has lower costs to the regulator and it is easier to enforce, as discussed in Section (4.2).

The results are demonstrated numerically by using the base case parameters, except that now the regulator sets a cap on executive ownership, rather than on asset risk. As in Section (4.1), the level of asset risk which maximizes the value of the public’s position is 8.33% for leverage ratio of 0.92 and for loss due to bank failure of 0.6 ($\beta=0.6$). At the next step, the regulator searches for the amount of equity compensation, $\alpha$, which maximizes the value of the executive position for asset risk of 8.33%, this level is equal to 0.388% of the financial institution’s ownership. The stockholder, who has a position which increases in value with asset risk, would award the executive with the maximum feasible amount of equity compensation (0.388%). Consequently, the value of the public position would be maximized with respect to asset risk, and equal to 30.49. The value of the executive position and the stock would be equal to 0.1726 and 58.90 respectively. At the case that leverage increases to 0.95, as in Section (4.2), the position of the public would be maximized at a level of 7.07%. However, due to the higher sensitivity of the executive position to leverage, the regulator would have to increase the limit on executive ownership to 0.452% in order to maximize the executive position at that level of asset risk.
risk. The value of the executive position would decrease to 0.0782 and the value of the public position and the stock would decrease to 19.57 and 39.12 respectively. These results are identical to the results in equilibrium in the case where claimholders have a full control of their decisions and the regulator can limit asset risk directly at any level.

5.2 Restricted ability of regulator to cap executive ownership

While capping executive ownership may be easier to impose than regulatory limits on asset risk, a restricted control over this limit might increase asset risk in a nonlinear way. Panel-A of Figure 4 shows that the relationship between the regulatory limit on asset risk and the actual chosen level of asset risk are linear, and consequently a limited ability of the regulator to control directly asset risk would end up in a proportional increase of the level of asset risk. However, in the case of limited ability of the regulator to control executive’s ownership stockholder may be motivated to increase executive ownership till the point in which the relationship between asset risk and executive position are upward sloping and there is no interior maximum, as described in Theorem 2. This result is shown in Panel-A of Figure 6, where the relationship between the regulatory limit on executive ownership and the actual chosen level of asset risk on equilibrium are convex and a relative small change in executive ownership may lead to a large change in the chosen level of asset risk. As a result, social welfare, as captured by the value of the public position, would decline sharply (Panel C of Figure 6).

Furthermore, the relationship between the regulatory cap on executive ownership and the actual ownership in equilibrium is first linearly increasing till a point in which the relationship between asset risk and the executive position becomes nonlinear. In such situation, the stockholder would stop awarding any further stocks to the executive, since it would not change her motivation to increase asset risk (Panel B of Figure 6).
An important question is what may be the potential causes for the actual regulatory cap on executive ownership and the level that maximizes the public position to differ. In the next section, we relax the assumptions of homogenous beliefs derive equilibrium solution for this case.

5.3 Heterogeneous beliefs about the executive loss in case of bank failure.

To demonstrate the effect of restricted regulatory ability to impose limit on executive ownership we relax the assumption of homogenous beliefs and we assume that the executive and the regulator have different beliefs regarding the loss of the executive in the case of bank failure, $\beta$. Consequently, each of them estimates differently the effect of a cap on executive ownership on the chosen level of asset risk.

Our definition of loss in the case of failure includes intangible assets of the executive as well as "inside debt". Intangible assets that decline in value when the bank fails include reputation of the executive and non-diversifiable human capital in the firm. It is difficult to find proxies for the value of intangible assets as they are not traded. Thus, claimholders may develop heterogeneous beliefs regarding their value. To show the effect of heterogeneous beliefs on the equilibrium results, we consider two possible scenarios, where the regulator has higher or lower estimate of this cost component relative to the executive.

**Result 5.** If the regulator has a lower (greater) estimate of the executive’s loss in case of bank failure than the executive, i.e., $\beta^E > \beta^G$, ($\beta^E < \beta^G$), then the cap on executive ownership set by the regulator would motivate the executive to choose a level of asset risk which is smaller (greater) than the level that maximizes the public position, $\sigma_{\text{MaxGov}} > \sigma^* \ (\sigma_{\text{MaxGov}} < \sigma^*)$. 


The strategic choice is calculated first, as in all previous cases, by finding the risk level that maximizes the value of the public position, $\sigma_{MaxGov}$. As in Section (4.1), the regulator then sets the amount of executive ownership, $\alpha^*$, that maximizes the value of the executive position at that level of risk. However, instead of using the amount of units of loss in bank failure as assumed by the executive, $\beta^E$, the regulator assume that the loss is smaller and equal only $\beta^G$, where: $\beta^E > \beta^G$. Since, all else equal, the amount of equity based compensation, $\alpha$, that maximizes the executive position increases with the loss in bank failure, $\beta^E$, as can be noted from the proof of Theorem 2, the limit on equity based compensation sets by the regulator, would lead the executive to choose a level of asset risk which is below the level that maximizes the holding of the public.

The results of the opposite case, where the regulator assumes a smaller loss in bank failure that the executive, $(\beta^E > \beta^G)$, is consistent with the post crisis behavior of many financial institutions. Executives in financial institutions became more aware of the potential loss of bank failure after the crisis and increased their estimate of this component (Guiso et al, 2013). This fact may explain the low level of risk taken by financial institutions and freeze in lending to households and businesses which was observed at the financial markets (Ivashina and Scharfstein, 2010).

We demonstrate these results numerically by the following example. Suppose all parameters remain unchanged, except that now the executive estimates the loss in financial failure to be 0.90% of assets value, while the regulator believes that the loss to be 0.6% of assets value. Consequently, as in Section (4.1), the regulator sets a limit on executive ownership of 0.388%. At the next step, the stockholders, aware of the limit on equity based compensation allocate the maximum possible ownership of 0.388%. Since the executive estimates her loss in
case of failure to be higher than the one estimated by the regulator, she will choose a smaller level of asset risk than the level which is optimal from the regulator. The executive would choose a level of 5.92% instead of 8.33%, the optimal risk level for the public (Table 3). The value of the chosen decision variables by the executive's results in a smaller value of the positions for all claimholders compared to the case of homogeneous beliefs. The public, stockholder and executive positions are equal to 55.79, 30.01 and 0.1675 respectively (Table 2), where in the base case the values were equal to 58.90, 30.49 and 0.1726 respectively.

The importance of the second case, where the regulator is assuming a smaller loss in financial distress than the executive, is important for demonstrating the potential high loss for the public in such a case. Suppose all the data are identical to the base case parameters, except that now the executive estimates the loss due to bank failure to be 0.45% of the value of assets, while the regulator believes the loss to be 0.6% of assets value. Consequently, as in Section (4.1), the regulator sets a limit on executive ownership of 0.388%. This level maximizes the value of the public position if the loss due to bank failure is 0.6%. The stockholder, aware of the limits on equity based compensation awards the maximum feasible ownership of 0.388%. The executive, figures out that under this compensation structure the value of asset risk which maximizes her holding is equal to 15.15% instead of 8.33%, according to the regulator estimation (Table 3). The value of the chosen decision variables result in greater position value for the stockholder and the executive compared to the case of homogeneous beliefs, where their position is equal to 72.34 and 0.1508 respectively. However, the value of the public position is sharply decreased to 25.83 from a maximum value of 30.49 (See Table 2).

5.4 Two policy tools when beliefs regarding the executive’s loss in financial failure are heterogeneous
At all the previous described cases we have shown that regulatory limit on executive ownership can be a perfect substitute for limitation on asset risk. However, combining the two policy tools can make the public better off.

**Result 6.** *If the regulator has a higher estimate of the executive’s loss in bank failure than the one of the executive, i.e., $\beta^E < \beta^G$, then introducing a limit on the maximum level of asset risk may make the public better off.*

In this case, the first three steps for finding the equilibrium solution are identical to the solution which is explained in Result 5: the regulator find the optimal level of asset risk that maximizes the value of its holding and limit executive ownership to a level that motivate the executive to take asset risk which is exactly equal to that optimal level, basing this calculation on its estimate regarding the executive loss in financial failure, $\beta^G$. Next, the executive estimates a smaller level of loss in financial failure, $\beta^E$, and as a result she would choose a level of asset risk above the level that maximizes the public position, as in Result 6, where $\sigma^*_{MaxGov} < \sigma^*$. However, if the government can impose by direct regulation a level of asset risk which is below $\sigma^*$, then the public is better off, even if this level of asset risk is above its optimal.

The results at equilibrium can be analyzed based on the previous case at Section (4.3), where limit on executive ownership is presented, by adding a second policy tool as well – direct regulation of asset risk. As in previous section, the executive underestimates the loss in bank failure compared to the regulator estimate and thus the equilibrium level of asset risk will be above the level that maximizes the public position and equal to 15.15%. However, if the regulator can enforce effectively a limit on asset risk which is below the level that the executive
would choose, then the value of the public position in equilibrium is greater than in the case of when only a limit on executive ownership is imposed.

While using simultaneously the two policy tools improve the position of the public at equilibrium, the effectiveness of using the two tools together depends on the added cost of using more than one policy tool. Such analysis which considers the cost versus the benefit of adding a second policy tool is beyond the scope of our paper. However, it is clear that the effectiveness of introducing a second policy tool increases with the degree of divergence in opinion between the executive and the regulator and the ability of the regulator to have reliable information about the executive estimate of her potential loss due to bank failure.

6. Conclusion

In this paper we develop a valuation model for the positions of the claimholders in a financial institutions, and we find the equilibrium solution for the level of asset risk chosen by the executive, who manage the bank, the level of executive’s ownership set by the stockholders, and the limits on asset risk and/or executive’s ownership set by the regulator. The paper objectives are both descriptive and normative, in that we seek to obtain insights into how existing regulatory policies affect the risk level which is chosen by financial institutions and how far this level is from the public optimal risk level, as well as the discussion on the optimal design of prudential regulation and the coordination mechanism between banks’ regulators.

First, we show that if the regulator can limit asset risk to any chosen level, in equilibrium, the maximum limit on asset risk set by a benevolent regulator would be the level that maximizes public welfare and the chosen level of asset risk by the executive equal to that level as well.
Moreover, as leverage increases the chosen level of asset risk decreases and executive ownership increases.

Second, we relax the assumption of a regulator who can bound asset risk to any level, and we show that if the regulatory limit on asset risk is above the level which maximizes the public position, then in equilibrium, the executive would choose that level. Consequently, executive ownership is greater than in the case where the regulatory upper bound on asset risk is equal to the level which maximizes the public position. These results have an explanatory implication for the debate regarding the causes of the 2007-2009 financial crisis, since we demonstrate that an increase in executive ownership is a necessary, but not a sufficient condition for an increase in a financial institution’s asset risk.

Third, we analyze the case where a limit on executive ownership set by the regulator is replacing the direct limit on asset risk. We show that the equilibrium solution in the case of a limit on executive’s ownership is identical to the case of a regulatory limit on asset risk, if the regulator can fully control these limits. Thus, supervising a bank asset risk and regulating executive compensation are perfect substitute and a regulator should choose the less costly and the more effective tool to supervise a bank activity. However, the deviation from the public optimal solution in equilibrium with imperfect regulatory control of this limit are higher than in the case of imperfect control of the limit on assets risk.

Fourth, we relax the assumption of homogeneous information regarding the executive loss in financial failure and assume heterogeneous beliefs between the executive and the regulator regarding the value of this component. When the regulator has a higher assessment than the executive of loss due to bank failure, the executive would choose a level of risk which is lower than the one maximizes the public position. These results are consistent with observed post
crisis levels of asset risk taken by many financial institutions, and may explain the freeze in lending to households and businesses, which was observed at the financial markets (Ivashina and Scharfstein, 2010). At the opposite case, if the regulator overestimates the executive’s loss due to bank failure, the executive would choose an excessive risk level above the level that maximizes the public position.

Finally, we demonstrate that incorporating the two policy tools, limit on asset risk and limit on executive ownership, can make public better off in the case of heterogeneous beliefs between the regulator and the executive regarding the potential loss of the executive due to bank failure.
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Appendix 1

The value of the replicating options

In this section the value of each position is calculated by using a plain vanilla option replicating method and the sensitivity of the position to the different factors that can affect its value is demonstrated as well. To model the value of these options we use the standard Black-Scholes and Merton (1973, 1974) assumptions where the value of the firm’s asset a follows a geometric Brownian motion, where the drift under the risk-neutral measure is equal to the risk-free rate $r$, and $\sigma$ is the instantaneous constant standard deviation of the assets’ rate of return. The general pricing equations for the call and put options can be expressed under the standard assumptions for risk-neutral contingent-claim valuation as:

$Call(T, K) = e^{-rT}VN(d(K)) - KN(d(K) - \sigma\sqrt{T}) \tag{1}$

$Put(T, K) = e^{-rT}KN(\sigma\sqrt{T} - d(K)) - VN(-d(K)) \tag{2}$

where $K$ is the option strike price, $N()$ is the cumulative normal density and the function $d(K)$ is defined as:

$$d(K) = \frac{\ln(V/K) + (r + \sigma^2 / 2)T}{\sigma\sqrt{T}} \tag{4}$$

Appendix 2

Theorem 1: The public’s position may have a global maximum with respect to asset risk if the tax rate is positive and the size of subordinated debt is positive. All else equal, the level of asset
risk that maximizes the public position increases with the size of subordinated debt and the tax rate and decreases with total leverage.

Proof: The public position is composed of $\tau$ units of long call option with a strike price of $F^D + F^S$ and a short put option with a strike price equal to the face value of the secured deposit $F^D$.

To find out the maximum value of the position we calculate first the derivate of the position with respect to asset risk:

$$\frac{\partial G}{\partial \sigma} = \frac{\pi \partial \text{Call}(V, F^D + F^S, \sigma) - \partial \text{Put}(V, F^D, \sigma)}{\partial \sigma}$$ (1)

$$\frac{\partial G}{\partial \sigma} = \frac{\pi V \sqrt{T}}{\sqrt{2\pi}} e^{\frac{d(V,F^D + F^S)^2}{2}} - \frac{V \sqrt{T}}{\sqrt{2\pi}} e^{\frac{d(V,F^D)^2}{2}}$$ (2)

where:

$$d(S,K) = \frac{\ln(S/K) + (r + \frac{\sigma^2}{2})T}{\sigma \sqrt{T}}$$ (3)

By rearranging equation (2) the derivatives can be decomposed to two components, where the first one is always positive:

$$\frac{\partial G}{\partial \sigma} = \frac{V \sqrt{T}}{\sqrt{2\pi}} \left[ e^{\frac{d(F^D, F^S)^2}{2}} - e^{\frac{d(F^D)^2}{2}} \right]$$ (4)

The equation can be expressed as well as:

$$\frac{\partial G}{\partial \sigma} = \frac{V \sqrt{T}}{\sqrt{2\pi}} [a - b]$$ (5)
Theorem 2: The executive’s position has a global maximum with respect to asset risk if the units of equity based compensation, $\alpha$, is larger (smaller) than the number of units of loss due to bank failure, $\beta$, and the total face value of debt, $F^D + F^S$, is larger (smaller) than the strike price of the equity based compensation, $H$. Otherwise, there is no internal maximum to the position value.

Proof: The executive position is composed of $\alpha$ units of long call option with a strike price of $H$ and $\beta$ units of short put option with a strike price equal to the total face value of debt $F^D + F^S$. To find out the maximum value of the position we calculate first the derivative of the position with respect to asset risk:

$$
\frac{\partial E}{\partial \sigma} = \frac{\partial \text{Call}(V, H, \sigma)}{\partial \sigma} - \beta \frac{\partial \text{Put}(V, F^D + F^S, \sigma)}{\partial \sigma}
$$

(1)

$$
\frac{\partial E}{\partial \sigma} = \frac{\alpha V \sqrt{T}}{\sqrt{2\pi}} e^{-\frac{d(V,H)^2}{2}} - \frac{\beta S \sqrt{T}}{\sqrt{2\pi}} e^{-\frac{d(V,F^D+F^S)^2}{2}}
$$

(2)
\[
\begin{align*}
d(S, K) &= \frac{\ln(S/K) + (r + \frac{\sigma^2}{2})T}{\sigma \sqrt{T}} \\
\end{align*}
\] (3)

By rearranging equation (2) the derivative can be decomposed to two components, where the first one is always positive:

\[
\frac{\partial E}{\partial \sigma} = \frac{V \sqrt{T}}{\sqrt{2\pi}} \left[ a e^{-\frac{d(V, H)^2}{2}} - \beta e^{-\frac{d(V, F^D + F^S)^2}{2}} \right]
\] (4)

The equation can be expressed as well as:

\[
\frac{\partial E}{\partial \sigma} = \frac{V \sqrt{T}}{\sqrt{2\pi}} \left[ a a - \beta b \right]
\] (5)

where: \( a = e^{-\frac{d(V, F^D + F^S)^2}{2}} \) and \( b = e^{-\frac{d(V, F^D)^2}{2}} \)

When equation (5) is equal to zero there is an interior solution for the maximum level of asset risk. Such solution exists if the number of units of equity based compensation, \( \alpha \), is greater (smaller) than the units of loss due to bank failure, \( \beta \), and the parameter \( b \) is greater (smaller) than \( a \). Since the exponent term is an increasing function of the strike price \( K \), the strike price of the equity based compensation should be below (above) the total face value of debt, i.e., \( H \leq F^D + F^S \), in order to have a solution where the parameter \( b \) is greater (smaller) than \( a \), where interior solution for the maximum level of compensation exist.

When the performance linked compensation of the executive is composed of stock only the strike price, \( H \), is equal to the total face value of debt, \( F^D + F^S \), and expressions \( a \) and \( b \) are equal. Therefore, the derivative would be always positive (negative) in case that \( \alpha \) is greater
(smaller) than $\beta$, and the value of the executive’s position would always increase (decrease) with asset risk.

**Appendix 3: Discussion of the Base Case Parameters**

**Characteristics of the Financial Institution**

**Maturity ($T$):** We consider a financial institution whose claims mature in one year ($T= 1$), following Marcus and Shaked (1984) and Ronn and Verma (1986). The one-year maturity is reasonable with the annual frequency of regulatory audits, because if the market value of assets is found to be less than the value of total liabilities in an audit, regulators have the ability to size the bank.

**Leverage ratio of the financial institution (LR):** We define the leverage ratio $LR = \frac{F e^{-\alpha T}}{V}$. We set the total face value of the financial institution’s debt ($F$) to 1,000, and calculate for each level of leverage ratio the appropriate level for a firm’s asset value, $V$. The leverage ratios is set to 0.92, similar to the median level which is reported by John, Mehran and Qian (2010) for 143 bank holding companies between 1993 and 2007. This level is also consistent with Tung and Wang (2011) that analyzed a database of 83 U.S banks from 2006, and found out that their median level of liabilities to assets is equal to 0.91 with a standard deviation of 3%.

**Percentage of Managerial ownership:** The parameter $\alpha$ is the percentage ownership of the executive in the bank. John, Mehran and Qian (2010) calculate the median value of CEO ownership in financial institution as being equal to 0.29%. However, one standard deviation in their study is equal to 3.97%. Thus, all the results in our numerical analysis is within the range of one standard deviation.

**Units of loss in financial failure:** The parameter $\beta$ is the percentage loss of the executive in financial distress in percentage of the total value of assets. The estimation of this component is
difficult since it is composed from tangible assets like uninsured pension benefits that would be foregone and intangible assets as reputation costs and loss of future employment opportunities. Recently, Graham et al., (2013) found that the average present value of wage losses from the year of bankruptcy to five years after bankruptcy amount to almost 30% of the market value of assets measured one year prior to bankruptcy. Thus, this component in our analysis is moving between 0.45% and 0.9% of assets value.

Face value of subordinated debt: The total debt is composed of deposit, with a face value of $F^D$ and subordinated debt with a face value of $F^S$. The face value of the subordinated debt is set to 6% of the total debt face value. In our analysis we define subordinated debt as any liabilities which are not insured by the government. Therefore, we search for a lower and upper boundary for this level. Belkhir (2012), who analyzed a database of US commercial banks over the 1995 – 2009 period found out that the average value of the subordinated debt tranche is equal to 1.79% of the total banks’ liabilities. John, Mehran and Qian (2010) found that deposits constitute 81% of total debt for an average banking holding company.

Risk free rate: We set the risk-free rate $r$ to 3.5% to match the average short-term U.S. treasury rate over the period 1991 – 2008. We consider this time period because the Basel I Accord was published in 1988 and enforced by G-10 countries in 1992. The risk-free rates are downloaded from Kenneth French’s website.

The strike price of the equity-based compensation (H): because the convention in the market is to set the strike price of stock options as being at the money.\(^\text{12}\)

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\(^{12}\) Palmon, Bar-Yosef, Chen, and Venezia (2008) study the optimality of option grants (with choice of the strike price) and find that unless there are tax-related disadvantages, in-the-money options are better for shareholders.
Table 1: The base case parameters

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Source</th>
<th>Symbol</th>
<th>Base Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Leverage ratio</td>
<td>John, Mehran and Qian (2010)</td>
<td>LR</td>
<td>0.92</td>
</tr>
<tr>
<td>Face value of total debt</td>
<td>John, Mehran and Qian (2010)</td>
<td>F</td>
<td>1,000</td>
</tr>
<tr>
<td>Value of the firm’s assets</td>
<td></td>
<td>V</td>
<td>1,049.6</td>
</tr>
<tr>
<td>Time to maturity</td>
<td>Marcus and Shaked (1984) and Ronn and Verma (1986).</td>
<td>T</td>
<td>1</td>
</tr>
<tr>
<td>Risk-free rate</td>
<td>Kenneth’s French database</td>
<td>( r )</td>
<td>3.5%</td>
</tr>
<tr>
<td>Executive ownership</td>
<td>John, Mehran and Qian (2010)</td>
<td>( \alpha )</td>
<td>0.3%</td>
</tr>
<tr>
<td>Executive loss in default</td>
<td></td>
<td>( \beta )</td>
<td>0.6%</td>
</tr>
<tr>
<td>Face value of subordinated debt</td>
<td>Belkhir (2012)</td>
<td>( F^S )</td>
<td>60</td>
</tr>
<tr>
<td>Bank’s asset risk</td>
<td>Meheran and Rosenberg (2009)</td>
<td>( \sigma )</td>
<td>5.3%</td>
</tr>
<tr>
<td>Strike of the equity based compensation</td>
<td>Palmon et al., (2008)</td>
<td>( H )</td>
<td>1,049.6</td>
</tr>
<tr>
<td>Corporate tax rate</td>
<td>Federal tax rate</td>
<td>( \tau )</td>
<td>35%</td>
</tr>
</tbody>
</table>
Table 2: The Equilibrium Solution for the Base parameters under different claimholders control and regulatory supervision method

The Table presents the equilibrium solutions for the base case parameters for different regulatory supervision method and ability of the claimholders to control the decision variables. At each row we first report the tools that the regulator is using to control asset risk and its ability to control that tool. The value of each decision variable at equilibrium is reported at the next columns and the resulting positions value of the stockholder, executive and the public are reported at the last columns.

<table>
<thead>
<tr>
<th>Description of claimholders control</th>
<th>Decisions Variables (in %)</th>
<th>Position Value</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Executive Ownership ($\alpha^*$)</td>
<td>Asset risk ($\sigma^*$)</td>
</tr>
<tr>
<td>Full control of the decisions variables and $LR=0.92$ (Result 1)</td>
<td>0.388</td>
<td>8.33</td>
</tr>
<tr>
<td>Full control of the decisions variables and $LR=0.95$ (Result 2)</td>
<td>0.450</td>
<td>7.07</td>
</tr>
<tr>
<td>Limited regulatory ability to control asset risk, $\sigma_{\text{UBound}}=11%$ and $LR=0.92$ (Result 3)</td>
<td>0.462</td>
<td>11.00</td>
</tr>
<tr>
<td>Limited regulatory ability to control asset risk, $\sigma_{\text{UBound}}=11%$ and $LR=0.95$ (Result 3)</td>
<td>0.526</td>
<td>11.00</td>
</tr>
<tr>
<td>Limit on executive ownership only, $LR=0.92$, $\alpha_{\text{UBound}}=0.388$, (Result 4)</td>
<td>0.388</td>
<td>8.33</td>
</tr>
<tr>
<td>Limit on executive ownership only, $LR=0.95$, $\alpha_{\text{max}}=0.452$, (Result 4)</td>
<td>0.452</td>
<td>7.07</td>
</tr>
<tr>
<td>Heterogeneous beliefs regarding loss in financial failure, $\beta^G=0.6$, $\beta^E=0.90$, and $\alpha_{\text{UBound}}=0.388$ (Result 5)</td>
<td>0.388</td>
<td>5.92</td>
</tr>
<tr>
<td>Heterogeneous beliefs regarding loss in financial failure, $\beta^G=0.6$, $\beta^E=0.45$, and $\alpha_{\text{UBound}}=0.388$ (Result 5)</td>
<td>0.388</td>
<td>15.15</td>
</tr>
<tr>
<td>Two policy tools and heterogeneous beliefs regarding loss in financial failure, $\beta^G=0.6$, $\beta^E=0.45$, $\alpha_{\text{UBound}}=0.388$ and $\sigma_{\text{max}}=11%$ (Result 6)</td>
<td>0.388</td>
<td>11.00</td>
</tr>
</tbody>
</table>
Table 3: The executive choice of asset risk under different levels of executive’s ownership, $\alpha$, and units of loss in financial failure, $\beta$

The table presents the value of asset risk (in %) which maximizes the executive position for different executive ownership (the parameter $\alpha$) and units of loss in financial failure (the parameter $\beta$). All other data are the same as in Table 1. When the curve is upward sloping we use the symbol MAX. Otherwise, we report the value of asset risk that maximizes the value of the executive’s position.

<table>
<thead>
<tr>
<th>Executive ownership (in %)</th>
<th>Units of loss in financial failure (in %)</th>
<th>0.30</th>
<th>0.45</th>
<th>0.60</th>
<th>0.75</th>
<th>0.90</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.30</td>
<td>MAX</td>
<td>MAX</td>
<td>8.67</td>
<td>6.54</td>
<td>5.67</td>
<td>5.16</td>
</tr>
<tr>
<td>0.388</td>
<td>MAX</td>
<td>MAX</td>
<td>15.15</td>
<td>8.33</td>
<td>6.71</td>
<td>5.92</td>
</tr>
<tr>
<td>0.50</td>
<td>MAX</td>
<td>MAX</td>
<td>13.46</td>
<td>8.67</td>
<td>7.13</td>
<td></td>
</tr>
<tr>
<td>0.60</td>
<td>MAX</td>
<td>MAX</td>
<td>MAX</td>
<td>12.00</td>
<td>8.67</td>
<td></td>
</tr>
<tr>
<td>0.70</td>
<td>MAX</td>
<td>MAX</td>
<td>MAX</td>
<td>25.28</td>
<td>11.23</td>
<td></td>
</tr>
</tbody>
</table>
Figure 1: The value of the agents’ position at debt maturity versus asset value

The figure presents the payoffs at maturity of the positions which are sensitive to asset risk for the public, the stockholders and the executive for different asset value. Panel-A presents the public’s payment. Panel-B presents the stockholder’s payment and Panel-C presents the payment of the executive. All the data are the same as in Table 1.
Figure 2: The value of the agents’ position versus asset risk

The figure presents the value of the positions which are sensitive to asset risk for the stockholders, public and the executive for different levels of asset risk. Panel (1.A) presents the public’s position. Panel (1.B) presents the stockholder’s position and Panel (1.C) presents the position of the executive. All the data are the same as in Table 1.

Panel A: The Public position

Panel B: The Stockholder position

Panel C: The Executive position
Figure 3: The value of the executive’s position for different asset risk and size of equity based compensation

The figure presents the value of the executive’s position versus asset risk, where the units of equity based compensation is either low (α=0.15), moderate (α=0.3) or high (α=0.6). All the data are the same as in Table 1.

Panel A: “Low” equity compensation (α=0.15)                          Panel B: “Medium” equity compensation (α=0.30)

Panel C: “Large” equity compensation (α=0.6)
Figure 4: Asset risk, executive ownership and claim’s value at equilibrium with regulatory limit on asset risk.

The figure presents the chosen level of asset risk by the executive and executive’s ownership, as awarded by the equityholder, for different regulatory limit on asset risk, as well as the value of the stockholder, the executive and the public position for these levels. All other parameters are identical to the base case parameters which are presented in Table 1.

Panel A: Asset risk versus the regulatory limit on asset risk

Panel B: Executive ownership versus regulatory limit on asset risk

Panel C: The value of the executive, equityholder and public positions versus the regulatory limit on asset risk
Figure 5: The value of the executive position versus asset risk for different levels of leverage and ownership.

The figure presents asset risk and the value of executive positions for different leverage ratio, when the executive ownership is equal to 0.388% and 0.45% of the financial institution’s assets. All other parameters are identical to the base case parameters which are presented in Table 1.

**Panel A**: Executive ownership equal 0.388%.

**Panel B**: Executive ownership equal 0.45%
Figure 6: Asset risk, executive ownership and claim’s value at equilibrium with regulatory limit on executive’s ownership.

The figure presents the chosen level of asset risk by the executive, executive’s ownership, as awarded by the equityholder, for different regulatory limit on executive ownership, as well as the value of the stockholder, the executive and the public position for these levels. All other parameters are identical to the base case parameters which are presented in Table 1.

Panel A: Asset risk versus the regulatory limit on executive ownership

Panel B: Executive ownership versus regulatory limit on asset risk

Panel C: The value of the executive, equityholder and the public positions versus the regulatory limit on executive ownership