

Optimal Regulation, Executive Compensation and Risk Taking by Financial Institutions

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Abstract

This paper presents an equilibrium model of financial institutions in which we can examine the optimal regulation of risk taking. Choice risk levels result from strategic interactions of three stakeholders: (1) regulators (e.g. FDIC, OCC), (2) shareholders of financial institutions, and (3) management. Regulators put caps into place either on equity-based executive compensation or on asset risk; shareholders choose levels of management's ownership; and management chooses the level of asset risk. We show that when using either of the two policy tools it is possible to achieve a socially 'optimal' level of financial risk taking. This optimal level is the result of a tradeoff between the benefits of a well-functioning financial sector and the expected social cost of financial distress. If the regulator is limited in its ability to enforce such limits, capping equity based compensation becomes a less efficient tool than setting an upper limit on asset risk. Furthermore, if stockholders and management are better informed than regulators about losses to executive in the case of bank failure, 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 (Brunnermeier, 2009). However, there are two main schools of thought as to the factors that brought about the observed increase in asset risk and resulting impairment of financial stability. The first is executive pay with its 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 and argues that there may have been inadequate regulation and lax supervision and enforcement of existing laws and regulations (Blanchard, 2008; Caprio, Demirgucx-Kunt and Kane, 2010; Delis and Staikouras, 2011).

In response to the crisis and its potential causes, policymakers initiated reforms designed to increase the resilience of financial institutions and markets. The Basel III Accord (2011) adopted more stringent regulations regarding the level and quality of capital requirements, risk management and compensation practices. 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 risk taking by financial institutions. In 2013, the European Union adopted a provision that limits the amount of bankers' bonuses to the amount of fixed remuneration.

However, the issues of the social optimal level of asset risk, executive compensation structures, and the appropriate policy measures have yet to be fully addressed. This paper attempts to fill this gap by exploring first the risk-taking motivations of bank management under (a) different compensation structures, (b) banks' capital structure, and (c) the limits set by regulators on asset risks and/or executive compensation. Second, it examines the socially optimal

¹ See the Consumer Protection Act (2010), in Part (b) of Section 956.

level of risk² and the tools regulators should use to induce owners and executives of financial firms to attain this level of asset risk. In other words, should regulation focus on capping executive pay, 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?

We present a simple equilibrium model of financial regulation and stability that uses an option pricing approach. In our model regulators have limited ability to enforce the optimal level of asset risk on financial institutions. Thus the regulator uses imperfect instruments to affect the level of asset risk, which is in turn the result of choices made by stockholders and management. Management chooses the level of asset risk, while stockholders determine executive pay in the form of an ownership share in the bank. Taking these choices into account, the benevolent regulator maximizes social welfare by setting limits on asset risk and/or executive compensation.

We next characterize the equilibrium levels of asset risk, executive compensation and regulatory limits on asset risk or on executive compensation, as well as management and stockholder wealth and social welfare. The equilibrium results of our model provide a setting to understand and interpret recent developments in the financial sector. 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 directly or indirectly 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

² We note here that the public optimal level of risk (represented by a benevolent regulator) may differ from the private optimal level.

positive payoff from *tax payments* by banks when they do well. A broader interpretation of this component is the social welfare created by a well-functioning banking system (Demirguc-Kunt and Maksimovic, 1998; Wurgler, 1999; Gertler, 1988; and Levine, 1997). The second component is a negative payoff in the form of *deposit insurance*. More broadly, this liability when banks do poorly captures 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 constrained maximum with respect to asset risk. Thus, in the interest of social welfare the regulator will avoid putting in place regulation that may result in either excessive risk-taking or risk avoidance (“credit freeze”).

Management’s position also has two components. The first is *equity-based compensation*, which increases with bank asset value. The second component is *loss due to bank failure*. This component may include “inside debt,” 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 sensitivities to changes in asset risk, a single constrained maximum for the executive’s position may exist. However, the relationship may also be upward sloping, in which case the position is maximized by choosing the highest possible level of asset risk. Furthermore, as leverage increases, the level of asset risk that maximizes the value of the position decreases. We generalize the analysis by Sundaram and Yermack (2007), who considered the special case where executive compensation only includes stock, and leverage has no effect on risk taking.

Using this setting, we analyze the strategic interaction between the different claimholders. We first consider the case where the regulator can enforce an upper bound on asset risk, and find the equilibrium level of asset risk that maximizes social welfare. Next, we examine

the more realistic case where the regulator is limited in its ability to control the maximum level of asset risk.³ In this case we obtain an equilibrium solution with excessive risk taking, lower social welfare and greater equity based compensation. This 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; namely, as leverage increases, as was the case during the crisis, the limit on asset risk should be reduced to maximize social welfare and avoid possible negative effects from a credit freeze.

Given the evidence on the restricted regulatory ability to enforce bounds on asset risk, we consider an alternative regulatory tool: a cap on equity based compensation (ownership), where initially we assume that the regulator can enforce any chosen limit. Under this assumption, we show that the resulting equilibrium solution is identical to the case of a regulatory upper bound on asset risk where the regulator is unlimited in its ability to enforce the upper bound on asset risk.

The drawback of using a limit on executive ownership as a tool to control asset risk is apparent in the case of asymmetric information between the stockholder and the executive on the one hand and the regulator on the other, regarding the potential loss of the executive due to bank failure. The loss due to bank failure is composed of intangible components that are difficult to estimate, and insiders who are better informed have better estimates of these components than the regulator. As the difference between the assessments increases, the deviation of the level of

³ This is because over the last few decades, as the size and complexity of financial firms have increased, the ability of regulators to control bank asset risk has become more difficult (Berger, Davies, and Flannery, 2000; DeYoung et al., 2001)

asset risk from the social optimum increases and the value of the position of the stockholders and management increase.

Following the discussion in the previous section we analyze the case where both policy tools are used simultaneously and when the regulator has limited ability to enforce both tools. We show that applying both tools increases social welfare in the case of asymmetric information regarding the size of the executive loss due to bank failure.⁴

We contribute to the large literature on prudential regulation and the much smaller body of work that considers regulation of banker pay and its interaction with more traditional regulatory measures. Early literature on agency problems focuses on the conflict between executives, shareholders and debtholders, but disregards the regulator and social welfare. Jensen and Meckling (1976) consider the conflict between executives versus debtholders and show that an executive who is paid in equity will be motivated to increase risk if debtholders cannot control the investment choice after debt has been issued. To reduce agency costs, they suggested that the manager should hold an equal proportion of the firm's equity and debt. In line with this work, Sundaram and Yermack (2007) consider the conflict between owners and executives. They analyze the risk- taking motivation of an executive given both equity based compensation and inside debt, which is part of the wealth that an executive can lose in the case of financial failure.⁵ Equity based compensation is represented by a call option and the potential loss in default by a put option. We expand this framework for equity based compensation other than stock, and consider the leverage effects on risk taking. Moreover, we introduce a third player; namely, a benevolent regulator who aims to maximize social welfare.

⁴ Using the two policy tools simultaneously may result in additional costs which could offset the benefit of using more than one policy tool. Careful analysis of such costs goes beyond the scope of this paper.

⁵ In an empirical paper, Anderson and Core (2013) use a similar method to estimate executive risk taking

The implications of agency problems, executive compensation and risk-taking in banking attracted increased attention in the literature after the 2008 financial crisis. Some papers argue that excessive risk-taking by managers is a result of competition between risk-neutral banks and talented bankers who are risk-averse (Acharya et al., 2011; Acharya and Volpin, 2010; and Bannier, Feess and Packham, 2012). Thanassoulis (2012) analyzes the cap on bonus payments and suggests that competition for bankers induces a negative externality which drives up bankers' compensation and implicitly the default risk of rival banks. Our paper differs from this strand of the literature since we consider the motivation for excessive risk taking to be an economic imperfection resulting from the limited ability of the regulator to control either asset risk or the executive pay. Moreover, these papers assume that risk-neutral banks compete for risk-averse managers, whereas our model is not based on specific assumptions about preferences and risk is determined in equilibrium according to the positions and decisions of the claimholders.

Hakenes and Schnabel (2014) relate 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. Social welfare is measured in terms of the value of deposits alone. We also include the value of a well-functioning financial system (see Korinek and Kreamer, 2014). In addition, in our model a potential reason for excessive risk taking is asymmetric information between the regulator and executives regarding the potential loss of the executive in bank failure.

Our paper also relates to studies that explore the ways in which the design of executive compensation affects risk-taking in banking and how a regulator can enhance social welfare. John, Saunders and Senbet (2000) argue that bank risk-taking can be moderated by making the

insurance premiums that a bank pays a direct function of the parameters of the compensation contract. Bolton, Mehran, and Shapiro (2010) model the risk-taking incentives of a CEO of a financial firm and show that linking CEO compensation to firm default risk can reduce firm risk-taking. Chaigneau (2013) considers the interaction among the executive, stockholder and regulator and finds out that an optimal level of risk can be achieved by either imposing bounds on equity based compensation or by sanction on CEOs of failed banks. Hilscher and Raviv (2014) show that adding contingent capital to a bank's capital structure can make stockholders indifferent to the level of asset risk, whereas in our model the presence of inside debt can reduce risk-taking. Besley and Ghatak (2011) study the effect of bonus taxation and find that an optimal bonus structure can be achieved by a combination of regulation on the structure of bonuses and a tax on their level.

The rest of this paper is organized as follows: Section 2 presents the analysis of the risk taking motivations of all claimholders and derives the valuation of their positions. An equilibrium solution for the level of asset risk, executive ownership and the regulatory limit on the level of asset risk is presented in Section 3. The equilibrium solution is calculated in section 4, where now the regulator caps executive ownership, and the analysis is extended to the case of asymmetric information. Section 5 concludes.

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

In this section we derive the value of the claimholders' positions. For each of the claimholders (the public –represented by the regulator, stockholder, 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 of US banks

over the period before and during the 2008 crisis as reported by empirical papers. The base case parameters are described in Table 1 and discussed in Appendix 3.

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

2.1. The Public

An important feature of our model is a market imperfection in the form of an incomplete insurance market between bankers and the rest of the society, (Korinek and Kreamer, 2014). More generally, the holdings of bank equity are not proportionally distributed across the financial elite and the rest of society and thus the level of risk that maximizes the stockholder position does not maximize the position value of the entire public. 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 benefit created by a well-functioning banking system. We assume that at debt maturity, if the asset value exceeds the total face value of the debt ($F^D + F^S$), a fraction τ ($0 \leq \tau \leq 1$) of the residual value, the difference between the value of the financial institution's assets and the total face value of the debt, is paid to the public.

The second component is a negative payoff that is paid by the public to the insured depositors in the case of default. It is paid if at maturity the value of the financial institution's assets is smaller than 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:

$$G_T = \tau \max(V_T - F^D - F^S, 0) - \max(F^D - V_T, 0). \quad (1)$$

The position of the public can be replicated by two options. The first is τ 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 .⁶ The value of the position can be written as:

$$G = \tau \text{Call}(V, F^D + F^S, \sigma) - \text{Put}(V, F^D, \sigma) \quad (2)$$

We define the leverage ratio of the financial institution in a way similar to Merton (1974) as:

$LR = ((F^D + F^S)e^{-rT})/V$, where we normalize the total face value of the debt to one and express the asset value in terms of the leverage: $V = 1/(LR e^{rT})$. Thus, we can substitute the inverse of the leverage for the asset value. Panel A in Figure 1 plots the payoff to the public at maturity for different asset values. This position is known as a “risk-reversal” position, and it 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 constrained maximum with respect to asset risk if the tax rate is positive and the size of the subordinated debt is positive. All else equal the level of asset risk that maximizes the public position increases with the size of the subordinated debt and the tax rate and decreases with total leverage.*

Proof: See Appendix 2.

⁶ The pricing of the different options and positions is presented in Appendix 1.

The two components of the public position have opposite sensitivities to asset risk. As asset volatility increases, both the expected value generated from taxes as well as the cost of deposit insurance increase. We show that for certain parameter combinations, there can be levels of volatility for which these two effects exactly offset each other. The level of bank asset volatility that maximizes social welfare is defined here as ‘optimal’.

Panel A in Figure 2 presents the value of the public position with respect to asset risk for different levels of leverage. In our numerical analysis, the leverage ratio is assumed to equal 0.92, the subordinated debt is 6% of the total face value of the debt, all debt instruments mature in one year, and the risk-free rate is equal to 3.5%.⁷ We show that the public position is hump-shaped with respect to asset risk and that the constrained maximum is reached when asset risk is equal to 8.33%. The results are consistent with the regulators’ goal of reducing the risk-taking incentive and the leverage of financial institutions (Kim and Santomero, 1994). These results are also in line with the financial literature that has highlighted the lack of market discipline since deposits have been insured by the government, and regulators are left with the task of constraining risk-taking by banks (Houston and James, 1995).

Furthermore, if the leverage is increased to 0.95, the level of risk that maximizes the payoff of the public decreases to 7.07% (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 the regulator should consider a bank's capital structure when limiting the level of risk as discussed at Sections (3) and (4).

⁷ All other parameters are at their base case values as listed in Table 1, unless stated otherwise. The justification for choosing these specific levels is presented in Appendix 3.

2.2. Management

The executive's position also has two different components which are sensitive to the value of the financial institution's assets value and asset risk: *equity-based compensation* and *loss due to bank failure*.⁸ We assume that the executive holds α units of equity based compensation, which has a positive payoff at maturity equal to the difference between the value of the assets and a strike price of H , which is assumed to be equal or greater than the total face value of the debt, $H \geq (F^D + F^S)$. In the special case where the equity based compensation only includes stock, the strike price is equal to the total face value of the debt.⁹ The second component is a loss of β units due to bank failure ($0 \leq \beta \leq 1$). This component 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. We assume that the payoff at maturity is equal to β times the difference between the total face value of the debt ($F^D + F^S$) and asset value, V_T . The executive payoff at maturity can be expressed as:

$$E_T = \alpha \max(V_T - H, 0) - \beta \max(F^D + F^S - V_T, 0). \quad (3)$$

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

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

⁸ We do not consider other components of executive pay that are not sensitive to asset risk.

⁹ We assume that in the case of executive stock options, the dilution effect is relatively small and only has a secondary effect on the other liabilities that were issued by the financial institution.

Panel C in Figure 1 plots the payoff of the position as a function of the asset value. Once again we have a “risk - reversal” position where the components have opposing sensitivities to asset risk. When risk increases, the value of equity based compensation increases while the value of the inside debt decreases, resulting in larger expected losses for the executive.¹⁰ Therefore, it is again possible to have a constrained maximum.

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

Proof: See Appendix 2.

Thus, all else being equal the level of asset risk that 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 as a function of asset risk for a leverage ratio of 0.92, as in our base case. For relatively low and medium levels of equity based compensation we consider the cases where the executive holds 0.15%, 0.30% of the financial institution's stocks, and the relationship between the value of the position and asset risk is hump- shaped with a single constrained maximum.¹¹ The maximum value of the executive’s position increases with

¹⁰ The pricing of the different options and positions is presented in Appendix 1.

¹¹ John, Mehran and Qian (2010) calculate the median value of CEO ownership in financial institution as equal to 0.29%.

equity based compensation, where it is reached at an asset risk of 4.59% and 6.54% for executive ownership of 0.15% and 0.30% respectively. When executive ownership increases to a relatively high level of 0.6% the relationship between the value of the executive's position and asset risk becomes upward sloping and there is no constrained maximum for the value of the position. In this case the executive will aspire to reach the highest possible level of risk. Panel C in Figure 2 presents the effect of leverage on the value of asset risk. When the leverage increases to 0.95 and executive ownership equals 0.3%, the maximum is achieved at a level of asset risk of 4.43%, as compared to 6.54% when the leverage is equal to 0.92.

A special case is when the strike price of the equity based compensation is set to equal the leverage ratio, as in Sundaram and Yermack (2007). In this case, the executive's only compensation is in the form of common stocks and leverage has no effect on the risk-taking motivation of the executive. Unlike the general case where the executive position is maximized at some internal level, in this case there is always a corner solution. The relationship between the value of the executive's position and asset risk will either increase or decrease linearly depending on the relationship between α and β .

2.3. Stockholder

The stockholder's position equal the residual value of the financial institution: $\max(V_T - F^D - F^S, 0)$, minus the taxes paid and the equity based compensation awarded to the executive. Therefore, the value of the stockholder decreases with the tax rate and the units of equity based compensation. The stockholder's payoff at maturity T is equal to

$$S_T = (1 - \tau) \max(V_T - F^D - F^S, 0) - \alpha \max(V_T - H, 0). \quad (5)$$

Again, 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 the debt. The second is a short position of α 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 stockholder's payoff at debt maturity as a function of asset value is presented in Panel B in Figure 1. The current value of the stockholder's position can be written in options terms as follows:

$$S = (1-\tau)Call(V, F^D + F^S, \sigma) - \alpha Call(V, H, \sigma) . \quad (6)$$

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

$$S = (1-\alpha-\tau)Call(V, F^D + F^S, \sigma) \quad (7)$$

The value of the stockholder's position always increases with asset volatility and decreases with the tax rate, executive ownership and leverage as presented in Panel B in Figure 2.

3. 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 payoff of each of the claimholders. First, we consider the baseline case where the upper bound on the level of asset risk set by the regulator is binding thus there is full compliance by the different claimholders. Furthermore, we show the equilibrium solution under different bank leverage ratios. Finally, we analyze the equilibrium solution in the case where the regulator is unable to fully enforce the maximum level on asset risk.

The equilibrium solution for the decision variables and the stakeholders' positions is determined by backward induction in three steps. First, the executive chooses the level of asset

risk that maximizes the value of her position, σ^* . This decision is made after receiving information on the upper bound on asset risk set by the regulator and the units of equity based compensation (managerial ownership) awarded by the stockholders. Next, stockholders maximize the value of their position S^* by determining the number of units of equity based compensation awarded to the executive, α^* , given the regulatory maximum limit on asset risk. Last, after analyzing the decisions of the stockholders and the executive, the regulator chooses the upper bound on asset risk, σ_{UBound}^* , that maximizes the value of the public position, G^* . If each claimholder has chosen a strategy and no other claimholder can benefit by changing their strategy while the other claimholders keep theirs unchanged, the 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: $\langle (\sigma^*, \alpha^*, \sigma_{UBound}^*), (E^*, S^*, G^*) \rangle$.

We use the framework of a non-cooperative game; hence there are no side payments. In the first stage of the analysis, we assume a complete information environment, where each claimholder is fully informed about the payoff function and the possible strategies of all other claimholders. Since the equilibrium results of a sequential game would be identical to the results of simultaneous game, the starting point of the game has no effect on the results in equilibrium and we solve the equilibrium problem by backward induction that starts arbitrarily with one of the players.

3.1 The regulator's limit on maximum asset risk

In the baseline case all claimholders have full control over 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 ownership

where: $\alpha \in [0,1]$, the regulator can impose any upper bound on asset risk and thus $\sigma_{UBound} \in [0,\infty)$ and the executive can decide on any level of asset risk between zero and the upper bound on asset risk, which is set and fully enforced by the regulator, $\sigma \in [0, \sigma_{UBound}]$.

Result 1. *Assuming internal solutions to the public and management maximization problems (see Theorems 1 and 2), if claimholders have full control over their decisions, in equilibrium, the upper bound on asset risk set by the regulator is the level that maximizes its position, and the level of asset risk chosen by the executive is equal to that level as well: $\sigma^* = \sigma_{UBound}^* = \sigma_{MaxPub}$.*

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

$$\sigma_{MaxPub} = \arg \max G(\sigma, V, F^D, F^S) \quad (8)$$

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

$$\left. \frac{\partial G}{\partial \sigma} \right|_{\sigma=\sigma_{MaxPub}} = 0 \quad (9)$$

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

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

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 in the second step, we calculate the units of equity compensation that maximize the value of the stockholder's position at this level of risk. The value of the stock increases with asset risk. However, asset risk is bounded at the level of σ_{UBound}^* . Moreover, as executive ownership increases the value of the stockholder's position decreases. Therefore, the stockholder will award the minimum ownership to the executive that still motivates to take a level of risk which is equal to the regulatory upper bound on 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 on asset risk, σ_{UBound}^* :

$$\left. \frac{\partial E(\sigma = \sigma_{UBound}^*)}{\partial \sigma} \right|_{\alpha = \alpha^*} = 0 \quad (11)$$

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

$$\frac{\partial E(\sigma = \sigma_{UBound}^*)}{\partial \sigma} = \frac{\alpha^* S \sqrt{T}}{\sqrt{2\pi}} e^{-\frac{d(H)^2}{2}} - \frac{\beta S \sqrt{T}}{\sqrt{2\pi}} e^{-\frac{d(F^D + F^S)^2}{2}} = 0 \quad (12)$$

In the third step, the executive, given her ownership of α^* , chooses the level of asset risk that maximizes the value of her position σ_{MaxEx} :

$$\sigma_{MaxEx} = \arg \max E(\alpha^*, \beta, \sigma, V, F^D, F^S) \quad (13)$$

This level is calculated similarly to Equation (12) and the result is the level of risk which equals the upper bound on asset risk: $\sigma_{MaxEx} = \sigma^* = \sigma_{UBound}^*$.

The calibration of the model to the base case parameters yields a level of asset risk of $\sigma_{MaxEx} = \sigma^* = \sigma_{UBound}^* = 8.33\%$, where the chosen level of asset risk is equal to the regulatory upper bound on asset risk (See Panel A in Figure 2). The stockholder compensates the executive with 0.388% of the firm's stock (See Table 2). Thus, if the regulator's efforts to impose the upper bound on asset risk are effective, the executive will be motivated to take this level of risk with any ownership equal to or greater than α^* .¹²

The level of executive ownership awarded by the stockholder for different upper bounds on asset risk, σ_{UBound} set by the regulator is presented in Panel B in Figure 4. For relatively low levels of upper bounds on asset risk (between 0% and 3%) the stockholder will not award 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 stockholder to award the executive the amount of ownership which will motivate her to take the maximum possible level of asset risk allowed by the regulator. The regulator, who is aware of this information, will set the upper bound on asset risk to be equal to the level that maximizes its holding. In equilibrium, all the three will be equal: the regulatory upper bound on asset risk, σ_{UBound}^* , the level of risk chosen by the executive, σ^* and the level of risk that maximizes social welfare, σ_{MaxPub} .

¹² For example, for the base case parameter, an executive ownership of 0.6% of the bank's stock, as depicted in Panel C in Figure 3, would motivate the executive to take a risk equal to the limit on asset risk. However, such a choice would decrease the value of the stockholder's position, since the same level of asset risk can be achieved by a lower level of ownership (0.388% as in Panel A in Figure 2).

3.2 The effect of leverage

The leverage of the financial sector in the period from 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 caused among other things by disappearing liquidity in 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, the effect of leverage on asset risk and executive ownership may be non trivial.

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

When leverage increases, the public's 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 equity based compensation, since the executive's position is even more sensitive to asset risk than the public. Both 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 institution's assets and more sensitive to asset risk.

In the numerical example, leverage increases from 0.92 to 0.95 as a result of a decline in the value of the assets. Under leverage ratio of 0.95 the value of the public position is maximized at a lower level of 7.07% compared to a level of 8.33% before (Panel A in 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 in 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%. In response the stockholder increases executive ownership to 0.45%, and under such compensation the executive is motivated to take the maximum level of asset risk, which in turn maximizes the stockholder's position (Panel B in 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 by awarding them ownership or changing the strike of their stock options.

3.3 Limited ability of the regulator to set maximum asset risk

The regulator may not be able to enforce an effective upper limit of asset risk on financial institutions, especially in the case of large and complex financial institutions. This may be due to “regulatory inertia,” caused either by inadequate supervisory review processes, leniency of laws and regulations and lax enforcement. In the following analysis we assume that the regulator is limited in its ability to enforce the upper limit on assets risk. Thus, the regulator can only attain an upper bound on 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: $\sigma_{MinReg} > \sigma_{MaxPub}$, and σ_{MinReg} is the minimum level that the regulator can set as an upper bound on asset risk.

In such a case, the stockholder will increase the equity based compensation up to the point where the executive is motivated to choose the level of asset risk that maximizes the value of her position: $\sigma^* = \sigma_{UBound}^* = \sigma_{MinReg}$. As presented in Panel B in Figure 4, all else being equal, an increase in the upper bound on asset risk will lead to an increase in executive ownership. Moreover, as presented in Panel C in Figure 4, as the upper bound on asset risk increases, the

position value of the executive and the stockholder increase, while the value of the public position decreases below its unconstrained maximum value.

Result 3. *If the minimum level that the regulator can set as an upper bound on asset risk is greater than the level that maximizes the position of the public, $\sigma_{MinReg} > \sigma_{MaxPub}$, then at equilibrium the executive will choose this level of asset risk: $\sigma^* = \sigma_{UBound}^* = \sigma_{MinReg}$. Consequently, executive ownership is greater than in the case where the regulator can enforce asset risk that maximizes the public position.*

The stockholder who is aware of the actual limit on asset risk, $\sigma_{UBound}^* = \sigma_{MinReg}$, and as in Section (3.1), finds the amount of equity based compensation, α , which maximizes the value of the executive position at this 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 only be willing to shift to a higher level of asset risk for a greater equity compensation; thus in equilibrium executive ownership is increased.

Result 3 is consistent with the excessive risk-taking by financial institutions observed prior to the 2008 financial crisis and with the increase in executives' equity based pays. Thus we have shown that the two necessary conditions for executives to engage in excessive risk taking stem from an increase in executive equity based compensation and supervisory inertia.

We demonstrate these results numerically in 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% as in Section (3.1). However, in the current case, we assume that the regulator can only impose a limit on an asset risk of 11% or more: $\sigma_{UBound}^* = \sigma_{MinReg} = 11\%$. At this level of risk the

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 would happen at the expense of social welfare since the value of the public's position would decline from 30.49 to 29.72 (See Table 2).

4. Regulatory cap on equity based compensation

The difficulties involved in controlling bank risk-taking with traditional measures can lead to excessive risk-taking by financial institutions, as described in Section (3.3). In this section, we show how regulatory limits on executive equity pay can replace (or augment) limits on risk-taking.

4.1 Full ability of the regulator to cap executive ownership

In this baseline scenario, as in Section (3.1), all claimholders have full control over their chosen strategy and they can respond to changing market conditions. Since the regulator can impose any level of executive ownership, maximum executive ownership can get any value where $\alpha_{UBound} \in [0,1]$.

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

The equilibrium solution is calculated in three steps. As in Section (3.1), the risk level that maximizes the value of the public position is found first, σ_{MaxPub} . The regulator caps executive ownership, α_{UBound}^* , at the level that maximizes both the value of the executive position and the public position and consequently social welfare.. Next, the stockholder chooses to award this amount of equity based compensation, thus: $\alpha^* = \alpha_{UBound}^*$. Note that the value of α_{UBound}^* equals the value chosen by the stockholder in the case of complete regulatory control over asset risk (Section 3.1). Thus, the outcome of the equilibrium consisting 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 involves lower costs to the regulator and is easier to enforce, as discussed in Section (3.2).

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 (3.1), the level of asset risk that maximizes the value of the public's position is 8.33% for a leverage ratio of 0.92 and for a loss due to bank failure of 0.6 ($\beta=0.6$). In the next step, the regulator finds the equity compensation, α , that maximizes the value of the executive position for an asset risk of 8.33%: this level is equal to 0.388% of the financial institution's ownership. The stockholder, who has a position that increases in value with asset risk, awards the executive with the maximum feasible amount of equity compensation (0.388%). Consequently, the value of the public position is maximized with respect to asset risk, and equals 30.49. The value of the executive position and the stock equals 0.1726 and 58.90 respectively. In the case where the leverage increases to 0.95, as in Section (3.2), the position of the public is maximized at a level of asset risk of 7.07%. However, due to the higher sensitivity to leverage of the executive position, the regulator needs to increase the limit on executive ownership to 0.452% in order to

maximize the executive position at that level of asset risk. The value of the executive position decreases to 0.0782 and the value of the public position and the stock decreases to 19.57 and 39.12 respectively. These results are identical to the results in equilibrium in the case where claimholders have full control over their decisions and the regulator can limit asset risk directly at any level.

4.2 Limited ability of the regulator to enforce a cap on executive ownership

While capping executive ownership may be easier to enforce than restricting asset risk, such a limit may nevertheless exist and may increase asset risk in a nonlinear way. As shown in Panel A in Figure 4 the relationship between the regulatory limit on asset risk and the actual chosen level of asset risk is linear, and consequently a limited ability on the part of the regulator to control asset risk directly may end up in a proportional increase in the level of asset risk. However, in the case of limited ability of the regulator to control executive ownership, stockholders may be motivated to increase executive ownership up to the point in which the relationship between asset risk and executive position is upward sloping and there is no interior maximum, as described in *Theorem 2*. This result is shown in Panel A in Figure 6, where the relationship between the regulatory limit on executive ownership and the actual chosen level of asset risk on equilibrium is convex and a relatively 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 in Figure 6).

Furthermore, the stockholder will increase executive ownership subject to the regulatory cap, up to the point where asset risk as a function of executive ownership becomes very large (Panel A in Figure 6). In such a situation, the stockholder will stop increasing executive ownership, since the dilution effect will become dominant (Panel B in Figure 6).

The reasons why there may be differences between an actual regulatory cap on executive ownership and the level that maximizes the public position deserve attention. In the next section, we relax the assumptions of symmetric information between executive and stockholder on the one hand and regulator on the other and derive an equilibrium solution for this case.

4.3 Asymmetric information about executive loss in case of bank failure.

The inability to impose a limit on executive ownership is attributed in this section to asymmetric information. The executive and the stockholder are better informed than the regulator about the loss of the executive position due to bank failure, β . Consequently, the private information that creates a positive gap between the assessment of the uninformed regulator and the actual level of β . Consequently, the result in equilibrium is an increase in the value of the executive and the stockholder positions, while social welfare decreases.

The existence of asymmetric information on loss in case of bank failure can be justified by the fact that it includes intangible assets. Intangible assets that decline in value when the bank fails include the reputation of the executive and non-diversifiable human capital in the firm. Since it is difficult to find proxies for the value of these assets because they are not traded, asymmetric information can emerge, and the result is a stockholder and executive position with a greater value at the expense of a lower value of the public position.

Result 5. *If the regulator estimates the executive loss in case of bank failure to be higher than the actual level, i.e., $(\beta < \beta^G)$, the cap on executive ownership set by the regulator will motivate the executive to choose a higher level of asset risk than the level that maximizes the public position, $\sigma_{MaxPub} < \sigma^*$.*

The strategic choice is calculated first, as in all previous cases, by finding the risk level that maximizes the value of the public position, σ_{MaxPub} . As in Section (4.1), the regulator sets a cap on executive ownership, α_{UBound}^* . However, the executive, as well as the stockholder, are better informed about the actual loss due to bank failure and know the actual value, which is lower than the one estimated by the regulator: $\beta < \beta^G$. Since, as the loss due to bank failure increases the level of asset risk that maximizes the executive position for a given equity based compensation decreases, the chosen level of asset risk by the executive would be greater than the level predicted by the regulator under the assumption of a loss in default of β^G . Consequently, the regulator caps executive ownership at a level that motivates the executive to take a level of risk which is above the level that maximizes the public position where $\sigma_{MaxEx} = \sigma^* > \sigma_{MaxPub}$. However, under this equilibrium, the value of both the executive and stockholder positions increases.

We now illustrate the potential loss of the public position due to asymmetric information. Suppose all the data are identical to the base case parameters, except that now the actual loss due to bank failure is equal to either 0.55% or alternatively to 0.45% of the bank's asset value, while the regulator estimates that the loss is greater and equal to 0.6%. Consequently, as in Section (4.1), the regulator sets a cap on executive ownership of 0.388%. The stockholder, aware of the cap on ownership, awards the executive with the maximum feasible ownership of 0.388%. Under this compensation the value of asset risk which maximizes the executive position is equal to 9.39% and 15.15% for an actual β of 0.55% and 0.45% respectively (Table 3 and Panel A in Figure 7). The value of the decision variables result in a greater position value for the stockholders and the executive compared to the case of symmetric information. The value of the executive position equals 0.1766 and 0.1929 for an actual β of 0.55% and 0.45% and the value of

the stockholder position equals 60.70 and 72.34 for the same levels of β . However, the value of the public position is reduced to 30.37 and 25.83 for an actual β of 0.55% and 0.45% respectively, compared to the case of symmetric information where the maximum value is 30.49 (see Table 2).

4.4 Combining the two policy tools in the case of a handicapped regulator

In this section we analyze the case of combining the two policy tools – the cap on executive ownership and an upper bound on asset risk under the assumptions of: (1) asymmetric information regarding the executive loss due to bank failure, where the stockholders and executive are better informed than the regulator; (2) a limited ability of the regulator to enforce an upper bound on asset risk.

Result 6. *In case of asymmetric information between the executive and the regulator regarding the executive loss due to bank failure where $\beta < \beta^G$, and limited ability of the regulator to set an upper bound on asset risk where, $\sigma_{MinReg} > \sigma_{MaxPub}$, then using the two policy tools simultaneously; i.e., an upper bound on the maximum level of asset risk and a cap on executive ownership can make the public better off.*

In this case, as in all previous cases, the regulator finds the optimal level of asset risk that maximizes the value of the public position, σ_{MaxPub} . As in the case of using a cap on pay as the only policy tool (*Result 5*), the uninformed regulator sets a limit on executive ownership which is based on a greater executive loss due to bank failure than its actual size: $\beta < \beta^G$. However, in this case, the regulator adds a second policy tool – an upper bound on the level of asset risk. We

assume that the regulator is limited in its ability and the actual bound is above the level that maximizes the public position: $\sigma_{MinReg} = \sigma_{UBound}^* > \sigma_{MaxPub}$.

In equilibrium, there are two scenarios. In the first, the uninformed regulator sets a cap on executive ownership which motivates the executive to choose a higher level of asset risk than the level that maximizes the public position, but one that is lower than the upper bound on asset risk: $\sigma_{UBound}^* > \sigma^* > \sigma_{MaxPub}$. In this case the effective constraint is the cap on executive ownership, and the public is better off than in the case of only using an upper bound on asset risk. In the second possible scenario, the difference between the regulator's assessment and the actual level of loss due to bank failure is relatively high. Thus, if the stockholder awards the executive with ownership which is equal to the cap level, the executive is motivated to take an asset risk which is greater than the upper bound on asset risk. However, this level is not feasible. Therefore, the informed stockholders reduce executive ownership below its cap: $\alpha_{UBound}^* > \alpha^*$, to the level that motivates the executive to take a risk level that is exactly equal to the upper bound on asset risk where $\sigma_{UBound}^* = \sigma^* > \sigma_{MaxPub}$. In this case the effective constraint is the upper bound on asset risk and the public is better off than in the case of only using a cap on executive ownership.

We illustrate these results numerically by using the base case parameters, where now the executive can set an upper bound on asset risk of 11%. Moreover, the regulator assumes that executive loss due to bank failure equals 0.6% of the total asset value in default and calculates the optimal executive ownership as equal to 0.388%. In the first case where the stockholder awards the executive with ownership which is equal to the cap level, we assume the actual executive loss due to bank failure to equal 0.55. Given this loss, the executive would be motivated to take a level of risk of 9.33%. The stockholder is aware that this level is below the

upper bound on the asset risk of 11%, and awards the executive with ownership which is equal to the cap on executive ownership of 0.388%. The equilibrium results are executive, stockholder and public positions of 0.1766, 60.70 and 30.37 respectively (Table 2 and Panel B in Figure 7). The effective constraint in this case is the cap on executive ownership, where with no such cap, the chosen level of asset risk would be 11%, which is equal to the upper bound on the asset risk, as in *Result 3*, where the value of the executive and stockholder positions are greater and equal to 0.2171 and 63.58 respectively, and the value of the public position drops to 29.72.

The second case, where the stockholder awards the executive with ownership below the cap level, we assume the executive's loss due to bank failure to equal 0.45% of the assets. Given this loss, the executive would be motivated to take a level of asset risk of 15.15%. The stockholder is aware that this level is above the effective upper bound on asset risk of 11% and will award the executive with ownership of only 0.347%, which motivates the executive to take a risk of exactly 11%. The equilibrium results are executive, stockholder and public positions of 0.1631, 63.58 and 29.72 respectively (Table 2 and Panel B in Figure 7). The effective constraint in this scenario is the upper bound on asset risk, where with no such bound, the chosen level of risk would be 15.15%, as in the case of only using a cap on executive ownership (*Result 5*), where the value of the executive and stockholder positions are greater and equal to 0.1929 and 72.34 respectively, and the value of the public position drops to 25.83.

Although using these two policy tools simultaneously increases the value of the position of the public, the cost of using the two tools together rather than using one policy tool should be considered. This type of analysis, which considers the costs versus the benefits of adding a second policy tool, is beyond the scope of this paper. However, it is clear that the benefits of

introducing a second policy tool increases as asymmetric information and the costs of enforcing an upper bound on executive pay increase.

5. Conclusion

In this paper we develop a valuation model for the positions of the claimholders of a financial institution involving the owner, executive and a regulator who represents the public. We derive the equilibrium solution for the level of asset risk chosen by the executive who manages the bank, the level of executive's equity based compensation set by the stockholder, and the limits on asset risk and/or executive pay set by the regulator. The paper's objectives are both positive and normative, in that we aim to obtain insights into how existing regulatory policies affect the risk level chosen by financial institutions and the disparity between this level and the socially optimal risk level. We also suggest an optimal prudential regulation and a coordination mechanism between regulation of executives' pay packages and more traditional regulation tools.

We show that if the regulator can limit asset risk to any chosen level, in equilibrium, the upper bound on asset risk set by a benevolent regulator is the level that maximizes public welfare and the level of asset risk chosen by the executive is equal to that level as well. Moreover, as leverage increases, asset risk decreases and executive ownership increases. We next relax the assumption of a regulator who can set an upper bound for asset risk at any level, and show that if the regulatory limit on asset risk is above the level that maximizes the public's position, in equilibrium, the executive will choose that level. Consequently, executive ownership becomes greater than in the case where the regulatory limit on asset risk is equal to the level that maximizes the public's position. These results have implications in terms of the ongoing debate on the causes of the 2008 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.

Furthermore, we analyze the case where a cap on executive ownership set by the regulator replaces the direct limit on asset risk. We show that the equilibrium solution in the case of a cap on executive ownership is identical to the case of a regulatory limit on asset risk if the regulator can fully control these limits. In that case the two policy tools lead to the same level of social welfare and supervising bank asset risk and regulating executive compensation are perfect substitutes. We also show that the deviation from the public's optimal solution in equilibrium with imperfect regulatory control over the cap on executive ownership is greater than in the case of imperfect control of the upper bound on asset risk.

Finally, we relax the assumption of symmetric information regarding the executive loss through bank failure and assume that the executive and the stockholder are better informed than the regulator regarding this loss. Thus, if the regulator makes a higher assessment of this component than its actual value, the executive will choose a higher level of risk than the one that maximizes social welfare. We show that combining the two policy tools by limiting asset risk and capping executive ownership, may make the public better off in the case where the regulator has a limited ability to enforce these two tools.

References

- Acharya, V. M. Pagano, M., and P., Volpin, 2013. Seeking alpha: excess risk taking and competition for managerial talent. mimeo NYU Stern.
- Acharya, V. and P. Volpin, 2010. Corporate governance externalities. *Review of Finance* 14, 1-33.
- Bannier, C.E., E. Feess and N. Packham, 2012. Competition, bonuses and risk-taking in the banking industry. *Review of Finance* 27, 1-38.
- Bebchuk, L.A., A. Cohen, and H. Spamann, 2010. The wages of failure: executive Compensation at Bear Stearns and Lehman 2000-2008. *Yale Journal on Regulation* 27, 257–282.
- Berger, A., S. Davies, and M. Flannery, 2000. Comparing market and supervisory assessments of bank performance: Who knows what when?. *Journal of Money, Credit, and Banking* 32, 641-667.
- Besley, T., and M. Ghatak, 2013. Bailouts and the optimal taxation of bonus pay. *American Economic Review, Papers and Proceedings*, 103, 163–167.
- Blanchard, O., 2008. The tasks ahead. International Monetary Fund Working Paper No. 08/262, International Monetary Fund.
- Black, F., and M., Scholes, 1973. The pricing of options and corporate liabilities. *Journal of Political Economy* 81, 637-654.
- Bolton, P., H., Mehran, and J., Shapiro, 2011. Executive compensation and risk taking. Working paper.
- Brunnermeier, M., 2009. Deciphering the liquidity and credit crunch 2007–2008. *Journal of Economic Perspectives* 23, 77–100.
- Caprio, G., Demirgucx-Kunt, A., and E., Kane, 2010. The 2007 meltdown in structured securitization: Searching for lessons, not scapegoats. *World Bank Research Observer* 25, 125–55.
- Chaigneau, P., 2013, Risk-shifting and the regulation of bank CEOs' compensation, *Journal of Financial Stability* 9, 778-789.
- Coles, J., N., Daniel, and L., Naveen, 2006, Managerial incentives and risk-taking. *Journal of Financial Economics* 79, 431-468.
- Delis, M.D., and P.K., Staikouras, 2011. Supervisory effectiveness and bank risk. *Review of Finance* 15, 511–545.

- Demirguc-Kunt, A., and E., Kane, 2002. Deposit Insurance around the globe: Where does it work?. *Journal of Economic Perspectives* 16, 175–195.
- DeYoung, R., M. Flannery, W. Lang, and S. Sorescu, 2001. The information content of bank exam ratings and subordinated debt prices. *Journal of Money, Credit, and Banking* 33, 900–925.
- Edmans, A., and Q., Liu, 2011. Inside Debt. *Review of Finance* 15, 75-102.
- Fama, E., 1980. Agency problems and the theory of the firm. *Journal of Political Economy* 88, 288-307.
- Galai, D., and R., Masulis, 1976. The option pricing model and the risk factor of stock. *Journal of Financial Economics* 3, 631–44.
- Gerakos, J., 2007. CEO pensions: disclosure, executive power, and optimal contracting. Working Paper, Wharton School.
- Gilson, S.C., 1989. Management turnover and financial distress. *Journal of Financial Economics* 25, 241–262.
- Graham, J.R., H. Kim, S. Li and J.Qiu, 2013. Human capital loss in corporate bankruptcy. Working paper.
- Hakenes, H., and I., Schnabel, 2014. Bank bonuses and bailouts, *Journal of Money, Credit and Banking*, 46. 259-288.
- Hilscher, J., and A., Raviv, 2014. Bank stability and market discipline: The effect of contingent capital on risk taking and default probability. *Journal of Corporate Finance* 29, 542-560.
- Hirshleifer, D., and R., Suh, 1992. Risk, managerial effort, and project choice. *Journal of Financial Intermediation* 2, 308-345.
- Hirshleifer, D. and A., Thakor, 1992. Executive conservatism, project choice, and debt. *Review of Financial Studies* 5, 437-470.
- Houston, J.F., and C., James, 1995. CEO compensation and bank risk: is compensation in banking structured to promote risk taking?. *Journal of Monetary Economics* 36, 405–431.
- Jensen, M.C., and W.H., Meckling, 1976. Rights and production functions: An application to labor-managed firms and codetermination. *Journal of Business* 52, 469-506.
- John, K., H., Mehran, and Y., Qian, 2010. Outside monitoring and CEO compensation in the banking industry. *Journal of Corporate Finance* 16, 383–399.

- John, K., A., Saunders, and L., Senbet, 2000. A theory of bank regulation and management compensation. *Review of Financial Studies* 13, 95–112.
- Kalemli-Ozcan, S., Sorensen, B., Yesiltas, S., 2012. Leverage across firms, banks, and countries. *Journal of International Economics* 88, 284–298.
- Kim, D., and A.M., Santomero, 1988. Risk in banking and capital regulation. *Journal of Finance* 35, 1219–1233.
- Korinek A., and K., Kreamer, 2014. The redistributive effects of financial deregulation. *Journal of Monetary Economics*. Forthcoming.
- Marcus, A., and I., Shaked, 1984. The valuation of FDIC deposit insurance using option pricing estimates. *Journal of Money, Credit and Banking* 16, 446-460.
- Merton, R.C., 1974. On the pricing of corporate debt: the risk structure of interest rates. *Journal of Finance* 29, 449-470.
- Merton, R. C., 1977. An analytic derivation of the cost of deposit insurance and loan guarantees: An application of modern option pricing theory. *Journal of Banking and Finance* 1, 3–11.
- Palmon, O., S., Bar-Yosef, R., Chen, and I., Venezia, 2008. Optimal strike prices of stock options for effort-averse executives. *Journal of Banking and Finance* 32, 229-239.
- Raviv, A., and E., Sili Ciammara, 2013. Executive compensation, risk taking and the economy. *Journal of Financial Stability* 9, 55-68.
- Ronn, E.I., and A.K., Verma, 1986. Pricing risk-adjusted deposit insurance: An option based model. *Journal of Finance* 41, 871-896.
- Smith, C.W., and R.M., Stulz, 1985. The determinants of firms' hedging policies. *Journal of Financial and Quantitative Analysis* 20, 391-405.
- Sundaram, R., and D., Yermack 2007. Pay me later: Inside debt and its role in managerial compensation. *Journal of Finance* 62, 1551-1588.
- Thanassoulis, J., 2012. The case for intervening in bankers' pay. *Journal of Finance* 67, 849-895.
- Tung, F., 2010. Pay for banker performance: structuring executive compensation for risk regulation. *Northwestern University Law Review* 105, Forthcoming.
- Tung, F., and X., Wang, 2011. Bank CEOs, inside debt compensation, and the financial crisis. Working paper.
- Wei, C. and D., Yermack, 2011. Investor reactions to CEOs inside debt incentives. *Review of Financial Studies* 24, 3813-3840.

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. The sensitivity of the position to the 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 assets follows a geometric Brownian motion, where the drift under the risk-neutral measure is equal to the risk-free rate r , and σ 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:

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

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

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

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

Appendix 2

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

Proof: The public position is composed of τ units of long call options 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 insured deposit F^D . To find the maximum value of the position we first calculate the derivative of the position with respect to asset risk:

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

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

where:

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

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

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

The equation can be expressed as well as:

$$\frac{\partial G}{\partial \sigma} = \frac{V \sqrt{T}}{\sqrt{2\pi}} [\tau a - b] \quad (5)$$

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

There is a constrained maximum for the public position with respect to asset risk in cases where the value of the derivative is equal to zero. Since the exponent of any number is positive, expressions a and b in Equation (5) are positive for any leverage, positive tax rate and asset risk. Moreover, since the value of expression d in Equation (3) decreases with parameter K , the value of expression a is always greater than expression b in equation (5). Therefore if the tax rate, τ , is between zero and one, the derivative can be equal to zero and there may be a level of asset risk that results in a constrained maximum for the public position.

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

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

$$\frac{\partial E}{\partial \sigma} = \alpha \frac{\partial \text{Call}(V, H, \sigma)}{\partial \sigma} - \beta \frac{\partial \text{Put}(V, F^D + F^S, \sigma)}{\partial \sigma} \quad (1)$$

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

where:

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

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

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

The equation can be expressed as well as:

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

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. This solution exists if the number of units of equity based compensation, α , is greater (smaller) than the units of loss due to bank failure, β , and 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 parameter b is greater (smaller) than a , where there is an interior solution for the maximum level of compensation.

When the performance-linked compensation of the executive is composed solely of stock the strike price, H , is equal to the total face value of the debt, $F^D + F^S$, and expressions a and b are equal. Therefore, the derivative will be always positive (negative) in the case that α is greater (smaller) than β , and the value of the executive position will 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). This one-year maturity is reasonable given the annual frequency of regulatory audits, because if the market value of the 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 $LR = Fe^{-rT} / V$. 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 ratio is set to 0.92, similar to the median level 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), who analyzed a database of 83 U.S. banks from 2006, and found that their median level of liabilities to assets was equal to 0.91 with a standard deviation of 3%.

Percentage of managerial ownership: The parameter α is the percentage of ownership of the executive in the bank. John, Mehran and Qian (2010) calculated the median value of CEO ownership in financial institutions as equal to 0.29%. However, one standard deviation in their study was equal to 3.97%. Thus, all the results in our numerical analysis are within the range of one standard deviation.

Units of loss due to bank failure: Parameter β is the percentage loss of the executive in financial distress as a percentage of the total value of the assets. The estimation of this component is difficult since it is composed of tangible assets such as uninsured pension benefits that would be foregone and intangible assets such 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 amounted to almost 30% of the market value of the assets measured one year prior to bankruptcy. Thus, this component in our analysis ranges from 0.45% and 0.6% of the asset value.

Face value of subordinated debt: The total debt is composed of deposits, 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's face value. In our analysis we define subordinated debt as any liabilities which are not insured by the government. Therefore, we looked for a lower and upper boundary for this level. Belkhir (2012), who analyzed a database of US commercial banks between 1995 and 2009 found that the average value of the subordinated debt tranche was equal to 1.79% of the total banks' liabilities. John, Mehran and Qian (2010) found that deposits constitute 81% of the 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 rates over the period between 1991 and 2008.

The strike price of the equity based compensation (H): We set the strike price to be equal to the asset value, based on the convention in the market to set the strike price of stock options as being at the- money.¹³

¹³ Palmon, Bar-Yosef, Chen, and Venezia (2008) study the optimality of option grants (with a choice of the strike price) and find that unless there are tax-related disadvantages, in-the-money options are better for shareholders.

Table 1: Parameters used in the base case of the model

Parameter	Source	Symbol	Base Value
Leverage ratio	John, Mehran and Qian (2010)	LR	0.92
Face value of total debt		F	1,000
Value of the firm's assets		V	1,049.6
Time to maturity	Marcus and Shaked (1984) and Ronn and Verma (1986).	T	1
Risk-free rate	Kenneth's French database	r	3.5%
Executive ownership	John, Mehran and Qian (2010)	α	0.3%
Executive loss in bank failure		β	0.6%
Face value of subordinated debt	Belkhir (2012)	F ^S	60
Bank's asset risk	Meheran and Rosenberg (2009)	σ	5.3%
Strike of the equity based compensation	Palmon et al., (2008)	H	1,049.6
Corporate tax rate	Federal tax rate	τ	35%

Table 2: The Equilibrium solution for the base case parameters under different claim holders' control and regulatory supervision methods

The Table presents the equilibrium solutions for the base case parameters for different regulatory supervision methods and abilities of the claimholders to control the decision variables. Each row shows the tools that the regulator uses to limit risk and its ability to control that tool. The value of each decision variable at equilibrium is reported in the next columns and the resulting position values of the stockholder, executive and the public are reported in the last columns.

Description of claimholders control	Decisions Variables (in %)				Position Value		
	Executive Ownership (α^*)	Asset risk (σ^*)	Limit on Asset risk (σ_{UBound}^*)	Limit on Executive Ownership (α_{UBound}^*)	Stock	Executive Position	Public Position
Full control of the decision variables, $\sigma_{UBound} \in [0, \infty)$ and $LR=0.92$ (Result 1)	0.388	8.33	8.33	NR	58.90	0.1726	30.49
Full control of the decision variables, $\sigma_{UBound} \in [0, \infty)$ and $LR=0.95$ (Result 2)	0.450	7.07	7.07	NR	39.12	0.0782	19.57
Limited regulatory ability to control asset risk, $\sigma_{UBound} \in [0.11, \infty)$ and $LR=0.92$ (Result 3)	0.462	11.00	11.00	NR	63.58	0.2171	29.72
Limited regulatory ability to control asset risk, $\sigma_{UBound} \in [0.11, \infty)$ and $LR=0.95$ (Result 3)	0.526	11.00	11.00	NR	47.54	0.1056	17.41
Limit on executive ownership only, $LR=0.92$, $\alpha_{UBound} = [0, \infty)$, (Result 4)	0.388	8.33	NR	0.388	58.90	0.1726	30.49
Limit on executive ownership only, $LR=0.95$, $\alpha_{UBound} = [0, \infty)$ (Result 4)	0.452	7.07	NR	0.452	39.12	0.0782	19.57
Asymmetric information regarding loss due to bank failure, $\beta^G=0.6\%, \beta=0.55\%$, (Result 5)	0.388	9.39	NR	0.388	60.70	0.1766	30.37
Asymmetric information regarding loss due to bank failure, $\beta^G=0.6\%, \beta=0.45\%$, (Result 5)	0.388	15.15	NR	0.388	72.34	0.1929	25.83
Two policy tools and asymmetric information regarding loss due to bank failure, $\beta^G=0.6\%, \beta=0.55\%$, and $\sigma_{UBound} \in [0.11, \infty)$ (Result 6).	0.388	11.00	11.00	0.388	60.70	0.1766	30.37
Two policy tools and asymmetric information regarding loss due to bank failure, $\beta^G=0.6\%, \beta=0.45\%$, and $\sigma_{UBound} \in [0.11, \infty)$ (Result 6)	0.347	11.00	11.00	0.388	63.65	0.1629	29.72

Table 3: The executive choice of asset risk under different levels of executive ownership, α , and units of loss due to bank failure, β

The values of asset risk (in %) that maximize the executive position for different executive ownerships (parameter α) and units of loss due to bank failure (parameter β). All other data are identical to those 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 position.

		Units of loss due to bank failure (in %)			
Executive ownership (in %)		0.45	0.50	0.55	0.60
	0.300	8.67	7.67	7.01	6.54
	0.347	11.00	9.20	8.10	7.40
	0.388	15.15	11.20	9.39	8.33
	0.500	MAX	MAX	20.07	13.46

Figure 1: The value of the claimholders' positions at debt maturity versus asset value

The figure presents the payoffs at maturity of the positions sensitive to asset risk for the public, the stockholder and the executive for different asset values. 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 identical to those in Table 1.

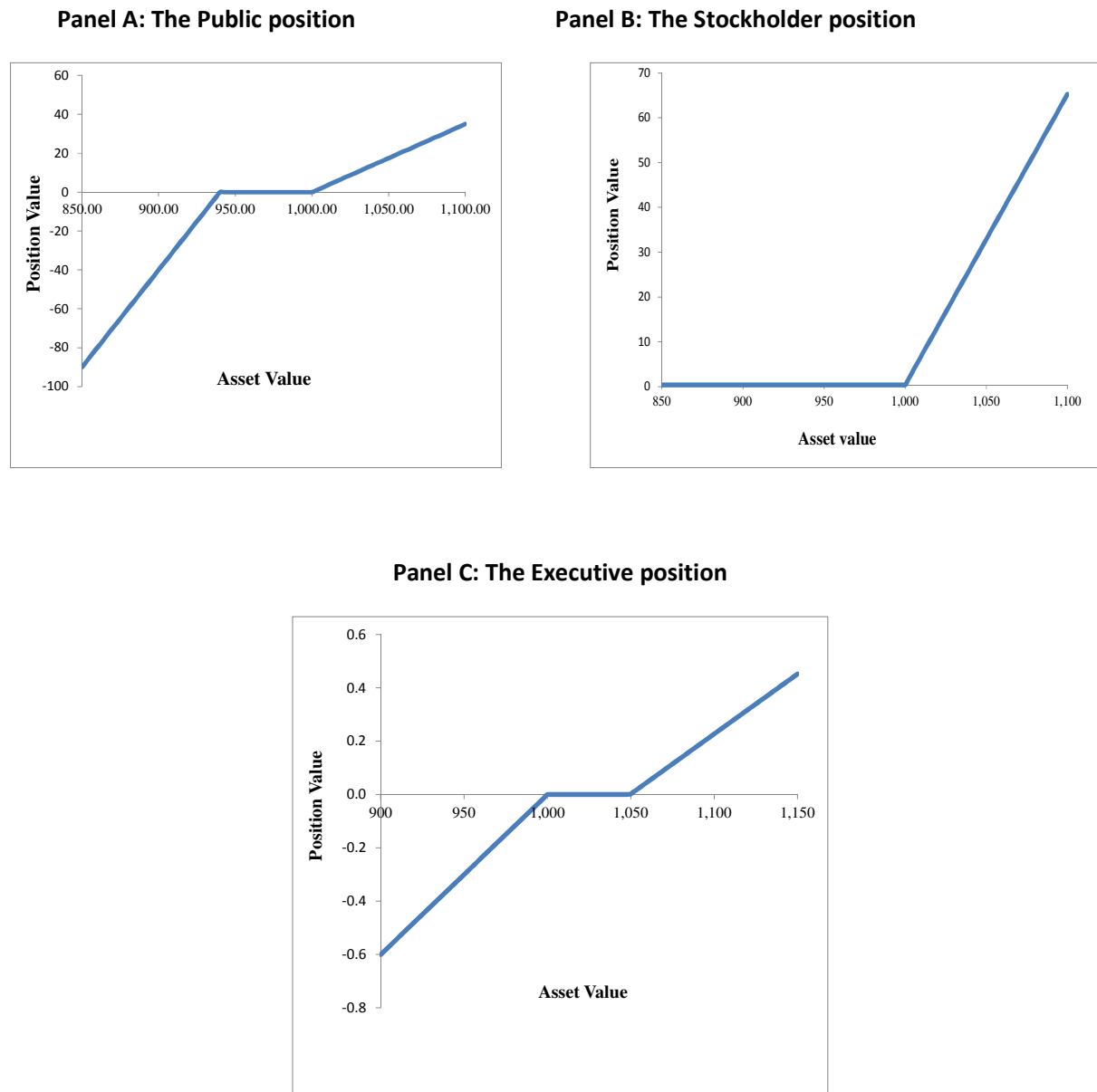
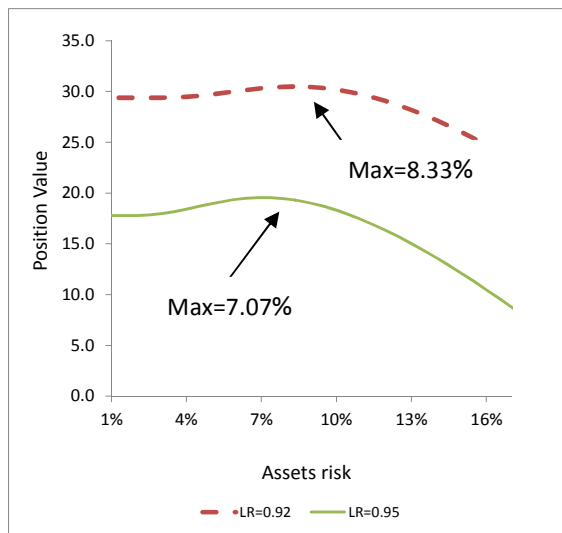


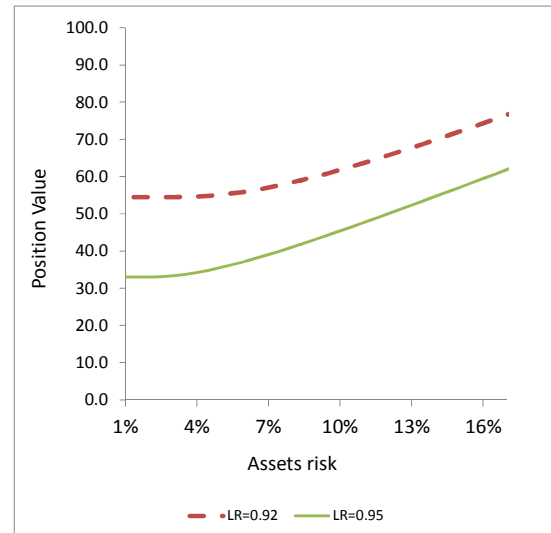
Figure 2: The value of the claimholders' positions versus asset risk

The figure presents the value of the positions sensitive to asset risk for the stockholder, the 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 identical to those in Table 1.

Panel A: The Public position



Panel B: The Stockholder position



Panel C: The Executive position

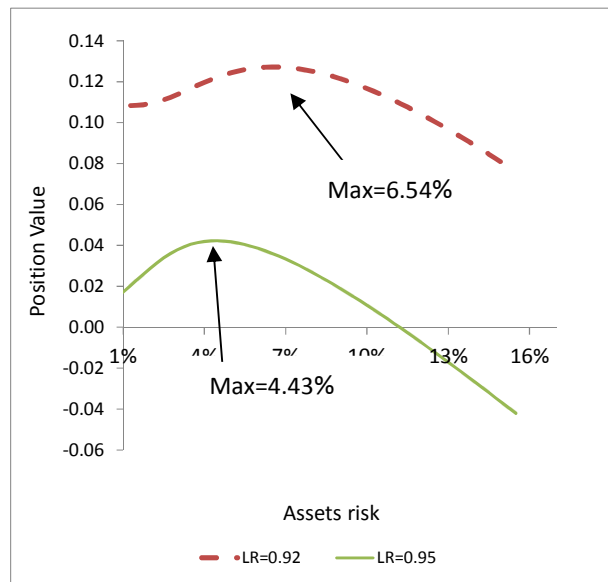
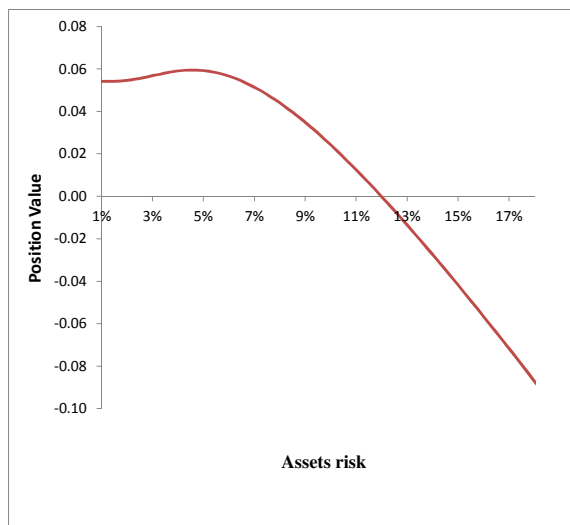


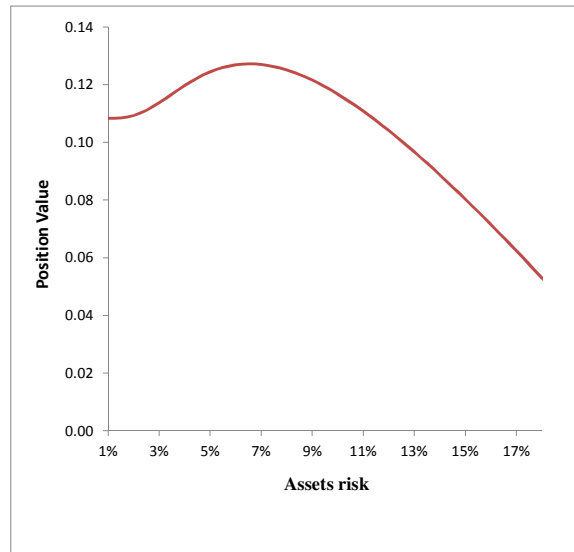
Figure 3: The value of the executive’s positions for different asset risks and size of equity based compensation

The figure presents the value of the executive position versus asset risk, where the units of equity based compensation is either low ($\alpha=0.15\%$), moderate ($\alpha=0.3\%$) or high ($\alpha=0.6\%$). The data are identical to those in Table 1.

Panel A: “Low” equity compensation ($\alpha=0.15\%$)



Panel B: “Medium” equity compensation ($\alpha=0.30\%$)



Panel C: “Large” equity compensation ($\alpha=0.6\%$)

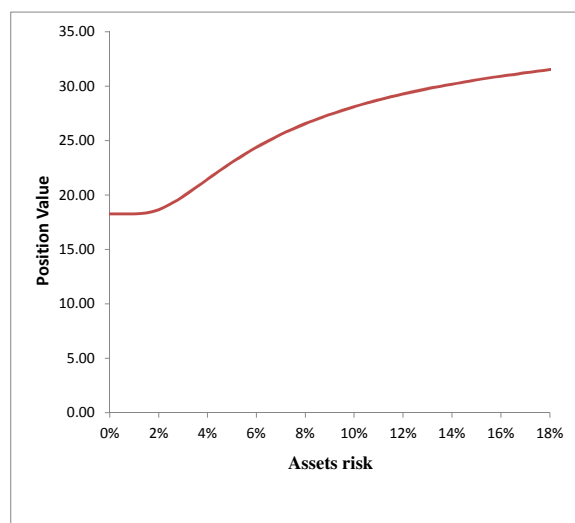
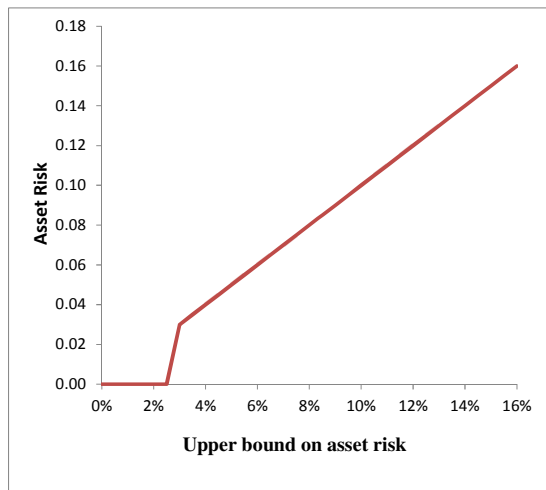


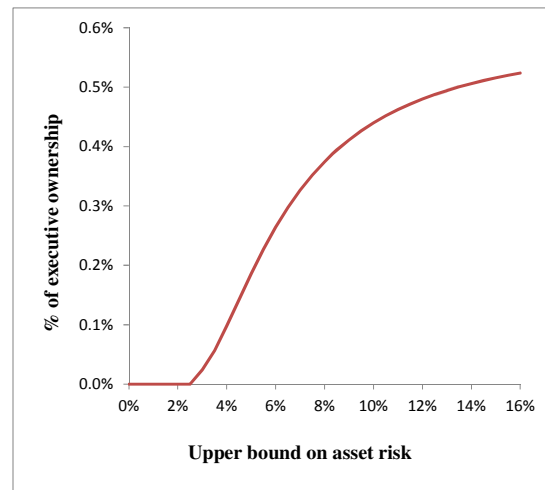
Figure 4: Asset risk, executive ownership and claim's value at equilibrium with regulatory limit on asset risk.

The figure presents the level of asset risk chosen by the executive and executive ownership, as awarded by the stockholder, for different regulatory limits 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 presented in Table 1.

Panel A: Asset risk versus the regulatory upper bound on asset risk



Panel B: Executive ownership versus regulatory upper bound on asset risk



Panel C: The value of the executive, stockholder and public positions versus the regulatory upper bound on asset risk

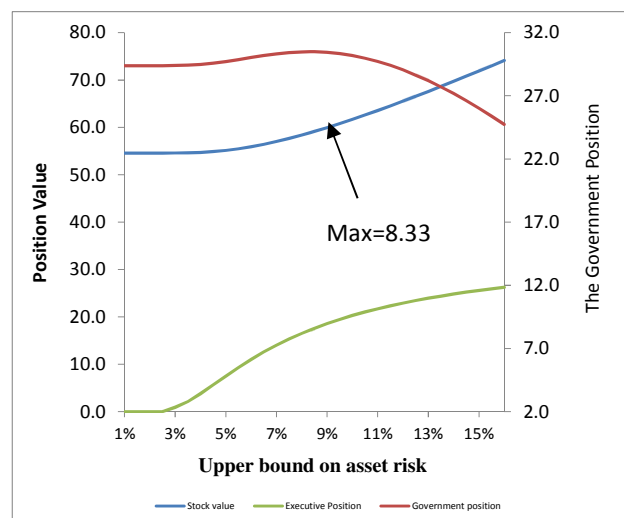
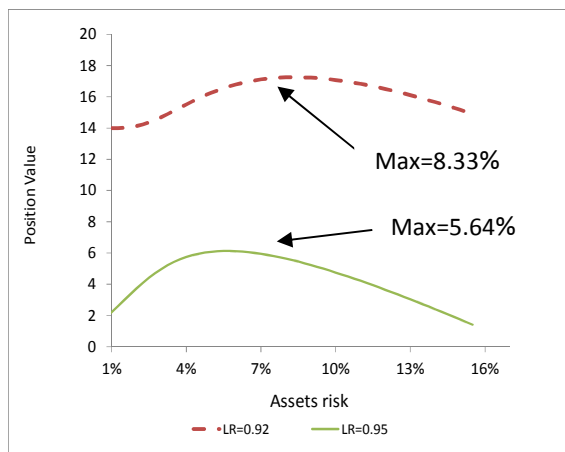


Figure 5: The value of the executive position versus asset risk for different levels of leverage and ownership.

The figure presents asset risk and the value of executive positions for different leverage ratios, 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 presented in Table 1.

Panel A: Executive ownership equals 0.388%.



Panel B: Executive ownership equals 0.45%.

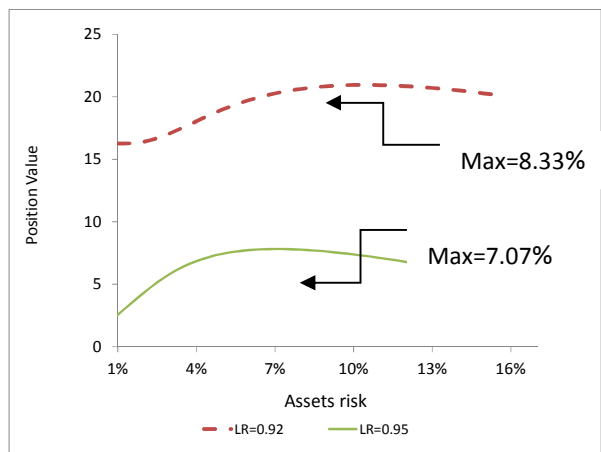
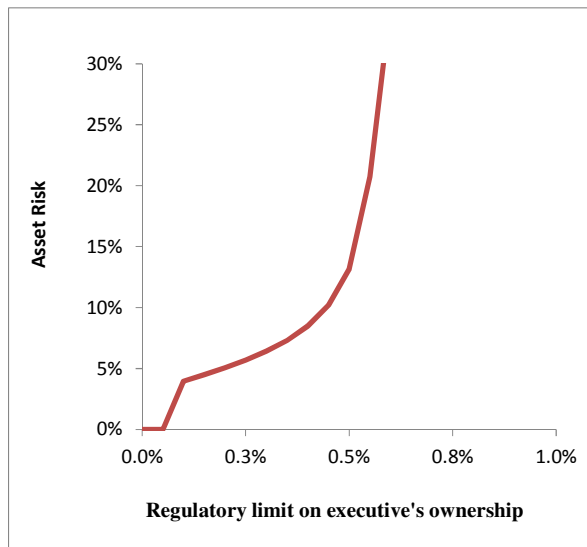


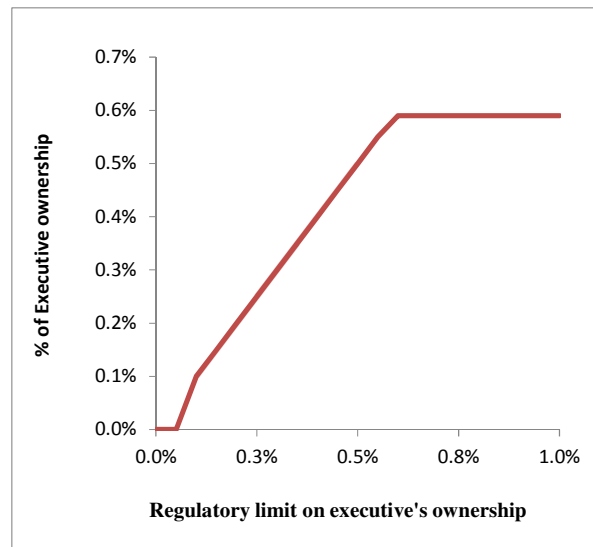
Figure 6: Asset risk, executive ownership and positions values at equilibrium with regulatory cap on executive ownership.

The figure presents the level of asset risk chosen by the executive, the executive's ownership as awarded by the stockholder, for different caps 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 presented in Table 1.

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



Panel B: Executive ownership versus regulatory cap on asset risk



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

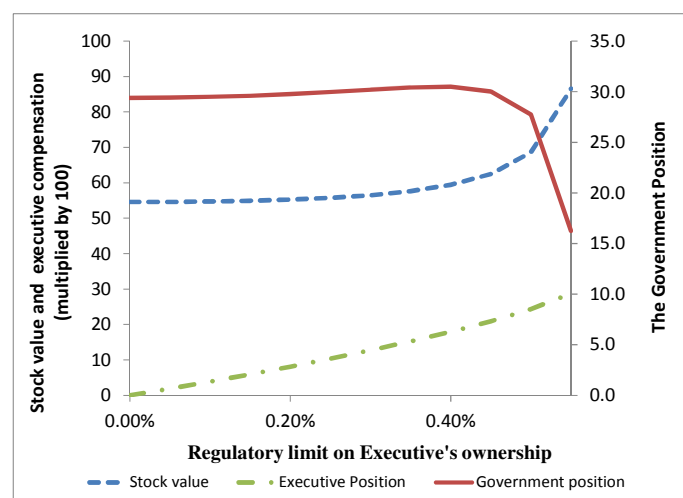
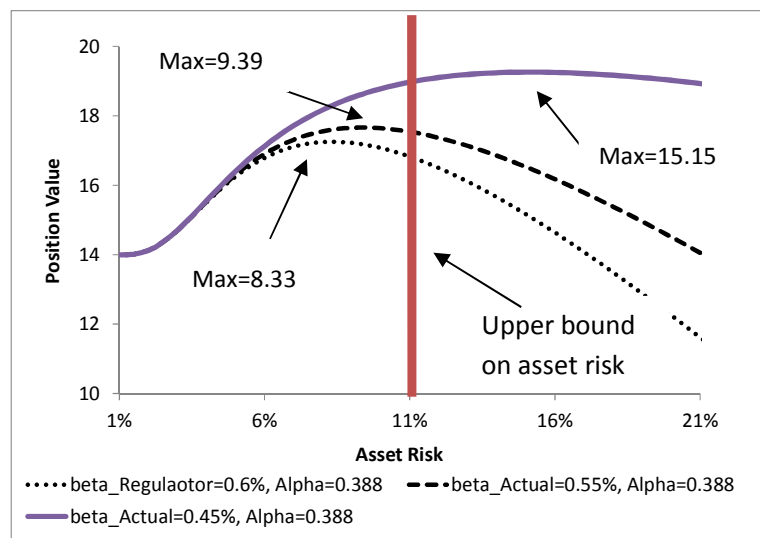


Figure 7: The value of the executive position with asymmetric information about the executive loss due to bank failure and the upper bound on asset risk

The regulator has imperfect information and assumes that the loss due to bank failure, β , is equal to 0.6% of the asset value and therefore awards these executives with 0.388% of the bank's ownership. According to the regulator's calculation the executive position is maximized at a level of 8.33%. However, the actual size of β is lower and equal in one example to 0.55% and in the other to 0.45%. The result is an executive position which is maximized either at an asset risk of either 9.39% or 15.15% for β of 0.55% and 0.45% respectively. In Panel B, the stockholder is informed about the actual level of β and therefore reduces executive ownership to 0.345%, to motivate the executive to take a level of risk which is equal to the upper bound set by the regulator (11%).

Panel A: The value of the executive position with uninformed stockholder



Panel B: The value of the executive position with informed stockholder

