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**The Regulation of Financial Institutions, Executive  
Compensation and Risk Taking**

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# The Regulation of Financial Institution, Executive Compensation and Risk

## Taking

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### Abstract

Excessive risk taking by financial institutions has been widely identified as a major cause of the 2008 financial crisis. The crisis raised a number of crucial issues: What is the effect of a financial institution's pay package, executive ownership and the type of regulations on risk taking? What should be the relationship between the different policy tools for controlling risk: regulation of compensation, traditional measures such as capital adequacy and direct control of bank activities? Are these measures complementary or substitutes?

To answer these questions we develop a valuation model for the different positions held by the claimholders in a financial institution - the stockholder, an executive that hold equity based compensation and has potential loss in financial failure, and the government which acts as the deposits insurer. By using an equilibrium solution we show the level of assets risk chosen by the executive, the level of executive's ownership set by the stockholders, and the limits on assets risk and/or executive's ownership set by the regulator. The paper demonstrates that direct limit on the level of assets risk would lead the executive to choose the maximum possible level of risk and this level decreases with leverage. Equity based compensation can lead to excessive risk taking only in case of regulatory inertia, where the regulator is limited in its ability to directly supervise assets risk. Moreover, a regulatory limit on executive ownership can be a substitute for direct supervision of bank activities. However, if the claimholders have heterogeneous beliefs regarding the executive's potential loss in the case of failure, then the executive can either choose an excessive risk level or shy away from risk. Thus, using simultaneously, the two policy tools can reduce the problem of excessive risk taking.

**JEL classification:** G12, G13, G21, G28, G38, E58.

**Keywords:** executive compensation; risk taking; regulation; equity based compensation; economic crisis

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## **1. Introduction**

A major suspect commonly named for the 2007-2009 financial crisis is excessive risk taking by financial institutions. While the increase in asset risk was clearly identified by regulator, market participant and policymakers, there is ongoing debate regarding the elements which enable the observed increase in assets risk. The first approach claims that executives in financial institutions were motivated to take excessive risk due to pay packages that include a dominant component of equity based component (Bebchuk, Cohen and Spamann, 2010; Bolton, Mehran and Shapiro, 2011). A second approach explains the excessive level of risk by supervisory inertia (Blanchard, 2008; Caprio, Demirgucx-Kunt and Kane, 2010; Delis and Staikouras, 2011). According to this approach, inadequate supervisory review process and low stringency of law and regulations enforcement lead to the 2007-2009 financial crisis.

As a response to the crisis and to its potential causes, policymakers are focusing on reforms which aim to strength the resilience of both financial institutions and markets. The Dodd-Frank Wall Street Reform and Consumer Protection Act (2010), in Part (b) of Section 956, prohibits, financial institutions from adopting any incentive plan that regulators determine encourages inappropriate risks by covered financial institutions. The European Union, adopted at February 2013, a provisional deal which limit the amount of bankers' bonuses to the amount of fixed remuneration, where the cap could be increased to 2:1 with the backing of a supermajority of shareholders.

While reforms to avoid excessive risk taking in financial institutions are widely adopted around the world, the strategic implementation of such rules still need to be elaborated and major issues need to be addressed. First and foremost, what is the risk taking motivation of an executive under different structure of compensation, bank's capital structure and limits, set by

regulators, on assets risk and/or on executive's ownership. A second issue, what are the ways that regulators can and should use to induce financial firms owners and executives achieve a level of assets risk which is consistent with the government goals?. Is there a policy tradeoff between the regulation of executive pay packages and more traditional regulatory policy tools such as capital adequacy requirements and direct control of a bank activities to achieve these level of assets risk?. Put differently, are these measures complementary or substitutes? And, consequently, what should be the relationship between the authorities that regulates them? The answers to these questions should consider the possible conflict between the private optimal level of risk taking (owners and executives) and the public (represented by the government), the nature of banks' operations and regulatory policies.

This paper attempts to fill this gap by developing a continuous time model to analyze the value of the claims of the stockholders, the bank's executive and the government (regulator). In our model the bank's executive can choose the level of assets risk, the stockholders determines the executive's pay in the form of ownership share and the regulator can limit assets risk or/and executive ownership. The claimholders decisions are made by using a Nash equilibrium framework, where the objective of each claimholders is to maximize the value of its position's monetary value, while taking into account the strategic behavior of all others claimholders. The equilibrium solution determines the level of assets risk of the financial institution, executive ownership and the regulatory chosen limit on assets risk or on executive's ownership. 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 government optimal risk level, as well as the discussion on the optimal design of prudential regulation and the coordination mechanism between banks' regulators.<sup>1</sup>

First, we present the analysis of the risk taking motivation of all claimholders and derive the valuation of their positions. Consistent with the financial literature (Jensen and Meckling, 1976; Galai and Masulis, 1976), the stockholder's position in our model is composed of the residual assets after paying taxes and allocating equity based compensation to the executive. Thus, the value of the stockholder position increases with assets value and assets risk. On the other hand, the government has two different positions in the financial institution. The first component is a positive payoff from tax payments by banks, where a possible broader interpretation of this component is the benefits of "financial stability", the welfare created by a well-functioning banking system, this effect is documented by large number of studies (Demirguc-Kunt and Maksimovic, 1998; Wurgler, 1999; Gertler, 1988; and Levine, 1997). The value of this position increases with the value of the bank's assets. The second position is a negative payoff in the form of *deposit insurance*, which the government pays the insured depositor in the case of bank failure, in a broader sense this can be interpreted as the costs of financial distress. We prove that the value of the government position can have a global maximum with respect to asset risk. This result may explain the motivation of regulators to avoid excessive risk taking on the one hand and avoidance of risk taking by banks that may result in a situation of credit freeze, on the other hand.

The bank's executive, has a dual position as well, it is composed of *equity-based compensation* that may include stocks and stock options, bonus payments, as well as other pecuniary or non-pecuniary benefits whose value increase with the value of the bank's assets, and

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<sup>1</sup> We would like to stress that by calculating the optimal level of assets risk for the government we are not trying to calculate the level which maximizes the welfare of the society, rather we narrow the definition to the level which maximizes the value of the government holding under the described terms.

a negative position of *loss due to financial failure* –which is the decrease in the executive’s position if the bank she is managing fails. 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 future employment opportunities (Gilson, 1989; Graham et al., 2013).

We prove that when the number of units of executive’s ownership is lower than the number of units of loss due to financial failure, and the strike price of the equity based compensation is above the face value of debt, the relationship between the executive’s position value and asset risk has a humped shape with a single global maximum. The global maximum value of the position increases with executive ownership till the relationship between assets risk and the executive’s position becomes upward sloping and there is no global maximum for the value of the position. Furthermore, as leverage increases the level of assets risk which maximizes the value of the compensation decreases. In our analysis we generalize the analysis by Sundaram and Yermack (2007), who considered the special case where executive compensation includes only stock and leverage has no effect on risk taking motivation.

After analyzing the single position of each claimholders we find an equilibrium solution for the chosen level of assets risk, executive ownership and regulatory limits on the level of assets risk and/or executive ownership. Thus, our framework enables us to calibrate the model to the data of typical regulated financial institution and to explain the risk taking motivation before and during the financial crisis of 2007-2009. We derive first the equilibrium in a setting with unrestricted ability of the regulator to limit banks’ assets risk taking, where a bank’s executive can choose the level of assets risk inside this domain, and the stockholder can determine the level

of executive ownership. Under this setting the government would choose as its limit the level of risk that maximizes the value of its position and the stockholder would optimally award the executive with the minimum equity based compensation that would motivate her to take the maximum possible level of assets risk allowed by the government. Although the existence of such regulator may be unrealistic, this case serves us as a yardstick to the later analysis.

Over the past decades, as the size and complexity of financial firms have increased, supervising and regulating banking organizations became more difficult and thus the ability of regulator to control banks assets risk (Berger, Davies, and Flannery, 2000; DeYoung et al., 2001 and Evanoff and Wall, 2000). Moreover, in the years before the financial crisis of 2007-2008 many financial institutions undertook excessive assets risk despite governmental regulation, a factor that was identified as one of the major causes of the crisis (Brunnermeier, 2009).<sup>2</sup> Therefore, we next analyze the more realistic case, in which the regulator is limited in its ability to control the maximum level of assets risk. In such case, the executive would be incentivized to take the maximum possible level of assets risk, which may be above the level that maximizes the government's position. While the result is consistent with the excessive risk taking in financial institutions as observed prior to the 2008 financial crisis we also show that an increase in executive ownership cannot cause by itself an increase in the level of assets risk. Instead, it is the stockholder' reaction to observed supervisory inertia which motivate the stockholder to increase executive's ownership, which in turn motivates the executive to take the maximum possible level of risk.

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<sup>2</sup> The U.S. Financial Crisis Inquiry Commission, reported its findings in January 2011, find out that the crisis was caused by widespread failures in financial regulation, including the Federal Reserve's failure to stem the tide of toxic mortgages; Dramatic breakdowns in corporate governance including too many financial firms acting recklessly and taking on too much risk.

Furthermore, we demonstrate that all else equal, an increase in the leverage ratio of a financial institution reduces the motivation of executives to take risk. However, if equityholders can adjust the compensation package and increase the equity based component they can realigned their interest with that of the executive and to incentivize her to undertake the maximum possible level of assets risk. Such result is consistent with the Dot.com crisis of 2001-2003, where stockholders were increasing the value of executives' equity based compensation, by either awarding them with more units of ownership or by changing the strike of their stock options. Moreover, the result highlights the need to non-flat regulations for financial institutions with different leverage ratio.

The equilibrium result of excess risk taking in the case of limited regulatory control of the limit on assets risk and a full control of executive's ownership by the stockholder, motivates us to analyze the case where a limit on executive ownership by the regulator is replacing the direct limit on assets 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 assets risk, if the regulator can completely control these limits. However, a limit on executive ownership is preferable over a limit on assets risk, either if imposing a limit on assets risk has higher costs, or if the regulator a bounded ability, and cannot impose the limit on assets risk which maximizes its holding. Therefore, under the assumption of a full control of the limitations and no asymmetric information between the regulator and the executive, supervising a bank assets risk and regulating executive compensation are a complete substitute.

The framework is extended to analyze the case of heterogeneous beliefs regarding the potential loss of the executive in financial distress. While the financial literature traditionally focus on the effect of "inside debt" on the risk taking motivation of executive, which is defined



as debt, or any security with payoffs very similar to debt, held by the manager (Edmans and Liu, 2011; Gerakos, 2007; Sundaram and Yermack, 2008), we relate to a broader concept and include, as part of it, intangible assets that can be lost in financial distress, as reputation. We show that when the regulator has a higher assessment than the executive of the loss due to financial failure, then the maximum limit on executive ownership set by the government would motivate the executive to choose a level of assets risk lower than the one which maximizes the government position. These results are consistent with observed post crisis levels of assets 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 has a greater estimation of the executive's position of loss in financial failure than the one made by the executive, then the maximum limit on executive ownership set by the government would motivate the executive to choose a level of assets risk which is greater than the level that maximizes the government position.

Finally, while under homogenous beliefs and symmetric information between the claimholders, there is a policy tradeoff between the regulation of executive pay packages and direct control of banks activities, we show that incorporating the two policy tools, limit on assets risk and limit on executive ownership, may make the government better off in the case of heterogeneous beliefs regarding the potential loss of the executive in financial distress between the regulator and the executive.<sup>3</sup>

The rest of this paper is organized as follows: Section 2 briefly reviews the related literature. In section 3 we present the analysis of the risk taking motivation of all claimholders and derive the valuation of their positions. An equilibrium solution for the chosen level of assets

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<sup>3</sup> 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.

risk, executive ownership and regulatory limits on the level of assets risk and/or executive ownership is presented in Section 4. Section 5 concludes

### **3. Decision makers: their positions and its sensitivity to assets risk**

In this section we derive the value of the positions of the three claimholders of the financial firm (bank): government, stockholder and the executive and their sensitivity to asset risk. In our model the decision of a claimholder may affect the value of the position of the other claimholders. To demonstrate the theoretical results of each section, 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 with a that is financed by equity  $S_t$ , one secured deposit obligation, maturing at time  $T$ , with a face value of  $F^D$  and subordinated debt with a face value of  $F^S$  which has a similar maturity as the deposit. We assume that the value of the financial institution's asset follows a geometric Brownian motion with a dynamic given by:

$$dV = rVdt + \sigma VdW \quad (1)$$

where  $W$  is a standard Brownian motion,  $r$  is the risk free rate, and  $\sigma$  is the instantaneous constant standard deviation of the assets' rate of return.

#### **3.1 The government position and its sensitivity to asset risk.**

The position of the government has two different components in the financial institution. The first component is a positive payoff from tax collection in the form of participation in 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. In our model, the corporate tax payments at the rate of  $\tau$ , where,  $(0 \leq \tau \leq 1)$ , are paid if the value of the financial institution's assets at debt maturity, is greater than the total face value of debt  $(F^D + F^S)$ . In such case, government's payoff is equal to the tax rate,  $\tau$ , times the difference between the value of the financial institution's assets and the total value of debt.

The second component is a negative payoff in the form of a deposit insurance which is given to the depositors in the event of default of the financial institution. The insurance is activated at maturity if the value of the financial institution's assets is below the value of the secured deposit. In such event, the government would pay the difference between the face value of the secured deposit and the value of assets. The payoff of these two components at maturity can be expressed as:

$$G_T = \tau \max(V_T - F^D - F^S, 0) - \max(F^D - V_T, 0) \quad (2)$$

The current value of the government position 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 which equal to the face value of the insured deposit,  $F^D$ .<sup>4</sup> The current value of the position can be written as:

$$G = \tau \text{Call}(V, F^D + F^S, \sigma) - \text{Put}(V, F^D, \sigma) \quad (3)$$

If we define the quasi leverage ratio of the financial institution as being equal to  $LR = ((F^D + F^S)e^{-rT})/V$ , then we can normalize the total face value of debt to one, and the

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<sup>4</sup> The pricing of the different options and position is presented in Appendix 1.

current value of this position can be replicated by two options: the first is a long position in  $\tau$  unit of a plain vanilla call option with a strike price of one, and the second is a short position in a plain vanilla put option with a lower strike price of  $(1 - F^S)$ , i.e., the face value of the secured deposits.

The sensitivity of the present value of the government position to asset risk is presented in Panel A of Figure 1. 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. The value of the government is calculated using the standard Black, Scholes and Merton (1973, 1974) pricing equations (See Appendix 1).

**Theorem 1:** *The government’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 government position increases with the size of subordinated debt and the tax rate and decreases with total leverage.*

**Proof:** See Appendix 2.

To demonstrate the effect of assets risk on the government position we calibrate the model to data that are typical to U.S. banks over the period before the and during the 2008 crisis. Panel-A of Figure -2 presents the value of the government position with respect to asset risk under different level of leverage. In our example, the quasi leverage ratio between debt and assets is equal to 0.92, where 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 2.5%.<sup>5</sup> While calibrating

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<sup>5</sup> All other parameters are at their base case values as listed in Appendix 1, unless stated otherwise. The motivation for choosing these specific levels is explained in Appendix 3.

equation (3) to the data of the numerical example we find that the value of the government position has a global maximum at the value of 8.33% and is humped shape with respect to assets risk. The results are consistent with regulators' goal of reducing the risk taking 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). When leverage increases to 0.95 the level of risk which maximizes the government payoff decreases to 7.07% (See Figure 2 and Table 2).

### 3.2 The executive position and assets risk.

The executive's position has two different components which are sensitive to the value of the financial institution's assets: *equity-based compensation* and *loss due to financial failure*. 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 equal or greater than the total face value of debt,  $H \geq (F^D + F^S)$ . In the special case where the equity based compensation include only stock the strike price is equal to the total face value of debt (See *Lema 1*).<sup>6</sup>

The second component of the executive position which is also sensitive to assets risk is composed of  $\beta$  units of loss due to financial failure. Since these losses are mostly subordinated to the secured deposits in financial institutions, the payoff at maturity is modeled as being equal

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<sup>6</sup> We assume that in the case of executive stock option the dilution effect is relative small and has only secondary effect on the other liabilities that were issued by the financial institution.

to  $\beta$  times the difference between the total value of debt ( $F^D + F^S$ ) and the value of the firm assets. The executive payoff at maturity can be expressed as follow:

$$E_T = \alpha \max(V_T - H, 0) - \beta \max(F^D + F^S - V_T, 0) \quad (4)$$

The current value of this position can be replicated by two options: the first is 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 put option with a strike price equal to the total face value of the bank's debt:

$$E = \alpha \text{Call}(V, H, \sigma) - \beta \text{Put}(V, F^D + F^S, \sigma) \quad (5)$$

The value of the position, as valued by the standard Black, Scholes and Merton (1973, 1974) pricing equations is a function of the total leverage ratio, the moneyness of the equity based compensation and the financial institution assets volatility.<sup>7</sup>

**Theorem 2:** *The executive's position has a global maximum with respect to asset risk at the following states (1) The difference between the number of units of equity based compensation,  $\alpha$ , and the number of units of loss due to financial failure,  $\beta$ , is positive and the total face value of debt,  $F^D + F^S$ , is greater than the strike price of the equity based compensation,  $H$ . (2) The difference between the number of units of equity based compensation,  $\alpha$ , and the number of units of loss due to financial failure,  $\beta$ , is negative and the total face value of debt,  $F^D + F^S$ , is smaller than the strike price of the equity based compensation,  $H$ . Otherwise, there is no internal maximum to the position value.*

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<sup>7</sup> The pricing of the different options and position is presented in Appendix 1.

**Proof:** See Appendix 2.

**Lemma 1:** *In the special case, where the equity based compensation is composed of stock only, and  $F^D + F^S = H$ , the sensitivity of the executive position to assets risk depends only on the number of units of equity based compensation,  $\alpha$ , and loss due to financial failure,  $\beta$ .*

*If the number of units of loss due to financial failure,  $\beta$ , is greater (smaller) than the number of units of equity based compensation,  $\alpha$ , the executive's position value decreases (increases) with assets risk. If the two are equal, the executive position is not sensitive to assets risk.*

**Proof:** See Appendix 2.

In a typical executive compensation the strike price of the equity based compensation is greater than the total face value of debt and therefore in our numerical calibration we will relate to this case. All else equal, the value of assets risk which maximizes the value of the executive's position increases with the units of equity based compensation and decreases with the units of loss due to financial failure. The results is consistent with the agent conflict, as documented in the financial literature, where the risk taking motivation of the executive may not be aligned with the motivation of the equityholder, where the executive would try to target a lower level of assets risk than the stockholder.

Figure 3 describes the value of the executive position versus asset risk for leverage ratio of 0.92, as in our base case. For relatively low 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 humped shape with a single global

maximum.<sup>8</sup> The maximum value of the executive's position increases with the units of equity based compensation. The maximum value of the position is achieved at asset risk of 4.5% and 6.42% 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 when asset risk is equal to 4.4%, more than 1.8% 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 equal to 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 units of equity based compensation is greater (smaller) than the number of units of loss due to default ( $\alpha > \beta$ ) 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 financial failure.

### **3.3 The stockholder position and asset risk.**

The stockholder position includes the residual stocks of the financial institution after paying taxes and allocating equity based compensation to the executive. Therefore, the value of the

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<sup>8</sup> John, Mehran and Qian (2010) calculate the median value of CEO ownership in financial institution as being equal to 0.29%.



stockholders position is decreasing with an increase in the tax rate or in the units of equity based compensation. The stockholder's payoff at maturity,  $T$ , can be expressed as follow:

$$S_T = (1 - \tau) \max(V_T - F^D - F^S, 0) - \alpha \max(V_T - H, 0) \quad (6)$$

The current value of this position can be replicated by two options. The first is a long position in  $(1 - \tau)$  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 in  $\alpha$  unit of a plain vanilla call option with a strike price equal  $H$ , i.e., the strike price of the equity based compensation. The current value of the executive position can be written in options term as follow:

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

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

$$S = (1 - \alpha - \tau) \text{Call}(V, F^D + F^S, \sigma) \quad (8)$$

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

#### **4. Risk Taking and Executive compensation under different claimholders' control**

In this section we analyze different policy tools of the regulator, their effectiveness and their effect on the optimal decisions and the derived payoff of each of claimholders. The analysis

in this section is developed as follow: first, in Section (4.1), we assume that the regulator sets limit on the maximum level of assets risk and there is a full compliance by the different claimholders. Furthermore, we show equilibrium under different bank's leverage ratios. This assumption of agent with complete control on the decision of the other agents may not be realistic. However, it serves us as a yardstick and a starting point and will be relaxed in later sections. In Section (4.2), we analyze the equilibrium solution in case where the ability of the regulator to impose maximum level on assets risk is limited. Section (4.3) deviates from the previous analysis by showing the equilibrium solution in case that the regulatory limit on the maximum level on assets risk is replaced by a limit on executive equity based compensation. We relax the assumption of perfect information in section (4.4) and we analyze the case in which the regulator and the executive have different assessment of the value of executive position. The two positions holders estimate differently the loss in financial failure, which is composed of intangible components that are difficult to estimate and the learning ability is limited. We show how the government position can be improved by using a combination of two policy tools simultaneously – limit on assets risk and limit on executive ownership.

The equilibrium solution for the decision variables and the claimholders' position is determined in three steps. At 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. At the next stage, the equityholder maximizes her 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 government holding,  $\sigma^{\max*}$ . 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 “Nash equilibrium”. Let us defined the set of parameter and payoffs in such equilibrium is donated as follow:  $\{\sigma^*, \alpha^*, \sigma^{\max*}, E^*, S^*, G^*\}$ <sup>9</sup>.

We use a framework on 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 Equilibrium with limit on assets risk under complete claimholders control**

In this baseline scenario all claimholders has a full control of their chosen strategy and they can immediately respond to changing market conditions. Moreover, the claimholders’ 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 level of maximum risk and thus  $\sigma^{\max} \in [0, \infty]$  and the executive can decide about any level of asset risk between zero and the maximum level which enforced by the regulator,  $\sigma \in [0, \sigma^{\max}]$ .

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<sup>9</sup> 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.

**Result 1.** *If all claimholders have a full control of their decisions, in equilibrium, the maximum limit on assets risk set by the government would be the level that maximizes its position,  $\sigma^{G^*} = \sigma^{\max^*}$ . The chosen level of assets risk by the executive would be equal to that level as well,  $\sigma^* = \sigma^{\max^*} = \sigma^{G^*}$ .*

The strategy choice can be calculated in three stages. First, we find the risk level that maximizes the value of the government position:

$$\sigma^{G^*} = \arg \max G(\sigma, V, F^D, F^S) \quad (9)$$

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 (9) can be calculated by setting the derivative of the government position with respect to assets risk to zero:

$$\frac{\partial G}{\partial \sigma} \Big|_{\sigma=\sigma^{G^*}} = 0 \quad (10)$$

Relying on the standard option valuation model as presented at Appendix 1, the derivative at Equation (10) can be derived as follow:

$$\frac{\partial G}{\partial \sigma} = \frac{\tau S \sqrt{T}}{\sqrt{2\pi}} e^{-\frac{d(F^D+F^S)^2}{2}} - \frac{S \sqrt{T}}{\sqrt{2\pi}} e^{-\frac{d(F^D)^2}{2}} = 0 \quad (11)$$

where:

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

Second, after deriving the equilibrium level of assets risk, we calculate the unit of equity compensation that maximizes the value of the equityholder position. The value of the stock increases with assets risk. However, the level of assets risk is bounded at the level of  $\sigma^{G^*}$ . Moreover, as the unit of executive ownership increases the value of the stockholder's position decreases. Therefore, the stockholder would award the minimum ownership to the executive that would still motivate her to take a level of risk which is equal to the regulatory limit on assets risk.

As described in the proof of *Theorem 2*, in order to derive the amount of equity based compensation that maximizes the value of the position of the executive given the regulatory limit on assets risk, we set to zero the derivative of the executive position with respect to assets risk, while keeping fixed the level of assets risk to  $\sigma^{G^*}$  :

$$\frac{\partial E(\sigma = \sigma^{G^*})}{\partial \sigma} \Big|_{\alpha = \alpha^{S^*}} = 0 \quad (12)$$

The derivative of Equation (12) can be calculated as follow:

$$\frac{\partial E(\alpha = \alpha^{S^*})}{\partial \sigma} = \frac{\alpha^{S^*} S \sqrt{T}}{\sqrt{2\pi}} e^{-\frac{d(H)^2}{2}} - \frac{\beta S \sqrt{T}}{\sqrt{2\pi}} e^{-\frac{d(F^D + F^S)^2}{2}} = 0 \quad (13)$$

In the third stage, the executive is has now a compensation of  $\alpha^* = \alpha^{S^*}$  percentage of the firm's ownership and a limit on the maximum level of assets risk equal to  $\sigma^{G^*} = \sigma^{\max^*}$ . The executive will take the maximum allow level of assets risk  $\sigma^* = \sigma^{\max^*}$ , which maximizes the value of its holding given its position as expressed at Equation (13).

The calibration of the model to the base case parameters yields a level of assets risk of 8.33%, where the chosen level of assets risk is equal to the regulatory limit on assets risk (See Panel-A of Figure 2). The equityholder would compensate the executive with 0.394% of the firm's stock (See Table 2).

It should be noted, that if the regulator's efforts to impose the maximum level on assets risk are effective then the executive would be motivated to take this level of risk with any ownership which equal or greater than  $\alpha^{S^*}$ . For example, for the base case parameter, an executive ownership of 0.6% of the bank's stock, as described at Figure (3.C), would motivate the executive to take a risk which equal to the limit on assets risk. However, such a choice would decrease the value of the stockholder position, since the same level of assets risk can be achieved by a lower level of ownership (0.394 as in Panel A of Figure 2). Panel-B of Figure 4 presents, for the base case parameters, the level of executive ownership, in equilibrium, which is awarded by the stockholder for each given regulatory limit,  $\sigma^{\max}$ . For relatively low regulatory limit on 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 limit on assets risk to be equal to the level that maximizes its holding, and in equilibrium, all the three would be equal: the regulatory limit on assets risk,  $\sigma^{\max^*}$ , the chosen level of risk by the executive,  $\sigma^*$  and the level of risk that maximizes the government position,  $\sigma^{G^*}$ .

#### 4.1.1 The effect of Leverage on Equilibrium with a complete claimholders control

The leverage of the financial sector in the period 2000 to 2008 remained almost constant (Kalemli-Ozcan, Sorensen and Yesiltas, 2012), during the 2008 financial crisis the leverage of many financial institutions increased mainly due to a decrease in assets value and 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. The effect of leverage may be non-trivial effect. This is demonstrated here:

**Result 2.** *If all claimholders have a full control of their decisions, in equilibrium, a financial institution's assets 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 government position is maximized with a lower level of assets risk and the limit on assets risk is decreased. However, in order to motivate the executive to take this level of assets 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 government position. The government and the executive hold a bullish spread position, which becomes more sensitive to assets 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 government, and therefore it is more sensitive to assets risk.

In our numerical example, leverage increases from 0.92 to 0.95, as a result of a depreciation of the value of the firm's assets. Under a leverage ratio of 0.95 the value of the government position is maximized at a lower level of 7.07% compare to a level of 8.33% (Panel A of Figure 2 and Table 2). However, the value of the executive's position is even more sensitive

to changes in leverage, the executive is motivated to reduce assets risk from 8.33% to 5.46%, as presented in Panel-A of Figure 5. In order to maximize the value of the government position the regulator sets a new limit on assets risk at the level of 7.07%. The stockholder in response increase executive ownership to 0.45%, since under such compensation the executive is motivated to take the maximum level of assets risk, which in turn maximizes the stockholder position as well (Panel B of Figure 5). Our results are consistent with the Dot.com crisis of 2001-2003. As a result of a decrease in the value of assets and increase in leverage of financial institutions and other corporations stockholders counteracted these by increasing the executives' equity based compensation, by either awarding them with more units of ownership or by changing the strike of their stock options.

#### **4.2 Equilibrium with limited ability of the regulator to control assets risk**

The ability of regulators to enforce an effective limit on assets risk of financial institutions may be limited, especially for complex and big financial institutions. This may be due to "regulatory inertia", caused either by inadequate supervisory review processes and/or low stringency of law and regulation. In the following analysis we assume that the regulator is aware of its limits of power and the reactions of the other agents. Therefore, the regulator can only sets a maximum level of assets risk that greater than the level of risk that maximizes the value of its position, i.e.,

$$\sigma^{\max*} > \sigma^{G*} .$$

In such case, the equityholder would increase the units of equity based compensation to the executive till the maximum possible level of assets risk is targeted by the executive. As presented at Figure (4.B), all else equal an increase in the maximum level of assets risk would lead to an increase of executive ownership. Moreover, as presented in Figure (4.C), as the maximum level of assets risk increases the positions' value of the executive and the stockholder



would increase as well. However, the value of the government position would be below its maximum value.

**Result 3.** *If the regulatory limit on assets risk is above the level which maximizes the government position,  $\sigma^G > \sigma^{G^*}$ , then at equilibrium the executive would take the maximum possible level of risk,  $\sigma^* = \sigma^{\max*} = \sigma^G$ . Consequently, executive ownership is greater than in the case where the regulatory limit on asset risk is equal to the level which maximizes the government position.*

The stockholder, who is aware of the actual limit on assets risk  $\sigma^{\max*} > \sigma^{G^*}$ , 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 assets risk, while fixing the level of assets risk to the new higher regulatory maximum level  $\sigma^G$ . Since all else equal, the executive would be willing to shift to a higher level of assets risk only for a greater ownership, in the form of more units of equity based compensation, thus at equilibrium executive ownership would be increased.

These results are consistent with the excessive risk taking by financial institutions as observed prior to the 2008 financial crisis and with the increase in executive's ownership. *Result 3* shows that an increase in executive ownership cannot cause by itself an increase in the level of assets risk. Instead, it is the stockholder's reaction to observed supervisory inertia which motivate the stockholder to increase executive's ownership, which in turn motivates the executive to take the maximum possible level of risk.

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 0.39% of the firm's stock as found in Section (4.1). However, in the current case, the regulator can only restrict assets risk at any level which equal or greater than 11%. If the maximum allow level of assets risk is shifted up from 8.33%, as the value which maximize the government position, to the level of 11%, the stockholder would increase executive ownership from 0.394% to 0.467% and the executive, in response, would increase the level of assets risk to 11%. The value of the executive position would increase from 1.83 to 2.28 and the stock value would increase from 58.89 to 63.57. However, the value of the government position would decline from 30.49 to 29.72 only (See Table 2).

#### **4.3 Equilibrium with a limit on executive equity compensation**

The common practice in most countries is to regulate banks' assets risk by formal rules that include regulation and supervision (Basel II and Basel Accords III make up the international rules). However, in recent decades, as the size and complexity of financial firms have increased, supervising and regulating banking organizations became more difficult and thus the ability of regulators to control banks assets risk (Berger, Davies, and Flannery, 2000; DeYoung et al., 2001 and Evanoff and Wall, 2000). The difficulties to control a bank risk with traditional measure can lead to excessive risk taking by financial institutions as described in Section (4.2). In this section, we show that regulatory limits on executive equity pay can replace limits on risk taking as a tool to achieve the optimal regulatory risk level.

***Result 4.*** *If all claimholders have a full control over their decisions, in equilibrium, the maximum limit on executive ownership, set by the regulator, would motivate the executive to*

*choose a level of assets risk which is identical to the level that maximizes the government position,  $\sigma^{G^*} = \sigma^{E^*} = \sigma^*$ . The amount of ownership awarded by the stockholders to the executive would be equal to the regulatory limit on executive ownership.  $\alpha^* = \alpha^{\max^*}$ .*

The strategic choice can be calculated in this case in three steps. As in section (4.1), first the risk level that maximizes the value of the government position is found,  $\sigma^{G^*}$ . Next, the regulator calculates the amount of executive ownership,  $\alpha$ , that maximizes the value of the executive position at the same level of assets risk which maximizes the government's position,  $\sigma^{G^*}$ . Finally, the stockholder would choose to award this quantity of equity based compensation, since the increase in the value of the stock due to the higher level of assets risk more than offsets the decrease in value due to dilution and as a result:  $\alpha^* = \alpha^{\max^*}$ . The calculation made by the regulator, is identical to the one which the stockholder makes while calculating executive ownership in the case of a full control over the limit on assets risk by the regulator, as analyzed in section (4.1). Thus, the equilibrium result in the case of a limit on assets risk by the regulator and a limit on the maximum level of executive ownership are identical. However, limit on executive ownership may be preferable over a limit on assets risk since it usually has lower costs to the regulator, or in the case where the regulator is unable impose the limit on assets risk which maximizes the value of its position as in Section (4.2).

We demonstrate these results numerically in the following analysis. Suppose all the values of the parameters are identical to those of the base case, except that now the regulator sets a limit on executive ownership, rather than a limit on assets risk. Moreover, as in section (4.2), the regulator cannot fully control the maximum limit on assets risk and thus assets risk is limited by direct supervision to only 11%. At first, the regulator calculates the level of assets risk which

maximizes the value of its holding for a given leverage ratio (0.92 at our example), and for a given units of loss due to financial *failure* ( $\beta=0.6$ ). At the next stage, the regulator searches for the amount of equity compensation,  $\alpha$ , which maximizes the value of the executive position at a level of assets risk of 8.33%, which is identical to the level that maximizes the value of the government position. As in section (4.1), this level is equal to 0.349% of the financial institution's ownership. As in section (4.1), this level is equal to 0.349% of the financial institution's ownership. The stockholder, who has a position which increases in value with assets risk, would award the executive with the maximum allowed units of equity compensation (0.349%). Consequently, the government position would be maximized with respect to assets risk, and equal to 30.49. The value of the executive position and the stock would be equal to 0.827 and 58.89 respectively. At the case that leverage increases to 0.95, as in Section (4.1.1) the government position would receive its maximum value at a level of 7.22%. 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 assets risk. The value of the executive position would increase to 0.854 and the value of the government position and the stock would decrease to 19.57 and 39.11 respectively. These results are identical to the results in equilibrium in the case where claimholders has a full control of their decisions and the regulator can limit assets risk directly at any level.

#### **4.4 Equilibrium under heterogeneous beliefs regarding the value of the executive's position**

In this section we relax the basic assumptions of homogenous beliefs about the value of the executive's position and complete information. Under the current framework, 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 limit on executive ownership on the chosen level of assets risk.

Previous works based their estimation of the compensation loss in the case of *failure* on the value of “inside debt”, defined as debt, or any security with payoffs similar to debt, held by the executive (Edmans and Liu, 2011; Gerakos, 2007; Sundaram and Yermack, 2008). We adopt a broader definition and include intangible assets of the executive as well as “inside debt”. Intangible assets that may decline in value when the bank fails include reputation of the executive and non-diversifiable human capital in the firm. While there are accepted methods for estimating the value of inside debt, based on accounting and market data (Sundaram and Yermack, 2007; Gerakos, 2007; Wei and Yermack, 2011), the value of intangible assets is difficult to estimate mostly since they are not traded and it is difficult to find proxies for their value. This may lead to heterogeneous beliefs among the different claimholders about this component. To show the effect of heterogeneous beliefs on the equilibrium solution, we consider two possible scenarios, where the regulator either overestimates or underestimates the estimation of the loss due to financial *failure* made by the executive.

#### **4.4.1 Equilibrium when the regulator underestimates the executive’s loss in financial failure**

In this case, the executive estimates that her potential loss is greater than the loss expected by the regulator, i.e.,  $\beta^E > \beta^G$ .

**Result 5.** *If the regulator has a lower estimate of the executive’s loss in financial failure than the executive, i.e.,  $\beta^E > \beta^G$ , then the maximum limit on executive ownership set by the government*

would motivate the executive to choose a level of assets risk which is lower than the level that maximizes the government position,  $\sigma^{G^*} > \sigma^{E^*} = \sigma^*$ .

To find out the equilibrium solution, as in all the previous cases, the regulator calculates first the value of assets risk which maximizes its holding,  $\sigma^{G^*}$ . Next, the regulator derives the amount of equity based compensation,  $\alpha$ , which maximizes the value of the executive position at that level of assets risk. To find out this maximum value, the regulator set the derivative of the executive's position to be equal to zero by changing the size of executive ownership, as in equation (13). However, this solution would lead the executive to take a lower level of assets risk than the maximum, since the executive is estimating a greater loss in financial failure,  $\beta^E$ , than the regulator and the value of the derivative is negative.

These results are consistent with post crisis behavior of many financial institutions. Executives in financial institutions became more aware of the potential loss in financial *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 the unchanged, except that now the executive estimates the loss in financial *failure* to be 0.90% of the value of assets, while the regulator believes that the loss to be 0.6% of assets value. Consequently, as in section (4.3), the regulator sets a limit on executive ownership of 0.394%. At the next step, the stockholders, aware of the limits on equity based compensation allocate the maximum possible ownership of 0.349%, since the value of stock increases with assets risk. At last, the executive is searching for the level of assets risk which maximizes the

value of her holding. However, instead of an estimated loss in case of *failure* of 0.6%, the estimate is increased to 0.90%.

The executive estimates the value of its ownership and the potential loss in distress, and search for the level of assets risk which maximizes the value of her holding. Since the executive estimates her loss in case of failure is higher than the one estimated by the regulator, she will choose a lower level of assets risk than the optimal risk of the regulator. The executive would choose a level of 5.86% instead of 8.33% according to the regulator's estimation (Table 3). The value of the chosen decision variables by the executive's results in a lower value of the positions of all claimholders compared to the case of homogeneous beliefs. The stockholder, government and executive positions are equal to 55.72, 29.99 and 1.723 respectively (Table 2), where in the base case the values were equal to 58.89, 30.49 and 18.35 respectively.

#### **4.4.2 Equilibrium when the regulator overestimates the executive's loss in financial failure**

In this case the regulator overestimate the executive's assessment of the units of loss due to financial *failure* held by her, where the executive assumes that her potential loss is lower than the one which is made by the regulator, i.e.,:  $\beta^E < \beta^G$ .

**Result 6.** *If the regulator has a greater estimation of the executive's position of loss in financial failure than the one made by the executive, i.e.,  $\beta^E < \beta^G$ , then the maximum limit on executive ownership set by the government would motivate the executive to choose a level of assets risk which is greater than the level that maximizes the government position,  $\sigma^{G*} < \sigma^{E*} = \sigma^*$ .*

To find out the equilibrium solution, as in all the previous cases, the regulator calculates first the value of assets risk which maximizes its holding,  $\sigma^{G*}$ . At the next stage, the number of units of equity based compensation,  $\alpha$ , which maximizes the value of the executive's position at that

level of assets risk is calculated. However, this solution would lead the executive to take a higher level of assets risk than the one which maximizes the government position, since the executive is estimating a lower loss in financial failure,  $\beta^E$ , than the regulator estimation,  $\beta^G$ .

We demonstrate these results numerically by the following example. Suppose all the data are identical to the base case parameters, except that now the executive estimates the units of loss in financial failure as equal to 0.45% of the value of assets, while the regulator believes that the executive estimates it as equal to 0.6% of assets value. Consequently, as in section (4.3), the regulator set a limit on the units of executive ownership at the level of 0.394%. A level which supposed to maximizes the government holding according to its estimation of the number of units of loss in financial failure held by the executive. At the second step, the stockholder, aware of the limits on equity based compensation awards the maximum possible ownership of 0.349. The executive, figure out that under this compensation structure the value of assets risk which maximizes her holding is equal to 15.83% instead of 8.33%, which was supposed to be chosen according to the regulator estimation (Table 3). The value of the chosen decision variables is leading for a greater position value for the stockholder and the executive  $c$  compared to the case of no heterogeneous beliefs, where their position is equal to 73.85 and 2.284 respectively. However, the value of the government position is sharply decreased to 24.96 from a maximum value of 30.49.

#### **4.4.3 Equilibrium with two policy tools - under heterogeneous beliefs regarding the executive's loss in financial failure**

At all the previous described cases we have shown that regulatory limit on executive ownership can be a perfect substitute for limitation on the level of assets risk. However, incorporating the two policy tools may make the government better off.



**Result 7.** *If the regulator has a higher estimate of the executive's loss in financial failure, than the one made by the executive, i.e.,  $\beta^E < \beta^G$ , then introducing a limit on the maximum level of assets risk may make the government better off, if the limit on assets risk is above the level which maximizes the government position,  $\sigma^G > \sigma^{G*}$ .*

The results at equilibrium can be analyzed based on the previous case at section (4.4.3), where limit on executive ownership is presented, by adding a second policy tool as well – direct regulation of assets risk. As in previous section, the executive underestimate the units of loss in financial failure compare to the regulator estimation and thus the equilibrium level of assets risk is supposed to be above the level that maximizes the government position and equal to 15.83%. However, if the regulator can enforce effectively a direct limit on assets risk which is below the level that the executive would choose then the value of the government position in equilibrium is greater than in the case of only with limit on executive ownership.

While using simultaneously the two policy tools improve the position of the government at equilibrium, the effectiveness of using these two tools simultaneously 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 executive and the ability of the regulator to have reliable information about the executive estimation of her potential loss in financial failure.

## 5. 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 assets risk chosen by the executive, who manage the bank, the level of executive's ownership set by the stockholders, and the limits on assets 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 government 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 assets risk to any chosen level, in equilibrium, the maximum limit on assets risk set by the government would be the level that maximizes its position and the chosen level of assets risk by the executive equal to that level as well. Moreover, as leverage increases the chosen level of assets risk decreases and executive ownership increases.

Second, we relax the assumption of a regulator who can bound assets risk to any level, and we show that if the regulatory limit on assets risk is above the level which maximizes the government position, then at equilibrium the executive would chose that level, and consequently, executive ownership is greater than in the case where the regulatory limit on asset risk is equal to the level which maximizes the government 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 assets risk.

Third, we analyze the case where a limit on executive ownership set by the regulator is replacing the direct limit on assets 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 assets risk, if the regulator can fully control these limits. Thus, supervising a bank assets 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.

Fourth, we relax the assumption of symmetric information regarding the executive potential loss in financial failure and assume heterogeneous beliefs between the executive and the regulator regarding the value of this component. We show that when the regulator has a higher assessment than the executive of loss due to financial failure, then the executive would choose in equilibrium an assets risk lower than the one maximizes the government position. These results are consistent with observed post crisis levels of assets 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 in financial failure, then the executive would choose an excessive risk level above the level that maximizes the government position.

Finally, we demonstrate that incorporating the two policy tools, limit on assets risk and limit on executive ownership, can make governments better off in the case of heterogeneous beliefs between the regulator and the executive regarding the potential loss of the executive in financial 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  $V$  follows a geometric Brownian motion with a dynamic given by:

$$dV = (r - \delta)Vdt + \sigma VdW \quad (1)$$

where  $W$  is a standard Brownian motion,  $r$  is the risk free rate,  $\delta$  is the institution's payout ratio 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:

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

$$Put(T, K) = e^{-rT} KN(\sigma\sqrt{T} - d(K)) - VN(-d(K)) \quad (3)$$

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 government'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 government position increases with the size of subordinated debt and the tax rate and decreases with total leverage.*

**Proof:** The government 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:

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

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

where:

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

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

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

The equation can be expressed as well as:

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

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

There is a global maximum for the government position with respect to assets risk in cases where the value of the derivative is equal to zero. Since the exponent of any number is positive, the variables  $a$  and  $b$  at expression (5) are positive as well. Moreover, since the value of expression  $d$  in equation (3) always increases with the parameter  $K$  the value of the parameter  $a$  at expression (5) is always greater than the parameter  $b$ . Therefore if the tax rate,  $\tau$ , is between zero and one the derivative can be equal to zero and there may be a level of assets risk that result in a global maximum for the government position.

**Theorem 2:** *The executive's position has a global maximum with respect to asset risk at the following cases (1) if the difference between the number of units of equity based compensation,  $\alpha$ , and the number of units of loss due to financial failure,  $\beta$ , is positive and the total face value of debt,  $F^D + F^S$ , is greater than the strike price of the equity based compensation,  $H$ . (2) ) if the difference between the number of units of equity based compensation,  $\alpha$ , and the number of units of loss due to financial failure,  $\beta$ , is negative and the total face value of debt,  $F^D + F^S$ , is 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 a  $\beta$  units of short put option with a strike price which 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 derivate of the position with respect to asset risk:

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

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

where:

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

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

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

The equation can be expressed as well as:

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

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

When equation (5) is equal to zero there is an interior solution for the maximum level of assets risk. Such solution exists if the units of equity based compensation,  $\alpha$ , is greater (smaller) than the units of loss due to financial 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 the parameter  $a$  and  $b$  at equation (5) 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 seize 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 100, 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.<sup>10</sup> This means that the current value of the stock price is equal to the strike price. The value of the equity based component is calculated by using fix asset risk. We set asset risk equal to 5.3%, similar to the average asset risk of bank found in a large sample studied by Mehran and Rosenberg (2008). Although asset risk is an endogenous parameter in our model, we check the robustness of the assumption by changing assets risk by two standard deviations up or down. We figure that the move did not change significantly the level of the strike price or the robustness of our results. Using the base case parameter, the value of assets which result in "at the money" compensation is when the strike price is equal 104.66.

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<sup>10</sup> 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**

<b>Parameter</b>	<b>Source</b>	<b>Symbol</b>	<b>Base Value</b>
Leverage ratio	John, Mehran and Qian (2010)	LR	0.92
Face value of total debt		F	100
Value of the firm's assets		V	104.96
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)	$\alpha$	0.3%
Executive loss in default		$\beta$	0.6%
Face value of subordinated debt	Belkhir (2012)	$F^S$	6
Bank's assets Risk	Meheran and Rosenberg (2009)	$\sigma$	5.3%
Strike of the equity based compensation	Palmon et al., (2008)	H	104.66
Corporate tax rate	Federal tax rate	$\tau$	35%

**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 government are reported at the last columns.

Description of claimholders control	Decisions Variables (in %)				Position Value (for debt's face value of \$10,000)		
	Executive Ownership ( $\alpha^*$ )	Assets Risk ( $\sigma^*$ )	Limit on Assets Risk ( $\sigma^{\max}$ )	Limit on Executive Ownership ( $\alpha^{\max}$ )	Stock	Executive Position	Government Position
Full control of the decisions variables and $LR=0.92$ (Result 1)	0.394	8.33	8.33	NR	58.89	1.835	30.49
Full control of the decisions variables and $LR=0.95$ (Result 2)	0.452	7.07	7.07	NR	39.11	0.854	19.57
Limited regulatory ability to control assets risk, $\sigma^{\max}=11\%$ and $LR=0.92$ (Result 3)	0.467	11.00	11.00	NR	63.57	2.284	29.72
Limited regulatory ability to control assets risk, $\sigma^{\max}=11\%$ and $LR=0.95$ (Result 3)	0.527	11.00	11.00	NR	47.53	1.137	17.41
Limit on executive ownership only, $LR=0.92$ , $\alpha^{\max}=0.394$ , (Result 4)	0.394	8.33	NR	0.394	58.89	1.835	30.49
Limit on executive ownership only, $LR=0.95$ , $\alpha^{\max}=0.452$ , (Result 4)	0.452	7.07	NR	0.452	39.11	0.854	19.57
Heterogeneous beliefs regarding loss in financial failure, $\beta^G=0.6$ , $\beta^E=0.90$ , and $\alpha^{\max}=0.394$ (Result 5)	0.394	5.86	NR	0.394	55.72	1.723	29.99
Heterogeneous beliefs regarding loss in financial failure, $\beta^G=0.6$ , $\beta^E=0.45$ , and $\alpha^{\max}=0.394$ (Result 6)	0.394	15.83	NR	0.394	73.85	2.043	24.96
Two policy tools and heterogeneous beliefs regarding loss in financial failure, $\beta^G=0.6$ , $\beta^E=0.75$ , $\alpha^{\max}=0.394$ and $\sigma^{\max}=11\%$ (Result 7)	0.394	11.00	11.00	0.394	63.57	2.284	29.72



**Table 3: The executive choice of assets risk under different levels of executive’s ownership,  $\alpha$ , and units of loss in financial failure,  $\beta$**

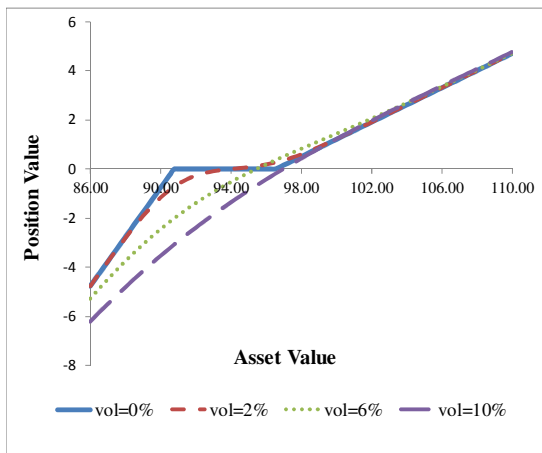
The table presents the value of assets risk (in %) which maximizes the executive position for different executive ownership (the parameter  $\alpha$ ) and units of loss in financial failure (the parameter  $\beta$ ). All other data are the same as in Table 1. When the curve is upward sloping we use the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

		<b>Units of loss in financial failure (in %)</b>				
		<b>0.30</b>	<b>0.45</b>	<b>0.60</b>	<b>0.75</b>	<b>0.90</b>
<b>Executive ownership (in %)</b>	<b>0.30</b>	US	8.49	6.42	5.56	5.07
	<b>0.394</b>	US	15.83	8.33	6.67	5.86
	<b>0.50</b>	US	13.15	8.49	6.99	13.15
	<b>0.60</b>	US	US	US	11.74	8.49
	<b>0.70</b>	US	US	US	24.44	10.99

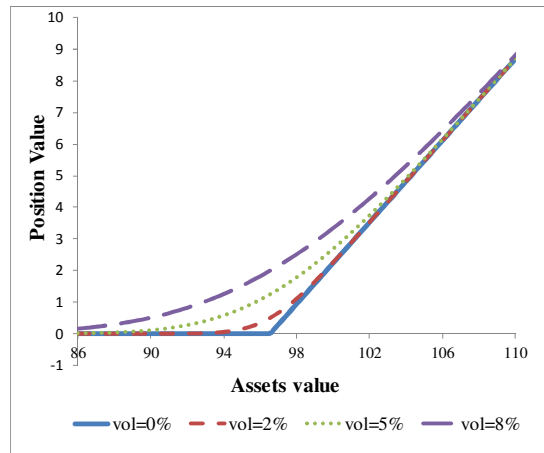
**Figure 1: The value of the agents' position versus leverage for different levels of assets risk.**

The figure presents the value of the positions which are sensitive to assets risk for the government, the stockholders and the executive for different levels of leverage and assets risk. Panel (1.A) presents the government'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.

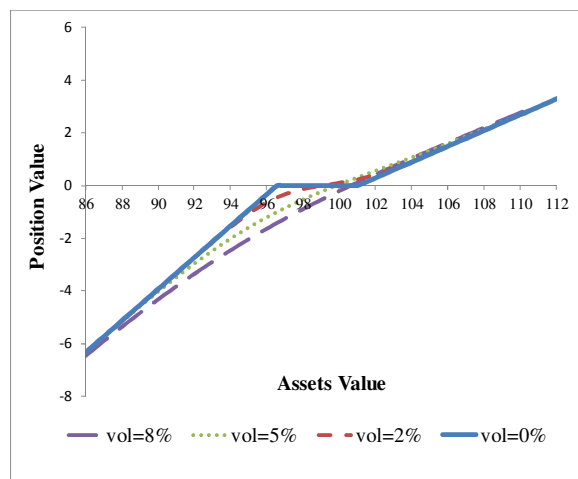
**(1.A) The Government position**



**(1.B) The Stockholder position**



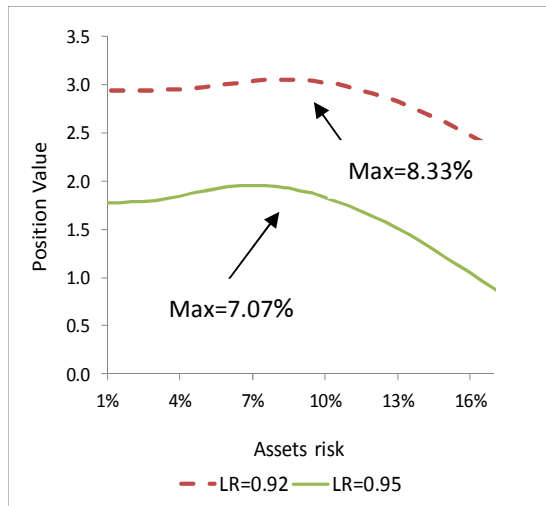
**(1.C) The Executive position**



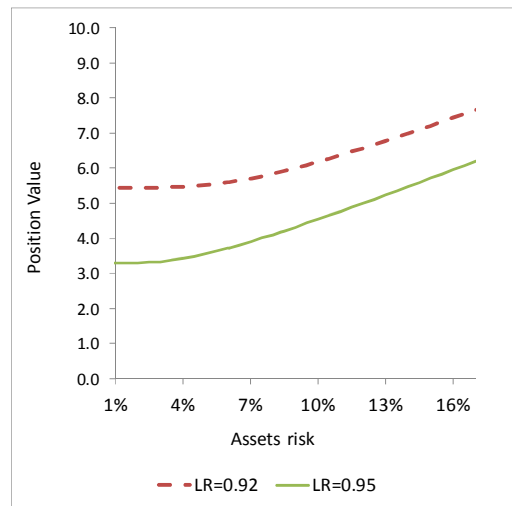
## Figure 2: The value of the agents' position versus assets risk

The figure presents the value of the positions which are sensitive to assets risk for the government, the stockholders and the executive for different levels of assets risk. Panel (1.A) presents the government'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.

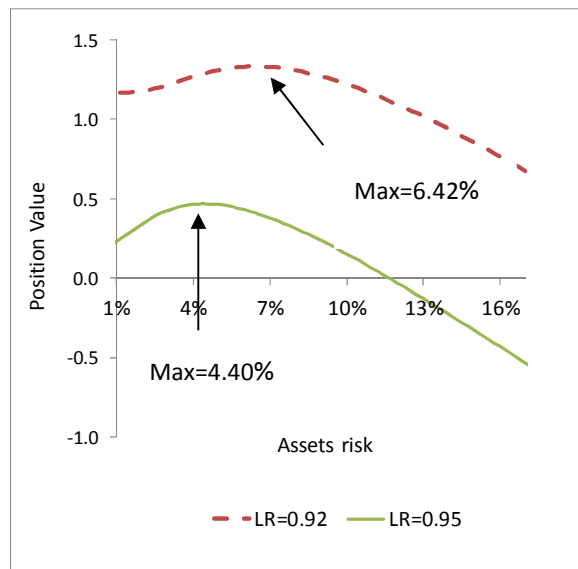
### (2.A) The Government position



### (2.B) The Stockholder position



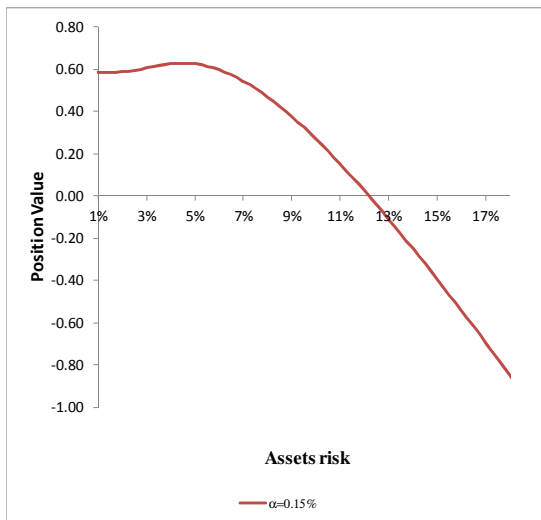
### (2.C) The Executive position



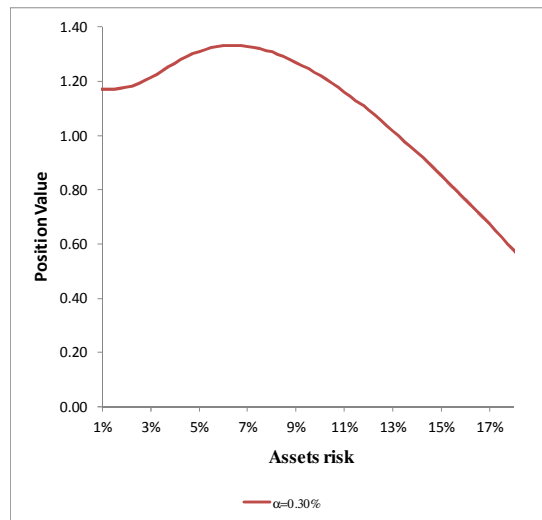
**Figure 3: The value of the executive' position for different asset risk and size of equity based compensation**

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

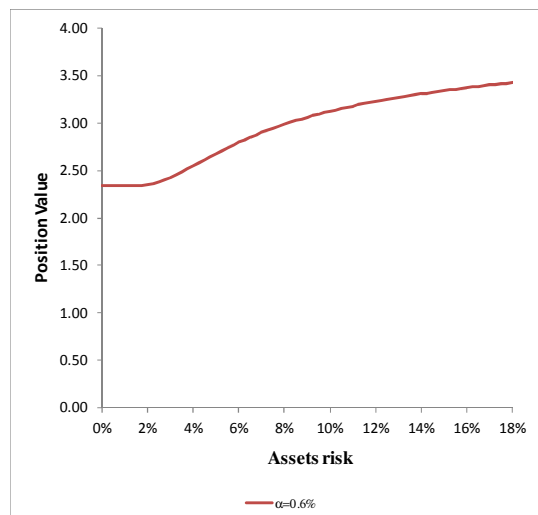
**(3.A) "Low" equity compensation ( $\alpha=0.15$ )**



**(3.B) "Medium" equity compensation ( $\alpha=0.30$ )**



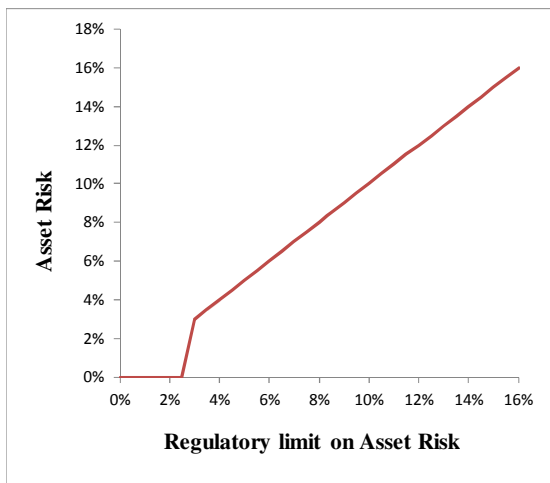
**(3.C) "Large" equity compensation ( $\alpha=0.6$ )**



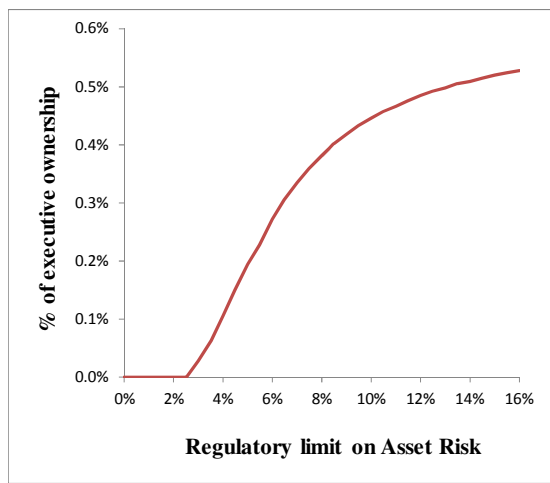
**Figure 4: Asset Risk, Executive ownership and Claim's value at equilibrium with regulatory limit on assets risk.**

The figure presents the chosen level of assets 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 government position for these levels.. All other parameters are identical to the base case parameters which are presented in Table 1.

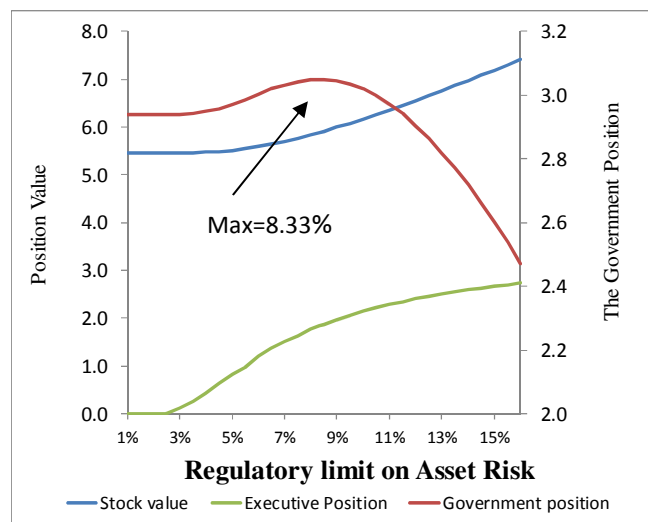
**(4.A) Assets risk versus the regulatory limit on asset risk**



**(4.B) Executive ownership versus regulatory limit on asset risk**



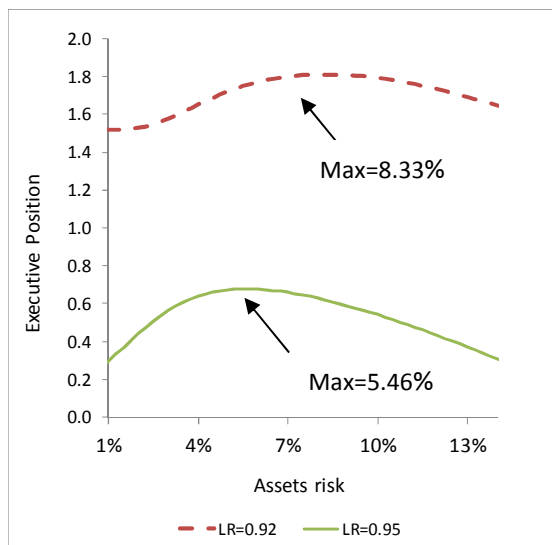
**(4.C) The value of the executive, equityholder and government positions versus the regulatory limit on assets risk**



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

Figure 5 presents assets risk and the value of the government and the executive position for different leverage ratio, when the executive ownership is equal to 0.39% 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 0.39%.



**Panel B:** Executive ownership equal 0.45%

