Optimal Regulation, Executive Compensation and Risk Taking by Financial Institutions

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Abstract

The paper derives an equilibrium model of optimal regulation of risk taking by financial institutions which is the result of strategic interactions of three stakeholders: (1) regulators (e.g. FDIC, OCC), (2) shareholders of financial institutions, and (3) management. Regulators put into place caps either on executive equity based compensation or on asset risk; shareholder chooses levels of compensation; and management chooses the level of asset risk. We show that when using either of the two policy tools it is possible to achieve the socially ‘optimal’ level of financial risk taking, which trades off the benefit of a well-functioning financial sector and the expected social cost of financial distress. However, if the regulator is limited in its ability to enforce such limits, capping equity based compensation is less efficient tool than setting an upper limit on asset risk. Moreover, if the stockholder and management are better informed than the regulator about the executive potential loss due to 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 approaches regarding the factors that brought about the observed increase in asset risk and resulting impairment of financial stability. The first is the increase in executive pay with a dominant component of equity-based compensation (Bebchuk, and Spamann, 2010; Bebchuk et al., 2010; Bolton, Mehran and Shapiro, 2011). The second focuses on supervisory inertia: there may have been inadequate regulations and lax supervision and enforcement of existing laws and regulations (Blanchard, 2008; Caprio, Demirgüç-Kunt and Kane, 2010; Delis and Staikouras, 2011).

As a response to the crisis and to its potential causes policymakers initiated reforms that aimed to strengthen the resilience of financial institutions and markets. The Basel III Accord (2011) adopted more stringent regulation regarding 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 risks taking by financial institutions. Recently, the European Union adopted, in 2013, a provision which limits the amount of bankers’ bonuses to the amount of fixed remuneration.

However, the issues of the social optimal level of asset risk and executive compensation structures as well as the appropriate policy measures need to be further examined. The open questions we address in this paper are, first what is the risk taking motivation of bank management under (a) different structures of compensation, (b) bank’s capital structure, and (c) limits set by regulators on asset risk and/or on executive compensation. Second, what is the

\(^1\) See the Consumer Protection Act (2010), in Part (b) of Section 956.
socially optimal level of risk and what are the tools regulators should use to induce owners and executives of financial firms to attain this level of asset risk. 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? In this context it is important to note that the public optimal level of risk (represented by a benevolent regulator) may differ from the private optimal (bank owner and executive).

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

The equilibrium results of our model provide a setting to understand and interpret recent developments in the behavior of 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 affect asset risk. The stockholder is a residual claimholder, where the value of her position increases with asset value and asset risk (Jensen and Meckling, 1976; Galai and Masulis, 1976). The public, as represented by a benevolent regulator, has a position made up of two components. The first is a positive payoff from tax payments by banks. A possible broader interpretation of this component is the social welfare created by a well-functioning banking system (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. In a broader sense, this can be interpreted as the social cost of financial distress (Merton 1977, Ronn and Verma, 1986). We show that the value of the public’s position may have a global maximum with respect to asset risk. This provides a motivation for the regulator to avoid both excessive risk-taking as well as risk avoidance (“credit freeze”) in order to maximize social welfare.

Management’s position is also composed of two components. The first is equity-based compensation, where its value increases with bank assets. The second component is a loss due to bank failure. This component may include “inside debt” i.e., an executive’s uninsured pension benefits that would be foregone (Edmans and Liu, 2011; Gerakos, 2007; Sundaram and Yermack, 2007; Bolton, Mehran and Shapiro, 2010), reputation costs (Fama, 1980; Hirshleifer and Thakor, 1992), and loss of specific human capital (Gilson, 1989; Graham et al., 2013). Since these two components have opposite signs sensitivities to changes in asset risk, a single global maximum for the executive’s position may exist. However, the relationship may also be upward sloping so that the position is maximized by choosing the highest possible level of asset risk. Furthermore, as leverage increases the level of asset risk which maximizes the value of the position decreases. In our analysis we generalize the analysis by Sundaram and Yermack (2007), who consider the special case where executive compensation includes only stock and leverage has no effect on risk taking.
Given the positions of the claimholders 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. In this case we obtain an equilibrium solution with excessive risk taking, lower social welfare and a greater equity based compensation. That is consistent with the excessive risk taking in financial institutions observed prior to the 2008 financial crisis. The analysis demonstrates that excessive risk taking is a result of both regulatory inertia and the structure of executive pay package. We further demonstrate the need to adjust regulations of financial institutions to changes in the leverage ratio – as leverage increases, as was the case during the crisis, the limit on asset risk should be reduced to maximize social welfare and to avoid credit freeze.

Because of the evidence of limited regulatory ability to enforce limits 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 such conditions, we show that 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. Thus, the policymaker should consider the cost of implementing the two measures.

The drawback of using limit on executive ownership as a tool to control asset risk is demonstrated in the case of asymmetric information between the stockholder and the executive at the one hand and the regulator at the other hand, regarding the potential loss of the executive

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2 Since over the past decades, as the size and complexity of financial firms have increased, the ability of regulator to control banks asset risk became more difficult (Berger, Davies, and Flannery, 2000; DeYoung et al., 2001; and Evanoff and Wall, 2000).
due to bank failure. The loss due to bank failure is composed of intangible components that are difficult to estimate and insiders that are better informed have better estimates of this component than the regulator. As the difference between the assessments increases, the deviation of the level of asset risk from the social optimum increases and the value of the position of the stockholders and management increase.

As a conclusion of the above discussion we finally analyze the case where the two policy tools are used simultaneously, i.e., - where the regulator has a limited ability to enforce both tools. We show that applying the two policy tools will increase social welfare in the case of asymmetric information regarding the size of the executive loss due to bank failure.\(^3\)

The rest of this paper is organized as follows: Section 2 briefly discusses the most related literature. Section 3 presents the analysis of the risk taking motivation of all claimholders and derives the valuation of their positions. An equilibrium solution for the level of asset risk, executive ownership and the regulatory limit on the level of asset risk is presented in Section 4. The equilibrium solution is calculated in Section 5, where now the regulator caps executive ownership, the analysis is extended to the case of asymmetric information. Section 6 concludes.

2. Related Literature

The presented work relates to the literature on prudential regulation. While the literature on prudential regulation is very broad, the effect of regulating bankers pay and its interaction with more traditional regulatory measures is limited.

The earlier literature on agency problems focused on the conflict between executive, shareholders and debtholder, disregarding the regulator and social welfare. Jensen and Meckling

\(^3\) 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.
(1976) consider the conflict between executives versus debtholders and show that an executive who is paid in equity has the motivation to increase risk if the debt holders cannot control his project choice after debt has been issued. To reduce the agency costs they suggest the manager should hold 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 analyzed 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 loss in a case of financial failure. As in our paper, the equity based compensation is represented by a call option and the potential loss in default by a put option. In our paper, 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 - a benevolent regulator who aims to maximize social welfare where executive ownership is endogenous.

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

\[\text{\footnotesize{4 In an empirical paper, Anderson and Core (2013) use a similar method to estimate executive risk taking}}\]
manager, while our model is “preference free” and risk is determined in equilibrium according to the positions and decisions of the claimholders.

Another approach is presented by Hakenes and Schnabel (2014) that relates executive pay to corporate governance problems and the weakness of shareholder rights. They suggest that a sufficiently large increase in bailout perceptions makes it optimal for a welfare-maximizing regulator to impose caps on bank bonuses. Social welfare is measured in terms of the value of deposits only, where in our paper the value of a well-functioning financial system is considered as well, as suggested by Korinek and Kreamer (2014). Moreover, in our paper a potential reason for excessive risk taking is asymmetric information between regulator and executive regarding the potential loss of the executive in bank failure.

Our paper also belongs to the general literature that studies how the design of executive compensation affects risk taking decisions in banking and how a regulator can enhance social welfare. John, Saunders and Senbet (2000) argue that banks’ risk taking can be improved by making the insurance premiums that a bank pays a direct function of the parameters of the compensation contract. Bolton, Mehran, and Shapiro (2010) model the risk taking incentives of a CEO of a financial firm, showing that linking the CEO compensation to the firm’s default risk could reduce firm risk taking. Hilscher and Raviv (2014) suggest that adding contingent capital to a bank’s capital structure can make the stockholder indifferent to the level of asset risk while the use of inside debt can reduce risk taking. The analysis in our paper is comprehensive where the regulator is maximizing social welfare, and not just maximizes the value of deposits or minimizes risk as in Bolton, Mehran, and Shapiro (2010) and Hakenes and Schnabel (2014). Besley and Ghatak (2011) study the effect of bonus taxation and find that the optimal bonus
structure can be achieved by a combination of a regulation on the structure of bonuses and a tax on their level.

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

In this section we derive the value of the claimholder’s position. For each of the claimholders (the public, stockholders, and executives) we specify their claims to bank assets and then analyze how their payoffs depend on asset risk. We discuss how the decisions of any claimholder can affect the value of the position of the other claimholders. To demonstrate the theoretical results, we calibrate the model to data that are typical to US banks over the period before and during the 2008 crisis 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 face value $F^D$, and subordinated debt with face value of $F^S$ with the same maturity. We assume that asset value follows a geometric Brownian motion and calculate the value of the various claims (discussed below) using the standard Black and Scholes (1973) and Merton (1974) pricing equations (see Appendix 1).

3.1. The Public

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

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

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

The position of the public can be replicated by two options. The first is \(\tau\) units of a long call position on the value of the bank’s assets with a strike price equal to the total face value of debt, and the second is a short put option with a strike price equal to the face value of the insured deposit, \(F^D\).\(^5\) The value of the position can be written as:

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

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

\(^5\) The pricing of the different options and position is presented in Appendix 1.
Panel A of Figure 1 plots the payoff of the public at maturity for different asset values. The position is known as a “risk – reversal” position, which is composed of a short put option and a long call option with a higher strike price.

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

**Proof**: See appendix 2.

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

Panel A of Figure 2 presents the value of the public position with respect to asset risk for different levels of leverage. In our example, the leverage ratio between debt and assets is equal to 0.92, the subordinated debt is 6% of the total face value of debt, all debt instruments mature in one year and the risk-free rate is equal to 3.5%. We show that the public position is hump shaped as we vary asset risk and that the global maximum is reached when asset risk is equal to 8.33%. 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

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

Furthermore, if leverage is increased to 0.95 the level of risk which maximizes the payoff of the public decreases to 7.07% (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 a benevolent regulator should consider a bank capital structure while limiting its level of risk as discussed at Sections (4) and (5).

3.2. Management

The executive’s position also has two different components which are sensitive to the value of the financial institution’s assets and asset risk: equity-based compensation and loss due to bank failure. We assume that the executive holds $\alpha$ units of equity-based compensation, which has a positive payoff at maturity equal to the difference between the value of assets and a strike price of $H$, which is assumed to be 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 includes only stock the strike price is equal to the total face value of debt. The second component is a loss of $\beta$ 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 $\beta$ times the difference

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7 We do not consider other components of executive pay that are not sensitive to asset risk.
8 We assume that, in the case of executive stock options, the dilution effect is relatively small and has only a secondary effect on the other liabilities that were issued by the financial institution.
between the total face value of debt \((F^D + F^S)\) and firm assets, \(V_T\). The executive payoff at maturity can be expressed as:

\[
E_x = \alpha \max(V_T - H, 0) - \beta \max(F^D + F^S - V_T, 0).
\] (3)

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

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

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

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

**Proof:** See Appendix 2.

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⁹ The pricing of the different options and position is presented in Appendix 1.
All else equal, the level of asset risk which maximizes the value of the executive’s position increases with the value of equity based compensation and decreases with the value of loss due to bank failure. The results of the calibrated model are shown in Figure 3 where the value of the executive position is shown with respect to asset risk for leverage ratio of 0.92, as in our base case. For relatively low and medium levels of equity based compensation we consider the case where the executive hold 0.15%, 0.30% of the financial institution stocks, the relationship between the value of the position and asset risk is hump shaped with a single global maximum.\(^{10}\) The maximum value of the executive’s position increases with the units of equity based compensation. The maximum is achieved at asset risk of 4.59% and 6.54% for executive ownership of 0.15% and 0.30% respectively. When executive ownership increases to 0.6% the relationship between the value of the executive’s position value and asset risk becomes upward sloping and there is no global maximum for the value of the position. Panel C of Figure 2 presents the effect of leverage on the value of asset risk. Where executive ownership equal 0.3% and leverage increases to 0.95 the maximum is achieved at level of asset risk of 4.43%, more than 2.12% below the maximum level when leverage is equal to 0.92.

A special case is when the strike price of the equity based compensation is set to equal the leverage ratio, as in Sundaram and Yermack (2007). In this case, the executive 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 an always a corner solution. The relationship between

\(^{10}\) John, Mehran and Qian (2010) calculate the median value of CEO ownership in financial institution as being equal to 0.29%.
the value of the executive’s position and asset risk would become either linearly increasing or decreasing depending on the relationship between $\alpha$ and $\beta$.

3.3. Stockholders

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

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

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

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

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

$$S = (1 - \alpha - \tau) \text{Call} (V, F^D + F^S, \sigma) \quad (7)$$
The value of the stockholder position always increases with asset volatility and decreases with the tax rate and the percentage of executive ownership and leverage as presented in Panel B of Figure 2.

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

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

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

We use a framework of a non-cooperative game and thus there are no side payments. 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 start arbitrarily with one of the players.

### 4.1 Unrestricted ability of regulator to set maximum asset risk

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

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

\[\text{11} \quad \text{If each claimholder has chosen a strategy and no other claimholders can benefit by changing its strategy while the other claimholders keep theirs unchanged, then the current set of strategy choices and the corresponding payoffs.}\]
\( \sigma^* = \sigma^*_{UBound} = \sigma_{MaxPub} \). We outline the proof this result in three steps. First, we find the risk level that maximizes the value of the public position:

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

(8)

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

\[
\frac{\partial G}{\partial \sigma} \bigg|_{\sigma = \sigma_{MaxPub}} = 0
\]

(9)

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

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

(10)

where:

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

The benevolent regulator would limit asset risk to this level and thus at the second step, we calculate the units of equity compensation that maximize the value of the stockholder position at this level of risk. The value of the stock increases with asset risk. However, asset risk is bounded at the level of \( \sigma^*_{UBound} \). Moreover, as the units of executive ownership increase, the value of the stockholder’s position decreases. Therefore, stockholder will award the minimum ownership to
management that still motivates them to take a level of risk which is equal to the regulatory upper bound 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, $\sigma^*_{\text{UBound}}$:

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

(11)

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

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

(12)

At the third step, the executive, given its ownership of $\alpha^*$, chooses the level of asset risk that maximizes the value of her position $\sigma_{\text{MaxEx}}$:

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

(13)

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

The calibration of the model to the base case parameters yields a level of asset risk of $\sigma_{\text{MaxEx}} = \sigma^* = \sigma^*_{\text{UBound}} = 8.33\%$, where the chosen level of asset risk is equal to the regulatory upper bound on asset risk (See Panel-A of Figure 2). The stockholder would compensate 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 then the executive would be motivated to take this level of risk with any ownership which equal or greater than $\alpha^*$.\textsuperscript{12}

The level of executive ownership which is awarded by the stockholder for different upper bounds on asset risk, $\sigma^*_{\text{UBound}}$ set by the regulator is presented at Panel-B of Figure 4. For relatively low levels of upper boundary 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 upper bound on asset risk to be equal to the level that maximizes its holding, and in equilibrium, all the three would be equal: the regulatory upper bound on asset risk, $\sigma^*_{\text{UBound}}$, the chosen level of risk by the executive, $\sigma^*$ and the level of risk that maximizes social welfare, $\sigma_{\text{MaxPub}}$.

4.2 The effect of leverage

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

\textsuperscript{12} For example, for the base case parameter, an executive ownership of 0.6% of the bank’s stock, as described in Panel C of Figure 3, would motivate the executive to take a risk which is equal to the limit on asset risk. However, such a choice would decrease the value of the stockholder position, since the same level of asset risk can be achieved by a lower level of ownership (0.388% as in Panel A of Figure 2).
demonstrated here the effect of leverage on asset risk and executive ownership may be non-trivial.

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

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

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

4.3 Restricted ability of regulator to set maximum asset risk

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

In such case, stockholder would increase the equity based compensation up to the point where the executive position reaches its maximum level at a level of asset risk, $\sigma_{\text{UBound}}^* = \sigma_{\text{MinReg}}^*$. As presented in Panel B of Figure 4, all else equal an increase of the upper bound of asset risk would lead to an increase of executive ownership. Moreover, as presented in Panel C of Figure 4, as the upper bound of asset risk increases the positions’ value of the executive and the stockholder would increase, while the value of the public position decreases below its global maximum value.

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

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

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

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

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

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

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

5.1 Unrestricted ability of regulator to cap executive ownership

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

$$\alpha_{UBound} \in [0,1].$$

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

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

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

5.2 Restricted ability of regulator to cap executive ownership

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

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

**5.3 Asymmetric information about the executive loss in case of bank failure.**

The effect of restricted regulatory ability to impose limit on executive ownership is shown by relaxing the assumption of symmetric information, where now the executive and the stockholder are better informed than the regulator about the loss of the executive due to bank failure, $\beta$. Consequently, the stockholder and the executive have incentive to keep private information that creates a positive gap between the assessment of the uninformed regulator and the actual level of $\beta$, since the value of their position increases, while social welfare decreases.

Our definition of loss in case of bank failure includes intangible assets of the executive as well as pecuniary assets as uninsured pension benefits ("inside debt"). Intangible assets that decline in value when the bank fails include reputation of the executive and non-diversifiable human capital in the firm. Since it is difficult to find proxies for the value of these assets, as they are not traded, asymmetric information about the size of this loss can appear and the results are greater value for the stockholder and the executive at the cost of a lower value for the public position.

**Result 5. If the regulator has a greater estimate of the executive’s loss in case of bank failure than the actual level, i.e., ($\beta < \beta^G$), then the cap on executive ownership set by the regulator would motivate the executive to choose a level of asset risk which is greater than the level that maximizes the public position, $\sigma_{\text{MaxPub}} < \sigma^*$.**
The strategic choice is calculated first, as in all previous cases, by finding the risk level that maximizes the value of the public position, $\sigma_{\text{MaxPub}}$. As in Section (5.1), the regulator sets a cap on executive ownership, $\alpha_{\text{UBound}}^*$. However, the executive, as well as the stockholder, are better informed about the actual amount of units of loss due to bank failure and observe the actual value which is lower than the one observed by the regulator: $\beta < \beta^i$. As the units of loss due to bank failure increases the same level of asset risk is achieved by increasing the equity based compensation. Consequently, the regulator cap executive ownership in a level that motivates the executive to take a level of risk which is above the level that maximizes the public position and as a result $\sigma_{\text{ExecMax}} = \sigma^* > \sigma_{\text{GovPub}}$. However, under this equilibrium the value of both the executive and stockholder positions increase.

This case is important for demonstrating the potential high loss for the public. Suppose all the data are identical to the base case parameters, except that now the actual loss due to bank failure is equal in one realization to 0.55% and in another possible realization to 0.45% of asset value, while the regulator believes the loss is greater and equal 0.6%. Consequently, as in Section (5.1), the regulator sets a cap on executive ownership of 0.388%. This level maximizes the value of the public position if the actual loss due to bank failure equals 0.6%. The stockholder, aware of the cap on ownership, awards the executive with the maximum feasible ownership of 0.388%. The executive, figures out that under this compensation the value of asset risk which maximizes their holding is equal to 9.39% and 15.15% for actual $\beta$ of 0.55% and 0.45% respectively (Table 3 and Panel A of Figure 7). The value of the chosen decision variables result in greater position value for the stockholder and the executive compared to the case of symmetric information. The value of the executive position equal 0.1766 and 0.1929 for actual $\beta$ of 0.55% and 0.45% and the value of the stockholder position equal 60.70 and 72.34 for the
same levels of $\beta$. However, the value of the public position is reduced to 30.37 and 25.83 for actual $\beta$ of 0.55% and 0.45% respectively, compared with the case of symmetric information where the maximum value is 30.49 (See Table 2).

5.4 Combining the two policy tools in case of asymmetric information

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

**Result 6.** In case of asymmetric information between the executive and the regulator regarding the executive’s loss due to bank failure where: $\beta < \beta^G$, using the two policy tools simultaneously: 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 find the optimal level of asset risk that maximizes the value of its holding, $\sigma_{MaxPub}$. As in the case of using cap on pay as a single policy tool (Result 5), the uninformed regulator set a limit on executive ownership which is based on an executive loss due to bank failure greater 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 to enforce such bound and the actual bound is above the level which maximizes the public position: $\sigma^*_{UBound} > \sigma_{MaxPub}$. The actual level of loss due to bank
failure is known to the better informed executive and stockholder, who will make an effort to create a difference between the regulator’s assessment and the actual level.

In equilibrium, there are two possible types of realization. In the first realization, the uninformed regulator set a cap on executive ownership which motivates the executive to choose a level of asset risk greater than the level that maximizes the public position, but smaller than the upper bound on asset risk: \( \sigma^*_{\text{UBound}} > \sigma^* > \sigma_{\text{MaxPub}} \). In this case the effective constraint is the cap on executive ownership, and the public is better off than in the case of using only an upper bound on asset risk. In the second realization, the difference between the regulator assessment and the actual level of loss due to bank failure is relatively high, and if the stockholder awards the executive with ownership which is equal to the cap level, the executive is motivated to take asset risk which is greater than the upper bound on asset risk. Therefore, the informed stockholder reduces executive ownership below its cap: \( \alpha^*_{\text{UBound}} > \alpha^* \), to the level that motivates the executive to take the risk level which exactly equal to the upper bound on asset risk where \( \sigma^*_{\text{UBound}} = \sigma^* > \sigma_{\text{MaxGov}} \). In this case the effective constraint is the upper bound on asset risk and the public is better off than in the case of using only a cap on executive ownership.

While using simultaneously the two policy tools 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. 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 benefit of introducing a second policy tool increases as asymmetric information increases.

We shows these results by using the base case parameters, where now the executive can set an upper bound on asset risk of 11%, above the level of 8.33%, which maximizes the public position. Moreover, the regulator assumes that executive loss due to bank failure equals 0.6% of
total asset value in default and calculates the optimal executive’s ownership as being equal 0.388%. However, the executive and the stockholder are better informed about the actual loss and know its real value.

The possible first type of realization, where the stockholder awards the executive with ownership which is equal to the cap level is presented in the case where the executive loss due to bank failure equal 0.55. Having 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 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 of Figure 7). The effective constraint in this realization is the cap on executive ownership, where with no such cap, the chosen level of asset risk would be 11%, equal to the upper bound on asset risk, as in Result 3, where the value of the executive and stockholder positions are greater and equal 0.2171 and 63.58 respectively, and the value of the public position reduces to 29.72.

The second type of realization, where the stockholder awards the executive with ownership below the cap level is presented in the case where the executive loss due to bank failure equal 0.45% of assets. Having this loss, the executive would be motivated to take a level of asset risk of 15.15%. The stockholder is aware that the level is above the effective upper bound on asset risk of 11% and will award the executive with ownership of 0.347%, which exactly motivates the executive to take a risk of 11%. The equilibrium results are executive, stockholder and public positions of 0.1631, 63.58 and 29.72 respectively (Table 2 and Panel B of Figure 7). The effective constraint in this realization 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 using only cap on
executive ownership (*Result 5*), where the value of the executive and stockholder positions are greater and equal 0.1929 and 72.34 respectively, and the value of the public position reduces to 25.83.

**6. Conclusion**

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

First, 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 would be the level that maximizes public welfare and the chosen level of asset risk by the executive equal to that level as well. Moreover, as leverage increases asset risk decreases and executive ownership increases.

Second, we relax the assumption of a regulator who can bound asset risk to any level, and we show that if the regulatory limit on asset risk is above the level which maximizes the public position, then in equilibrium, the executive would choose that level. Consequently, executive ownership is greater than in the case where the regulatory limit on asset risk is equal to the level which maximizes the public position. These results have an explanatory implication for the debate regarding the causes of the 2008 financial crisis, since we demonstrate that both an
increase in executive ownership are necessary, but not sufficient condition for an increase in a financial institution’s asset risk.

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

Fourth, we relax the assumption of symmetric information regarding the executive loss in bank failure and assume that the executive and the stockholder are better informed than the regulator regarding the executive loss due to bank failure. Thus, if the regulator has an assessment of this component which is greater than its actual value the executive would choose a level of risk which is greater than the one maximizes social welfare. Finally, we demonstrate that combining the two policy tools, limit on asset risk and capping executive ownership, can make public better off in the case of limited ability of the regulator to enforce these two policy tools.
References


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 follows a geometric Brownian motion, where the drift under the risk-neutral measure is equal to the risk-free rate \( r \), and \( \sigma \) is the instantaneous constant standard deviation of the assets’ rate of return. The general pricing equations for the call and put options can be expressed under the standard assumptions for risk-neutral contingent-claim valuation as:

\[
\text{Call}(T,K) = e^{-rT} N(d(K)) - KN(d(K) - \sigma \sqrt{T}) \tag{1}
\]

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

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

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

Appendix 2

Theorem 1: The public’s position may have a global maximum with respect to asset risk if the tax rate is positive and the size of subordinated debt is positive. All else equal, the level of asset risk that maximizes the public position increases with the size of subordinated debt and the tax rate and decreases with total leverage.
**Proof:** The public position is composed of $\tau$ units of long call option with a strike price of $F^D + F^S$ and a short put option with a strike price equal to the face value of the insured deposit $F^D$.

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

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

$$\frac{\partial G}{\partial \sigma} = \tau V \sqrt{T} \frac{\sigma}{\sqrt{2\pi}} e^{-\frac{d(V, F^D + F^S)^2}{2}} - \tau V \sqrt{T} \frac{\sigma}{\sqrt{2\pi}} e^{-\frac{d(V, F^D)^2}{2}}$$  \hspace{1cm} (2)

where:

$$d(S, K) = \frac{\ln\left(\frac{S}{K}\right) + \left(r + \frac{\sigma^2}{2}\right)T}{\sigma \sqrt{T}}$$  \hspace{1cm} (3)

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

$$\frac{\partial G}{\partial \sigma} = \frac{V \sqrt{T}}{\sqrt{2\pi}} \left[ e^{-\frac{d(V, F^D + F^S)^2}{2}} - e^{-\frac{d(V, F^D)^2}{2}} \right]$$  \hspace{1cm} (4)

The equation can be expressed as well as:

$$\frac{\partial G}{\partial \sigma} = \frac{V \sqrt{T}}{\sqrt{2\pi}} [a - b]$$  \hspace{1cm} (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 global 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 expression $a$ 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 the parameter $K$, the value of expression $a$ is always greater than expression $b$ in equation (5). 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 asset risk that result in a global maximum for the public position.

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

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

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

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

where:

$$d(S, K) = \frac{\ln(S/K) + (r + \sigma^2/2)T}{\sigma \sqrt{T}} \quad (3)$$
By rearranging equation (2) the derivative can be decomposed to two components, where the first one is always positive:

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

(4)

The equation can be expressed as well as:

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

(5)

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

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

When the performance linked compensation of the executive is composed of stock only the strike price, \(H\), is equal to the total face value of debt, \(F^{D} + F^{S}\), and expressions \(a\) and \(b\) are equal. Therefore, the derivative would be always positive (negative) in case that \(\alpha\) is greater (smaller) than \(\beta\), and the value of the executive’s position would always increase (decrease) with asset risk.
Appendix 3: Discussion of the Base Case Parameters

Characteristics of the Financial Institution

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

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

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

Units of loss due to bank 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 of 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 0.6% 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):** We set the strike price equal to asset value, due to the convention in the market is to set the strike price of stock options as being at the money.\(^\text{13}\)

\(^{13}\) 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: Parameters used in the base case of the model

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Source</th>
<th>Symbol</th>
<th>Base Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Leverage ratio</td>
<td>John, Mehran and Qian (2010)</td>
<td>LR</td>
<td>0.92</td>
</tr>
<tr>
<td>Face value of total debt</td>
<td>John, Mehran and Qian (2010)</td>
<td>F</td>
<td>1,000</td>
</tr>
<tr>
<td>Value of the firm’s assets</td>
<td></td>
<td>V</td>
<td>1,049.6</td>
</tr>
<tr>
<td>Time to maturity</td>
<td>Marcus and Shaked (1984) and Ronn and Verma (1986).</td>
<td>T</td>
<td>1</td>
</tr>
<tr>
<td>Risk-free rate</td>
<td>Kenneth’s French database</td>
<td>r</td>
<td>3.5%</td>
</tr>
<tr>
<td>Executive ownership</td>
<td>John, Mehran and Qian (2010)</td>
<td>α</td>
<td>0.3%</td>
</tr>
<tr>
<td>Executive loss in bank failure</td>
<td></td>
<td>β</td>
<td>0.6%</td>
</tr>
<tr>
<td>Face value of subordinated debt</td>
<td>Belkhir (2012)</td>
<td>F^S</td>
<td>60</td>
</tr>
<tr>
<td>Bank’s asset risk</td>
<td>Meheran and Rosenberg (2009)</td>
<td>σ</td>
<td>5.3%</td>
</tr>
<tr>
<td>Strike of the equity based compensation</td>
<td>Palmon et al., (2008)</td>
<td>H</td>
<td>1,049.6</td>
</tr>
<tr>
<td>Corporate tax rate</td>
<td>Federal tax rate</td>
<td>τ</td>
<td>35%</td>
</tr>
</tbody>
</table>
Table 2: The Equilibrium Solution for the base case 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 limit risk and its ability to control that tool. The value of each decision variable at equilibrium is reported at the next columns and the resulting positions value of the stockholder, executive and the public are reported at the last columns.

<table>
<thead>
<tr>
<th>Description of claimholders control</th>
<th>Decisions Variables (in %)</th>
<th>Position Value</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Executive Ownership ($\alpha^*$)</td>
<td>Asset risk ($\sigma^*$)</td>
</tr>
<tr>
<td>Full control of the decisions variables, $\sigma^*$&lt;sub&gt;UBound&lt;/sub&gt; $\in [0, \infty)$ and $LR=0.92$ (Result 1)</td>
<td>0.388</td>
<td>8.33</td>
</tr>
<tr>
<td>Full control of the decisions variables, $\sigma^*$&lt;sub&gt;UBound&lt;/sub&gt; $\in [0, \infty)$ and $LR=0.95$ (Result 2)</td>
<td>0.450</td>
<td>7.07</td>
</tr>
<tr>
<td>Limited regulatory ability to control asset risk, $\sigma^*$&lt;sub&gt;UBound&lt;/sub&gt; $\in [0.11, \infty)$ and $LR=0.92$ (Result 3)</td>
<td>0.462</td>
<td>11.00</td>
</tr>
<tr>
<td>Limited regulatory ability to control asset risk, $\sigma^*$&lt;sub&gt;UBound&lt;/sub&gt; $\in [0.11, \infty)$ and $LR=0.95$ (Result 5)</td>
<td>0.526</td>
<td>11.00</td>
</tr>
<tr>
<td>Limit on executive ownership only, $LR=0.92$, $\alpha^*$&lt;sub&gt;UBound&lt;/sub&gt; $\in [0, \infty)$, (Result 4)</td>
<td>0.388</td>
<td>8.33</td>
</tr>
<tr>
<td>Limit on executive ownership only, $LR=0.95$, $\alpha^*$&lt;sub&gt;UBound&lt;/sub&gt; $\in [0, \infty)$ (Result 4)</td>
<td>0.452</td>
<td>7.07</td>
</tr>
<tr>
<td><strong>Asymmetric information</strong> regarding loss due to bank failure, $\beta^<em>=0.6%$, $\beta^</em>=0.55%$, (Result 5)</td>
<td>0.388</td>
<td>9.39</td>
</tr>
<tr>
<td><strong>Asymmetric information</strong> regarding loss due to bank failure, $\beta^<em>=0.6%$, $\beta^</em>=0.45%$, (Result 5)</td>
<td>0.388</td>
<td>15.15</td>
</tr>
<tr>
<td><strong>Two policy tools and asymmetric information</strong> regarding loss due to bank failure: $\beta^<em>=0.6%$, $\beta^</em>=0.55%$, and $\sigma^*$&lt;sub&gt;UBound&lt;/sub&gt; $\in [0.11, \infty)$ (Result 6).</td>
<td>0.388</td>
<td>11.00</td>
</tr>
<tr>
<td><strong>Two policy tools and asymmetric information</strong> regarding loss due to bank failure: $\beta^<em>=0.6%$, $\beta^</em>=0.45%$, and $\sigma^*$&lt;sub&gt;UBound&lt;/sub&gt; $\in [0.11, \infty)$ (Result 6)</td>
<td>0.347</td>
<td>11.00</td>
</tr>
</tbody>
</table>
Table 3: The executive choice of asset risk under different levels of executive’s ownership, \(\alpha\), and units of loss due to bank failure, \(\beta\)

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

<table>
<thead>
<tr>
<th>Executive ownership (in %)</th>
<th>Units of loss due to bank failure (in %)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>0.45</td>
</tr>
<tr>
<td>0.300</td>
<td>8.67</td>
</tr>
<tr>
<td>0.347</td>
<td>11.00</td>
</tr>
<tr>
<td>0.388</td>
<td>15.15</td>
</tr>
<tr>
<td>0.500</td>
<td>MAX</td>
</tr>
</tbody>
</table>
Figure 1: The value of the claimholders’ positions at debt maturity versus asset value

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

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

Panel A: The Public position

Panel B: The Stockholder position

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

The figure presents the value of the executive’s position versus asset risk, where the units of equity based compensation is either low ($\alpha=0.15\%$), moderate ($\alpha=0.3\%$) or high ($\alpha=0.6\%$). All the data are the same as 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 chosen level of asset risk by the executive and executive’s ownership, as awarded by the stockholder, for different regulatory limit on asset risk, as well as the value of the stockholder, the executive and the public position for these levels. All other parameters are identical to the base case parameters which are presented in Table 1.

Panel A: Asset risk versus the regulatory 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

Max=8.33
Figure 5: The value of the executive position versus asset risk for different levels of leverage and ownership.

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

Panel A: Executive ownership equal 0.388%.

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

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

Panel A: Asset risk versus the regulatory 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

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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, $\beta$, to be equal 0.6% of asset value and therefore award these executive 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 $\beta$ is lower and equal at one example to 0.55% and at the other to 0.45%. The result is an executive position which is maximized either at asset risk of either 9.39% or 15.15% for $\beta$ of 0.55% and 0.45% respectively. At Panel B, the stockholder are informed about the actual level of $\beta$ and therefore reduces executive ownership to 0.345%, to motivate the executive to take the level of risk which 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