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# Bankers' compensation: Sprint swimming in short bonus pools?



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# *Bankers' Compensation: Sprint Swimming in Short Bonus Pools? \**

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## **Abstract**

The global financial crisis of 2007-2008 has given rise to new regulatory initiatives to put restrictions on the size and term of bankers' pay. We revisit the question whether these regulations are justified, both theoretically and empirically. We model bonuses as a series of sequential call options on profits and show that they provide the higher risk-taking incentives the shorter is the time between the payment points. However, using data on CEO bonuses at the end of 2006 and our model, we find no robust relationship between risk-taking incentives and US banks' stock returns during the global financial crisis. The crisis returns are related negatively to leverage and positively to the market to book equity ratio. Our findings suggest that regulating leverage would be more effective than regulating bankers' compensation.

**Keywords:** Banking, bonuses, regulation, compensation

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# 1 Introduction

In the aftermath of the global financial crisis that started in 2007, bankers' compensation has become a major issue both for banks' corporate governance and regulation. The main question is whether large short-term bonuses spurred too much risk-taking that partly caused the crisis. For instance, Rajan (2005), who foresaw some of the key developments that eventually led to the crisis, emphasizes the role of short-term compensation. In response to the compensation concerns, both regulators and banks themselves have started to take restrictive measures on compensation.<sup>1</sup>

In this paper we revisit the question whether the new regulatory initiatives to restrict the size and term of bankers' pay are justified on the basis of excessive risk-taking incentives, induced by short-term bonuses. We derive the theoretical value of a banker's expected future bonus stream, and measure the banker's risk-taking incentive by the derivative of the present value of the bonuses with respect to the bank's levered earnings volatility. Thus, we measure the banker's incentive to increase risk and the risk-taking is done by raising leverage or by buying riskier assets. Due to the option-like nature of bonuses, bonuses are only paid out of positive profits and the value of future bonuses is convex with respect to the profits. Therefore, the present value of future bonuses is a series of sequential call options on the bank's levered earnings (i.e., the profits). In other words, we use the standard continuous-time asset pricing framework to model the value of the future bonus stream to a banker, and to derive the banker's risk-taking incentives within that framework.

We obtain two key theoretical results with the model. First, we show that the series of bonuses is worth the more, the shorter is the time interval between bonus determination points. Intuitively, we may compare this result with Merton (1973) who shows that a portfolio of options on individual stocks is worth more than an option on the basket consisting of those stocks. However, in our case this analysis is over the duration of bonus options, not over stocks in a portfolio. Our theoretical result

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<sup>1</sup>For instance, the European Union has limited the bonus per salary ratio. In the US, the Dodd-Frank Act imposes clawback policies on bonuses. Many banks, such as the UBS and Deutsche Bank, have introduced or are considering clawback policies voluntarily, perhaps in anticipation of the increasing regulatory pressure. Liikanen Group suggests that bankers' compensation should include debt instruments subject to bail-in clauses (Liikanen 2012).

suggests that bankers (and similarly, e.g., hedge fund and private equity managers) have a strong incentive to negotiate themselves compensation contracts with short payment horizons.<sup>2</sup> Second, we show that the shorter the bonus determination interval is, the higher the banker’s risk-taking incentive in terms of increasing the levered earnings volatility.<sup>3</sup> Although our model does not generate any predictions as to how the terms of a banker’s compensation contract are determined, this result is important because it formalizes the common notion that short-term bonus contracts spur risk-taking.<sup>4</sup>

In the empirical part we test whether our model with a sample of 86 large US banks at the end of 2006 predicts the crisis time stock price performance of these banks, measured as a buy and hold return from 1 July 2007 to 31 December 2008. The crisis performance can be seen as an ex post measure of a bank’s risk-taking (cf. Fahlenbrach and Stulz (2011)), hence also capturing materialized tail risks which are difficult to measure ex ante. In addition, we test whether the model risk-taking incentive, which is a non-linear function of four elements [1) CEO bonus over net income, 2) CEO’s expected tenure, 3) volatility of levered earnings, and 4) book equity], adds value over its elements and other control variables in explaining the crisis returns.<sup>5</sup>

Our empirical results suggest that regulating leverage would be more effective than regulating bankers’ compensation. More specifically, we first find that our model risk-

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<sup>2</sup>In the hedge fund industry, the effect on risk-taking incentives of short payment horizons can be controlled by the so called high-water marks (see e.g. Panageas and Westerfield (2009)).

<sup>3</sup>We show that also the expected tenure matters. The time interval between standard bonuses is one year, and this is what we also use in the empirical part. Our theoretical result may be suggestive of the incentive effects of other forms of convex compensation such as executive options in which vesting periods are typically longer than one year. In case of executive options the underlying asset is the bank’s stock price, not the bank’s profit. Therefore, the current model is not directly applicable to option grants but, assuming that earnings and stock prices are highly correlated, the model can be used as an approximation for option grants (for instance, Durre and Giot (2005) find a significant long-run relationship between stock indexes and earnings).

<sup>4</sup>See e.g. Edmans et al. (2011) for a model which derives the optimal level and performance-sensitivity of CEO compensation contract. Short-term bonus contracts and their effects are also commonly discussed in financial press (see e.g. Bloomberg, 19 June 2013, U.K. Banker Bonuses Face Decade Delays in Industry Overhaul).

<sup>5</sup>Note that each of the elements (1-4) could alone predict bank crisis return. CEO bonus per net income is a similar risk-taking incentive measure as the one used by Fahlenbrach and Stulz (2011). Volatility of levered earnings (i.e. profits) is a measure of bank riskiness, and book equity may proxy for bank size which could be related to high risk-taking via the bank taking advantage of the implicit public guarantee allegedly enjoyed by too-big-to-fail banks. CEO’s expected tenure may also be related to risk-taking but in principle the direction of the relationship could go either way. However, by our model and empirical results with banks’ z-score data (Table 6), tenure raises risk-taking as that implies a greater number of future bonus options.

taking incentive is negatively related to crisis returns and significant but explains only about 3% of the variation of the crisis returns in the bank sample. Second, the model risk-taking incentive is no longer significant if its four elements are added as control variables. When we add further control variables we find that two of them, market to book value of equity and bank leverage, have a robust relationship with the crisis returns. Banks with higher market to book ratios did relatively better during the crisis and highly leveraged banks did relatively poorly. Together these two variables explain about 17% of the crisis return variation in the sample, leverage being the more important driver. Interestingly, we find that banks which increased their leverage during the last two run-up years to the crisis had relatively low market to book ratios at the end of 2004 (cf. Acharya et al. (2013)). However, there is no evidence that our model risk-taking incentive at the end of 2004 explained the leverage changes between 2004 and 2006. Therefore, our results support the view that regulating leverage would be more effective than regulating bonuses.

More than two thirds (61) of the 86 sample banks actually paid zero bonuses at the end of 2006. The relationship between our model risk-taking incentive and crisis return is much stronger among the 25 banks that paid positive bonuses, but the relationship is not robust with respect to the set of control variables. The few banks with extremely large risk-taking incentives based on our model did have relatively poor stock performance during the crisis, but there were also plenty of banks who paid zero bonuses before the crisis and still did quite badly during the crisis. With a subsample of 51 banks that have granted CEO options we also test the risk-taking incentives of the CEO option grants using the theoretical option vega. The option vega obtains a negative coefficient as expected but is not significant. When run together with our model's risk-taking incentive measure, our measure turns out to be significant with a negative coefficient. Hence, of the two risk-taking incentives, our bonus measure works better in this subsample. This indicates that in the empirical studies that analyze executives' incentives, it is not enough to use data on executive option plans; also bonuses are important. Adding leverage as a control does not increase the explanatory power significantly with this subsample of 51 banks but has the effect that none of the three variables is significant. This suggests that our results are somewhat sensitive to the sample choice, as leverage played a major

role in our results with all the 86 banks sample. We also test our model with z-score (a proxy for overall bank risk, see e.g. Dam and Koetter (2012)) and a subsample of 57 banks and find similar results as with the crisis returns with all the 86 banks. However, consistent with our theoretical model, in the z-score regression model CEO tenure has a significant negative sign, giving some indication that younger CEOs may have taken more risk.

In sum, our empirical setting is similar to that of Fahlenbrach and Stulz (2011) who test the ability of CEO cash bonus per salary at the end of 2006 to predict banks' crisis returns. Our contributions are as follows. First, we derive a theoretical model for bonus related risk-taking incentive which is a nonlinear function of CEO bonus as a share of bank net income, bonus payment interval, the expected remaining CEO tenure, the bank's book equity, and the levered earnings volatility. Thus, the model's risk-taking incentives change nonlinearly with respect to several factors. Second, we run additional model tests: We analyze separately banks that paid positive bonus in 2006, hence accounting for the fact that the great majority of banks did not pay bonuses that year (although all banks in the sample had positive net income indicating that the zero bonus banks did not have bonus program). After that we consider also the effect of our risk-taking incentive measure at the end of 2004, as there was a final spurt in the growth of banks' securitization related risk exposures starting 2004.<sup>6</sup> Finally, we use some additional control variables such as liquidity ratio and different proxies for banks' business model and use z-score as the dependent variable instead of the crisis return. However, regardless of the new theoretical model and the additional model tests our empirical results are not inconsistent with Fahlenbrach and Stulz (2011) who conclude that bonus-based CEO risk-taking incentives do not explain banks' crisis time stock performance. The robust empirical predictors of the crisis time bank stock performance when the whole sample of 86 banks is used are bank leverage and the market to book equity ratio (also in accordance with Fahlenbrach and Stulz (2011)). As said, this indicates that regulating directly the leverage would be more effective than regulating bankers' compensation.

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<sup>6</sup>See Acharya et al. (2013) who argue that regulatory changes at that time may have been the reason for the increased growth rate of the securitized assets.

The paper is organized as follows. After a literature review in Section 2, the model setup is presented in Section 3 and the value of the future bonus stream is derived in section 4. Section 5 presents the empirical results and Section 6 concludes.

## 2 Literature review

In this section we briefly review the literature on risk-taking incentives in corporations and banks especially, which are related to compensation, ownership, and the influence of the board. We then review a selection of recent papers which are more directly related to our work from two perspectives; banks' contractual risk-taking incentives in general and, specifically, the length of payment horizon in compensation contracts.

There are studies which find that the aggressiveness of managerial compensation does increase risk-taking in corporations (e.g. Coles et al. (2006) and Low (2009)). These papers are consistent with our theoretical model.<sup>7</sup> The reason to design such contracts is that managers are inherently too risk averse (cf. Beatty and Zajec (1994)) which may, however, depend on the amount and composition of their personal wealth (see Korkeamäki, Liljeblom, and Pasternack (2013)). Interestingly, Houston and James (1995) did not find bankers' compensation to promote more risk-taking than in other industries. Further, Anderson and Fraser (2000) found that management's ownership in banks is positively related to bank risk-taking but that this relationship became negative (management ownership reduces bank risk-taking) in conjunction with regulatory changes in the US around 1990. Leaven and Levine (2009) and Pathan (2009) show that bank risk-taking may be determined at the level of a board which strongly represents shareholder interests.

The link between bankers' risk-taking incentives and the timing of their compensation is analyzed in several recent papers. The paper which provides most direct evidence that shorter-term compensation contracts increase risk-taking is by Gopalan, Milbourn, Song, and Thakor (2011). Using a carefully constructed measure of executive compensation duration for both financials and non-financials, they show that CEOs with shorter pay

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<sup>7</sup>However, empirically we find that bonus-based risk-taking incentives are not related to bank stock price performance during the global financial crisis; leverage is more important in explaining the crisis time bank stock returns.



durations are more likely to engage in myopic investment behavior (this is consistent with our theoretical results). The average CEO pay duration of the 109 US banks in their sample is little more than one year. However, not all papers agree that compensation duration is crucial for bankers' risk-taking; Acharya, Pagano, and Volpin (2011) show in a theoretical model that the impact of pay duration is minor. Their model is set in the context of a labor market competing for managerial talent.

Different evidence is obtained by Fahlenbrach and Stulz (2011) who show that "(b)anks with higher option compensation and a larger fraction of compensation in cash bonuses for their CEOs did not perform worse during the crisis". Unlike Gopalan et al. (2011), Fahlenbrach and Stulz do not use data on the actual vesting periods in CEOs' compensation packages. However, they find some evidence that CEOs with incentives better aligned with those of shareholders took more risks prior to the crisis. Fahlenbrach and Stulz conjecture that these CEOs took risks bona fide, believing that these risks looked profitable for shareholders. Alternatively, this could be additional evidence reported in Leaven and Levine (2009) and Pathan (2009) that bank risk-taking may be determined at the level of a board which strongly represents shareholder interests, and, as discussed in Haldane (2009), bank shareholders have incentive to increase risks due to deposit insurance and other government support mechanisms. Also Murphy (2012) finds only little evidence that the pay structures provided incentives for risk-taking among top-level banking executives. In a theoretical paper, Gennaioli, Schleifer, and Vishny (2011) emphasize the role of neglected risks leading to the crisis. Our theoretical model predicts that compensation affects risk-taking in a nonlinear way but empirically, we find that banks' leverage is the most important variable in explaining the banks' stock returns during the crisis. Neither do we find evidence that compensation would explain increases in leverage (which is one form of increasing bank risk).<sup>8</sup>

Recent empirical papers which find that compensation based risk-taking incentives in banks did increase risk-taking include Bhagat and Bolton (2013) and DeYoung, Peng and Yan (2012) (see also Bhattacharyya and Purnanandam (2011), Balachandran, Kogut and Harnal (2010), and Tung and Wang (2012)). Bhagat and Bolton (2013) study the

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<sup>8</sup>One possible explanation is that bank risk-taking is determined at the board level as reported in Leaven and Levine (2009) and Pathan (2009).

development of total compensation of a sample of large US bank CEOs over 2000-2008 and find a link between compensation and risk-taking. DeYoung et al. (2012) measure a bank CEO's contractual risk-taking incentives in the years preceding the crisis, ending their sample in 2006, and relate the annual risk-taking incentive measures with the bank's actual risk-taking the following year, measured from the bank's daily stock returns that year. To measure risk-taking incentives, they use a procedure from earlier studies to empirically determine the delta and the vega of the banks' compensation contracts. They find evidence that stronger contractual risk-taking incentives for CEOs led to higher risks. The effects are largest and most persistent in the largest banks. They attribute the increase in contractual risk-taking incentives for CEOs at large U.S. commercial banks to deregulation around 2000, which in effect expanded these banks' growth opportunities. These results are consistent with our theoretical model but not our empirical findings, and they also partly contrast with the empirical results of Fahlenbrach and Stulz (2011). The different conclusions from these studies may reflect the fact that while DeYoung et al. (2012) use stock return data until 2006 to measure bank risk, Fahlenbrach and Stulz (2011) as well as we focus precisely on the crisis time bank stock returns. The advantage with focusing on the crisis returns is that, almost by definition, they capture the tail risks which materialized in the crisis. Exposures to these risks may not have been fully reflected in banks' stock return variation prior to the crisis. Another reason for the different results from these studies may be, as discussed above, the different ways to measure compensation-based CEO risk-taking incentives.

More generally, our paper is also related to principal-agent models (see e.g. Grossman and Hart (1983), Holmstrom (1979, 1982, 1983, 1999), Holmstrom and Milgrom (1991, 1994), Myerson (1982), Rogerson (1985), and Sannikov (2008)). However, in the present paper, we do not use principal-agent modeling since we take the bankers' compensation as given and then model their risk-taking incentives. In our theoretical part, we focus on the effects of the duration of the convex pay components.<sup>9</sup>

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<sup>9</sup>See e.g. Inderst and Mueller (2004) and Mueller and Inderst (2005) for models in which convex pay components such as stock options and bonuses can be used to solve for various efficiency problems arising in the principal-agent setting.

### 3 Model

We consider a risk-neutral banker who receives bonuses with certain frequency during her tenure  $[0, T]$ . The banker's bonuses are calculated from the bank's earnings and the earnings depend on the change of the bank's asset values.

There are two assets, a risk-free asset and a risky asset. The risky asset can be viewed as the bank's main business and the risk-free asset as a source of leverage. Thus, the bank debt is risk-free in our model and its dynamics is given by

$$B(t) = \exp(rt),$$

where  $r$  is the risk-free rate and  $r > 0$ . When the bank borrows money from the market, it sells the bonds, i.e., the holding is negative and its borrowing cost is the risk-free rate.<sup>10</sup>

Under the risk-neutral probability measure  $Q$  (for more on risk-neutral pricing see e.g. Duffie (2001)), the risky asset follows

$$dS(t) = S(t)r dt + S(t)\sigma dW(t),$$

where  $S(0) > 0$ ,  $\sigma$  is the volatility and it satisfies  $\sigma > 0$ , and  $W(t)$  is a standard Wiener process under  $Q$ . We denote by  $\{F_t\}$  the information filtration generated by the Wiener process. Thus,  $F_t$  is the information at time  $t$ .

The bank controls its asset holdings in continuous time in such a way that it keeps the fractions invested in the risk-free and risky assets constant. Since the bank use leverage, it has a negative holding in the risk-free asset. Then it invests all its equity and debt into the risky asset that can be viewed as its loan portfolio. Therefore, under the risk-neutral probability measure  $Q$  the bank's net portfolio value, i.e., its equity

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<sup>10</sup>This is approximately correct due to deposit insurance and other government support mechanisms, see e.g. Haldane (2009). We also tested a model where the borrowing rate depends on the CDS spread. That model did not work significantly better than the one presented here. However, interesting enough, the CDS spread depends on the bank size, indicating that big banks have a lower funding cost. This could be due to their too big to fail status.

value evolves according to (see e.g. Merton (1971))

$$(1) \quad dA(t) = A(t)r dt + A(t)\sigma_\theta dW(t),$$

where  $A(t)$  is the equity value and  $A(0) > 0$ , levered volatility  $\sigma_\theta = (1 + \theta)\sigma$ , and  $\theta$  is the bank debt relative to the equity value. Thus,

$$\theta = -\frac{n_B(t)B(t)}{A(t)},$$

where  $n_B(t)$  is the bond holding (negative) at time  $t$ . This gives  $n_B(t) = -\theta A(t)/B(t)$ , i.e., the bank adjust its borrowing all the time to keep  $\theta$  constant. For instance, when the equity  $A(t)$  falls then the bank borrows less.

We analyze how the levered volatility  $\sigma_\theta$  affects the compensation value. Note again that  $\sigma_\theta$  rises in  $\theta$  and  $\sigma$ , i.e., the banker can increase risk by increasing the leverage and/or the risky asset volatility, and here we do not focus on the mechanism how the banker changes  $\sigma_\theta$  (but clearly there are two ways).

From (1) we get

$$(2) \quad A(t) = A(0) \exp \left( \left( r - \frac{1}{2}\sigma_\theta^2 \right) t + \sigma_\theta W(t) \right)$$

or

$$A(t_2) = A(t_1) \exp \left( \left( r - \frac{1}{2}\sigma_\theta^2 \right) (t_2 - t_1) + \sigma_\theta [W(t_2) - W(t_1)] \right),$$

where  $t_2 > t_1$ .

For calculating the banker's compensation, tenure  $[0, T]$  is divided into  $n$  equal length intervals, where  $n$  is bounded. That is,  $\Delta = T/n$ , where  $\Delta$  is the length of the intervals. At the end of each interval, the bank pays a bonus to the banker and the bonus depends on the change of the net asset value during the time period. More specifically, at the end of  $i$ 'th interval, the bonus payoff is given by

$$(3) \quad \Pi(A(i\Delta), A((i-1)\Delta)) = k \max[A(i\Delta) - A((i-1)\Delta), 0]$$

for all  $i \in \{1, 2, \dots, n\}$ , where  $k \in (0, 1)$  and it represents the fraction of profits paid

out as compensation to the banker,  $\Delta$  is the time interval between the time points and  $n\Delta = T$ . Thus, at the end of each time interval the bank pays bonus to the banker if the net asset value has risen.

For example, if  $n = 1$  then we have just one payoff and this happens at time  $T$ :

$$\Pi(A(T), A(0)) = k \max[A(T) - A(0), 0].$$

## 4 Value of the compensation

In this section we analyze how the bonus frequency affects the compensation value and the banker's risk-taking incentives. More specifically, we model the incentives given the asset dynamics (1) and the bonuses (3), and do not consider explicitly the banker's effort.

Let us define the following Black and Scholes (1973) call option price:

$$\begin{aligned} (4) \quad C(\Delta) &= E \left[ \exp(-r\Delta) \max \left[ \frac{A(\Delta)}{A(0)} - 1, 0 \right] \right] \\ &= \Phi(d_1(\Delta)) - \exp(-r\Delta) \Phi(d_2(\Delta)), \end{aligned}$$

where  $\Phi(x) = \int_{-\infty}^x \phi(y) dy$  is standard cumulative normal distribution and  $\phi(x) = \frac{1}{\sqrt{2\pi}} \exp\left(-\frac{x^2}{2}\right)$  is standard normal density,

$$d_1(\Delta) = \left( \frac{1}{2}\sigma_\theta + \frac{r}{\sigma_\theta} \right) \sqrt{\Delta}, \quad d_2(\Delta) = d_1(\Delta) - \sigma_\theta \sqrt{\Delta}.$$

Thus,  $C(\Delta)$  is  $\Delta$ -maturity European call option on  $\frac{A(\Delta)}{A(0)}$  with strike price equal to one. Our model can be extended to more complicated asset processes, such as a jump diffusion process for the assets (see e.g. Kou (2002)), and then this would change the pricing of  $C(\Delta)$  and the rest of our analysis would be the same.

By the risk-neutral pricing and (3), the present value of the banker's compensation

package is given by

$$\begin{aligned}
(5) \quad \pi_n &= \sum_{i=1}^n E [\exp(-ri\Delta) \Pi(A(i\Delta), A((i-1)\Delta))] \\
&= \sum_{i=1}^n E (\exp(-ri\Delta) k \max[A(i\Delta) - A((i-1)\Delta), 0]).
\end{aligned}$$

Thus, the compensation package is a sequence of call option contracts. The number of contracts in the sequence depends on  $\Delta$ . For instance, if  $\Delta = T$  then  $\pi_1$  equals one call option with maturity date  $T$ . By (5) and iterated expectation, we get the following result.

**Proposition 1** *The value of the compensation package with  $n$  payout periods on  $[0, T]$  is given by*

$$\pi_n = nkA(0)C(T/n),$$

where  $C$  is the call option price (4),  $k$  is the fraction of profits paid out as compensation, and  $A(0)$  is the initial net asset value.

**Proof:** By (5) and iterated expectation, we get

$$\begin{aligned}
\pi_n &= \sum_{i=1}^n E \left( \exp(-ri\Delta) k A((i-1)\Delta) \max \left[ \frac{A(i\Delta)}{A((i-1)\Delta)} - 1, 0 \right] \right) \\
&= \sum_{i=1}^n E \left[ E \left( \exp(-ri\Delta) k A((i-1)\Delta) \max \left[ \frac{A(i\Delta)}{A((i-1)\Delta)} - 1, 0 \right] \middle| F_{(i-1)\Delta} \right) \right] \\
&= \sum_{i=1}^n E \left[ \exp(-r(i-1)\Delta) k A((i-1)\Delta) E \left( \exp(-r\Delta) \max \left[ \frac{A(i\Delta)}{A((i-1)\Delta)} - 1, 0 \right] \middle| F_{(i-1)\Delta} \right) \right] \\
&= \sum_{i=1}^n \exp(-r(i-1)\Delta) k C(\Delta) E [A((i-1)\Delta)]
\end{aligned}$$

and, since  $E [A((i-1)\Delta)] = A(0) \exp(r(i-1)\Delta)$ , we get the result.  $\square$

Thus, the value of the compensation equals  $nkA(0)$  many call options with maturity  $T/n$ . From Proposition 1 we get the following corollary.

**Corollary 1** *Let  $0 < r < \sigma_\theta^2 \left( 1 + \sqrt{\frac{5}{4} + \frac{1}{\sigma_\theta^2 y}} \right)$  for all  $y \in [0, \frac{T}{n}]$ . Then  $\pi_n$  rises in  $n$ , i.e.,  $\pi_{n+1} \geq \pi_n$ .*

**Proof:** By Boyle and Scott (2006), the constraint on  $r$  gives a sufficient condition for  $C(y)$  being increasing and concave in  $y$  for all  $y \in [0, \frac{T}{n}]$ . Let us set  $n = k$  and then, since  $\pi_n$  is continuous in  $n$ , we have

$$\begin{aligned}\pi_{k+1} - \pi_k &= \int_k^{k+1} \frac{\partial \pi_n}{\partial n} \Big|_{n=i} di = kA(0) \int_k^{k+1} \left( C(T/i) - \frac{T}{i} \frac{\partial C(\Delta)}{\partial \Delta} \Big|_{\Delta=T/i} \right) di \\ &= kA(0) \int_k^{k+1} \left( \int_0^{\frac{T}{i}} \frac{\partial C(\Delta)}{\partial \Delta} \Big|_{\Delta=y} dy - \frac{T}{i} \frac{\partial C(\Delta)}{\partial \Delta} \Big|_{\Delta=T/i} \right) di \geq 0,\end{aligned}$$

where  $k \in \{1, 2, \dots\}$ . The inequality holds because  $C(y)$  is concave for all  $y \in [0, \frac{T}{k}]$  and, thus, we have  $\frac{\partial C(\Delta)}{\partial \Delta} \Big|_{\Delta=y} \geq \frac{\partial C(\Delta)}{\partial \Delta} \Big|_{\Delta=T/i}$  for all  $y \in [0, \frac{T}{i}]$ , which gives  $C(T/i) - \frac{T}{i} \frac{\partial C(\Delta)}{\partial \Delta} \Big|_{\Delta=T/i} \geq 0$ .  $\square$

Corollary 1 is a sufficient condition for  $C(\Delta)$  being increasing and concave for all  $\Delta \in [0, \frac{T}{n}]$  and this guarantees  $\pi_{n+1} \geq \pi_n$ . Even though it is possible to find parameter values, where  $C(\Delta)$  is locally convex in  $\Delta$ ,<sup>11</sup> we have not found a case, where the result ( $\pi_{n+1} \geq \pi_n$ ) does not hold since this would require convexity for a wide range of  $\Delta$  values.

Since the compensation value is a portfolio of call options, the value rises in the levered volatility  $\sigma_\theta$ . That is,  $\frac{\partial \pi_n}{\partial \sigma_\theta} > 0$  and, by Proposition 1 and Black and Scholes (1973), we get the formula for the bonus vega:

$$(6) \quad \frac{\partial \pi_n}{\partial \sigma_\theta} = nkA(0) \frac{\partial C(T/n)}{\partial \sigma_\theta} = nkA(0) \exp(-rT/n) \sqrt{T/n} \phi(d_2(T/n)),$$

where  $\phi(x) = \frac{1}{\sqrt{2\pi}} \exp\left(-\frac{x^2}{2}\right)$  is standard normal density. Now we can state the following corollary that gives how the vega changes with respect to  $n$ .

**Corollary 2** *The sensitivity of the compensation value with respect to levered volatility  $\sigma_\theta$  rises in the number of periods  $n$ :*

$$\frac{\partial \pi_{n+1}}{\partial \sigma_\theta} \geq \frac{\partial \pi_n}{\partial \sigma_\theta}.$$

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<sup>11</sup>For instance,  $A(0) = 100$ ,  $r = 0.06$ ,  $\Delta = 0.2$ , and  $\sigma_\theta = 0.02$  (see Boyle and Scott (2006)).

**Proof:** Since  $r > 0$ ,  $\sigma_\theta > 0$ , and  $\Delta > 0$ , we have

$$\begin{aligned}\frac{\partial^2 \pi_n}{\partial \sigma_\theta \partial n} &= kA(0) \left[ \frac{\partial C(\Delta)}{\partial \sigma_\theta} - \frac{\partial^2 C(\Delta)}{\partial \sigma_\theta \partial \Delta} \Delta \right] \\ &= kA(0) \left[ \frac{\sqrt{\Delta}}{8\sigma_\theta^2 \sqrt{2\pi}} \exp \left( -\frac{\Delta(2r + \sigma_\theta^2)^2}{8\sigma_\theta^2} \right) (4r^2 \Delta + 4\sigma_\theta^2 + 4r\Delta\sigma_\theta^2 + \Delta\sigma_\theta^4) \right] > 0.\end{aligned}$$

This gives

$$\frac{\partial \pi_{n+1}}{\partial \sigma_\theta} - \frac{\partial \pi_n}{\partial \sigma_\theta} = \int_n^{n+1} \frac{\partial \pi_k}{\partial \sigma_\theta \partial k} \Big|_{k=i} di > 0.$$

□

By Corollary 2, the shorter the time period  $\Delta = T/n$  is, the stronger the effect of the levered volatility. This implies that bankers with short term compensation packages have a high incentive to increase leverage and/or their business risk. This is consistent with Gopalan et al. (2012; see prediction 2), according to which the pay duration is shorter for firms with more volatile cash flows.

Figure 1 illustrates the compensation value (Corollary 1) and risk-taking incentives (6), i.e., bonus vega ( $\frac{\partial \pi_n}{\partial \sigma_\theta}$ ) with respect to the number of compensation time periods. Note that the higher the number, the shorter the compensation time interval  $\Delta$ . As can be seen, both the compensation value and the vega are positive, concave, and increasing in the number of periods. Thus, by our model and the numerical example of Figure 1, the higher the bonus payment frequency is, the higher the compensation value and the risk-taking incentives; however, their rates of increase fall in the number of periods.

Figure 2 illustrates the compensation value and risk-taking incentives with respect to the levered volatility. As can be seen, both the compensation value and the vega are positive. The compensation value rises in the levered volatility, while the risk-taking incentive is low at very low volatility values but rises rapidly.



## 5 Empirical analysis

### 5.1 Data and Variables

The aim of our empirical analysis is to calculate the theoretical CEO risk incentive measure, the model’s vega (6), for the largest US banks on the eve of the global financial crisis of 2007–2008 and test whether it explains the risk-taking behavior of these banks as materialized during the crisis. In particular, we test whether the vega explains a bank’s stock return during the crisis, from 1 July 2007 to 31 December 2008.<sup>12</sup> This crisis return is an ex post measure of the bank’s actual risk-taking and it has the advantage that it captures tail risks that are ”revealed” during banking crises and that may escape most ex ante risk measures. A similar approach and the corresponding data set have been previously used in Fahlenbrach and Stulz (2011). Their main measure of CEO risk-taking incentives is the cash bonus per salary.<sup>13</sup>

We obtain the CEO cash bonus data from the Execucomp database. Variables needed in calculating the vegas are measured as follows. Parameter  $k$  is CEO cash bonus divided by net income in year 2006, asset return volatility  $\sigma$  is the standard deviation of quarterly net income divided by the book value of assets from 2000Q1 to 2006Q4,<sup>14</sup> and  $\theta$  is debt over equity in book values. By (1),  $\sigma$  and  $\theta$  give the levered earnings volatility  $\sigma_\theta$ . The  $\Delta$  parameter, measuring the payment interval of bonuses, is set at one year. Parameter  $T$ , the remaining tenure of the CEO is estimated by taking the minimum of 10 years and the difference between the CEO’s retirement age and current age. The retirement age is assumed to be common for all CEOs in the sample and is proxied by the highest CEO age observation in the data, which is 77 years. The cap of 10 years on the remaining CEO tenure is motivated by studies on average CEO tenures.<sup>15</sup> We test the robustness of our results with an alternative tenure cap of 20 years and get almost identical results as

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<sup>12</sup>Bankrupt, merged, and delisted banks are treated using the procedure in Fahlenbrach and Stulz (2011). We also consider an alternative specification of the crisis return period; see below.

<sup>13</sup>To double-check our data accuracy, we replicate the regression of Fahlenbrach and Stulz (2011) in which they regress the crisis returns on the CEO cash bonus per salary. We obtain corresponding results (unreported here but available upon request).

<sup>14</sup>Our measure of return on assets, net income over the book value of total assets, is the same as used e.g. by Fahlenbrach and Stulz (2011).

<sup>15</sup>For instance, Kaplan and Minton (2012) finds that CEO turnover for a sample of large US companies was 15.8% from 1992 to 2007, implying an average tenure as CEO of less than seven years.

reported in subsection 5.2 with the 10-year cap.<sup>16</sup> Finally, all equity market information and bank balance sheet data needed in the regression analysis come from Compustat and BankScope, respectively. For our main regression, we end up with a balanced sample of 86 banks out of the 96 original sample banks.

## 5.2 Empirical results

Table 1 provides descriptive statistics of the variables, and Table 2 gives their correlations. The variables with the highest correlations in absolute terms with the crisis return (including both variables directly related to our theoretical model as well as additional control variables) are the share of real estate lending over total loans (26%), the leverage (-24% which is slightly higher than the closely related variable, levered earnings volatility  $\sigma_\theta$  with -23% correlation), total assets (-22%), non-performing loans over total loans (22%), trading assets over total assets (-19%), the market to book ratio (19%), and the vega which has a correlation of -17% with the crisis return. As it turns out that leverage and the market to book equity ratio are the two most important variables explaining crisis return in our regression models, Figures 3 and 4 illustrate the relationships between the crisis return, the vega, the leverage, and the market to book ratio. The negative relationship between crisis return and the vega is driven by the five biggest vega observations;<sup>17</sup> most vegas (in case of 61 banks) are in actuality zero, meaning that these banks have not paid any CEO cash bonuses in 2006. Figure 3 shows that if we restrict attention to the 25 banks which paid positive bonuses in 2006, the correlation between the vega and the crisis return rises (in absolute terms) to -39%.

Other interesting correlations in the data are the following. The share of trading assets in total assets has a high correlation of 86% with bank size, measured by total assets (at the end of 2004 this correlation is even higher, 93%). Further, deposits over total assets have a correlation of -55% with bank size (total assets) and -60% with the share of trading assets. These two correlations are consistent with the common view that

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<sup>16</sup>The two versions of our model risk-incentive measure, the vega, with the 10-year CEO tenure cap and the 20-year cap, have a correlation of 98% (see Table 2). It is hence no surprise that the regression results in subsection 5.2 are essentially unaltered if we use the 20-year tenure cap assumption instead of the 10-year cap. We report only the results for the 10-year case.

<sup>17</sup>The five banks with the highest vegas at the end of 2006, which stand out almost like outliers, are Bear Stearns, Citigroup, Goldman Sachs, JP Morgan, and Lehman Brothers.

the growth of trading activities before the crisis was mainly funded from the markets, not with deposits. The share of trading assets is also positively correlated with leverage (25%). Notably, our vega measure is quite strongly positively correlated with bank size (71%) and the share of trading assets (69%).<sup>18</sup> Accordingly, the vega is negatively correlated with the share of deposits over total assets. These correlations suggest that the bonus related risk-taking incentives, measured by the vega of our model, have been highest in banks focused on trading activities. Such banks are typically large and fund themselves less with deposits, and tend to have somewhat higher leverage. This is consistent with the fact that banks have two ways to raise risk - increase leverage and lower the asset quality - and, therefore, the levered earnings volatility (our risk measure) has high correlation with leverage (70%) and the share of trading assets (51%) that lowers the asset quality. Further, big banks seem to have higher incentive to increase their risks possibly due to deposit insurance and other government support mechanism (see e.g. Haldane (2009)).

Table 3 reports six regression models. In regression (1) we find that our model risk-taking incentive is negatively and significantly related to the crisis returns, but explains only about 3% of the variation in the banks' crisis returns. Regression (2) uses the four elements of the vega (CEO bonus over net income, CEO's remaining tenure, volatility of levered earnings, and the book value of equity) as explanatory variables. This regression may hence be taken as a test of a linearized version of our theory: our theory provides the variables that are related to CEO risk-taking incentives, and here we test them jointly with a linear regression, ignoring the specific form of their nonlinear interaction determined by our theory. Moreover, the expected signs of the regression coefficients are readily obtained by taking the vega's partial derivative with respect to each of the variables. By regression (2), each of the four vega's elements except parameter  $k$  obtains the correct sign, though only two of these (the levered earnings volatility and book equity) are significant. So, regression (2) provides some support to our model risk-taking incentives. We note, however, that the explanatory power of regression (2) is about three times higher than that of regression (1). This indicates that the explanatory

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<sup>18</sup>The correlation of the share of trading assets at the end of 2006 with the vega calculated at the end of 2004 is even higher (89%).

power of the vega's elements in regression (2) do not arise solely from our theory but represent also other effects on the crises returns. For instance, book equity proxies for bank size and may hence reflect higher risk-taking of too-big-to-fail banks, thanks to their cheaper funding costs (see e.g. Davies and Tracey (2014)). The levered earnings volatility in turn is a direct measure of bank riskiness and the risk-taking might be driven by other factors than CEO compensation such as deposit insurance and other government support mechanism (see e.g. Haldane (2009)).

In regression (3) the vega is no longer significant when its four elements are added as control variables. An  $F$ -test confirms that regression (3) does not improve upon regression (2). In regression (4) we add control variables that are outside our theory. These variables are market to book equity ratio and bank leverage which both have a robust relationship with the crisis returns. Adding total assets as a proxy for bank size in regression (4) did not change the results. According to regression (4), banks with higher market to book ratios at the end of 2006 did relatively better during the crisis, and highly leveraged banks did relatively poorly. These findings are consistent with Fahlenbrach and Stulz (2011).<sup>19</sup> Note that these two variables render all vega's elements individually insignificant, including  $\sigma_\theta$ , the role of which is apparently taken over by the leverage (the correlation between  $\sigma_\theta$  and leverage is 70%; see Table 2). Together market to book ratio and leverage explain about 17% of the crisis return variation in the sample, leverage being the more important driver.<sup>20</sup> However, the vega's elements jointly have a clear role as the  $R^2$  of regression (4) is about 23%. Note that it is expected that leverage (in book values) and the market to book ratio (as a proxy for leverage in market terms) are related to crisis returns. By the basic balance sheet mechanism, going back to Modigliani and Miller, a negative shock to a bank's assets value leads to a more negative equity return, the higher is the bank's leverage. In 2007-2008 the negative shock was a macro shock by nature, stemming from the US housing markets, and hence hit all the banks. Note that the market to book ratio may be positively related to the crisis return also because it may reflect a less risky bank asset portfolio and, hence, lower bank equity

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<sup>19</sup>In their Table 4, Fahlenbrach and Stulz (2011) find that book-to-market ratio is negatively and Tier 1 capital ratio positively related to the crisis return, defined in the same way as ours.

<sup>20</sup>These results were obtained by regressing crisis returns first on the market to book ratio and bank leverage jointly and then one at a time.

risk premium.

Since, by our theoretical model, increasing leverage is also a way of increasing risk (the other way is lowering asset quality), we further test whether our model risk-taking incentives in earlier years explained the banks' leverage increases. However, we find no evidence that the vega estimated at the end of 2004 explains banks' leverage change from 2004 to 2006, during the last two run-up years to the crisis (see Table 4). Instead we find that banks which increased their leverage had relatively low market to book ratios at the end of 2004.<sup>21</sup> In accordance with Acharya et al. (2013), this suggests that banks closer to financial distress may have had incentives to continue further risk-taking. By our empirical results, if such risk-taking incentives existed, they were unrelated to CEO bonuses. Interestingly, we also find no evidence from a dummy variable for investment banks that these would have increased leverage more than others. Finally, we find no evidence that banks that continued to increase leverage until the crisis did worse than other banks (e.g. by Table 2, the correlation between the leverage change from 2004 to 2006 and the crisis return is almost zero). However, the correlation between percentage leverage change from 2004 to 2006 and banks' stock return from 2004 to 2006 is roughly -10%. This indicates that the market had already discounted part of the increased risk resulting from higher leverage before the onset of the financial crisis.

As already noted above, more than two thirds (61) of the 86 sample banks actually paid zero bonuses at the end of 2006,<sup>22</sup> and the relationship between the vega and crisis return is much stronger among the 25 banks which paid positive bonuses (see Figure 3). Yet the relationship in this restricted sample is not robust in a regression (4, Table 3) type of setting with control variables (unreported here but available upon request). The few banks with extremely large risk-taking incentives based on our model did have relatively poor stock performance during the crisis, but there were also plenty of banks who paid zero bonuses before the crisis and still did quite badly during the crisis.

With a subsample of 51 banks for which we found CEO option grants we also tested the risk-taking incentive effect of these option grants, using vegas based on the Black-

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<sup>21</sup>In Table 4 we report the effects of a number of other control variables one by one and find that also a relative high liquidity ratio at the end of 2004 positively explains leverage increase.

<sup>22</sup>All banks had positive earnings in 2006 so the zero bonuses are not explained by that but rather appear to indicate that the zero-bonus banks did not have a bonus program for their CEOs.

Scholes model. The option vega obtains a negative coefficient as expected but is not significant. When run together, our bonus vega turns out to be significant with a negative coefficient (see Table 3, regression (6)). Hence, of the two risk-taking incentives, the bonus vega works better in this subsample. This suggests that in the empirical studies that analyze executives' incentives, it is not enough to use data on executive option plans; also bonuses are important. Adding leverage as a control does not increase the explanatory power significantly but has the effect that none of the three variables is individually significant. This suggests that our results are somewhat sensitive to the sample choice, as leverage played a major role in the results with the entire 86 banks sample. In unreported regressions, we also tried adding a dummy variable for investment banks but this did not essentially change the results. Thus, the sample sensitivity is not related to investment banks as we have also controlled for them.

Table 5 presents further robustness checks by adding to regression (4) of Table 3 additional control variables one by one.<sup>23</sup> In all these regressions we also control for the length (in years) of the CEO's tenure until the end of 2006. We also run the same regressions (including regression (4) of Table 3) for the subsample of banks with non-zero bonuses in 2006, and for an alternative definition of crisis return, namely from 2 July, 2007 to 19 September 2008 (results available upon request). The end date of the alternative crisis return period is after Lehman's bankruptcy but before the announcement of the TARP program. Note that in Table 5 as well as in the unreported additional regression models the sample size drops significantly from those in Table 3 because the new control variables were not available for all the banks in Table 3. We also tried quantile regressions for different quantiles of crisis returns but did not find any further robust effects. Overall, we find no further evidence for our vega measure from any of these regressions, nor any new control variables which would be significant. Perhaps due to the drop in sample sizes all previously significant variables (including leverage and market-to-book) largely lose their significance (see Table 5), although the levered earnings volatility partly captures the role of leverage (see e.g. regression (4)A.1). We also rerun corresponding regressions as in Table 3 by using the banks' z-score calculated at the end of 2007 as the dependent variable instead of the crisis return. The z-score

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<sup>23</sup>These data items are from Deposit Insurance Corporation and Federal Reserve Bank of Chicago.

has been widely used in the empirical literature as a proxy for overall bank risk (see e.g. Dam and Koetter (2012), Gropp et al. (2013), and Laeven and Levine (2009)). Table 6 shows that the results are generally similar as in Table 3 but overall less significant. The expected CEO tenure now appears with a significant negative sign, giving some indication that younger CEOs may have taken more risk, measured by the z-score.

In summary, even though we use a nonlinear risk-taking measure, our empirical results are not inconsistent with Fahlenbrach and Stulz (2011) who conclude that bonus-based CEO risk-taking incentives do not explain banks' crisis time stock performance. The empirical predictors of the crisis time bank stock performance, for which we mainly find support are bank leverage (with a negative effect) and the market to book equity ratio (with a positive effect). Our empirical findings suggest that regulatory efforts to control bank leverage would be more effective in limiting banks' risks than regulating bonuses.<sup>24</sup>

## 6 Conclusions

In this paper we have analyzed the risk-taking incentives of a banker whose compensation contract involves a convex element in the form of cash bonuses. We have derived in a standard continuous-time asset pricing framework the present value of the future stream of the banker's bonuses. Two key results are obtained from the theoretical model. First, the present value of bonuses is the higher, the shorter is their payment interval. Second, the shorter the bonus payment interval, the higher is the banker's incentive to increase risk.

For a sample of 86 large US banks, we find that our model's risk-taking incentive measure, estimated at the end of 2006, is negatively related to the 2007-2008 crisis time stock returns of the banks on a stand-alone basis but the relationship is not robust to control variables. Bank leverage and market to book equity ratio are the most significant control variables and together they explain about 17% of the crisis returns. These

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<sup>24</sup>For instance, Admati and Hellwig (2013) argue for a stringent non-risk-based leverage ratio requirement for banks. However, regulation on risk-based leverage can also have unintended consequences and, thus, there is a risk of doing harm, not improving the banking system (see e.g. Keppo, Kofman, and Xu (2010)).

findings suggest that regulatory efforts to control bank leverage are more effective in limiting banks' risks than regulating bonuses. To design even more effective regulation, future research will hopefully help us understand better the reasons why some banks used more leverage than others in the years before the crisis.

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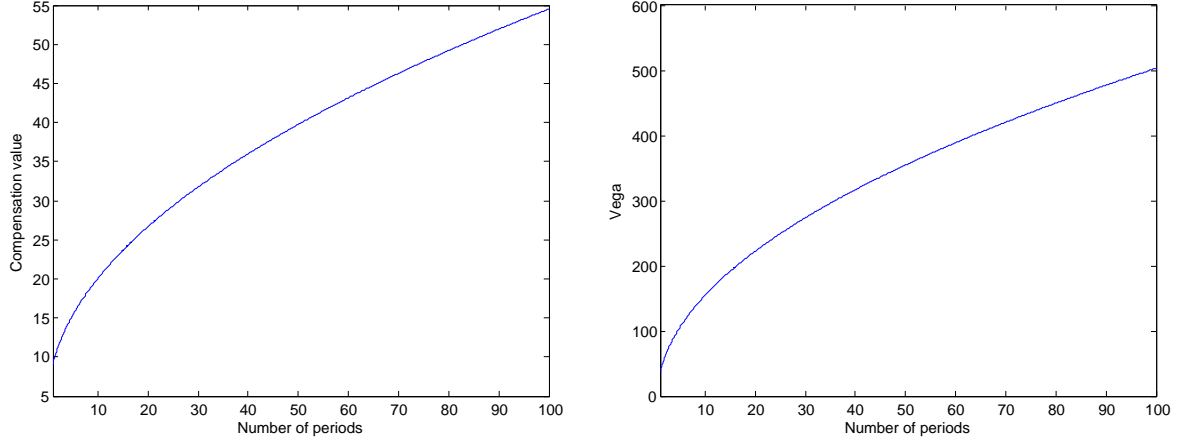


Figure 1: **Compensation value ( $\pi_n$ ) and the corresponding risk-taking incentive ( $\frac{\partial \pi_n}{\partial \sigma_\theta}$ , vega) with respect to the number of periods ( $n$ ).** Parameter values:  $A(0) = 100$ ,  $\sigma_\theta = 0.1$ ,  $r = 2\%$ ,  $T = 10$ , and  $k = 0.4$ .

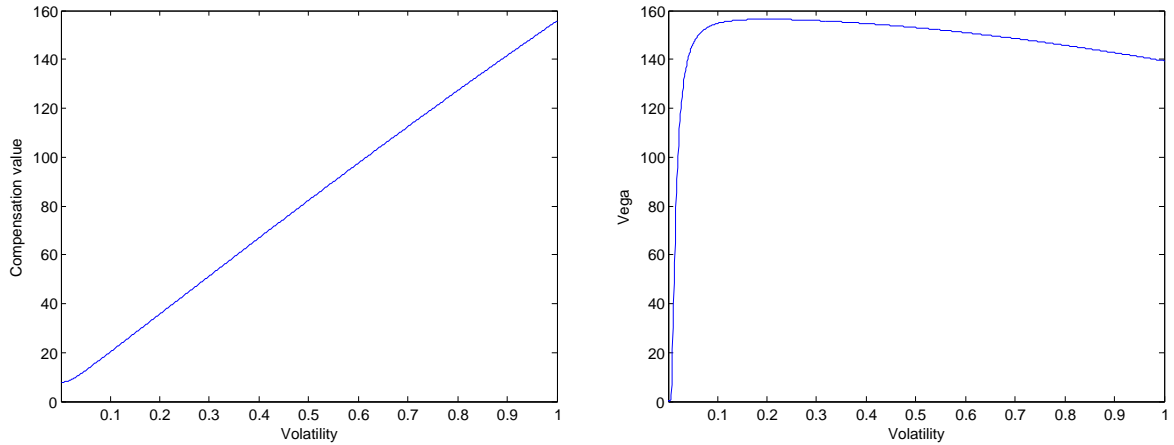


Figure 2: **Compensation value ( $\pi_n$ ) and the corresponding risk-taking incentive ( $\frac{\partial \pi_n}{\partial \sigma_\theta}$ , vega) with respect to the levered volatility ( $\sigma_\theta$ ).** Parameter values:  $A(0) = 100$ ,  $r = 2\%$ ,  $T = 10$ ,  $n = 10$ , and  $k = 0.4$ .

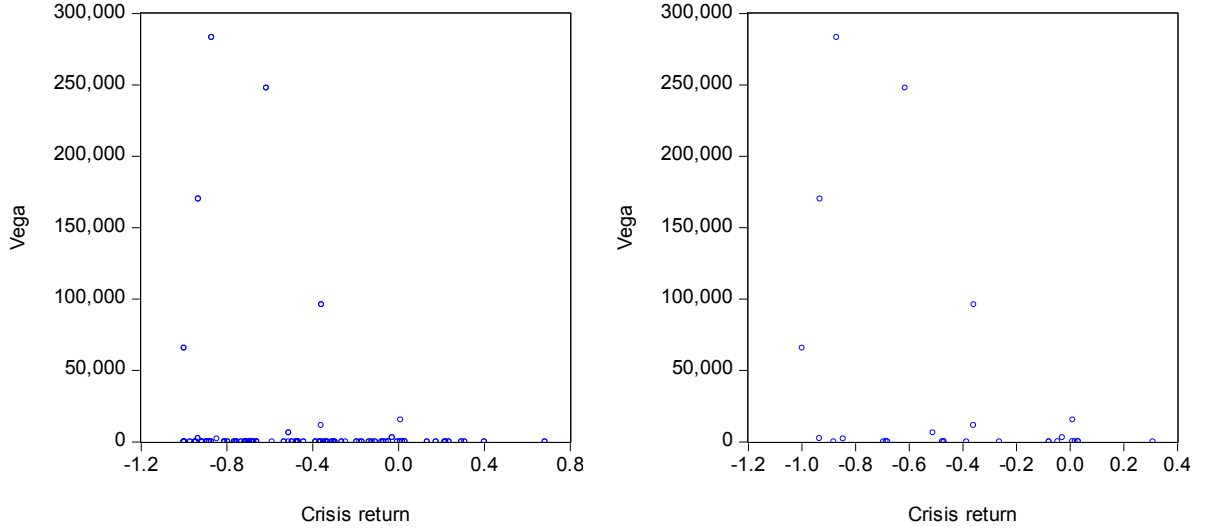


Figure 3: **Model risk-taking incentive ( $\frac{\partial \pi_n}{\partial \sigma_\theta}$ , vega) in 2006 vs the bank stock return during the crisis (crisis return).** The left panel is for the whole sample (86 banks, correlation: -17%) and the right panel is for the banks with non-zero CEO bonus at 2006 (25 banks, correlation: -39%).

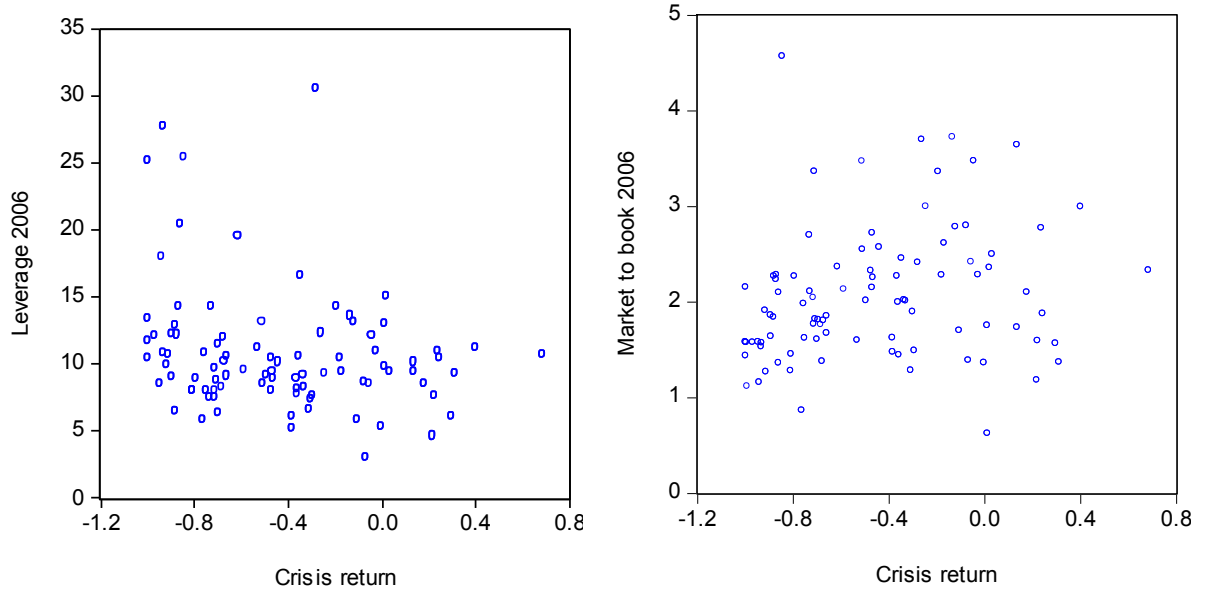


Figure 4: **Crisis return vs bank leverage ( $\theta$ ) in 2006 and market to book ratio in 2006.** The left panel is the crisis return vs leverage (correlation: -24%) and the right panel is the crisis return vs market to book ratio (correlation: 19%).



Table 1: **Descriptive Statistics (individual samples).** Variables for 2004 (or 2006) are measured at the end of 2004 (2006), expect crisis return (from 1 Jul 2007 to 31 Dec 2008) and leverage change (percentage change of leverage from year-end 2004 to year-end 2006). When compiling the investment bank dummy, JP Morgan is considered as an investment bank. Equation (6) is the vega of our model ( $\frac{\partial \pi_n}{\partial \sigma_\theta}$ ). CEO tenure (cap 10) is parameter  $T$  with 10 year tenure cap and vega(cap 10) is the corresponding model vega.

	Book equity 2006, A	Book equity 2004, A	Trading assets/total assets 2006	Investment bank dummy (1 for investment bank, 0 otherwise)	Cost-income ratio 2006	Deposit ratio (deposit/total assets) 2006	Liquidity ratio (average cash/average assets) 2006
Mean	9833.671	7653.154	0.015	0.064	0.376	0.547	0.033
Median	1382.040	1039.133	0.000	0.000	0.379	0.548	0.026
Maximum	135272.000	108166.000	0.268	1.000	0.596	0.858	0.326
Minimum	132.263	86.433	0.000	0.000	0.082	0.101	0.006
Std. Dev.	23831.880	19655.140	0.045	0.246	0.093	0.148	0.041
Skewness	3.906	4.131	4.046	3.569	-0.308	-0.835	5.974
Kurtosis	18.593	20.143	19.920	13.735	3.469	4.481	41.408
Jarque-Bera	1191.259	1373.065	1040.596	650.857	1.771	14.733	4786.342
Probability	0.000	0.000	0.000	0.000	0.412	0.001	0.000
Sum	924365.000	696437.000	1.064	6.000	26.723	38.807	2.352
Sum Sq. Dev.	52800000000.000	34800000000.000	0.140	5.617	0.603	1.540	0.116
Observations	94	91	71	94	71	71	71

(Table 1 cont'd)	Real estate loans/total loans 2006	Cash bonus per net income 2006, $k$	Market-to- book equity ratio 2004	Market-to- book equity ratio 2006	Nonperforming loans/total loans 2006	Crisis return	CEO tenure (cap 10) 2006, $T$	Total assets 2004	Total assets 2006
Mean	0.655	0.001	2.606	2.075	0.027	-0.439	9.714	103814.100	134122.100
Median	0.698	0.000	2.186	2.002	0.020	-0.471	10.000	13811.600	15190.790
Maximum	0.989	0.010	8.621	4.572	0.106	0.684	10.000	1484101.000	1884318.000
Minimum	0.000	0.000	1.249	0.627	0.000	-1.000	1.000	1004.809	1885.957
Std. Dev.	0.187	0.002	1.233	0.691	0.022	0.402	1.293	252637.400	327579.600
Skewness	-1.219	2.221	2.520	0.936	2.215	0.483	-5.033	3.627	3.486
Kurtosis	5.240	7.133	10.889	4.282	7.964	2.359	29.098	16.665	15.357
Jarque-Bera	32.429	141.146	303.074	19.957	130.950	5.092	2966.788	937.445	788.472
Probability	0.000	0.000	0.000	0.000	0.000	0.078	0.000	0.000	0.000
Sum	46.504	0.114	216.323	192.958	1.886	-39.904	884.000	9758527.000	12607480.000
Sum Sq. Dev.	2.441	0.001	124.732	43.987	0.035	14.523	150.571	594000000000.000	998000000000.000
Observations	71	92	83	93	71	91	91	94	94

(Table 1 cont'd)	Leverage 2004, $\theta$	Leverage 2006, $\theta$	Leverage change 2004-2006	Vega 2004 (cap 10)	Vega 2006 (cap 10)	Vega 2006 (cap 20)	CEO option grant vega 2006	Levered earnings volatility 2006, $\sigma_\theta$	CEO tenure until end 2006
Mean	11.186	10.762	-0.030	47461.110	10141.350	17976.450	71492.350	0.172	7.479
Median	10.175	9.704	-0.037	18945.290	0.000	0.000	31212.840	0.015	6.000
Maximum	28.964	30.689	0.619	679919.000	283190.900	566381.800	443293.500	4.416	22.000
Minimum	1.897	3.071	-0.536	0.000	0.000	0.000	0.000	0.004	0.000
Std. Dev.	4.424	4.670	0.165	94509.550	44616.740	83694.470	101786.200	0.591	6.053
Skewness	1.875	2.057	0.436	4.505	4.961	5.513	2.228	5.081	0.636
Kurtosis	8.079	8.448	6.319	27.967	27.428	33.701	7.399	32.289	2.347
Jarque-Bera	156.160	182.556	46.127	2260.414	2577.932	3946.083	89.866	3764.351	6.224
Probability	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.045
Sum	1051.464	1011.664	-2.804	3654505.000	902580.400	1599904.000	3932079.000	16.192	546.000
Sum Sq. Dev.	1820.110	2028.559	2.523	679000000000.000	175000000000.000	616000000000.000	559000000000.000	32.455	2638.219
Observations	94	94	94	77	89	89	55	94	73

(Table 1 cont'd)	Trading assets/total assets 2004	Deposit ratio (deposit/total assets) 2004	Cost-income ratio 2004	Liquidity ratio (average cash/average assets) 2004	Real estate loans/total loans 2004	Nonperforming loans/total loans 2004
Mean	0.015	0.533	0.480	0.035	0.621	0.025
Median	0.000	0.521	0.491	0.028	0.647	0.023
Maximum	0.249	0.856	0.663	0.315	0.993	0.089
Minimum	0.000	0.110	0.184	0.004	0.000	0.001
Std. Dev.	0.043	0.134	0.093	0.040	0.187	0.016
Skewness	4.057	-0.403	-0.809	5.906	-0.936	1.842
Kurtosis	19.796	3.867	4.360	40.872	4.355	7.874
Jarque-Bera	884.331	4.144	11.359	4000.081	13.574	94.858
Probability	0.000	0.126	0.003	0.000	0.001	0.000
Sum	0.938	37.847	29.280	2.124	37.866	1.505
Sum Sq. Dev.	0.112	1.263	0.520	0.097	2.093	0.015
Observations	61	71	61	61	61	61

Table 2: **Correlations between the variables.** Variables for 2004 (or 2006) are measured at the end of 2004 (2006), expect crisis return (from 1 Jul 2007 to 31 Dec 2008) and leverage change (percentage change of leverage from year-end 2004 to year-end 2006). When compiling the investment bank dummy, JP Morgan is considered as an investment bank. Equation (6) is the vega of our model ( $\frac{\partial \pi_n}{\partial \sigma_\theta}$ ). CEO tenure (cap 10) is parameter  $T$  with 10 year tenure cap and vega(cap 10) is the corresponding model vega.

	Book equity 2006, $A$	Book equity 2004, $A$	Trading assets/total assets 2006	Investment bank dummy (1 for investment bank, 0 otherwise)	Cost-income ratio 2006	Deposit ratio (deposit/total assets) 2006	Liquidity ratio (average cash/average assets) 2006
Book equity 2006, $A$	1.000	0.992	0.839	0.373	-0.065	-0.538	0.020
Book equity 2004, $A$	0.992	1.000	0.868	0.351	-0.057	-0.551	0.021
Trading assets/total assets 2006	0.839	0.868	1.000	0.680	0.003	-0.591	0.063
Investment bank dummy (1 for investment bank, 0 otherwise)	0.373	0.351	0.680	1.000	-0.018	-0.243	0.024
Cost-income ratio 2006	-0.065	-0.057	0.003	-0.018	1.000	-0.149	0.239
Deposit ratio (deposit/total assets) 2006	-0.538	-0.551	-0.591	-0.243	-0.149	1.000	-0.462
Liquidity ratio (average cash/average assets) 2006	0.020	0.021	0.063	0.024	0.239	-0.462	1.000
Real estate loans/total loans 2006	-0.245	-0.264	-0.212	-0.174	-0.475	0.448	-0.343
Cash bonus per net income 2006, $k$	-0.093	-0.099	-0.111	0.188	-0.281	0.247	-0.093
Market-to-book equity ratio 2004	-0.158	-0.168	-0.204	-0.151	0.095	0.067	0.084
Market-to-book equity ratio 2006	-0.075	-0.066	-0.127	-0.024	0.151	-0.015	0.298
Nonperforming loans/total loans 2006	0.142	0.161	0.236	0.052	-0.203	-0.089	-0.097
Crisis return	-0.195	-0.172	-0.193	-0.157	0.185	0.104	0.106
CEO tenure (cap 10) 2006, $T$	0.053	0.050	0.020	-0.113	-0.136	0.006	0.023
Total assets 2004	0.958	0.967	0.867	0.534	-0.058	-0.557	0.026
Total assets 2006	0.947	0.948	0.859	0.561	-0.062	-0.549	0.022
Leverage 2004, $\theta$	0.114	0.080	0.111	0.611	0.124	-0.038	0.095
Leverage 2006, $\theta$	0.168	0.141	0.251	0.657	0.074	-0.113	0.159
Leverage change 2004-2006	0.097	0.113	0.211	0.126	-0.116	-0.058	0.076
Vega 2004 (cap 10)	0.721	0.767	0.888	0.421	-0.035	-0.560	0.091
Vega 2006 (cap 10)	0.537	0.550	0.693	0.658	-0.017	-0.431	0.024
Vega 2006 (cap 20)	0.569	0.585	0.694	0.584	-0.014	-0.430	0.023
CEO option grant vega 2006	0.264	0.215	0.239	0.137	0.027	-0.368	0.056
Levered earnings volatility 2006, $\sigma_\theta$	0.140	0.098	0.507	0.530	0.001	-0.368	-0.057
CEO tenure until end 2006	-0.189	-0.188	-0.194	-0.235	-0.173	0.007	0.040

(Table 2 cont'd)	Real estate loans/total loans 2006	Cash bonus per net income 2006, $k$	Market-to- book equity ratio 2004	Market-to- book equity ratio 2006	Nonperforming loans/total loans 2006	Crisis return	CEO tenure (cap 10) 2006, $T$	Total assets 2004	Total assets 2006
Book equity 2006, $A$	-0.245	-0.093	-0.158	-0.075	0.142	-0.195	0.053	0.958	0.947
Book equity 2004, $A$	-0.264	-0.099	-0.168	-0.066	0.161	-0.172	0.050	0.967	0.948
Trading assets/total assets 2006	-0.212	-0.111	-0.204	-0.127	0.236	-0.193	0.020	0.867	0.859
Investment bank dummy (1 for investment bank, 0 otherwise)	-0.174	0.188	-0.151	-0.024	0.052	-0.157	-0.113	0.534	0.561
Cost-income ratio 2006	-0.475	-0.281	0.095	0.151	-0.203	0.185	-0.136	-0.058	-0.062
Deposit ratio (deposit/total assets) 2006	0.448	0.247	0.067	-0.015	-0.089	0.104	0.006	-0.557	-0.549
Liquidity ratio (average cash/average assets) 2006	-0.343	-0.093	0.084	0.298	-0.097	0.106	0.023	0.026	0.022
Real estate loans/total loans 2006	1.000	0.068	-0.132	-0.209	0.078	-0.256	0.225	-0.265	-0.249
Cash bonus per net income 2006, $k$	0.068	1.000	0.091	0.057	0.085	0.088	-0.040	-0.057	-0.048
Market-to-book equity ratio 2004	-0.132	0.091	1.000	0.556	-0.122	0.160	0.037	-0.159	-0.156
Market-to-book equity ratio 2006	-0.209	0.057	0.556	1.000	-0.288	0.189	-0.011	-0.029	-0.025
Nonperforming loans/total loans 2006	0.078	0.085	-0.122	-0.288	1.000	-0.211	-0.030	0.160	0.157
Crisis return	-0.256	0.088	0.160	0.189	-0.211	1.000	-0.044	-0.204	-0.210
CEO tenure (cap 10) 2006, $T$	0.225	-0.040	0.037	-0.011	-0.030	-0.044	1.000	0.035	0.033
Total assets 2004	-0.265	-0.057	-0.159	-0.029	0.160	-0.204	0.035	1.000	0.996
Total assets 2006	-0.249	-0.048	-0.156	-0.025	0.157	-0.210	0.033	0.996	1.000
Leverage 2004, $\theta$	-0.166	0.231	0.261	0.293	0.088	-0.238	-0.070	0.274	0.306
Leverage 2006, $\theta$	-0.143	0.255	0.121	0.303	0.300	-0.237	-0.118	0.347	0.381
Leverage change 2004-2006	0.013	0.054	-0.362	0.036	0.376	0.028	-0.262	0.147	0.151
Vega 2004 (cap 10)	-0.260	-0.049	-0.176	-0.089	0.273	-0.136	-0.047	0.695	0.664
Vega 2006 (cap 10)	-0.237	0.157	-0.113	-0.008	0.146	-0.173	-0.114	0.680	0.705
Vega 2006 (cap 20)	-0.233	0.097	-0.101	0.010	0.139	-0.154	-0.040	0.707	0.732
CEO option grant vega 2006	0.025	-0.118	0.282	0.312	0.350	-0.173	-0.051	0.248	0.274
Levered earnings volatility 2006, $\sigma_a$	0.074	0.074	0.294	0.305	0.419	-0.226	-0.028	0.268	0.307
CEO tenure until end 2006	0.090	0.007	0.014	-0.170	-0.146	-0.157	-0.055	-0.218	-0.226

(Table 2 cont'd)	Leverage 2004, $\theta$	Leverage 2006, $\theta$	Leverage change 2004-2006	Vega 2004 (cap 10)	Vega 2006 (cap 10)	Vega 2006 (cap 20)	CEO option grant vega 2006	Levered earnings volatility 2006, $\sigma_a$	CEO tenure until end 2006
Book equity 2006, $A$	0.114	0.168	0.097	0.721	0.537	0.569	0.264	0.140	-0.189
Book equity 2004, $A$	0.080	0.141	0.113	0.767	0.550	0.585	0.215	0.098	-0.188
Trading assets/total assets 2006	0.111	0.251	0.211	0.888	0.693	0.694	0.239	0.507	-0.194
Investment bank dummy (1 for investment bank, 0 otherwise)	0.611	0.657	0.126	0.421	0.658	0.584	0.137	0.530	-0.235
Cost-income ratio 2006	0.124	0.074	-0.116	-0.035	-0.017	-0.014	0.027	0.001	-0.173
Deposit ratio (deposit/total assets) 2006	-0.038	-0.113	-0.058	-0.560	-0.431	-0.430	-0.368	-0.368	0.007
Liquidity ratio (average cash/average assets) 2006	0.095	0.159	0.076	0.091	0.024	0.023	0.056	-0.057	0.040
Real estate loans/total loans 2006	-0.166	-0.143	0.013	-0.260	-0.237	-0.233	0.025	0.074	0.090
Cash bonus per net income 2006, $k$	0.231	0.255	0.054	-0.049	0.157	0.097	-0.118	0.074	0.007
Market-to-book equity ratio 2004	0.261	0.121	-0.362	-0.176	-0.113	-0.101	0.282	0.294	0.014
Market-to-book equity ratio 2006	0.293	0.303	0.036	-0.089	-0.008	0.010	0.312	0.305	-0.170
Nonperforming loans/total loans 2006	0.088	0.300	0.376	0.273	0.146	0.139	0.350	0.419	-0.146
Crisis return	-0.238	-0.237	0.028	-0.136	-0.173	-0.154	-0.173	-0.226	-0.157
CEO tenure (cap 10) 2006, $T$	-0.070	-0.118	-0.262	-0.047	-0.114	-0.040	-0.051	-0.028	-0.055
Total assets 2004	0.274	0.347	0.147	0.695	0.680	0.707	0.248	0.268	-0.218
Total assets 2006	0.306	0.381	0.151	0.664	0.705	0.732	0.274	0.307	-0.226
Leverage 2004, $\theta$	1.000	0.935	-0.125	0.130	0.389	0.304	0.405	0.699	-0.121
Leverage 2006, $\theta$	0.935	1.000	0.201	0.184	0.457	0.379	0.391	0.703	-0.203
Leverage change 2004-2006	-0.125	0.201	1.000	0.147	0.133	0.141	0.034	0.079	-0.224
Vega 2004 (cap 10)	0.130	0.184	0.147	1.000	0.375	0.369	0.276	0.185	-0.172
Vega 2006 (cap 10)	0.389	0.457	0.133	0.375	1.000	0.980	0.139	0.377	-0.210
Vega 2006 (cap 20)	0.304	0.379	0.141	0.369	0.980	1.000	0.156	0.357	-0.208
CEO option grant vega 2006	0.405	0.391	0.034	0.276	0.139	0.156	1.000	0.645	-0.119
Levered earnings volatility 2006, $\sigma_a$	0.699	0.703	0.079	0.185	0.377	0.357	0.645	1.000	-0.224
CEO tenure until end 2006	-0.121	-0.203	-0.224	-0.172	-0.210	-0.208	-0.119	-0.224	1.000

(Table 2 cont'd)	Book equity 2004, $A$	Trading assets/total assets 2004	Deposit ratio (deposit/total assets) 2004	Cost-income ratio 2004	Liquidity ratio (average cash/average assets) 2004	Real estate loans/total loans 2004	Market-to-book equity 2004	Nonperforming loans/total loans 2004	CEO tenure (cap 10) 2004, $T$	Total assets 2004	Leverage change 2004-2006	Vega 2004 (cap 10)
Book equity 2004, $A$	1.000	0.928	-0.544	-0.032	0.043	-0.270	-0.168	0.290	0.050	0.967	0.113	0.767
Trading assets/total assets 2004	0.928	1.000	-0.562	0.082	0.126	-0.301	-0.217	0.280	0.059	0.925	0.175	0.897
Deposit ratio (deposit/total assets) 2004	-0.544	-0.562	1.000	-0.035	-0.351	0.418	0.098	-0.277	0.051	-0.553	-0.088	-0.485
Cost-income ratio 2004	-0.032	0.082	-0.035	1.000	0.192	-0.314	0.246	0.108	0.024	-0.025	-0.237	0.047
Liquidity ratio (average cash/average assets) 2004	0.043	0.126	-0.351	0.192	1.000	-0.212	0.054	-0.008	0.027	0.047	0.129	0.147
Real estate loans/total loans 2004	-0.270	-0.301	0.418	-0.314	-0.212	1.000	-0.165	-0.110	0.240	-0.274	-0.012	-0.367
Market-to-book equity 2004	-0.168	-0.217	0.098	0.246	0.054	-0.165	1.000	-0.258	0.037	-0.159	-0.362	-0.176
Nonperforming loans/total loans 2004	0.290	0.280	-0.277	0.108	-0.008	-0.110	-0.258	1.000	0.020	0.308	0.234	0.189
CEO tenure (cap 10) 2004, $T$	0.050	0.059	0.051	0.024	0.027	0.240	0.037	0.020	1.000	0.035	-0.262	-0.047
Total assets 2004	0.967	0.925	-0.553	-0.025	0.047	-0.274	-0.159	0.308	0.035	1.000	0.147	0.695
Leverage change 2004-2006	0.113	0.175	-0.088	-0.237	0.129	-0.012	-0.362	0.234	-0.262	0.147	1.000	0.147
Vega 2004 (cap 10)	0.767	0.897	-0.485	0.047	0.147	-0.367	-0.176	0.189	-0.047	0.695	0.147	1.000

Table 3: **Bank buy-and-hold returns ("crisis return" from 2 Jul 2007 to 31 Dec 2008).** The estimated models are of the form:

$$crisis\ return = constant + \sum_i \beta_i x_i + \varepsilon,$$

where constant is the first row of the table,  $x_i$  is the  $i$ 'th explanatory variable measured at the end of 2006,  $\beta_i$  is the slope coefficient of  $x_i$  and it is reported in the  $(i + 1)$ 'th row of the table, and  $\varepsilon$  is an error term. The risk-taking incentives are measured as our model's vega, equation (6), and as the vega of CEO option grants (CEO option grant vega). CEO tenure (cap 10) is parameter  $T$  with 10 year tenure cap and vega 2006 (cap 10) is the corresponding model vega. Different columns correspond to different regression models with different explanatory variable sets. White corrected standard errors are reported in parentheses. Statistical significance at the 1%, 5%, or 10% level is indicated by \*\*\*, \*\*, and \*, respectively.

	(1)	(2)	(3)	(4)	(5)
Constant	-0.4370*** (0.0443)	-0.3119 (0.2253)	-0.2979 (0.2078)	-0.2477 (0.2214)	-0.4241*** (0.0628)
Vega 2006 (cap 10)	-1.52E-06*** (4.46E-07)		-4.43E-07 (7.88E-07)	6.79E-07 (6.81E-07)	-1.05E-06* (5.75E-07)
Cash bonus per net income, $k$		18.5171 (15.9935)	20.1871 (15.8410)	30.0174 (19.5134)	
CEO tenure (cap 10), $T$		-0.0111 (0.0239)	-0.0128 (0.0221)	-0.0228 (0.0142)	
Levered earnings volatility, $\sigma_\theta$		-0.1545*** (0.0481)	-0.1441*** (0.0447)	-0.0755 (0.0559)	
Book equity, $A$		-2.54E-06** (1.11E-06)	-2.10E-06 (1.44E-06)	-2.12E-06 (1.35E-06)	
Leverage, $\theta$				-0.0368*** (0.0124)	
Market-to-book equity ratio				0.1920*** (0.0586)	
CEO option grant vega					-5.89E-07 (4.21E-07)
No. of obs	86	86	86	85	51
$R^2$	0.030	0.095	0.096	0.23	0.061

Table 4: **Percentage change of leverage from 2004 to 2006.** The estimated models are of the form:

$$\text{leverage change } \% = \text{constant} + \sum_i \beta_i x_i + \varepsilon,$$

where constant is the first row of the table,  $x_i$  is the  $i$ 'th explanatory variable measured at the end of 2004,  $\beta_i$  is the slope coefficient of  $x_i$  and it is reported in the  $(i + 1)$ 'th row of the table, and  $\varepsilon$  is an error term. When compiling the investment bank dummy, JP Morgan is considered as an investment bank. The risk-taking incentive is measured as the model vega ( $\frac{\partial \pi_n}{\partial \sigma_\theta}$ , equation (6)). CEO tenure (cap 10) is parameter  $T$  with 10 year tenure cap and vega 2004 (cap 10) is the corresponding model vega. Different columns correspond to different regression models with different explanatory variable sets. White corrected standard errors are reported in parentheses. Statistical significance at the 1%, 5%, or 10% level is indicated by \*\*\*, \*\*, and \*, respectively.

	(1)	(1)A	(1)B	(1)C	(1)D	(1)E	(1)F	(1)S
Constant	0.1077 (0.1042)	0.1634 (0.0991)	0.0547 (0.0723)	0.0151 (0.0893)	0.0398 (0.0706)	0.0624 (0.0859)	0.0952 (0.1310)	0.0398 (0.0695)
Vega 2004 (cap 10)	1.58e-07 (1.12e-07)	-1.37e-08 (2.81e-07)	-2.65e-07 (3.04e-07)	1.13e-07 (2.36e-07)	7.67e-08 (3.06e-07)	1.07e-07 (2.51e-07)	1.57e-07 (2.62e-07)	7.62e-08 (9.27e-08)
Market-to-book equity ratio 2004	-0.0530** (0.0202)	-0.0590*** (0.0139)	-0.0521*** (0.0181)	-0.0527*** (0.0173)	-0.0561*** (0.0145)	-0.04667** (0.0197)	-0.0525*** (0.0149)	-0.0561*** (0.0143)
Leverage 2004, $\theta$	-0.0021 (0.0063)	0.0023 (0.0072)	0.0019 (0.0070)	0.0039 (0.0074)	0.0022 (0.0065)	0.0090 (0.0070)	0.0046 (0.0071)	0.0022 (0.0065)
Real estate loans/total loans		-0.1532 (0.1061)						
Trading assets/total assets			0.9497 (0.5887)					
Nonperforming loans/total loans				0.7977 (1.3156)				
Liquidity ratio (average cash/average assets)					0.6183*** (0.2238)			0.6184*** (0.2239)
Deposit ratio (deposit/total assets)						-0.1700 (0.1394)		
Cost-income ratio							-0.1414 (0.1999)	
Investment bank dummy (1 for investment bank, 0 otherwise)		0.0278 (0.1739)	0.0113 (0.1189)	-0.0181 (0.1472)	-0.00052 (0.1944)	-0.0522 (0.1429)	-0.0295 (0.1645)	
No. of obs	69	49	49	49	49	55	49	49
R <sup>2</sup>	0.1596	0.2758	0.2646	0.2509	0.2847	0.2274	0.2507	0.2847



Table 5: **Bank buy-and-hold returns ("crisis return" from 2 Jul 2007 to 31 Dec 2008).** The estimated models are of the form:

$$crisis\ return = constant + \sum_i \beta_i x_i + \varepsilon,$$

where constant is the first row of the table,  $x_i$  is the  $i$ 'th explanatory variable measured at the end of 2006,  $\beta_i$  is the slope coefficient of  $x_i$  and it is reported in the  $(i+1)$ 'th row of the table, and  $\varepsilon$  is an error term. The risk-taking incentive is measured as the model vega ( $\frac{\partial \pi_n}{\partial \sigma_\theta}$ , equation (6)). CEO tenure (cap 10) is parameter  $T$  with 10 year tenure cap and vega 2006 (cap 10) is the corresponding model vega. Different columns correspond to different regression models with different explanatory variable sets. Regression models (4)A.2 - (4)G have the same sample of banks. White corrected standard errors are reported in parentheses. Statistical significance at the 1%, 5%, or 10% level is indicated by \*\*\*, \*\*, and \*, respectively.

	(4)A.1	(4)A.2	(4)B	(4)C	(4)D	(4)E	(4)F	(4)G
Constant	-0.0084814 (0.2742333)	-0.6298529** (0.3130652)	-0.3768031 (0.3527498)	-0.6244245** (0.3055218)	-0.6502188** (0.3188963)	-0.6313942* (0.367197)	-0.7496474 (0.4828494)	-0.7855273* (0.3954728)
Vega 2006 (cap 10)	3.70e-07 (5.77e-07)	1.53e-06 (3.25e-06)	1.78e-06 (3.14e-06)	-2.28e-06 (6.54e-06)	1.53e-06 (3.30e-06)	1.54e-06 (3.30e-06)	1.53e-06 (3.34e-06)	1.71e-06 (3.33e-06)
Cash bonus per net income, $k$	25.97558 (15.70317)	14.99188 (18.61386)	16.44398 (18.79315)	16.74051 (18.81316)	14.52347 (18.17346)	14.94193 (19.53577)	12.66613 (20.72887)	18.61469 (20.10461)
CEO tenure (cap 10), $T$	-0.0276996 (0.0189392)	-0.0123336 (0.0159563)	-0.0001219 (0.0171337)	-0.0120639 (0.014935)	-0.0124413 (0.0168028)	-0.0122788 (0.0174403)	-0.0114281 (0.0162108)	-0.0098609 (0.0148141)
CEO tenure until end 2006	-0.0121231 (0.0082505)	-0.0066078 (0.009334)	-0.0059844 (0.0095264)	-0.0071846 (0.0096445)	-0.005886 (0.0096579)	-0.006594 (0.0095347)	-0.0061005 (0.0093907)	-0.0055845 (0.0098129)
Levered earnings volatility, $\sigma_e$	-0.0969966* (0.0575533)	-1.734649 (2.234639)	-1.970708 (2.172112)	0.4098131 (4.030751)	-1.722787 (2.281599)	-1.738131 (2.282142)	-1.686046 (2.315249)	-1.898484 (2.319168)
Book equity, $A$	-2.83e-06** (1.32e-06)	-2.46e-06* (1.24e-06)	-2.97e-06** (1.21e-06)	-5.49e-06 (4.22e-06)	-2.47e-06** (1.20e-06)	-2.46e-06* (1.25e-06)	-2.13e-06 (1.52e-06)	-2.28e-06* (1.24e-06)
Leverage, $\theta$	-0.0252024 (0.016285)	0.0216367 (0.0256334)	0.0118858 (0.0286487)	0.0166703 (0.0250042)	0.0157496 (0.0310497)	0.0217493 (0.0284559)	0.0247204 (0.0280084)	0.0208389 (0.0265771)
Market-to-book equity ratio	0.1108828 (0.0677278)	0.1053339 (0.0799795)	0.098598 (0.0770135)	0.1092592 (0.0809859)	0.1240955 (0.087411)	0.105565 (0.0846686)	0.1029894 (0.0818599)	0.1017528 (0.0799046)
Real estate loans/total loans			-0.4077989 (0.3607196)					
Trading assets/total assets				3.015596 (3.562067)				
Nonperforming loans/total loans					1.273611 (2.925746)			
Liquidity ratio (average cash/average assets)						-0.0171102 (0.7267176)		
Deposit ratio (deposit/total assets)							0.1466967 (0.4059009)	
Cost-income ratio								0.3576183 (0.591784)
No. of obs	67	54	54	54	54	54	54	54
$R^2$	0.2143	0.1837	0.2193	0.1951	0.1870	0.1837	0.1852	0.1903

Table 6: **Banks' distance to default at the end of 2007 measured by z-score.**

The estimated models are of the form:

$$z\text{-score} = \text{constant} + \sum_i \beta_i x_i + \varepsilon,$$

where constant is the first row of the table,  $x_i$  is the  $i$ 'th explanatory variable measured at the end of 2006,  $\beta_i$  is the slope coefficient of  $x_i$  and it is reported in the  $(i + 1)$ 'th row of the table, and  $\varepsilon$  is an error term. The risk-taking incentive is measured as the model vega ( $\frac{\partial \pi_n}{\partial \sigma_\theta}$ , equation (6)). CEO tenure (cap 10) is parameter  $T$  with 10 year tenure cap and vega 2006 (cap 10) is the corresponding model vega. Different columns correspond to different regression models with different explanatory variable sets. z-score = ( return on assets + capital asset ratio ) / asset volatility, where we estimate the asset volatility as the standard deviation of the return on assets over 10 quarters. White corrected standard errors are reported in parentheses. Statistical significance at the 1%, 5%, or 10% level is indicated by \*\*\*, \*\*, and \*, respectively.

	(1)	(2)	(3)	(4)	(5)
Constant	3.685059*** (0.1437734)	5.136346*** (0.1060295)	5.30519*** (0.1506665)	5.198608*** (0.8919584)	3.725279*** (0.2039645)
Vega 2006 (cap10)	-2.41e-06 (1.57e-06)		0.0000105 (8.51e-06)	0.0000113 (8.63e-06)	-2.31e-06 (1.57e-06)
Cash bonus per net income, $k$		29.76921 (59.12202)	24.51929 (60.39006)	39.47078 (68.17732)	
CEO tenure (cap 10), $T$		-0.1477454*** (0.0239834)	-0.1525841*** (0.0227487)	-0.1545354*** (0.0275524)	
Levered earnings volatility, $\sigma_\theta$		-2.961381** (1.15331)	-9.421775* (5.286845)	-9.754646* (5.171721)	
Book equity, $A$		1.02e-06 (4.01e-06)	-1.74e-06 (5.32e-06)	-4.45e-07 (5.19e-06)	
Leverage, $\theta$				-0.0475265 (0.0972575)	
Market-to-book equity ratio				0.2557594 (0.2721515)	
CEO option grant vega 2006					-2.01e-06 (2.06e-06)
No. of obs	57	57	57	57	38
$R^2$	0.0081	0.0567	0.0718	0.0929	0.0350

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