# Bank Risk-taking Investments and Managerial Incentives

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In this study, I adopt vega and delta as measures of CEO compensation structure. By applying various model specifications and econometric remedies, I find a strong causal relationship between managerial compensation structure and bank risk as well as banks' risk-taking investments. In particular, increased vega induces higher risk and excessive investments in non-conforming mortgage loans and non-government securities; excessive risky investments cause higher vega. While increased delta reduces bank risk. Moreover, increased vega/delta causes a lower/higher ROA and higher/lower amount of write-off; as banks expand into more risky investments, the level of write-offs goes up. The empirical findings of this study provide important implications for bank regulation and the current financial/mortgage crisis.
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## 1. Introduction

Bank's CEO compensation has become a central debate in the recent financial crisis. The use of equity-based compensation (i.e., stock and options) to motivate CEOs has become a major focus of this debate. Many people attribute the dramatic losses from trading mortgage loans and risky securities in banks to the failure to limit managerial incentives for exorbitant risk-taking.

Although there is rich literature about CEO compensation on non-banking firms, incredibly little attention was paid to CEO payment structure on banking. Houston and James (1995) find that the compensation structure in banks differs significantly from the structure in other industries, both in terms of total compensation and in terms of the relative importance of the individual elements that comprise total compensation. They report that bank CEOs who receive less cash compensation are less likely to participate in stock option plans. They receive a smaller percentage of their total compensation in the form of stock options than do their counterparts in other industries. Houston and James conclude that the compensation structure in the banking industry does not promote risk-taking. However, John et al. (2000) found contradictory results and argued that Houston and James (1995) only focus on comparing the compensation structure of banks to the compensation structure of industrial firms, rather than analyzing the impact of compensation on risk across banks. John et al. (2000) develop a theoretical model that explicitly incorporates bank management's compensation scheme into the risk-based pricing of deposit insurance. They demonstrate that, unlike capital and asset regulations that indirectly affect managerial decisions, altering the compensation structure provides a direct method of influencing managerial risk-taking incentives. Recently, Chen et al. (2006) attempted to examine the relationship between option-based executive compensation and market measures of risk in the banking industry. They found that the use of stock option-based compensation has become more wide-spread in banks in recent years, and the percentage of stock option-based compensation relative to total compensation has also increased. The structure of CEO compensation induces risk-taking.

However, Chen et al. (2006) and most previous and recent studies (Houston and James, 1995; Chhaochharia, 2009) use the ratio of stock option-based compensation to total compensation or the value of accumulated stock options as measures of compensation structure. Core and Guay (2002a)

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argue that such measures are noisy proxies for managerial incentives and cannot precisely capture risk-taking incentives of managers induced by their compensation schemes. For instance, a positive relationship between the ratio of stock option compensation to total compensation and stock return volatilities could result from certain factors having a positive effect on the volatility of stock returns. In such a case, the positive relationship is not the result of greater incentives for risk-taking by managers arising from the structure of their compensation.

In this study, I investigate the association between bank executives' compensation structure and CEOs' incentive for excessive risk-taking. Compared to previous studies, the main contributions of this study are: first, I adopt new measures of compensation to overcome the methodological issue mentioned above, which captures the CEOs' risk-taking incentives more precisely. The characteristics of compensation considered are the sensitivity of CEO wealth to stock return volatility, vega, and the sensitivity of CEO wealth to stock price, delta. I construct these measures in the manner of Guay (1999) using the Black-Scholes (1973) option valuation mode modified by Merton (1973). To check the robustness of the measures, I set up a direct test on compensation structure. The empirical evidence shows that by introducing vega and delta, the previous measures (i.e., option ratio or accumulative option) lose their explanatory power concerning bank risk. This finding supports the argument by Core and Guay (2002a) that the measures (i.e., option ratio and accumulative option) are noisy proxies for vega and delta. Second, in examining the effect of compensation structure on bank risk-taking, most studies focus only on stock return volatility. Incredibly little research has been done to examine banks' risk-taking investments and bank performance associated with CEOs' compensation scheme. Since the Federal Reserve Board passed Section 20 of the Glass-Steagall Act in 1987, commercial banks gradually expanded into non-banking business, such as trading securities and selling real estate, insurance, and computer services, which are riskier than traditional banking business. In this study, taking the advantage of the superior measures of vega and delta, I examine: (1) the causal relationship between CEO compensation structure and bank risk (defined as the logarithm of the variance of daily stock returns); (2) the causal relationship between CEO compensation structure and banks' risky investments, such as non-conforming mortgage loans and non-government securities; and (3) how a bank's compensation scheme affects the bank's performance (bank's ROA) and its total amount of loan write-offs.

By applying various model specifications and econometric remedies, I find a strong causal relationship between vega/delta and bank risk. In particular, increased vega induces higher risk; as banks increase risk, they tend to adopt more option-based compensation and thus cause higher vega. In contrast, increased delta reduces bank risk, which is consistent with the hypothesis that delta exposes managers to more risk, in which case managers would choose to avoid risk. Empirical results also indicate a strong causal relationship between banks' risky investments and vega. In particular, higher vega induces more risky investments in non-conforming mortgage loans and non-government securities; increased risky investments, in turn, increase vega. Delta is positively related to the investments in non-conforming mortgage loans and negatively related to the investments in non-government securities. Moreover, increased vega/delta causes a lower/higher ROA and higher/lower amount of write-off; as banks expand into more risky investments, the level of write-offs goes up.

## 2. Background

What distinguishes banks from other firms is their capital structure. Banks have very little equity relative to other firms. Banks typically receive 90 percent or more of their funding from debt, which is available to their creditors/depositors on demand. Their assets often take the form of loans that have longer maturities. Thus, banks provide a "special" liquidity production function for the economy by holding illiquid assets and issuing liquid liabilities.

Because banks keep only a fraction of deposits on reserve, they do not have sufficient funds on hand to pay all depositors at once. This causes a potential collective-action threat for banks. This threat will become more severe in unusual situations. For example, if for any reason, a large unanticipated withdrawal occurs, rational depositors will conclude that they must do the same thing before the bank's cash reserves are drained. Thus, collective-action can cause failure even for a solvent bank. Deposit insurance is justified on the grounds that it solves this problem by eliminating the incentive for a rush of withdrawals by depositors. Congress passed the banking Act of 1933, establishing the Federal Deposit Insurance Corporation (FDIC) and allowing the federal government to insure deposits in qualified banks. The creation of federal deposit insurance has been very effective in preventing bank runs and avoiding contagious effects of individual bank failure on the economy.

Despite the positive effect of FDIC insurance in preventing bank panics, the implementation of deposit insurance poses a regulatory cost of its own due to moral hazard problems. Because depositors are insured by the FDIC against losses, this gives the shareholders and managers of insured financial institutions incentives to engage in excessive risk-taking. They will be indifferent to the riskiness of a bank's investment and financing strategies. As a result, shareholders of financial institutions may face the consequences of greater risk taking incentives than shareholders of nonfinancial firms. The problem of moral hazard is exacerbated in situations where a bank is at or near insolvency. In such a situation, the shareholders have a strong incentive to increase risk because they can allocate their losses to third parties while still receiving gains that might result from the risky investments. Although nonfinancial firms that are close to insolvency also have an incentive to take additional risks, their ability to do so is limited by normal market forces and contractual obligations. For example, for nonfinancial firms, various devices serve to protect fixed claimants against excessive risk-taking while banks are not subject to such devices. FDIC insurance removes the incentive for insured depositors to control excessive risk-taking because their funds are protected regardless of what investment strategies the banks select. If management compensation policies are structured to promote risk taking, one would expect that compensation contracts in banking will provide managers with greater risk-taking incentives than in other industries.

It is well established in the literature that stockholders have an incentive to increase the risk of the firm, which will result in a wealth transfer from debtholders to stockholders. This problem is more prominent in banks because of their high debt-equity ratio and the existence of deposit insurance. Saunders et al. (1990) argue that since depositors (and deposit insurance funds) cannot perfectly monitor the actions of stockholders, stockholders can increase the value of their call option-like equity by increasing bank risk. Consequently, as the option-based CEO compensation increases and as the stock of option-based wealth grows, the CEOs face the same incentives as stockholders and, as such, will pursue high-risk investment strategies that increase bank risk.

Beginning in 1987, the Federal Reserve Board began to authorize securities subsidiaries to underwrite corporate debt and equity securities under Section 20 of the Glass-Steagall Act. These section 20 subsidiaries are originally subject to a substantial set of firewalls. For example, total revenue from these activities cannot exceed a specific amount (originally 5% of the subsidiary's revenue, later raised to 25%). Initially only limited activities are allowed, such as municipal bonds, government securities and commercial paper. In 1992, the Federal Reserve dropped some of the firewalls, allowing commercial banks to expand into other non-banking businesses. Thus, banks can get involved in high-risk investments such as mortgage-related investments and non-government securities trading. As a result, by 1996, most of the superregional and regional banks were conducting extensive securities activities. These relaxations are a further indication of the likelihood of banks expanding their nonbanking businesses in the future. However, the collapse of the housing bubble exposed these investment grade-rated securitizations of subprime mortgages that performed so abysmally once home prices stopped rising. The sub-prime mortgage crisis provides an illustration of the income volatility associated with fee-driven transactions banking. While the headlines in the financial press have justifiably dwelled on the over $2 trillion of capital losses suffered by banks and other investors in sub-prime mortgage-backed securities, transactions banking companies that originated, serviced, and securitized mortgages have experienced material and in some cases crippling reductions in fee income as investor demand for new Mortgage Backed

Securities dried up and household demand for both new and existing houses declined. Total industry noninterest income fell from 43% to 38% of operating income between 2006 and the first three quarters of 2008, the largest two-year decline since the mid-1970s. Many of the largest financial institutions with non-diversified, "mono-line" mortgage banking strategies failed (e.g., American Home Mortgage, New Century Financial, Countrywide Financial, Washington Mutual, Golden West-Wachovia) due to the combined impact of plummeting fee income and large losses in their portfolios of subprime mortgages and mortgage-backed securities. Among these non-interest, fee generated income, non-conforming mortgage loans (i.e., those that are not insured by government-sponsored enterprises (GSEs) such as Fannie and Freddie) and non-government securities are considered to be riskier investments.

From 1986-1994, the total assets of these subsidiaries grew from $20 billion to over $120 billion. They also account for a smaller but significant share of corporate equity and have substantial market shares in mortgage-backed and asset-backed securities. As commercial banks quickly expanded into corporate securities, they adopted an option-based incentive compensation system in the form of stock and options. CEO compensation structure, therefore, becomes a more sensitive issue in assessing banks' aggressive involvements in high-risk investments, such as non-conforming mortgage loans and non-government securities.

### 3. Measures and Methodology

The primary characteristic of compensation considered in this study is the sensitivity of CEO wealth to stock return volatility or vega. Vega is defined as the change in the dollar value of the CEOs' wealth for a one percentage point change in the annualized standard deviation of stock returns. Delta is defined as the change in the dollar value of the CEOs' wealth for a one percentage point change in stock price. Guay (1999) shows that option vega is many times higher than stock vega. Therefore, in this study, I measure CEOs' incentives to increase risk using the vega of stock options, rather than by the vega of the stock and option portfolio. Rajgopal and Shevlin (2002), Rogers (2002) and Coles et al. (2006) adopt the same approach.

Estimates of a stock option's value is calculated based on the Black-Scholes (1973) option valuation model for European call options, as modified by Merton (1973) to account for dividends.[2]

$$\text{Option value}=\left[Se^{-dT}N\left(Z\right)-Xe^{-rT}N\left(Z-\sigma T^{(1/2)}\right)\right], \quad (1)$$

where Z is the $\ln\left(S/X\right)+T\left(r-d+\sigma^2/2\right)/\sigma T^{(1/2)}$, *N(.)* the cumulative probability function for the normal distribution, *S* the price of the underlying stock, *X* the exercise price of the option, $\sigma$ the expected stock-return volatility over the life of the option, *r* the risk-free interest rate, *T* the time to maturity of the option in years, and *d* the expected dividend rate over the life of the option.

The vega and delta are calculated in the manner of Guay (1999) and Core and Guay (2002a). Vega is the partial derivative of the Black-Scholes option pricing model with respect to stock return volatility as follows:

$$\frac{\partial\left(option \quad value\right)}{\partial\left(stock \quad volatility\right)}=e^{-dT}N'\left(Z\right)ST^{(1/2)}, \quad (2)$$

where $N'$ is the normal density function. The dollar value measures the magnitude of managers' incentives of risk-taking. Indeed, the higher the sensitivity of the manager's compensation to risk the more he/she gains from increasing risk. Therefore, this measure captures directly the incentives of CEOs to increase risk. The sensitivity with respect to a 1% change in stock price, delta, is a partial derivative with respect to stock price:

[2] This measure is consistent with numerous recent papers such as Hall and Liebman (1998), Core and Guay (1999, 2002a), Guay (1999) and Rajgopal and Shevlin (2002), among others.

$$\frac{\partial\left(option \quad value\right)}{\partial\left(price\right)}\left(\frac{price}{100}\right)=e^{-dT}N\left(Z\right)\left(\frac{price}{100}\right), \tag{3}$$

Over the last fifteen years, the use of equity-based compensation in the form of stock options for bank CEOs has increased significantly. One effect of this growth has been a substantial increase in the sensitivity of CEO wealth to stock return volatility (vega) and stock price (delta) (Hall and Liebman, 1998; Jensen and Murphy, 1990). Therefore, the higher the compensation in the form of options is, the higher the managers' incentive for risk-taking would be. A second aspect of the increase in equity-based compensation potentially offsets this tendency—the sensitivity of CEO wealth to stock price or delta. It aligns the incentives of managers with the interests of shareholders. As managers are undiversified with respect to firm-specific risk, higher delta is supposed to expose managers to more risk than diversified shareholders. However, because convexity in compensation makes risk more valuable to managers, increase in vega will mitigate the effect of CEOs' risk aversion. Therefore, higher vega gives more incentives for managers to implement riskier investment strategies. Vega and delta as measures of compensation structure can capture the incentives faced by mangers more precisely. Therefore, the parameters of CEO compensation, such as vega, may be used to curb the risk-taking incentives and can be used as an input for banking regulatory schemes.

Prior studies tend to focus on only one dimension of compensation structure, such as delta or vega, without controlling for the other.[3] The mix of vega and delta are likely to have substantial cross-sectional differences and both affect risk-taking behavior. In this study, I include both vega and delta in empirical models, which allows me to isolate the effect of vega and delta. The empirical results in this study show that any attempt to isolate the relationship between risk-taking investments and vega should also control for delta.

Moreover, very few studies on the association between risk and compensation structure allow estimation of the underlying causal relationships. For example, Rogers (2002) questions if a positive association between stock return volatility and vega indicates that vega is used to implement high-risk decisions, or does it suggest that some underlying and omitted primitive factor drives the association between vega and volatility? Similar questions arise over the association between vega and other managerial decisions. All of these examples imply that causation is likely to run in both directions for vega and delta. It is critical to account for how investment choices and characteristics of the managerial compensation scheme are jointly determined. When both compensation characteristics and managerial decisions are endogenous, OLS results are not appropriate because the othogonality assumption is violated, and the use of OLS leads to biased and inconsistent parameter estimates. The usual *t* and *F* tests for these parameters are no longer valid. In this study, in order to avoid spurious inferences and to isolated causation, I apply various econometric remedies, including simultaneous equations, instrument variables, year dummies, etc., to disentangle the causality between compensation incentives and risk-taking.

## 4. Sample Data and Determinants of Vega and Delta

### 4.1 Data

I use the Standard & Poor Execucomp database for data on CEO compensation. Execucomp provides data on salary, bonus, and total compensation for the top five CEOs (ranked annually by salary and bonus) during the period 1992 to 2006. The data starts from the year 1992, after which the Securities and Exchange Commission required that all firms disclose detailed information on CEO compensation in the proxy statement, due to the prevalent use of incentive-based CEO compensation. Data for the control variables are also obtained from the Execucomp database. The data sample covers 189 banks, involving 1,256 CEOs. Data on daily returns used to calculate the risk measures are collected from the CRSP database. Bank characteristic data are obtained from the

[3] With the exceptions of Rogers (2002) and Coles et al. (2006).

Compustat database and the Federal Reserve Y-9C database. The Y-9C reports financial statement data for large U.S. bank holding companies. To be included in the sample, the bank has to have at least 4 consecutive years of observations.

Table 1 presents summary statistics of CEO and bank characteristics. Consistent with prior literature (Guay, 1999; Core and Guay, 1999), I winsorize vega, delta, and cash compensation at the 1st and 99th percentiles.

**Table 1**
**Summary Statistics**

| | N | Mean | Std | Min | Max |
|---|---|---|---|---|---|
| ***Characteristics of CEO*** | | | | | |
| Vega ($000s) | 1,256 | 12.838 | 75.182 | 0.000 | 119.500 |
| Delta ($000s) | 1,256 | 133.31 | 186.91 | 0.000 | 629.82 |
| Option ratio | 1,256 | 29.20% | 0.175 | 0.000 | 96.40% |
| Accumulated option ($000s) | 1,256 | 8,562.0 | 9,290.7 | 0.000 | 201,950.0 |
| ***Bank Characteristics*** | | | | | |
| Bank risk | 1,256 | 0.0189 | 0.0083 | 0.0071 | 0.0566 |
| Bank size | 1,256 | 7.150 | 1.396 | 3.201 | 18.566 |
| Tenure (years) | 1,256 | 6 | 9 | 1 | 12 |
| ROA | 1,256 | 1.08 | 2.62 | -10.12 | 32.62 |
| Book leverage | 1,256 | 0.902 | 0.109 | 0.815 | 0.958 |
| Market-to-book ratio | 1,256 | 1.116 | 0.119 | 0.913 | 2.157 |
| Non-interest income ratio | 1,256 | 28.8% | 0.7126 | 0.28% | 91.2% |
| Cash compensation ($000s) | 1,256 | 3,264.3 | 1,065.4 | 472.92 | 5,286.00 |
| Invested capital ($millions) | 1,256 | 7,435.8 | 14,485 | 30.899 | 109,270.0 |
| Non-conforming mortgage loans ($millions) | 1,256 | 271.13 | 0.119 | 0.000 | 567.12 |
| Non government security ($millions) | 1,256 | 220.40 | 0.097 | 0.000 | 635.23 |
| Loan loss write off ($millions) | 962 | 4.367 | 3.153 | 0.000 | 36.548 |

The measures of CEO compensations include: (1) vega; (2) delta; (3) option ratio, which is the total value of annual stock options granted (based on Black-Scholes model) as a percentage of the total annual compensation of the CEO; (4) accumulated option, which is the Black-Scholes value of accumulated, in-the-money stock options paid and held to date. Mean vega is $12,838 and mean delta is $133,317. The option ratio is 29.2% and accumulated option is $8,562,007, consistent with Chen et al. (2006).

Bank investment and characteristic variables are: (1) bank risk, defined as the logarithm of the variance of daily stock returns; (2) investments in non-conforming mortgage loans scaled by bank assets; (3) non-government securities scaled by bank assets; (4) loan loss write-off scaled by bank assets; (5) ROA, defined as EBITDA scaled by assets proxy for bank profitability and performance. The control variables used are all based on existing literature. Specifically: (1) logarithm of assets to proxy for bank size; (2) invested capital scaled by bank assets; (3) book leverage, defined as total book debt scaled by book value of assets; (4) market-to-book, defined as market value of assets to book value of assets, as a proxy for investment opportunities; (5) stock price; (6) non-interest-income, a measure of income diversification calculated by dividing total non-interest income by the sum of interest income and non-interest income; (7) geodummy, a dummy variable controlling for geographic diversification, which takes the value of one if the bank operates in more than one state, zero otherwise; (8) CEO cash compensation, defined as salary plus bonus. I use CEO tenure and CEO cash compensation to proxy for the level of CEOs' risk aversion. For instance, Coles (2006) argues that CEOs with longer tenures and higher cash compensation are more likely to be entrenched and will seek to avoid risk. Guay (1999) argues that CEOs with higher total cash compensation are better diversified, as they have more money to invest outside the firm and, therefore, are less risk averse.

## 4.2 Determinants of Vega and Delta

I draw a number of general conclusions from previous studies for determinants of vega and delta. Coles et al. (2006) show that larger banks are expected to have a higher vega and lower delta of CEOs' option portfolio; cash compensation, market-to-book ratio, and book leverage are also determinants of vega and delta. Cash compensation does not affect delta but positively relates to vega, while tenure does not affect vega but positively relates to delta. Chen et al (2006) find that stock price affects CEOs' compensation incentives. Guay (1999) suggests that vega and delta are interactively determined. The regressions will use above variables as determinants of vega and delta. Moreover, as banks quickly expanded into risky investments, they adopted more option-based incentive compensation. Therefore, in this study I consider the risky investments that banks implement, including investments in non-conforming mortgage loans and non-government securities as determinant factors for vega and delta. I also include banks' invested capital as a control variable for vega.

Unlike previous studies that examine the determinants of either delta or vega in an OLS setting without controlling for the fact that both are chosen simultaneously, I include both vega and delta in a simultaneous equation model. Empirical results show that vega and delta are jointly determined.

## 5. CEO Incentive, Vega, Delta and Bank Risk

Chen et al. (2006) examine the relationship between CEO compensation and risk-taking in the banking industry. They use stock option ratio (total value of annual stock options as a percentage of total annual compensation of the CEO) and accumulated stock options to proxy CEO compensation structure, and they find that the structure of CEO compensation induces risk-taking in the banking industry and that risk also impacts compensation structure. Many other studies also use similar measures as proxies of CEO compensation structure. However, Core and Guay (2002a) argue that such measures are noisy proxies for vega and delta and, thus, cannot precisely capture CEOs' compensation incentives.

I set up a model testing the explanatory power of the measures used by Chen et al. (2006), as well as vega and delta. I start with the estimation by Chen et al. (2006), where option ratio and accumulated option are used as measures of CEO compensation. I use 2SLS instead of OLS estimation. The empirical results in Table 2 are consistent with Chen et al. (2006). Panel A reports the results of the simultaneous equations on bank risk and option ratio, while Panel B has the results of the simultaneous equations on bank risk and accumulated option. In the equation of bank risk, the coefficients on option ratio in Panel A and accumulated option in Panel B are significant, and they are positively related with bank risk. For both Panels, bank size is significant with the expected negative sign. It suggests that bigger banks are usually associated with less risk; the coefficients on book leverage are positive and significant (it is slightly significant at 10% level in Panel B) while non-interest income and geodummy are insignificant in explaining bank risk, which are all consistent with Chen et al. (2006). In the equation of option ratio, the coefficients on bank risk, bank size and stock prices are positive and significant. Similarly results exist for the equation of accumulated option. Based on these results, Chen et al (2006) argue that option-based compensation structure induces bank risks.

In Table 3, I run a 3SLS estimation by adding vega as a measure of compensation in addition to Chen's measures. For comparison, I use the same explanatory variables for the equations of bank risk, option ratio and accumulated option. For the equation of vega, I use bank risk, size, book leverage, cash compensation and market-to-book ratio as determinants. To address the possibility that there are other omitted variables, all specifications throughout include industry (two-digit SIC) fixed and year effects. Panel A reports the simulation equations on bank risk, vega and option ratio; Panel B shows the simulation equations on bank risk, vega and accumulated option.

The results are noteworthy. In the equation of bank risk in both Panel A and Panel B, the coefficient on vega is positive and significant. As expected, increased vega induces higher risk in banks. However, by adding vega the explanatory power of option ratio (and accumulated option) disappear—the coefficients on option ratio and accumulated option become insignificant. It implies that vega is a superior measure in capturing CEOs' compensation incentive for risk-taking. This result confirms the finding by Core and Guay (2002a), showing that option ratio and accumulated option are noisy proxies of vega. The coefficients of other variables in the equations of bank risk, option ratio and accumulated option, are very robust and consistent with the results in Table 2.

**Table 2**
**Simultaneous Equations (2SLS): Bank Risk and CEO Option-based Compensation**

| | Panel A: Bank risk & option ratio | | Panel B: Bank risk & accumulated option | |
|---|---|---|---|---|
| Independent variables | Bank risk | Option ratio | Bank risk | Accum. option |
| Option ratio | 0.0006** | | | |
| Accumulated option | | | 0.0002** | |
| Bank risk | | 182.2300*** | | 286.7200** |
| Size | -0.0554*** | 0.2825** | -0.0465*** | 0.2287*** |
| Book leverage | 0.5652*** | | 0.0755* | |
| Non-interest income | 0.0065 | | 0.0113 | |
| Stock prices | | 0.0011* | | 0.0192* |
| Geodummy | -0.0163 | | -0.0543 | |
| Year dummy | YES | YES | YES | YES |
| R-square | 15.1% | 12.6% | 12.2% | 11.3% |

**Table 3**
**Simultaneous Equations (3SLS): Bank Risk and CEO Option-based Compensation (with vega)**

| | Panel A: Bank risk, vega & option ratio | | | Panel B: Bank risk, vega & accumulated option | | |
|---|---|---|---|---|---|---|
| Independent variables | Bank risk | Vega | Option ratio | Bank risk | Vega | Accumulated option |
| Vega | 0.0028*** | | | 0. 0015*** | | |
| Option ratio | 0.0003 | | | | | |
| Accumulated option | | | | 0.0002 | | |
| Bank risk | | 79.245*** | 22.580* | | 73.258*** | 19.080 |
| Size | -0.0794*** | 5.874*** | 0.022*** | -0.0204*** | 5.212*** | 0.027*** |
| Book leverage | 0.1197** | 4.825 | | 0.1304* | 4.003 | |
| Cash Compensation | | 0.017*** | | | 0.017*** | |
| Market-to-book | | 5.821*** | | | 5.225*** | |
| Non-interest income | 0.0074 | | | 0.0088 | | |
| Stock prices | | | 0.056* | | | 0.021* |
| Geodummy | 0.0657 | | | -0.0172 | | |
| Year dummy | YES | YES | YES | YES | YES | YES |
| R-square | 28.2% | 42.9% | 15.3% | 32.6% | 42.9% | 14.2% |

In the equation of vega, the coefficient on bank risk is significant with an expected positive sign. It indicates that not only does high vega induce bank risk, but also that increased bank risk will increase vega. This result shows a causal relationship between bank risk and vega, which implies that bank risk and vega are positively related and jointly determined. The coefficients on bank size, cash compensation, and market-to-book ratio are positive and significant, which is consistent with literature. The coefficient on book leverage is insignificant. It is not surprising because banks have very high leverage ratio compared to other industries and the leverage ratios are relatively stable across time and, therefore, have no explanatory power on vega. The R-square is 28.2% for the equation on bank risk in Panel A and 32.6% in Panel B, which is a significant improvement on the R-square in Table 2. It implies that adding vega improves the model's overall fitness.

In Table 4, I run a simultaneous regression of 3SLS on bank risk, vega and delta. In particular, for the equation of bank risk, I include delta, invested capital and tenure as additional explanatory variables. For the equation of vega, I use bank risk, delta, cash compensation, size, book leverage, market-to-book, and invested capital as explanatory variables. For the equation of delta, consistent with previous literature, I include bank risk, vega, size, book leverage, market-to-book ratio, tenure and stock prices as explanatory variables.

The 3SLS system is used in order to explore the causal relationship between compensation structure and risk-taking in banks, where both risk and incentive measures are contemporaneously determined. The 3SLS estimate could avoid spurious inferences in the OLS estimate and provide asymptotically correct estimates of the standard errors (Sawa, 1969).

In the equation of bank risk, all interested variables are significant (the coefficient on invested capital is slightly significant at 10% level). As expected, bank risk is positively related with vega, and it has been confirmed in Table 3 that higher vega induces more risk. The effect of delta on bank risk is of some interest. John and John (1993) suggest that higher delta increases the incentive to shift risk to debt holders. If higher NPV projects tend to be relatively risky, increased delta could provide the incentive to implement higher risk projects. On the other hand, higher delta exposes the manager to more risk, in which case managers could choose less risky projects (Guay, 1999). The empirical result in this study shows that delta is negatively associated with bank risk. It confirms the finding by Guay (1999). Empirical results also show that higher total invested capital is associated with higher risk; increased bank size decreases bank risk level. Bank risks are positively associated with book leverage and market-to-book ratio; moreover, CEOs' tenure is negatively related with bank risk.

In the equation of vega, as we observed in Table 3, the coefficient on bank risk is positive and significant, which indicates that increased bank risk also increases vega. Delta is slightly significant and positive related with vega. Moreover, the coefficients on cash compensation, bank size, book leverage, market-to-book ratio and invested capital are positive and significant, which is consistent with the literature. In the equation of delta, increased vega is associated with a higher delta. Delta is positively related with market-to-book ratio, tenure and stock price. Bank size is negatively related with delta. Increasing book leverage decreases delta. These results are consistent with the literature. Moreover, the empirical results show that bank risk is an insignificant determinant on delta.

**Table 4**
**Bank Risk and CEO Compensation (with vega and delta)**

| Independent variables | Bank risk | Vega | Delta |
|---|---|---|---|
| Bank risk | | 14.74*** | 0.33 |
| Vega | 0.0059*** | | 1.12*** |
| Delta | -0.0045** | 0.34* | |
| Cash compensation | -0.0293*** | 0.02*** | |
| Size | -0.0772*** | 1.12*** | -1.82* |
| Book leverage | 0.6898*** | 1.48* | -0.64* |
| Market-to-book | 0.0148*** | 1.83** | 1.16*** |
| Invested Capital | 0.2891* | | |
| Tenure | -0.0029** | | 0.28** |
| Stock prices | | | 0.19** |
| Year dummy | YES | YES | YES |
| R-square | 53.6% | 79.3% | 72.4% |

Overall, Table 4 provides strong empirical evidence showing that (1) a causal relationship exists between bank risk and vega. Increasing vega induces higher risk level in banks; on the other hand as bank risk increases, vega increases, which implies that riskier banks tend to adopt more option-based compensation; (2) increasing delta, in contrast, will reduce bank risk. It is consistent with the hypothesis that delta exposes managers to more risk, in which case managers could choose to avoid risk. This result confirms the finding by Guay (1999). R-square is 53.6% for the equation on bank risk, 79.3% on vega and 72.4% on delta. Compared to previous regression, the R-square increases significantly, which suggests that the fitness is improved sizably on the model with vega and delta.

## 6. CEO Incentive, Vega, Delta and Banks' Risky Investments

Convexity in compensation structure makes risk more valuable to managers, higher vega gives them incentives to implement excessive risky investments. On the other hand, as banks conducted extensive securities activities and non-conforming mortgage loans, they adopted more equity-based compensation, which will increase vega. If the relationship between vega and risky investment choice is persistent, it is likely that the causation runs in both directions. In other words, compensation incentives and banks' risky investments are likely to be jointly determined.

### 6.1 Vega, Delta and Non-conforming mortgage loans

In this section I assess the relationship between vega, delta, and banks' investments in non-conforming mortgage loans. I apply three simultaneous equations using 3SLS method in which vega, delta and investments in non-conforming mortgage loans are treated as endogenous variables and jointly determined.

While I focus on vega as the primary explanatory variable, here and in subsequent sections, all model specifications include both delta and control variables based on evidence elsewhere in the literature (Servaes, 1994; Bhagat and Welch, 1995; and Opler et al., 1999). Accordingly, I control for bank size, cash compensation, book leverage, market-to-book ratio, invested capital, tenure, stock price and bank risk in different equations. An important reason to include control variables is to represent forces that drive both vega and delta together with investments.

Table 5, Panel A reports the empirical results for non-conforming mortgage loans, vega and delta. Here and throughout, reported *t*-statistics are based on robust standard errors. The estimated coefficient on vega is positive and is significant at 1% level. It suggests that higher vega induces more investments in mortgage loan. The coefficient on delta is positive and slightly significant at 10%. Moreover, the coefficient on market-to-book ratio is positive and significant; it implies that a high M/B ratio induces more investments in non-conforming mortgage loans. Similarly, a higher level of invested capital is associated with higher non-conforming mortgage loans. The coefficient on bank size is positive and significant for non-conforming mortgage loans, which implies that bigger banks tend to invest more in non-conforming mortgage loans. The coefficient on book leverage is negative but insignificant. The reported R-square is 43.4% in the non-conforming mortgage loans equation, 76.1% in the equation on vega and 70.6% in the equation on delta.

**Table 5**
**CEO Compensation and Investments in Non-conforming mortgage loans and Non-government Securities**

| | Panel A: Mortgage loan, vega & delta | | | Panel B: Non-govern. Sec., vega & delta | | |
|---|---|---|---|---|---|---|
| Independent variables | Mortgage loan | Vega | Delta | Non-gov. security | Vega | Delta |
| Non-Conforming ML/Non-GS | | 16.75*** | 0.24 | | 12.38*** | 0.38 |
| Vega | 0.0372*** | | 1.12*** | 0.0652*** | | 1.22*** |
| Delta | 0.0087* | 1.82** | | -0.0112* | 1.25* | |
| Cash compensation | | 0.02*** | | | 0.05*** | |
| Size | 0.0589** | 1.41*** | -1.65* | 0.2391*** | 1.37*** | -1.51* |
| Book leverage | -0.6094 | 1.87 | -0.72* | 0.0202* | 1.96* | -1.01* |
| Market-to-book | 0.6038*** | 2.03** | 1.18*** | 0.1934*** | 2.32** | 1.18*** |
| Invested Capital | 0.7052*** | 0.29** | | 0.2069*** | 0.57** | |
| Tenure | | | 0.33** | | | 0.54** |
| Stock prices | | | 0.15** | | | 0.18** |
| Year dummy | YES | YES | YES | YES | YES | YES |
| R-square | 43.4% | 76.1% | 70.6% | 45.1% | 76.4% | 71.6% |

Since the results on determinants of vega and delta are similar across all the specifications, rather than discuss the results in each subsection separately, I will provide a consolidated discussion in this section. I draw independent variables from the prior literature (e.g., Bizjak et al., 1993; Guay, 1999; Core and Guay, 1999) for vega and delta. In the equation on vega, the coefficient on delta is positive and significant, which is consistent with prior literature. Moreover, vega is positively associated with invested capital. The coefficient on cash compensation, bank size and bank risk is positive and significant, which is consistent with prior literature, while the coefficient on book leverage is insignificant for vega (it is slightly significant in Panel B). For the equation of delta, delta depends positively on vega. The coefficients on vega, market-to-book ratio, tenure and stock prices are positive and significant, while delta is negatively related with bank size and book leverage ratio. These findings are consistent with Guay (1999, 2002) among others. Moreover, I find that bank risk has no explanatory power for delta.

**6.2 Vega, Delta and Non-government Security**

Empirical results in Table 5, Panel B show the joint determination of vega, delta, and banks' investments in non-government security. For non-government security, the estimated coefficient on vega is positive and significant at 1%. As expected, higher vega implements higher investments in non-government security while delta is negatively associated with investments in non-government securities. Moreover, the coefficients on bank size, book leverage, market-to-book ratio, and invested capital are significant with the expected sign. It implies that bigger banks invest more in non-government securities; invested capital is positively associated with investments in non-government securities; banks with higher market-to-book ratio tend to invest more in non-government securities. R-square is 45.1% for the equation of non-government securities. Empirical results for vega and delta are similar to those of Panel A.

Overall, Table 5 provides empirical evidence showing that (1) a causal relationship exists between banks' risky investments and vega. In particular, higher vega induces more risky investments in non-conforming mortgage loans and non-government securities; on the other hand, as banks expand investments in non-conforming mortgage loans and non-government securities, they tend to adopt more option-based compensation, thus increasing vega; (2) delta is positively associated with investments in non-conforming mortgage loans and negatively associated with non-government securities.

**6.3 Robustness Check**

I check for robustness in several ways. All specifications include year dummy variables. I use logarithmic values of vega and delta rather than the raw values. The results are robust to all these alternative specifications with one exception, namely, the coefficient on delta is insignificant in the 3SLS regression of non-government securities when year dummies are included, but vega continues to have a significant positive effect. I include additional explanatory variables, such as total loan investments, dividend pay, and an indicator variable that takes the value of one if the bank does not pay dividends in the current year. In all cases, the inferences remain the same.

**7. CEO Incentive, Vega, Delta and Bank Performance**

**7.1 Vega, Delta and ROA**

In order to assess the relationship between CEO compensation structure and banks' performance, I run three simultaneous equations using 3SLS method in which vega, delta and ROA are treated as endogenous variables and jointly determined. I use ROA as proxy for bank performance and profitability. Table 6, Panel A reports the results for vega, delta and ROA. I expected that on average, as banks adopt incentive compensation, they will experience lower profitability.

As expected, the estimated coefficient on vega is negative and significant at 5% level. It implies that higher vega, or more option-based compensation, induces lower ROA. In contrast, the coefficient on delta is positive and significant, which implies that a bank's ROA is positively associated with delta. Moreover, bigger banks and the banks with higher market-to-book ratio generate higher ROA, where the coefficients on bank size and market-to-book ratio are positive and significant. ROA is also positively associated with invested capital. Similarly, the coefficient on book leverage is also insignificant. R-square is 21.9%. The empirical results for vega and delta are consistent with previous findings. I don't find a causal relationship between vega/delta and bank ROA. From the empirical results, both vega and delta have significant effects on ROA. However, no evidence indicates that ROA has significant explanatory power for vega or delta.

**Table 6**
**Simultaneous Equations (3SLS): CEO Compensation, Bank ROA and Loan Write-offs**

| | Panel A: ROA, vega & delta | | | Panel B: Write-offs, vega & delta | | |
|---|---|---|---|---|---|---|
| Independent variables | ROA | Vega | Delta | Write-offs | Vega | Delta |
| ROA/Write-offs | | 3.25 | 0.33 | | 2.21 | 0.61 |
| Vega | -0.0048** | | 1.53*** | 0.0008*** | | 1.54*** |
| Delta | 0.0035* | 1.21* | | -0.0002* | 1.58* | |
| Cash compensation | | 0.01*** | | | 0.05*** | |
| Size | 0.0138** | 2.38*** | -1.43* | 0.0002 | 1.58*** | -2.11* |
| Book leverage | -0.0239 | 1.59* | 0.85** | 0.0035 | 1.26* | -0.52* |
| Market-to-book | 0.0365*** | 1.35** | 1.62*** | -0.0012** | 1.24** | 1.25*** |
| Invested Capital | 0.0232* | 0.56** | | 0.0076 | 0.55** | |
| Tenure | | | 0.47** | | | 0.42** |
| Stock prices | | | 0.35** | | | 0.13** |
| Year dummy | YES | YES | YES | YES | YES | YES |
| R-square | 21.9% | 75.3% | 73.1% | 32.6% | 77.3% | 72.9% |

### 7.2 Vega, Delta and Bank Loan Write-offs

As banks adopt incentive compensation and implement exorbitantly risky investments, the predicted loan loss write-offs are expected to be high. I expected that, on average, higher vega implies higher level of loan write-offs. Again, if loan write-offs and delta are substitute alignment devices, higher levels of write-offs should associate with lower delta.

The regression results in Table 6, Panel B are consistent with predictions. The estimated coefficient on vega is positive and is significant at 1% level. It suggests that higher vega induces higher loan write-offs. In contrast, the coefficient on delta is negative and significant, which implies that higher delta is associated with lower loan write-offs. Moreover, banks with high market-to-book ratios tend to have lower write-offs, while the coefficients on bank size, invested capital and book leverage ratio are insignificant. R-square is 32.6%. Moreover, I don't find any causal relationship between vega/delta and loan loss write-offs. For example, both vega and delta have significant effects on loan write-offs. However, loan write-offs have no explanatory power for vega or delta.

Overall, the results in Table 6 show that (1) bank's ROA is negatively associated with vega and positively associated with delta; (2) higher amounts of write-off are related to higher vega and lower delta; (3) as banks increase investments in high-risk investments, such as non-conforming mortgage loans and non-government securities, the level of write-offs goes up; (4) although both vega and delta have significant effects on bank's ROA and write-offs, there is no evidence showing that bank's ROA and write-offs have any explanatory power on vega or delta.

### 7.3 Robustness Check

I try several other approaches to test for robustness of the results. I include CEO age as an additional explanatory variable, and I use logarithmic values of vega and delta rather than the raw values. The results on vega are generally similar.

## 8. Conclusions

In this study, I investigate the relationship between compensation structure and CEOs' incentives to implement risky investments in mortgage loan and non-government securities and how the CEO incentives could affect bank performance.

By applying various model specifications and econometric remedies, I find a strong causal relationship between vega/delta and bank risk. In particular, increasing vega induces higher risk level in banks; on the other hand, as bank risk increases, vega increases, which implies that riskier banks tend to adopt more option-based compensation; increasing delta, in contrast, will reduce bank risk. As banks take excessively risky investments in non-conforming mortgage loans and non-government securities, both bank risk and vega increase. In addition, the empirical results indicate a strong causal relationship between banks' risky investments and vega. In particular, higher vega induces more risky investments; as banks take excessive risky investments, they adopt more option-based compensation and consequently increase vega; delta is positively associated with investments in non-conforming mortgage loans and negatively associated with non-government securities. Moreover, bank's ROA is negatively related to vega and positively related to delta. Higher amounts of write-off are associated with higher vega and lower delta; as banks involve in highly risky investments, the level of write-offs goes up.

The findings of this study provide important implications for bank regulation. It implies that regulatory oversight of the compensation structure employed in the banking industry is important. The results of this study suggest that regulators need to consider a new paradigm that provides appropriate incentives for risk-taking within the compensation structure. Especially in the banking industry, managerial incentives to shift risk to the deposit insurance agency (FDIC) depend on the sensitivity of compensation to managerial risk-taking. Subsequently, the parameter of CEO compensation, such as vega and delta, can be used as inputs for banking regulatory schemes to curb the risk-shifting incentives of banking managers. The empirical findings of this study also provide critical insights into the current financial/mortgage crisis as well as bank panic.

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