Essays on Executive Compensation

Managerial Incentives and Disincentives

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Essays on Executive Compensation

Managerial Incentives and Disincentives

Essays over Salarissen Topbestuurders

Thesis

to obtain the degree of Doctor from the
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by command of the
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謹以此論文獻給我的家人，特別是最敬愛的祖父母。

And to all of you (in this acknowledgement or not), I do remember.

Contents

[1] This chapter is based on Dittmann and Yu (2011).

[2]This chapter is based upon Dittmann and Yu (2008).

Chapter 1

Introduction

Executive compensation has been a central point of debates for the past 20 years, both in the academic circle and in Wall Street Journal. Have shareholders paid too much to the CEOs, or are the pay packages necessary for recruiting and keeping managerial talents? Are the structures of the pay packages reasonable, or are the compensation packages designed the way they are simply to facilitate more manipulation? The end to the debate between perspectives of "rent-seeking[1]" (i.e., executives are always stealing shareholders' money away) ands "efficient contracting[2]" (i.e., executive pays are set with economic rationales by their shareholders) does not appear to be coming any time soon. The thesis contributes to this debate by first identifying firms whose CEOs are more optimisitic about their firms' prospects are more likely to experience crashes in stock prices. Subsquently in Chapter 3 and 4, the thesis aims to offer economic explanations for current compensation structures.

Chapter 2, "CEO Optimism and Stock Crashes," examines what happens when CEOs hold on to more company equities than they need to. Standard agency theory assumes a conflict of interests in the risk dimension as illustrated in the subsequent two chapters. Specifically,

[1]Bebchuk and Fried's (2007) thought provoking book is often cited for this view.

[2]Edmans and Gabaix (2009) offer a comprehensive review of potential economic explanations on different aspects of CEO pays.

executives are more risk-averse to their own firms' equities because their wealth is tied significantly to the firm and they cannot hedge against the risk effectively like general shareholders. In that way, executives should unwind their positions in the company whenever they can. Why do executives keep on holding the stock and options when they do not need to? The chapter examines several potential reasons. In the end I conclude that these CEOs who choose to hold more equities are blindly optimistic about their firms' prospects. A measure of executive optimism is constructed based on the relative mix of restricted and unrestricted incentives. The measure shows that CEOs with higher optimistic ratios (i.e. a ratio of unrestricted incentive pay to total incentive pay) are more likely to spend more on R&D projects, but are less effective in innovation outputs, and their firms are more likely to experience stock price crashes. The results are robust to numerous empirical specifications and outperform existing predictors of stock price crashes.

In Chapter 3, "How Important are Risk Taking Incentive in Executive Compensation?" we consider a model in which shareholders provide a risk-averse CEO with risk-taking incentives in addition to effort incentives. This proposed model recognizes the fact that managers can be equally important in their effort decisions and their project choices, which essentially results in a dual-agency problem. A risk-averse CEO will typically require extra incentives to motivate him to assume high-risk-high-return projects preferred by risk-neutral shareholders. We calibrate the model to data on 727 CEOs and show that it can explain observed contracts much better than the standard model without risk-taking incentives. The optimal contract predicted by our model protects the CEO from losses for bad outcomes, is convex for medium outcomes, and concave for good outcomes. Moreover, a new measure of risk-taking (dis)incentives is proposed to measure the required probability an additional risky project must exceed in order to be adopted by the CEO. The median risk avoidance in our sample is 1.25 for a risk-aversion parameter of 2. Hence, the median CEO will adopt a project that increases firm risk by one percentage point if and only if it increases firm value by at least 1.25%.

Chapter 4, "Should Options be Issued in the Money? Evidence from Model Calibrations with Risk-Taking Incentives," investigates the optimal structure of CEO compensation contracts by specifically employing commonly used compensation mechanisms: fixed salary, stock, and options. We take the same model in Chapter 3 to individual CEO data and it turns out that the proposed model can explain observed compensation practice surprisingly well. In particular, it justifies large option holdings and high base salaries. We also show that the optimal compensation structure looks strikingly different from observed contracts. Specifically the optimal compensation package should replace at-the-money options and stocks by in-the-money options. If the tax discrimination against in-the-money options are taken into account, the model is then consistent with the almost uniform use of at-the-money stock options.

Chapter 2

CEO Optimism and Stock Price Crashes

Using Execucomp data from 1992 to 2009, we derive an optimistic ratio measure based on executives' relative portfolio compositions in unrestricted and restricted parts and show that CEO optimistic ratios are positively and signficantly related to firm-specific price crash risk. Optimistic CEOs tend to spend more on R&D projects while producing less innovation output in return. The paper provides new evidence that CEO personal portfolio decisions are related to firm performance. The results are robust to various empirical specifications and various previously identified factors of stock price crash risk.

2.1 Introduction

Standard agency theory suggests equity pay as one of the mechanisms to align the interests of executives and shareholders. However, executives as risk averse agents have incentives to unwind their positions to diversify as they value their equity portfolios less than plain cash. In particular, Carpenter, Stanton, and Wallace (2011) estimate that CEOs value their options with a 20% - 60% discount depending on parameter values. Why do they not unwind from their firm-related portfolio when they can legally do so? In this article, we attempt to analyze why

CEOs hold their equities longer than they should and construct a measure of executive optimism and show that CEOs with higher optimistic ratios, a ratio of unrestricted incentive pay to total incentive pay, are more likely to experience price crashes on their firms. Optimistic CEOs are also slightly more likely to spend more on R&D projects, but are less effective in innovation outputs. However, the relationship between CEO optimism and crashes is not due to the less efficient spending on R&D projects. The results are robust to various controls and empirical specifications.

To motivate the measure of managerial optimism, we attempt to distinguish from several potential reasons why CEOs keep on holding their equities. The first evident reason is that CEOs possess private information on the firms, and their portfolio decisions reflect that their firms are undervalued. When the company enters a promising project whose value is most likely correctly estimated by the private information of executives, the benefits of potential returns can outweigh the cost of bearing more firm-specific risk[1]. In this case, CEO voluntary ownership will denote better subsequent performance and less incidents of crashes. On the contrary, the CEOs may be simply too optimistic on the outlook of the firm; in this case, where CEO voluntary ownership will indicate an over-estimation of subjective firm value accompanied by an under-estimation of incidents of crashes. Yet another possible explanation that is popular in market gossips but rather not popular in academic circles is that CEOs are in fact risk loving in that they favor firm-specific risk to diversification. In this case, CEO voluntary ownership will be related to both incidents of crashes and booms as the distribution of return will be flatter. We evaluate all the hypotheses above and argue that CEOs who hold more equities than they need are optimistic. The reason is that CEOs who hold their equities longer than they should

[1] Among other insider trading papers, Ali, Wei, and Zhou (2011) showed that when firms face fire sales by mutual funds, their insiders can make a profit in their trading patterns. In addition, Henderson (2011) provides evidence that CEOs do make a profit in insider trading activities, and the board takes it into account when setting pays.

indicate more risk in price crashes and less efficiency in R&D spendings.

The paper is directly related to the literature on stock crashes in that we offer arguably a more direct and robust explanation to firm-specific stock price crashes: CEO optimism. Previous literature has shown that firm-specific crash risk is related to heterogeneous investor beliefs (Chen, Hong, and Stein 2001), transparency of financial reports (Hutton, Marcus, and Tehranian 2009), and incentive alignment of CFOs (Kim, Li, and Zhang 2011). In particular, Kim, Li, and Zhang (2011) argue that the sensitivities of CFOs' option portfolio value to stock prices are positively related to crash risks. The reason is that CFOs who have more incentives are more likely to manipulate stock prices; hence bad news are likely clustered together to induce price crashes. We argue that earning management is merely one of the many channels that top executives can do to manipulate stock prices to induce stock crashes. While incentives for CFOs matter more in earnings management behaviors (Jiang, Petroni, and Wang 2010, Chava and Purnanandam 2010), incentives for CEOs, as the main decision maker of the firm, arguably matter more in an array of firm policies, such as investment choices (Coles, Daniel, Naveen 2006), leverage ratio, and cash balances (Chava and Purnanandam 2010). These firm policies can also be related to uncertainty and transparency of the firm and result in firm-specific crashes. Our study incorporates both the incentive alignment measures proposed by the previous literature and the optmistic ratios for both CEOs and CFOs and show that CEO personal portfolio decisions play a more significant and lasting role in price crashes.

Several studies have examined the static mixture of unrestricted and restricted equity holdings of executives. Core and Guay (2002) arguably start the discussion by classifying the existing executive option holdings into exercisable ones and unexercisable ones, and use the information to estimate relative maturities of different options in the portfolio. Our measure of optimism takes the analogy from the over-confidence index proposed by Malmendier and

Tate (2005a, 2005b, 2008), in which the optimism ratio also measures the extent to which the executives fail to unwind their positions in the firms when they should. Closely related to our paper, Campbell et al. (2011) and Otto (2011) propose another measure of CEO optimism by examining the dynamic CEO option exercising and stock purchasing behaviors. The measure is most similar to the optimism ratio that we propose, but the ratio requires option exercising/stock purchasing data. Suppose an executive stays put by tying his entire wealth to the firm, the executive cannot be coded according to their algorithm. Also related to our measure are discretion ratio (Tumarkin (2010)) and duration measure (Gopalan, Milbourn, Sung, Thakor (2011)). These ratios share the same virtues with optimism ratio by calculating the percentage of unrestricted equity holdings in the entire incentive pay, but none of the papers relates the ratio of unrestricted and restricted equity mix to stock price crashes.

The CEO overconfidence/optimism literature after Malmendier and Tate (2005a, 2005b) has evolved into two strands. One strand argues that CEO overconfidence results in excessive risk-taking behaviors that are detrimental to the firms. Malmendier and Tate (2005a, 2005b, 2008) find that overconfident CEOs are involved in more value-decreasing investments. Ben-David, Graham, and Harvey (2011) show that managerial miscalibration, which is a standard measure of overconfidence, is related to overvaluing cash flows and usage of longer term of debts. Hribar and Yang (2011) also show that overconfident CEOs tend to overstate firm earnings forecasts. Another strand of literature on overconfidence argues that whereas excessive CEO overconfidence may be detrimental to the firms, a moderate value of CEO optimism may result in first-best investment decisions (Gervais, Heaton, and Odean 2011, Hirshleifer, Low, and Teoh 2010, Campbell et al. 2011). Our paper contributes to the literature by providing evidence that CEO optimsism can also result in adverse events such as stock price crashes.

Generally, the paper is also related to the general strand of literature linking both

CEO personal traits and incentives to corporate performance and policy making. Traditional executive compensation research focuses on the so-called pay-performance relationship, which stems from the classic paper by Jensen and Murphy (1990) that essentially askes the following question: how much incentives should be provided to CEOs to obtain the desired results asked by shareholders? In recent research, there have been an increasing number of studies that document the relationship between CEO personal traits and corporate policies in general. The paper contributes to the general literature in that it combines both aspects of recent research: incentives and personal traits–defined as managerial portfolio decisions surrounding incentives[2]. We show that, albeit in a limited setting of predicting price crashes, CEOs' personal traits deserve more attention.

The remainder of this paper is structured as follows. Section 2 presents the construction of the data. Section 3 presents the empirical analysis. Section 4 follows with some additional robustness checks. Finally, Section 5 concludes.

2.2 Data Construction

We consider all ExecuComp firms with both CEO and CFO compensation data available from fiscal year 1992 to 2009. We then match our data with Compustat and CRSP return data. We exclude data with missing returns in CRSP and missing financials in Compustat. The final sample consists of 2,874 unique firms, 18,482 firm-year observations with both CEO and CFO compensation data available.

[2]Bertrand and Schoar (2003) started the discussion by imposing a managerial fixed effect in firm performance.

2.2.1 Optimism Ratio

We construct the portfolio holdings of all the executives in ExecuComp. Following Core and Guay (2002), we estimate the option portfolio and separate the option holdings into three categories: exercisable, unexercisable, and newly issued. As granted options typically come with 3-5 years of vesting periods[3], we can safely assume that newly granted options are unexercisable. We then aggregate the option portfolios by executives and the coresponding option metrics (i.e., Black-Scholes values, deltas, and vegas). To construct our optimism ratio which measures the extent of executive voluntary incentives tied to the company, we take the ratio of exercisable option delta to total option delta in his portfolio. Specifically, the optimism ratio is calculated as follows:

$$Optimism\ Ratio = \frac{Exercisable\ Option\ Incentives}{Total\ Option\ Incentives} = \frac{delta_{exercisable\ options}}{delta_{total\ options}} \tag{2.2.1}$$

where delta is the dollar increase in the manager's wealth per percentage point increase in stock prices. The reason why we use deltas as the benchmark is that deltas provide a convenient way to aggregate different option data[4]. The optimism ratio measures the extent to which executives voluntarily choose to maintain exposures in the firms that they manage. We find that most of the CEOs have an optimism ratio higher than 0 because most CEOs keep part of their options unexercised. As shown in Table 1, the average (median) optimism ratio is 0.49 (0.54) for CEOs, and 0.42 (0.43) for CFOs. The ratio exhibits a uniform distribution. The distributions are largely invariant across all subsamples even when the sample counts for innovation variables are greatly reduced as the data are only available up to year 2006.[5]

[3]According to the calculation of Gopalan et al. (2011), 80% of stock grants come with 3–5 years of vesting period, whereas 85% of option grants come with 3–5 years of vesting periods.

[4]We also construct a more naive measure of optimism by dividing the number of exercisable options by total number of options. The results are basically identical to the results with our main measure of executive optimism.

[5]Adding to the two-year time lag convention, only compensation data ranging from fiscal year 1992 to year 2002 are available for the subsample analysis.

To further examine the composition of the voluntary holdings, we construct alternative forms of measures of CEO optimism using stock holding information and aggregate the deltas of exercisable options and unrestricted stock to construct a portfolio-wide optimism ratio:

$$Optimism\ Ratio\ (Stock) = \frac{Exercisable\ Stock\ Incentives}{Total\ Stock\ Incentives} = \frac{delta_{unrestricted\ stock}}{delta_{total\ stock}} \tag{2.2.2}$$

$$\begin{aligned} Optimism\ Ratio \quad (Portfolio) &= \frac{Exercisable\ Incentives}{Total\ Incentives} && (2.2.3) \\ &= \frac{delta_{exercisable\ options} + delta_{unrestricted\ stock}}{delta_{total\ options} + delta_{total\ stock}} && (2.2.4) \end{aligned}$$

The average (median) stock optimism ratio is 0.84 (1.00) for CEOs and 0.76 (1.00) for CFOs, suggesting that CEOs and CFOs do not unwind their portfolios by selling stocks in general. That also contributes to the fact that the portfolio optimism ratio for the average (median) CEO is 0.66 (0.72). Figure 1 shows the distribution of CEO and CFO optimism ratios, respectively. Interestingly, CEOs seem to hold on to the stock more compared to options. More than half of the executives have their entire stock portfolio unrestricted, whereas only approximately 10% of the CEOs choose to do so with options, suggesting a significant difference in treatments of stock and options.

We use the SOX (Sarbanes-Oxley Act) reform to further exploit why CEOs choose to exercise options rather than sell stock. The argument is that while on the tax front, stock sales and option exercises are treated the same[6]. Options are only reported in footnotes before the 2002, are relatively less transparent than stocks. In Figure 2, we separate the samples into

[6] Both are subject to capital gain taxes.

pre-2002 sample and after-2002 sample, the striking difference is that the optimism ratio is much higher after year 2002. In addition, prior to 2002, no CEO kept their exercisable options intact, whereas after 2002, 5% of the CEOs maintain their entire exercisable options. The argument is that SOX reforms make it relatively harder for CEOs to unwind their portfolios by increasing the real and implicit cost of exercising.

Aside from the main variable of interest, optimism ratio, we also construct a number of compensation related variables. In light of Kim, Li, and Zhang (2011) who document the possible effect on stock crashes through CFO incentives, we follow their approach and include their incentive alignment measures in our analysis.

$$Stock\ (Option)\ Alignment = \frac{Delta_{stock\ (option)}}{Delta_{stock\ (option)} + Fixed\ Pay}^{7} \tag{2.2.5}$$

The incentive alignment measures, which measure the relative proportion of stock or option versus total pay, are comparable with the evidence of Kim, Li, and Zhang (2011). The average (median) ratio of stock incentive pay versus total pay is around 13% (4%) for CEOs, and 3% (1%) for CFOs. The average (median) ratio of option incentive pay versus total pay is around 12% (8%) for CEOs and 8% (5%) for CFOs.[8]

To further explore the possibility of risk-taking incentives and crashes, we also include the risk avoidance measure for executives, as suggested by Dittmann and Yu (2011)[9]. For the risk avoidance measure, we need an estimation for non-firm wealth of the CEOs and CFOs. Due to the limited amount of information available in ExecuComp to construct estimate non-firm executive wealth, we follow a two-step approach to compute the estimations. First, we

[7] The variable *Stock (Option) Alignment* is essentially the variable INCENTIVE_STK (INCENTIVE_OPT) in Kim, Li, Zhang (2011).

[8] The numbers are comparable with Kim, Li, and Zhang (2011). The reason why our measures are slightly higher (around 0.5% on average) could be that we only consider stocks with full trading records throughout the fiscal year. This is evident by slightly less crash percentage in our sample. (12% compared to 17%)

[9] This is Chapter 3 in the thesis.

calculate non-firm wealth by summing all the historical cash inflows and outflows in salary, stock sales/purchases/grants, option grants, and exercises in ExecuComp[10]. The estimates are more likely biased if the CEO or CFO does not stay in ExecuComp long enough. Thus, we perform a kitchen sink estimation (untabulated), using the sample with more than a four-year history in ExecuComp to construct the estimates of predictive regression of non-firm wealth and then use the predictive regression to estimate non-firm wealth of CEOs. The average utility adjusted risk-avoidance for CEOs (CFOs) is 2.33 (2.11) indicating that the average CEO (CFO) will forgo positive NPV projects if these projects generate less than 2.33% (2.11%) of the return per percentage of volatility.

We also consider the recent literature on pay gaps of CEO versus management team[11]. The average short-term pay gap is 0.8 million, and the long-term gap is about 2.1 million. The vegas and deltas of CEOs and CFOs are also reported in Table 1[12].

2.2.2 Crash Risk, R&D Expenditure, and Innovation Intensity

Following the stock crash literature, we define stock crashes as when the firm experiences firm-specific weekly returns 3.2 standard deviation below the mean firm-specific weekly returns over the fisical year[13]. The variable Crash is a dummy variable defined as one when the firm experi-

[10]The approach is essentially identical to the method used in Chapter 3 and Chapter 4. The approach is first proposed in Dittmann and Maug (2007) and was used in Dittmann, Maug, and Spalt (2011), Dittmann, Maug, and Zhang (2011), Edmans (2011). The data is available for download at Ingolf Dittmann's website.

[11]Kale, Reis, and Venkateswaran (2009) interpreted the pay gap as the tournament incentive measure. They show that subsequent performance is better for firms with higher tournament incentives. On the other hand, Bebchuk, Cremers, and Peyer (2011) employ a similar measure "CEO Pay Slice" – the relative size of compensation of CEOs compared with other executive. They show that CPS are negatively related to Tobin's Q.

[12]Both average numbers (deltas, vegas) are slightly larger in our sample than those in Chava and Purnanandam (2011) since our sample consists of some extreme cases in which CEOs hold a lot of stock and options of the firm even after we throw away owner-CEOs like Warren Buffet of Berkshire Hathaway. Our median, however, is comparable with Chava and Purnanandam (2011).

[13]We follow the convention (Kim, Li, Zhang (2011), among others) of defining crashes as 3.2 standard deviations from the mean to match a 0.1% of tail probability in a normal distribution. Firm-specific returns are defined following their approach. We take the residuals from regressing weekly raw returns on CRSP value-weighted returns (with two leads and lag terms) to remove market components in returns. The measure of firm-specific return can thus be viewed as relative performance against the market. We also conduct a robustness check in substuting market returns by S&P index returns and CRSP equally weighted returns. The results are virtually identical.

ences one or more crashes in a fiscal year. In the same manner, we also construct the variable Boom as a dummy variable defined as one when a firm experiences firm-specific weekly returns 3.2 standard deviations. On average, 12.2% of the firms experience crashes in any given year, whereas slightly more firms (14.7%) experience booms in any given year, which is reasonable given that there are more "up" years than "down" years in the sample.

We also calculate three other measures shown to be related to incidents of crashes. NSCKEW measures the negative conditional return skewness first proposed by Chen, Hong, and Stein (2001). DUVOL is the down-to-up volatility measure defined as the ratio of down week volaility to up week volatility, where down and up weeks are defined when weekly firm-specific returns are lower or higher than annual means. Both measures represent the asymmetric nature of return properties. DTURNOVER is the de-trended turnover rates that proxy for the differences in investor opinions. All distributional variables are comparable with those in the previous literature.

We use the NBER patent data set that contains detailed information on all U.S. patent grants by U.S. Patent and Trademark Office (USPTO) from year 1976 to 2006. We lag the patent data for two years to allow for time to produce and then match with the ExecuComp data and crash risk data to evaluate the innovative effectiveness of firms. We use the following four indicators for innovative intensity of firms: number of patents, adjusted number of patent, number of citation, and adjusted number of citation. Owing to the data availability, the sample count is greatly reduced to 5,761 firm-year combinations. R&D intensity is calculated as the ratio of R&D expenditure to fixed capital inputs (proxied by PPENT). Other control variables are within the norms in the literature.

2.3 Empirical Analysis

2.3.1 Executive Optimism and Stock Crashes

To examine how executive optimism relates to future stock crash events, we begin our analysis by running the following logistic regression:

$$logit(Crash_{i,t+1}) = \beta_0 + \beta_1 \cdot Optimism\ Ratio(CEO)_{i,t} + \beta_1 \cdot Optimism\ Ratio(CFO)_{i,t} + Controls_{i,t} + \varepsilon_{i,t} \tag{2.3.1}$$

Following the literature on stock crashes, we employ NCSKEW, DUVOL, DTURNOVER as control variables. NCSKEW measures the persistence of skewness of firm-specific returns. DUVOL is the down-to-up volatility, which captures the relative information uncertainty in down markets versus up markets. DTURNOVER, the de-trended turnover rate, proxies for investor heterogeneity in which stocks with higher investor heterogeneity more likely suffer from crashes. We cluster our standard errors in both firm and year dimensions following Thompson (2011). The results are provided in Table 3. The positive coefficient on CEO optimism ratio indicates that crashes are more likely when CEOs are more optimistic about the firms prospects, as suggested by their portfolio holdings, whereas the optimism ratios of CFOs do not have such predictive power. The effect is highly significant across a number of different specifications. As expected in the literature, higher down-to-up volatility (DUVOL), lower firm-specific returns are associated with the higher likelihood of stock crashes[14]. However, NCSKEW and DTURNOVER turn out to be insignificant or even negatively related with stock crashes. As the effects of optimism persist in all specifications we have examined even after adding these NCSKEW and DTURNOVER variables, we argue that optimism ratios better explain the likelihood of stock crashes than other variables previously documented as determinants of stock crashes. In untabulated results, we

[14]The result is different from that in Kim, Li, and Zhang (2011).

find that the marginal effects of the average firm on optimism ratio is 0.036, which is about 6 times as much as all the other explanatory variables in the regression. The marginal effects may be small, but the effects are much more significant than other previously identified variables.

We have shown that optimistic CEOs are associated with future stock crashes, suggesting that CEOs do not make these portfolio decisions based on superior information. However, CEOs could be argued as risk-loving, as opposed the common assumption in the literature. CEOs simply prefer a risky portfolio to a diversified one. If that is the case, the reason why optimistic CEOs suffer from more crashes is that the return distribution is simply flatter than normal for them. Thus, there are more crashes, but there will be also more booms, which we define as mirrored events to crashes – 3.2 standard deviation *above* the annual mean. To this end, we run the same logistic regression but replace the crash dummies with booms. The results are shown in Table 4.

$$logit(Boom_{i,t+1}) = \beta_0 + \beta_1 \cdot Optimism\ Ratio(CEO)_{i,t} + \beta_1 \cdot Optimism\ Ratio(CFO)_{i,t} + Controls_{i,t} + \varepsilon_{i,t} \tag{2.3.2}$$

Across all specifications, the optimism ratios for both CEOs and CFOs turn out to be insignificant, which suggests that CEOs' holdings have no predictive power on future stock booms. This further confirms the over-confident story and reject the risk-loving story. In untabulated results, we also regress the same sets of variables on Tobin's Q. The coefficient on optimism ratio is marginally signficant and negative. The evidence also rejects the risk-loving and superior information story.

Kim, Li, and Zhang (2011) argue that sensitivities of CFOs' option portfolio value to stock prices are positively related to crash risks. To incorporate the arguments, we construct the incentive alignment measures following Kim, Li, and Zhang (2011) and run the logisitic regression again using these incentive alignment measures as additional controls. The incentive alignment ratios[15] measures the extent of the interest alignment in equity pay to total pay as defined in (2.2.5). For completeness, we also include other compensation variables that have been shown to be related to executive risk-taking behaviors.

Table 5 reports the results of the logistic regression incorporating the incentive alignment variables among other compensation variables. Our measures of CEO optimism remain significantly positive across all model specifications, whereas the incentive alignment measures are only significant in one out of the four settings. When CEOs are more optimistic about the prospects of the firm and opt to keep their wealth inside of the firm instead of benefiting from the potential inside information of the firm, their firms are more likely to crash, and thus hurting their portfolio values. The results also reject the hypothesis of incentive alignment story in that firms with more incentive alignments in CFOs are not typically likely to crash. We also construct estimates of the CEO risk avoidance following the method proposed in Chapter 3. The coefficient of risk avoidance index is insignificant which echoes our arguments in Chapter 3 that CEO risk-taking incentives, as a total package, are likely optimally determined as shareholders do consider risk-taking incentives when designing equity compensation packages.

In Table 6 we turn our attention to alternative specifications of optimism ratios. In the summary statistics in Table 1 along with Figure 1 and 2, we show that CEOs are more likely to keep their unrestrictive equity holdings in the form of unrestrictive stock rather than exercisable options. Keeping unrestricted stock in hand appears to be a common practice for CEOs as more than half of the CEOs have the entire stock holding unrestricted. The results in first two columns in Table 6 show that the portfolio decisions in stock sales/purchases have no significant predictive power on stock crashes. When CEOs do not exercise their options, the stocks are more

[15] The stock/option alignment variables are essentially INCENTIVE_STK_CEO, INCENTIVE_OPT_CEO, INCENTIVE_STK_CFO, and INCENTIVE_OPT_CFO as presented in Kim, Li, and Zhang(2011). In unreported tables, we show that our measure of optimism is not significantly correlated with the incentive measures.

likely to crash, whereas the effects are less significant when CEOs do not sell their unrestricted stock portfolio. One of the possible explanation is signaling. When top insiders such as CEOs sell stocks, the market views this as adverse events; thus the CEO portfolio value will drop. As CEOs cannot unwind their entire portfolio holdings in one shot, which is viewed as an even more adverse event, the costs of unwinding through stock sales outweigh the benefits. At the same time, options are less transparent (Bebchuk, Fried 2003) and only appear in footnotes before SOX reforms in year 2002. In addition, the default for most executives is immediately exercising the options right after the vesting period (when options are in the money). The result as to why CEOs choose to convey their view of optimism through option exercising but not through stock selling is not surprising.

To substantiate the view on the relative cost of exercising between stock and options, we separate our samples to before 2002 and after 2002. If our claim is true, the relationship between optimism and crashes will be stronger when exercisng costs are relatively low before 2002. The second half of the Table 6 shows that it is the case. Model (3) and Model (5) consider samples from fiscal years 1993 to 2001. Model (4) and (6) are run with data from fiscal years 2003 to 2009. The results confirm that after the SOX reform, as the unwinding costs become higher, CEOs do not reflect their views via their relevant portfolio decisions. However, we acknowledge that the disappearance of the relationship between optimism and crashes after 2002 can also be due to the increased transparency in financial reports (Arping and Sautner 2010) and thus less bad news will accumulate. In untabulated results, there have been slightly less incidents of stock crashes after year 2002 (11% compared with around 13% before 2002).

2.3.2 CEO Optimism and Innovation Effectiveness

To extend our analysis, we attempt to explain why CEO optimism is positively related to the probability of stock crashes. CEOs seem to fail to make good use of their insider knowledge of their respective firms and make clever personal investment decisions to stay financially tied to the firms when it is possible to unwind. One of the possible explanations for this is that CEOs choose to hold more equities on firms that are overly optimistic about the prospects of the firm going forward, and they tend to make unwise and risky managerial decisions. We find some supports for the claim in Table 7. We find that CEO optimism is positively (insignificantly) related to R&D intensity, which is a highly risky investment as argued in Coles, Daniels, and Naveen (2006), measured by the ratio of R&D expenditure to fixed assets (PPENT), and is negatively related to various innovation output variables (led by two years to allow for time to produce). Whereas the effects of optimism ratios on R&D and innovation are marginal, the effects on incentive alignment are strong and consistent with the literature: options increase executives' risk appetites while stocks have a mitigating effect[16]. To evaluate the efficiency of R&D expenses, we follow the literature in innovation and use patent and citation counts (adjusted following Acharya, Subramanian (2009)) as proxies for innovation output. Together with the evidence in the first two columns in Table 7, we show that optimistic CEOs are slightly likely to spend more on risky investment in R&D, but are less likely to succeed in doing so, which re-confirms an over-optimistic story. Consistent with the evidence found in Athanasakou, Goh, and Ferreira (2011) and Bereskin and Hsu (2010), firms with higher risk-taking incentives in options for CEOs are less efficient in innovation outputs.

The results from Table 7 suggest some possible omitted variables in our main analysis: R&D investment and innovation outputs. The less efficient investment decisions by companies

[16]Interested readers can refer to Chapter 3 for a discussion on the relative value of risk-taking incentives in stock and options.

are those that result in crashes. We run the same logistic regression in (2.3.1) by adding R&D and innovation efficiency variables in Table 8. The results show that R&D and innovation intensity do influence incidents of stock crashes, but the effects of optimism ratios remain strong and do not seem to be diluted by R&D and innovation efficiency.

2.4 Robustness Checks

2.4.1 Sample Selection

Although in Table 2 we show that the firms with both CEO and CFO compensation are not significantly different, our results are still possible to be caused by a sample selection problem in that we ignore some other factors that may separate firms with both CEO and CFO compensation data from regular ExecuComp firms. We re-examine the sample by excluding CFOs from the analysis in Table 9. Our results in Table 9 show otherwise. Although the level of significance drops slightly compared with the results in Table 3, the coefficients on CEO optimism remain positively significant across all specifications.

2.4.2 Incentive Alignment and Optimism Ratio Combined

In Table 3 and subsequently Table 5, we show that optimism ratio outperforms various incentive alignment measures that have been shown to be related to stock crashes. To further examine the relative importance of incentive alignment and optimism ratio, we separate the incentive alignment ratios defined in (2.2.5) into exercisable and unexercisable parts.

$$\mathit{Option\ Alignment\ (exercisable)} = \frac{\mathit{Delta}_{(\mathit{exercisable\ option})}}{\mathit{Delta}_{(\mathit{total\ option})} + \mathit{Fixed\ Pay}} \tag{2.4.1}$$

$$\mathit{Option\ Alignment\ (unexercisable)} = \frac{\mathit{Delta}_{(\mathit{unexercisable\ option})}}{\mathit{Delta}_{(\mathit{total\ option})} + \mathit{Fixed\ Pay}} \tag{2.4.2}$$

$$\mathit{Stock\ Alignment\ (unrestricted)} = \frac{\mathit{Delta}_{(\mathit{unrestricted\ stock})}}{\mathit{Delta}_{(\mathit{total\ stock})} + \mathit{Fixed\ Pay}} \tag{2.4.3}$$

$$\mathit{Stock\ Alignment\ (restricted)} = \frac{\mathit{Delta}_{(\mathit{restricted\ stock})}}{\mathit{Delta}_{(\mathit{total\ stock})} + \mathit{Fixed\ Pay}} \tag{2.4.4}$$

Note that the sum of option (stock) alignment measures of the exercisable and unexercisable (unrestricted and restricted) parts will become the option (stock) alignment measure in (2.2.5) as in Kim, Li, and Zhang (2011) where they document a significant relationship between CFO option alignment measure with stock crashes, but an insignificant relationship in CEO alignment. Table 10 presents the results obtained from adding these exercisable/unexercisable alignment measures in logistic regressions. As expected the coefficient on CEO option alignment incorporating exercisable parts only is still positive and significant, but interestingly, the coefficient for unexercisable CEO alignment measure is significantly negative, which explains why CEO option alignment is insignificant in the previous literature. In addition, the effect does not seem to hold for CFOs. Although we re-confirms that firms with higher CFO options alignment are more likely to crash, the effects fail to hold when the alignment measures are separated into exercisable and unexercisable parts. The results re-confirm optimism ratios as a superior measure for predicting crashes.

2.4.3 Optimal Optimism Ratio

In a closely related paper, Campbell et al. (2011) argue that moderate CEO optimism can lead to an optimal level of investment, as confirmed by its evidence on CEO exercising behavior and turnover data. To incorporate the argument, determining if a moderate optimism level can reduce the incidents of crashes is worthwhile. We separate our samples into three groups: top

10% of CEO optimism ratio (High), bottom 10% of CEO optimism ratio (Low), and the rest of the sample is defined as moderate (Mid). The High group consists of samples with CEO optimism ratios higher than 0.87, and the Low group consists of samples with CEO optimism ratios of 0, where the CEOs do not have any exercisable stock and option in hand. The summary statistics for each group is presented in Table 11. The probability of crashes are higher for High CEO optimism ratio group than the Mid group and Low group. The result is also confirmed by the return statistics. Panel B, however, confirms Campbell et al. (2011)'s theory in optimal optimism, in which CEOs with moderate optimism ratios are more efficient in innovation measured by number of patents and citations. However, these firms with moderate CEO optimism also spend more on their R&D budgets. The relationship between optimism ratio and crashes persists in the innovation sample as well.

2.4.4 Out-of-the-Money Options

One of the possible explanations why CEOs do not immediately exercise their options once vested is that the options are in fact, out of the money. Thus there is no benefit on exercising compared with keeping the options in hand. To cope with the concern, we re-do the analysis in Table 3 by removing the out-of-the-money options in our calculation. The results are shown in Table 12. The summary statistics are not much different from that in Table 3, and our results in Panel B re-confirm our results in Table 3 as well.

2.5 Conclusion

The paper constructs a measure of CEO optimism by comparing the relative proportion of unexercisable and exercisable incentives that CEOs choose to hold. Optimism ratios, constructed by exercisable option delta divided by the total option delta, are positively related to future stock crashes and the relationship is much stronger and robust than previously identified factors. The effects are much stronger when option exercising costs are relatively lower before 2002. Our article provides another dimension in CEO overconfidence literature that CEO personal portfolio decisions do matter in company performance.

Our study follows the recent literature that compares relative importance of CEO and CFO incentives on corporate policies. While CEOs and CFOs have different roles to play in their organizations, their incentives can affect firm policies and performance differently. In particular, Chava and Purnanandam (2010) provide evidence that the relative importance of CEO and CFO incentives varies in different aspects of firm policies – CEO incentives are more important in determining leverage ratios and cash balances, and CFOs incentives are more important in debt-maturity choices and earning smoothing behaviors. We incorporate both CEO and CFO incentive alignment measures and optimism ratios and empirically show that CEO optimism is of first-order importance in relation to stock price crashes.

One particular reason why CEOs voluntarily hold on to their options that we do not examine explicitly in this paper is signaling. By holding equities longer than they need to or even making voluntarily purchases, they signal better prospects of the firm. However, as Malmendier and Tate (2005a) demonstrate, these portfolio decisions are costly, and option expenses do not gain that much attention to obtain their signaling effects. As a result, we argue that it is unlikely that CEOs are simply signaling for future prospects.

We acknowledge that our analysis also suffers from the possibility of endogeneity as in other corporate finance research even after lagging our explanatory variables by one period. However, we argue that it is unlikely that the causality goes in the opposite direction, as executives sales in the event of crashes are prohibitted by law[17], Moreover, if CEOs can predict

[17] The "Up-Tick" rule dictates that insiders can only sell when stock price is going up. Even though short-term insider tradings are strictly forbidden by law and corporate charters, there are various ways that executives can reflect their private information: option exercises, voluntary stock purchases, and more recently, hedging. Option

crashes coming, as rational economic agents, they should try to unwind their portfolios rather than keep these options in their hands.

An obvious limitation of our construction of optimism ratio is that we cannot make any reference to CEOs who have no option in their portfolios. However, this inability is relatively rare in our sample of ExecuComp firms, in which only 743 CFO-years out of the 18,482 firm-year combinations, 1121 CEO-years out of 23,859 firm-year combinations suffer from the problem. In comparison with other optimism/overconfidence measures, ours are certainly at a disadvantage because we lose some part of the information available if CEOs choose to exercise more than once per year. However, exercising behavior is much more complicated than plain optimism or overconfidence alone[18], and our measure of executive optimism can be viewed as an aggregated snapshot view of exercising behavior.

Another limitation of our study is that we focus on ExecuComp (S&P 1500) firms similar to many studies which employed the dataset. Possibly the factors of predicting stock crashes are different for ExecuComp firms as they are typically larger and face less stock crash risk. Although whether optimistic CEOs would manage larger or smaller firms remains unclear, the fact that we employ a sample with relatively less incidents of crashes is, however, biasing against our results. In addition, even though we consider the pay gap measure in explaining stock crashes and there is no direct evidence suggesting other managers' roles in stock price crashes, whether other managers' incentives are related to price crashes is still an open question.

Our findings suggest that closer attention should be paid to managerial portfolio *decisions* in addition to managerial portofolio *compositions*. Traditionally in the literature, the attention is on how much incentives are contracted to the executives, without taking how much

exercising is arguably the most convenient way to unwind from firm-specific assests.

[18] In particular, Klein and Maug (2009) examine different rationales of CEO exercising behavior. Even though behavioral concerns accounts for a large part of the reason why CEOs exercise their options, overconfidence/optimism alone does not seem to be the only reason.

incentives executives can get rid of into account. Our findings have important implications in combining both aspects in executive compensation: the incentives CEOs receive and the incentives CEOs get rid of. We show that the incentives CEOs should get rid of, not the incentives CEOs receive, play a more significant role in stock price crashes. Our results call for further research on CEO personal portfolio decisions, personal traits and the combination of the two aspects in CEO pay.

2.6 Tables and Figures

Table 1
Descriptive Statistics – Compensation data

This table presents various descriptive compensation statistics for the sample firms from 1992 to 2009. Various forms of optimism ratios are defined as the ratio of exercisable incentives (deltas) to total incentives. We define *Optimism Ratio* as the ratio of delta of exercisable options to total option deltas. *Optimism Ratio (stock)* is defined as the ratio of number of unrestricted stock to the total number of stock grants, and *Optimism Ratio (portfolio)* is defined as the ratio of total exercisable delta (exercisable options plus unrestricted stocks) to total portfolio delta. *Stock (Option) Alignment* is defined as stock (option) delta divided by the sum of stock (option) delta and fixed pay following Kim, Li, and Zhang (2011). *Non-firm wealth* is defined as an estimate of executive non-firm wealth that can be calculated for a subset of the executives in ExecuComp. *Short-term compensation* is the total of salary and bonus. *Total Expected Wealth* is the certainty equivalent of the entire portfolio of the sample executives – including non-firm wealth, short-term compensation, stock and options assuming CRRA utility for executives with risk-aversion parameter 3. *Delta* measures a CEO's wealth increase per percentage point increase of stock prices. *Vega* measures by how much CEO wealth changes with a 0.01 change in volatility. *Risk avoidance* is defined as utility-adjusted vega divided by utility-adjusted delta scaled by firm market value. *ST_Gap* is the difference of short-term pay of CEOs and the average executive (CEO excluded) of the same firm as in Kale, Reis, and Venkateswaran (2009). *LT_Gap* is the long-term pay gap in Kale, Reis, and Venkateswaran (2009), which is defined as the difference of long-term pay of CEOs and the median executive (CEO excluded) of the same firm. Panel C presents the same summary statistics as in Panel A&B, only for samples with innovation and R&D expense data available.

Panel A: CEO Compensation Variables

	Mean	Std	P25	P50	P75
Optimism Ratio	0.49	0.30	0.25	0.54	0.75
Optimism Ratio (Stock)	0.84	0.29	0.78	1.00	1.00
Optimism Ratio (Portfolio)	0.66	0.26	0.51	0.72	0.87
Stock Alignment	0.12	0.20	0.01	0.04	0.13
Option Alignment	0.13	0.14	0.04	0.08	0.17
Non-firm Wealth ($000)	21.51	303.37	2.35	5.21	13.78
Short-term Compensation ($000)	1.51	2.37	0.63	1.01	1.66
Total Expected Wealth ($000)	56.92	404.87	5.32	13.49	35.61
Delta ($000)	828.60	6124.08	74.25	199.34	547.58
Vega ($000)	101.72	257.29	12.19	37.15	102.45
Risk Avoidance (Utility)	2.33	2.12	0.98	1.98	3.18
Risk Avoidance (Nominal)	1.77	1.51	0.72	1.35	2.36
ST_Gap ($000)	879.12	1995.95	249.62	506.07	954.54
LT_Gap ($000)	2112.68	8431.75	37.37	591.47	2134.97
Observations	23859				

Panel B: CFO Compensation Variables

	Mean	Std	P25	P50	P75
Optimism Ratio	0.42	0.29	0.17	0.43	0.66
Optimism Ratio (Stock)	0.76	0.34	0.56	1.00	1.00
Optimism Ratio (Portfolio)	0.52	0.27	0.32	0.55	0.73
Stock Alignment	0.03	0.07	0.00	0.01	0.03
Option Alignment	0.08	0.09	0.02	0.05	0.10
Non-firm Wealth ($000)	19.75	244.07	2.50	5.53	14.45
Short-term Compensation ($000)	1.47	2.27	0.63	1.00	1.61
Total Expected Wealth ($000)	52.93	356.79	5.32	13.28	34.71
Delta ($000)	91.84	239.48	14.11	35.69	88.58
Vega ($000)	27.88	70.11	4.11	11.35	28.72
Risk Avoidance	2.11	1.82	1.01	1.87	2.84
Observations	18482				

Panel C: Compensation Variables in Innovation Sample

CEO Compensation	Mean	Std	P25	P50	P75
Optimism Ratio	0.47	0.29	0.26	0.52	0.70
Optimism Ratio (Stock)	0.89	0.25	0.93	1.00	1.00
Optimism Ratio (Portfolio)	0.64	0.26	0.49	0.69	0.84
Stock Alignment	0.13	0.21	0.01	0.04	0.12
Option Alignment	0.15	0.16	0.05	0.10	0.19
Non-firm Wealth ($000)	30.66	503.02	2.27	4.69	12.15
Short-term Compensation ($000)	1.51	2.46	0.61	1.05	1.78
Total Expected Wealth ($000)	66.27	654.16	5.34	12.89	33.04
Delta ($000)	1191.61	12558.96	90.96	221.46	589.83
Vega ($000)	128.87	284.56	17.75	48.52	134.29
Risk Avoidance (Utility)	2.76	2.12	1.45	2.41	3.62
CFO Compensation	**Mean**	**Std**	**P25**	**P50**	**P75**
Optimism Ratio	0.39	0.27	0.16	0.39	0.61
Optimism Ratio (Stock)	0.86	0.28	0.88	1.00	1.00
Optimism Ratio (Portfolio)	0.49	0.26	0.28	0.51	0.69
Stock Alignment	0.03	0.07	0.00	0.01	0.03
Option Alignment	0.10	0.12	0.03	0.07	0.13
Non-firm Wealth ($000)	30.66	503.02	2.27	4.69	12.15
Short-term Compensation ($000)	1.51	2.46	0.61	1.05	1.78
Total Expected Wealth ($000)	66.27	654.16	5.34	12.89	33.04
Delta ($000)	116.58	291.66	18.37	42.38	103.72
Vega ($000)	35.91	69.56	6.21	14.92	37.03
Risk Avoidance (Utility)	2.51	1.74	1.47	2.24	3.26
Observations	4539				

Table 2
Descriptive Statistics – Firm Level Data
This table presents various descriptive statistics for the sample firms. Firm financial data are from 1992 to 2009. Panel A presents summary statistics for firm-level data. *Crash* is a dummy variable that equals one if the firm experiences any stock crash event in any given fiscal year. *Boom* is a dummy variable that equals one if the firm experiences any stock boom event in the given fiscal year. *Number of crashes* and *number of booms* are the number of crashes (respectively, booms) for any firm-year combination. *Weekly raw return* measures the cumulative return per calendar week for any firm-week combination. *Weekly firm-specific return* measures the abnormal return per calendar week multiplied by 100 for any firm-week combination. *DUVOL* and *DTURNOVER* measure, respectively, the average down-to-up volatility and the average monthly de-trended share turnover from Chen, Hong and Stein (2001) per each firm-year combination. *Market to book ratio* is market value of the firm divided by book value. *Log(Market value)* measures the log of market capitalization of the firm. Volatility is the stock return volatility. *ROA* is given by operating income before depreciation divided by total assets of the firm. *Book leverage* is the ratio of total book debt to book assets. *Market leverage* is the ratio of total debt to market value of the firm. Panel B presents the same summary statistics for sample with available CEO and CFO compensation data. Panel C presents the summary statistics for firms with R&D expense and innovation data. *R&D Intensity* is measured as the ratio of R&D expenses to fixed asset (PPENT). Innovation related variables (*Adjusted Number of patents, Adjusted Number of Citations)* are constructed following Acharya and Subramanian (2009), which represents number of patents/citation per firm-year combination.

Panel A: Firm Level Variables in CEO sample

	Mean	Std	P25	P50	P75
Crash	0.122	0.327	0.000	0.000	0.000
Boom	0.147	0.354	0.000	0.000	0.000
Number of Crashes	0.141	0.890	0.000	0.000	0.000
Number of Booms	0.150	0.364	0.000	0.000	0.000
Weekly Raw Return	0.022	0.130	-0.040	0.015	0.074
Weekly Firm-Specific Return	-0.075	0.964	-0.505	-0.046	0.364
NCSKEW	0.201	0.951	-0.390	0.141	0.700
DUVOL	-0.098	0.391	-0.337	-0.093	0.147
DTURNOVER	0.105	1.013	-0.124	0.048	0.295
Market to Book ratio	1.972	2.184	1.106	1.442	2.132
Log (Market Value)	7.393	1.609	6.294	7.291	8.411
Volatility	0.451	0.255	0.277	0.384	0.553
ROA	0.126	0.124	0.075	0.126	0.182
Book Leverage	0.229	0.194	0.071	0.213	0.342
Market Leverage	0.168	0.157	0.037	0.131	0.259
Observations	23859				

Panel B: Firm Level Variables in CEO + CFO sample

	Mean	Std	P25	P50	P75
Crash	0.121	0.327	0.000	0.000	0.000
Boom	0.148	0.355	0.000	0.000	0.000
Number of Crashes	0.144	0.971	0.000	0.000	0.000
Number of Booms	0.150	0.365	0.000	0.000	0.000
Weekly Raw Return	0.022	0.132	-0.040	0.015	0.074
Weekly Firm-Specific Return	-0.083	1.001	-0.525	-0.050	0.370
NCSKEW	0.212	0.959	-0.382	0.155	0.724
DUVOL	-0.099	0.393	-0.339	-0.093	0.147
DTURNOVER	0.116	1.078	-0.136	0.059	0.336
Market to Book ratio	1.936	2.033	1.105	1.439	2.097
Log (Market Value)	7.326	1.577	6.273	7.229	8.310
Volatility	0.465	0.261	0.286	0.397	0.573
ROA	0.125	0.119	0.075	0.125	0.180
Book Leverage	0.230	0.196	0.068	0.215	0.343
Market Leverage	0.170	0.158	0.037	0.133	0.262
Observations	18482				

Panel C: Firm Level Variables in Innovation Sample

	Mean	Std	P25	P50	P75
Crash	0.119	0.323	0.000	0.000	0.000
Boom	0.132	0.338	0.000	0.000	0.000
Number of Crashes	0.119	0.326	0.000	0.000	0.000
Number of Booms	0.135	0.350	0.000	0.000	0.000
Weekly Raw Return	0.019	0.149	-0.054	0.012	0.080
Weekly Firm-Specific Return	-0.040	0.943	-0.499	-0.028	0.400
NCSKEW	0.163	0.922	-0.410	0.110	0.627
DUVOL	-0.115	0.387	-0.355	-0.113	0.132
DTURNOVER	0.069	1.116	-0.140	0.029	0.232
Market to Book ratio	2.710	3.896	1.347	1.820	2.841
Log (Market Value)	7.650	1.696	6.401	7.558	8.717
Volatility	0.473	0.252	0.288	0.407	0.591
ROA	0.139	0.140	0.099	0.150	0.202
Book Leverage	0.198	0.167	0.053	0.189	0.299
Market Leverage	0.123	0.121	0.018	0.095	0.190
R&D Intensity	0.706	11.453	0.066	0.198	0.563
Adjusted Number of Patents	6.816	22.101	0.300	1.000	4.200
Adjusted Number of Citations	10.114	43.074	0.099	0.757	4.328
Number of Patents	6.865	22.252	0.300	1.000	4.200
Number of Citations	3.907	18.373	0.010	0.180	1.410
Observations	4539				

Table 3
Executive Optimism and Price Crashes
This table presents the results of logistic regressions with CEO optimism ratio and CFO optimism ratio as the main explanatory variables. The dependent variable in the regressions is Crash. Standard errors are clustered in both firm and time dimensions following Thompson (2011). The number of observations is given in the last row.

	(1)	(2)	(3)	(4)	(5)
CEO Optimism Ratio	0.287***	0.254***	0.287***	0.283***	0.251***
	(3.24)	(2.74)	(3.13)	(3.22)	(2.64)
CFO Optimism Ratio	0.00447	-0.00434	0.00343	-0.00734	-0.0169
	(0.03)	(-0.03)	(0.02)	(-0.05)	(-0.13)
Weekly Raw Return	0.0820		0.0745	0.156	
	(0.25)		(0.23)	(0.47)	
Weekly Firm-Specific Return		-0.393***			-0.379***
		(-5.41)			(-5.39)
Book Leverage	0.156	0.181		0.141	
	(0.86)	(0.94)		(0.79)	
Market Leverage			-0.142		-0.102
			(-0.50)		(-0.34)
DUVOL (Weekly)	0.345***	0.299**	0.333**		
	(2.59)	(2.48)	(2.52)		
DUVOL (Daily)				0.588***	0.520***
				(4.44)	(4.08)
NCSKEW	-0.0902*	-0.0741	-0.0849	-0.137***	-0.117***
	(-1.67)	(-1.56)	(-1.54)	(-3.40)	(-3.15)
DTURNOVER	-0.0165	-0.0207*	-0.0160	-0.0166	-0.0195
	(-1.18)	(-1.65)	(-1.17)	(-1.18)	(-1.64)
Market to Book ratio	-0.00594	-0.0222	-0.0103	-0.0000762	-0.0189
	(-0.16)	(-0.63)	(-0.30)	(-0.00)	(-0.59)
Log (Market Value)	0.00394	-0.0172	0.00569	0.00526	-0.0132
	(0.10)	(-0.52)	(0.15)	(0.14)	(-0.40)
Volatility	-0.100	-0.367	-0.107	-0.0714	-0.336
	(-0.33)	(-1.36)	(-0.36)	(-0.22)	(-1.17)
ROA	1.086**	1.211**	1.063**	1.105**	1.183**
	(2.35)	(2.42)	(2.32)	(2.41)	(2.43)
Constant	-2.228***	-2.006***	-2.169***	-2.193***	-1.929***
	(-7.70)	(-8.21)	(-7.24)	(-7.94)	(-7.74)
Observations	16455	16462	16520	16589	16660

t statistics in parentheses
* p<0.10, ** p<0.05, *** p<0.01

Table 4
Executive Optimism and Price Booms
This table presents the results of logistic regressions with CEO optimism ratio and CFO optimism ratio as the main explanatory variables. The dependent variable in the regressions is Boom. Standard errors are clustered in both firm and time dimensions following Thompson (2011). The number of observations is given in the last row.

	(1)	(2)	(3)	(4)	(5)
CEO Optimism Ratio	0.0351	0.0479	0.0325	0.0352	0.0414
	(0.42)	(0.56)	(0.40)	(0.41)	(0.47)
CFO Optimism Ratio	0.0484	0.0605	0.0427	0.0525	0.0608
	(0.59)	(0.68)	(0.50)	(0.63)	(0.65)
Weekly Raw Return	-0.795***		-0.780***	-0.838***	
	(-4.04)		(-3.95)	(-4.15)	
Weekly Firm-Specific Return		0.242***			0.245***
		(5.43)			(5.29)
Book Leverage	0.141	0.0774		0.148	
	(1.05)	(0.55)		(1.14)	
Market Leverage			0.0975		-0.0193
			(0.53)		(-0.10)
DUVOL (Weekly)	-0.259**	-0.210	-0.257**		
	(-2.35)	(-1.60)	(-2.29)		
DUVOL (Daily)				-0.195***	-0.142**
				(-2.91)	(-2.16)
NCSKEW	0.109**	0.101	0.109**	0.0750*	0.0702
	(2.05)	(1.53)	(2.05)	(1.79)	(1.52)
DTURNOVER	-0.0330**	-0.0304**	-0.0321**	-0.0344***	-0.0344**
	(-2.51)	(-2.15)	(-2.39)	(-2.65)	(-2.48)
Market to Book ratio	-0.0150	-0.0108	-0.0133	-0.0205	-0.0171
	(-0.67)	(-0.44)	(-0.59)	(-0.92)	(-0.71)
Log (Market Value)	-0.150***	-0.134***	-0.149***	-0.154***	-0.136***
	(-5.46)	(-4.14)	(-5.44)	(-5.60)	(-4.08)
Volatility	0.117	0.0934	0.109	0.142	0.119
	(0.49)	(0.31)	(0.45)	(0.62)	(0.42)
ROA	-0.179	-0.208	-0.173	-0.167	-0.188
	(-0.75)	(-0.84)	(-0.73)	(-0.71)	(-0.77)
Constant	-0.802***	-0.910***	-0.788***	-0.775***	-0.873***
	(-3.27)	(-3.12)	(-3.21)	(-3.11)	(-2.86)
Observations	16455	16462	16520	16589	16660

t statistics in parentheses
* p<0.10, ** p<0.05, *** p<0.01

Table 5

Executive Incentives and Price Crashes

This table presents the results of logistic regressions of the occurrence of price crashes on various incentive variables. The dependent variable in the regressions is Crash. Standard errors are clustered in both firm and time dimensions following Thompson (2011). The number of observations is given in the last row.

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
CEO Optimism Ratio	0.220***	0.248***	0.285***	0.286***	0.299***	0.245***		0.290***
	(2.61)	(2.76)	(3.35)	(3.26)	(3.50)	(2.65)		(3.41)
CFO Optimism Ratio	0.0250	-0.0290	-0.0517	0.00727	0.0365	-0.0315		0.0114
	(0.19)	(-0.20)	(-0.37)	(0.06)	(0.26)	(-0.22)		(0.09)
CEO Stock Alignment	-0.117	-0.114					-0.0321	
	(-0.69)	(-0.59)					(-0.22)	
CEO Option Alignment	0.602***	0.344				0.324	0.496*	
	(2.72)	(1.09)				(1.18)	(1.85)	
CFO Stock Alignment		0.0130	-0.0881				-0.00182	
		(0.03)	(-0.20)				(-0.00)	
CFO Option Alignment		0.777*	1.051***			0.751	0.600	
		(1.73)	(3.34)			(1.61)	(1.59)	
CEO Risk Avoidance				-0.00780		-0.0111		
				(-0.53)		(-0.73)		
CFO Risk Avoidance				-0.0129		-0.0173		
				(-0.80)		(-1.06)		
Delta ($000)							-8.40E-6	-5.90E-6
							(-0.87)	(-0.55)
Vega ($000)							0.0000362	0.000105
							(0.55)	(1.33)
ST_Gap ($000)							0.0000443	-0.00797
							(0.00)	(-0.68)
LT_Gap ($000)							-0.00270	-0.00125
							(-1.51)	(-0.94)

Weekly Raw Return	0.0189	0.00621	0.00169	0.0340	0.0435	0.0225	0.0179	0.0208
	(0.05)	(0.02)	(0.00)	(0.10)	(0.12)	(0.06)	(0.05)	(0.06)
NCSKEW	0.0274	0.0279	0.0291	0.0241	0.0202	0.0226	0.0326	0.0276
	(0.89)	(0.91)	(0.93)	(0.77)	(0.60)	(0.72)	(1.05)	(0.91)
DTURNOVER	-0.0181	-0.0176	-0.0177	-0.0198	-0.0180	-0.0177	-0.0174	-0.0192
	(-1.13)	(-1.11)	(-1.11)	(-1.21)	(-1.08)	(-1.12)	(-1.07)	(-1.19)
Market to Book ratio	-0.0184	-0.0275	-0.0258	-0.00340	-0.00175	-0.0250	-0.0265	-0.00493
	(-0.48)	(-0.66)	(-0.62)	(-0.09)	(-0.05)	(-0.62)	(-0.67)	(-0.13)
Log (Market Value)	-0.0151	-0.0238	-0.0178	0.00964	0.0107	-0.0206	-0.0131	0.00613
	(-0.36)	(-0.57)	(-0.43)	(0.24)	(0.27)	(-0.48)	(-0.27)	(0.15)
Volatility	-0.174	-0.186	-0.179	-0.0908	-0.109	-0.129	-0.236	-0.133
	(-0.57)	(-0.62)	(-0.60)	(-0.30)	(-0.36)	(-0.43)	(-0.79)	(-0.44)
ROA	1.245**	1.256**	1.234**	1.207***	1.239***	1.282***	1.157**	1.194**
	(2.55)	(2.52)	(2.46)	(2.61)	(2.72)	(2.62)	(2.35)	(2.52)
Book Leverage	0.194	0.198	0.197	0.179	0.159	0.206	0.199	0.180
	(1.02)	(1.03)	(1.02)	(0.93)	(0.85)	(1.07)	(1.05)	(0.92)
Constant	-2.162***	-2.099***	-2.140***	-2.309***	-2.295***	-2.099***	-2.032***	-2.308***
	(-6.90)	(-6.81)	(-6.95)	(-7.66)	(-7.39)	(-6.79)	(-6.37)	(-7.36)
Observations	15999	15997	16000	16001	16003	16001	16799	16003

t statistics in parentheses
* p<0.10, ** p<0.05, *** p<0.01

Table 6

Optimism in Stock or Option Holdings and SOX Reform

This table presents the results of logistic regressions of the occurrence of equity crashes on various executive optimism variables. The dependent variable in the regressions is Crash. The first two models were run with the full sample. Model (3) and Model (5) contain samples from fiscal years 1993 to 2001. Model (4) and (6) contain data from fiscal years 2003 to 2009. Standard errors are clustered in both firm and time dimensions following Thompson (2011). The number of observations is given in the last row.

	(1)	(2)	(3)	(4)	(5)	(6)
CEO Optimism Ratio (Stock)	0.178				0.345*	0.142
	(1.47)				(1.83)	(0.89)
CFO Optimism Ratio (Stock)	-0.0611				-0.301**	-0.000259
	(-0.75)				(-1.98)	(-0.00)
CEO Optimism Ratio (Portfolio)		0.166				
		(1.37)				
CFO Optimism Ratio (Portfolio)		-0.0532				
		(-0.45)				
CEO Optimism Ratio			0.346***	0.142		
			(2.84)	(1.19)		
CFO Optimism Ratio			-0.248	0.163		
			(-1.44)	(0.82)		
CEO Stock Alignment			0.255	-0.537*	0.0912	-0.597**
			(1.35)	(-1.89)	(0.48)	(-2.39)
CFO Stock Alignment			0.255	-0.0594	0.558	0.0539
			(0.35)	(-0.06)	(1.19)	(0.06)
CEO Option Alignment			-0.482	0.713	0.117	0.915***
			(-0.90)	(1.59)	(0.24)	(2.78)
CFO Option Alignment			1.555*	0.271	0.643	0.0657
			(1.78)	(0.51)	(0.96)	(0.13)
Weekly Raw Return	0.0320	0.0254	0.521	-0.787**	0.538	-0.671*
	(0.09)	(0.08)	(1.56)	(-2.15)	(1.59)	(-1.73)
NCSKEW	0.0323	0.0315	0.0205	0.0304	0.0234	0.0277

	(0.99)	(1.00)	(0.68)	(0.60)	(0.66)	(0.62)
DTURNOVER	-0.0212	-0.0181	-0.0140	-0.0125	-0.00520	-0.0152
	(-0.82)	(-1.08)	(-0.80)	(-0.44)	(-0.20)	(-0.49)
Market to Book ratio	-0.0209	-0.00792	-0.166***	0.0822*	-0.174***	0.0846
	(-0.55)	(-0.21)	(-9.44)	(1.86)	(-6.34)	(1.45)
Log (Market Value)	0.0303	0.0192	0.0218	-0.0352	0.0326	-0.0147
	(0.69)	(0.44)	(0.61)	(-0.42)	(0.99)	(-0.16)
Volatility	-0.194	-0.186	0.418	-0.633	0.444	-0.690
	(-0.62)	(-0.61)	(1.24)	(-1.33)	(1.35)	(-1.47)
ROA	1.329***	1.076**	2.208***	0.389	2.254***	0.403
	(2.84)	(2.33)	(5.31)	(0.79)	(4.43)	(0.54)
Book Leverage	0.0725	0.209	-0.129	0.368***	-0.132	0.369
	(0.32)	(1.08)	(-0.35)	(3.02)	(-0.34)	(1.59)
Constant	-2.384***	-2.299***	-2.490***	-1.907***	-2.571***	-2.001***
	(-9.03)	(-7.00)	(-9.24)	(-3.83)	(-9.53)	(-3.85)
Observations	14787	16708	7484	7399	6667	7093

t statistics in parentheses
* p<0.10, ** p<0.05, *** p<0.01

Table 7
Executive Optimism and R&D Intensity, Innovation Effectiveness
This table presents the results of OLS regressions of R&D intensity, innovation intensity on CEO optimism variables. The dependent variables in the regression are R&D intensity and number of patents/citations adjusted as in Acharya, Subramanian (2009). Standard errors are clustered in both firm and time dimensions following Thompson (2011). The number of observations is given in the last row.

	(1) R&D Intensity	(2) R&D Intensity	(3) Log (Adjusted Citations)	(4) Adjusted Number of Patents
CEO Optimism Ratio	0.0848		-0.164*	-1.336
	(1.05)		(-1.75)	(-1.09)
CFO Optimism Ratio	-0.138*		-0.138	-0.799
	(-1.79)		(-1.46)	(-0.55)
CEO Stock Alignment	-0.719***	-0.452***	0.352	-1.643
	(-4.22)	(-2.83)	(1.51)	(-0.58)
CEO Option Alignment	0.974***	0.912***	-0.618**	-4.978
	(3.36)	(3.62)	(-2.23)	(-1.10)
CFO Stock Alignment		-0.980**	-0.379	-7.421
		(-2.36)	(-0.75)	(-1.58)
CFO Option Alignment		1.710***	-0.301	-3.695
		(4.10)	(-0.64)	(-0.53)
R&D Intensity			0.0150	0.140
			(1.10)	(0.93)
Weekly Raw Return	-0.110	0.203	-0.228	-5.028***
	(-0.32)	(0.65)	(-0.95)	(-4.12)
Book Leverage	-1.029*	-1.057**	-0.349*	-3.097
	(-1.86)	(-2.09)	(-1.92)	(-1.51)
Market to Book ratio	0.132*		-0.0167	-0.527**
	(1.83)		(-1.29)	(-2.09)
Log (Market Value)	-0.0840**	-0.0795**	0.336***	5.457***
	(-2.34)	(-2.31)	(5.14)	(3.92)
Volatility	0.200	0.431***	0.579*	10.38**
	(1.02)	(2.58)	(1.75)	(2.53)
ROA	-5.564***	-5.088***	0.999**	1.898
	(-3.75)	(-3.66)	(2.24)	(0.43)
Constant	1.769***	1.691***	-1.660***	-36.13***
	(3.77)	(3.86)	(-5.11)	(-4.04)
Observations	9320	9667	2974	2974

t statistics in parentheses
* p<0.10, ** p<0.05, *** p<0.01

Table 8
R&D Intensity, Innovation Effectiveness, and Price Crashes
This table presents the results of logistic regressions with R&D intensity, innovation effectiveness, CEO optimism ratio and CFO optimism ratio as the main explanatory variables. Standard errors are clustered in both firm and time dimensions following Thompson (2011). The number of observations is given in the last row.

	(1)	(2)	(3)	(4)
CEO Optimism Ratio	0.620***	0.683***	0.642***	0.698***
	(2.72)	(3.25)	(2.84)	(3.34)
CFO Optimism Ratio	-0.500	-0.603*	-0.469	-0.572
	(-1.58)	(-1.67)	(-1.51)	(-1.62)
CEO Stock Alignment		0.0781		-0.00480
		(0.18)		(-0.01)
CEO Option Alignment		-0.717		-0.636
		(-1.46)		(-1.32)
CFO Option Alignment		1.679		1.711*
		(1.59)		(1.68)
CFO Stock Alignment		-0.988		-0.979
		(-0.73)		(-0.71)
R&D Intensity	0.0965**	0.0931**	0.0935**	0.0897*
	(2.19)	(2.02)	(2.11)	(1.92)
Adjusted Number of Patents			-0.00705	-0.00721
			(-0.89)	(-0.92)
Adjusted Number of Citations	-0.232***	-0.233***		
	(-3.21)	(-3.22)		
Weekly Raw Return	0.738	0.722	0.753	0.738
	(1.42)	(1.42)	(1.40)	(1.39)
Book Leverage	1.010	1.012	1.088	1.081
	(1.54)	(1.54)	(1.63)	(1.63)
NCSKEW	0.0137	0.00631	0.0299	0.0215
	(0.24)	(0.11)	(0.54)	(0.38)
DTURNOVER	-0.0669	-0.0667	-0.0698	-0.0690
	(-1.57)	(-1.54)	(-1.59)	(-1.54)
Market to Book ratio	-0.208***	-0.227***	-0.196***	-0.216***
	(-5.80)	(-4.30)	(-6.09)	(-4.39)
Log (Market Value)	0.0869*	0.0715	0.0477	0.0297
	(1.70)	(1.36)	(0.80)	(0.48)
Volatility	0.652	0.602	0.550	0.495
	(1.39)	(1.21)	(1.11)	(0.94)
ROA	4.836***	4.863***	4.472***	4.515***
	(5.88)	(5.55)	(6.04)	(5.65)
Constant	-3.358***	-3.206***	-3.196***	-3.024***
	(-5.85)	(-5.38)	(-4.80)	(-4.31)
Observations	2921	2921	2921	2921

t statistics in parentheses
* p<0.10, ** p<0.05, *** p<0.01

Table 9
CEO Optimism and Price Crashes
This table presents the results of logistic regressions of the occurrence of price crashes on CEO optimism variables. The results deviate from Table 3 because CFO incentives are no longer required in the regressions, so that the sample becomes larger. The dependent variable in the regression is Crash. Standard errors are clustered in both firm and time dimensions following Thompson (2011). The number of observations is given in the last row.

	(1)	(2)	(3)	(4)
CEO Optimism Ratio	0.176**	0.175**	0.171**	0.131*
	(2.16)	(2.14)	(2.05)	(1.66)
Vega ($000)		1.05E-4	1.06E-4	6.69E-5
		(1.29)	(1.25)	(0.85)
Delta ($000)		-2.84E-6	-2.06E-6	-6.00E-6
		(-0.37)	(-0.28)	(-0.72)
CEO Risk Avoidance			-0.0111	
			(-0.88)	
CEO Stock Alignment				0.0302
				(0.27)
CEO Option Alignment				0.438*
				(1.66)
Weekly Raw Return	0.165	0.167	0.173	0.162
	(0.48)	(0.49)	(0.50)	(0.47)
NCSKEW	0.0521*	0.0509*	0.0486*	0.0505*
	(1.95)	(1.92)	(1.86)	(1.92)
DTURNOVER	-0.0162	-0.0158	-0.0160	-0.0154
	(-1.07)	(-1.05)	(-1.06)	(-1.03)
Market to Book ratio	-0.00650	-0.00592	-0.00436	-0.0160
	(-0.20)	(-0.18)	(-0.13)	(-0.49)
Log (Market Value)	0.0132	0.00684	0.00726	-0.00530
	(0.39)	(0.19)	(0.20)	(-0.14)
Volatility	-0.195	-0.199	-0.176	-0.232
	(-0.71)	(-0.73)	(-0.64)	(-0.85)
ROA	1.180***	1.188***	1.200***	1.218***
	(3.32)	(3.32)	(3.41)	(3.35)
Book Leverage	0.226	0.226	0.225	0.243
	(1.31)	(1.30)	(1.30)	(1.44)
Constant	-2.291***	-2.252***	-2.241***	-2.170***
	(-9.65)	(-8.87)	(-8.84)	(-8.57)
Observations	21881	21881	21879	21877

t statistics in parentheses
* p<0.10, ** p<0.05, *** p<0.01

Table 10

Incentive Alignment and Optimism

This table presents the results of logistic regressions of executive incentive alignment variables classified by exercisable/unexercisable parts. The dependent variable is Crash. Controls are omitted for space constraints. Standard errors are clustered in both firm and time dimensions following Thompson (2011). The number of observations is given in the last row.

	(1)	(2)	(3)	(4)	(5)
CEO Incentive Alignment (Exercisable Option)	0.0521**	0.0490*			
	(2.02)	(1.71)			
CEO Incentive Alignment (Unexercisable Option)	-0.154**	-0.170**			
	(-2.47)	(-2.43)			
CEO Incentive Alignment (Unrestricted Stock)		0.0709			
		(0.78)			
CEO Incentive Alignment (Restricted Stock)		0.371			
		(0.28)			
CFO Stock Alignment			-0.108		
			(-0.26)		
CFO Option Alignment			0.986***		
			(3.16)		
CFO Incentive Alignment (Exercisable Option)				0.0706	0.0695
				(0.40)	(0.39)
CFO Incentive Alignment (Unexercisable Option)				-0.196	-0.195
				(-1.02)	(-1.04)
CFO Incentive Alignment (Unrestricted Stock)					0.154
					(0.42)
CFO Incentive Alignment (Restricted Stock)					-0.407
					(-0.15)
Constant	-2.202***	-2.194***	-2.047***	-2.188***	-2.190***
	(-8.82)	(-9.35)	(-6.58)	(-7.16)	(-7.81)
Observations	21843	21839	16802	16805	16802

t statistics in parentheses * $p<0.10$, ** $p<0.05$, *** $p<0.01$

Table 11

Optimal Optimism and Stock Crashes and Innovation

The table reports the summary statistics for firms grouped by optimism ratios, where Low indicates an optimism ratio of 0, High represents a higher than 0.874 optimism ratio, and Mid is everything in between. The cutoff points are chosen as 10% of the firm-year population fall into each extreme category (Low, High).

Panel A: Optimal Optimism Ratio and Crashes

	Low	Mid	High
Crash	0.111	0.122	0.128
	(0.314)	(0.327)	(0.334)
Boom	0.153	0.145	0.152
	(0.360)	(0.353)	(0.359)
Weekly Raw Return	0.0237	0.0225	0.0180
	(0.129)	(0.134)	(0.113)
Weekly Firm-Specific Returns	-0.0773	-0.0674	-0.117
	(0.919)	(0.974)	(0.938)
Volatility	0.460	0.454	0.418
	(0.267)	(0.254)	(0.243)
Book Leverage	0.231	0.229	0.228
	(0.226)	(0.186)	(0.203)
Market Leverage	0.177	0.167	0.171
	(0.172)	(0.154)	(0.161)
Observations	3045	17618	3072

Panel B: Optimal Optimism Ratio and Innovation

	Low	Mid	High
Crash	0.104	0.116	0.164
	(0.306)	(0.320)	(0.371)
Boom	0.141	0.136	0.0806
	(0.348)	(0.343)	(0.273)
Weekly Raw Return	0.0222	0.0186	0.0226
	(0.169)	(0.148)	(0.119)
Weekly Firm-Specific Return	0.0386	-0.0458	-0.115
	(0.994)	(0.941)	(0.834)
Volatility	0.509	0.472	0.421
	(0.296)	(0.248)	(0.213)
Book Leverage	0.167	0.204	0.183
	(0.180)	(0.166)	(0.145)
Market Leverage	0.108	0.126	0.117
	(0.131)	(0.119)	(0.118)
R&D Intensity	0.560	0.758	0.400
	(1.604)	(12.84)	(0.738)
Adjusted Number of Patents	5.233	7.308	4.686
	(16.96)	(23.59)	(11.91)
Adjusted Number of Citations	10.36	10.54	5.967
	(43.45)	(44.68)	(22.97)
Observations	546	3599	372

Table 12
Executive Optimism Removing Out-of-the-Money Options
Panel A presents the summary statistics of optimism ratios reconstructed by removing out-of-the-money options. Panel B presents the results of logistic regressions with the new optimism ratios as the main explanatory variables. The dependent variable in the regressions is Crash. Standard errors are clustered in both firm and time dimensions following Thompson (2011). The number of observations is given in the last row.

Panel A: Summary Statistics

	Mean	Std	P25	P50	P75
CEO Optimism Ratio	0.47	0.30	0.23	0.50	0.72
CFO Optimism Ratio	0.40	0.29	0.15	0.40	0.63

Panel B: Logistic Regression

	(1)	(2)	(3)	(4)	(5)
CEO Optimism Ratio	0.254***	0.227***	0.254***	0.249***	0.223***
	(3.06)	(2.68)	(2.98)	(3.09)	(2.59)
CFO Optimism Ratio	0.0148	-0.000157	0.0128	0.00248	-0.0130
	(0.11)	(-0.00)	(0.09)	(0.02)	(-0.10)
Weekly Raw Return	0.0736		0.0661	0.148	
	(0.23)		(0.20)	(0.45)	
Book Leverage	0.157	0.140		0.142	
	(0.87)	(0.72)		(0.79)	
Market Leverage			-0.141		-0.180
			(-0.50)		(-0.60)
DUVOL (Weekly)	0.344**	0.330**	0.332**		
	(2.57)	(2.56)	(2.50)		
DUVOL (Daily)				0.589***	0.529***
				(4.45)	(4.17)
NCSKEW	-0.0889	-0.0889*	-0.0835	-0.136***	-0.123***
	(-1.63)	(-1.81)	(-1.51)	(-3.38)	(-3.53)
DTURNOVER	-0.0167	-0.0233*	-0.0162	-0.0167	-0.0220*
	(-1.19)	(-1.74)	(-1.17)	(-1.18)	(-1.75)
Market to Book ratio	-0.00513	-0.0216	-0.00947	0.000675	-0.0199
	(-0.14)	(-0.60)	(-0.27)	(0.02)	(-0.60)
Log (Market Value)	0.00382	-0.0132	0.00557	0.00522	-0.00917
	(0.10)	(-0.39)	(0.15)	(0.14)	(-0.27)
Volatility	-0.112	-0.647***	-0.119	-0.0819	-0.615***
	(-0.37)	(-3.06)	(-0.39)	(-0.25)	(-2.74)
ROA	1.085**	1.224**	1.062**	1.103**	1.188**
	(2.36)	(2.44)	(2.33)	(2.42)	(2.45)
Constant	-2.210***	-1.944***	-2.150***	-2.175***	-1.862***
	(-7.47)	(-7.92)	(-7.03)	(-7.71)	(-7.35)
Observations	16455	16462	16520	16589	16660

t statistics in parentheses
* p<0.10, ** p<0.05, *** p<0.01

Figure 1.A

Distribution of CEO optimism ratio

(exercisable option delta / total option delta)

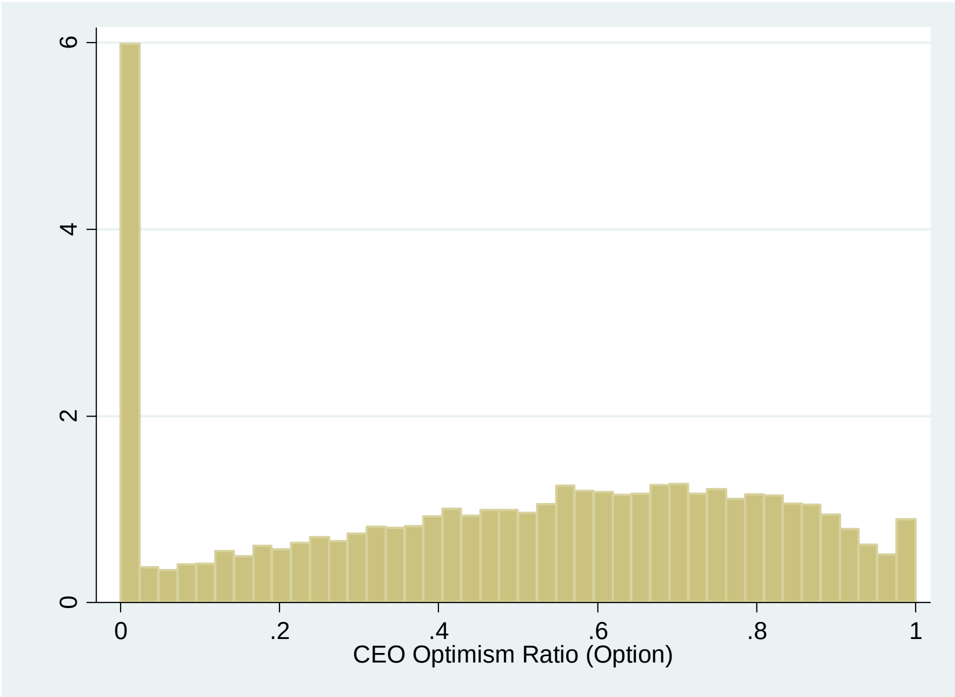


Figure 1.B

Distribution of CEO optimism ratio (Stock)

(unrestricted stock delta / total stock delta)

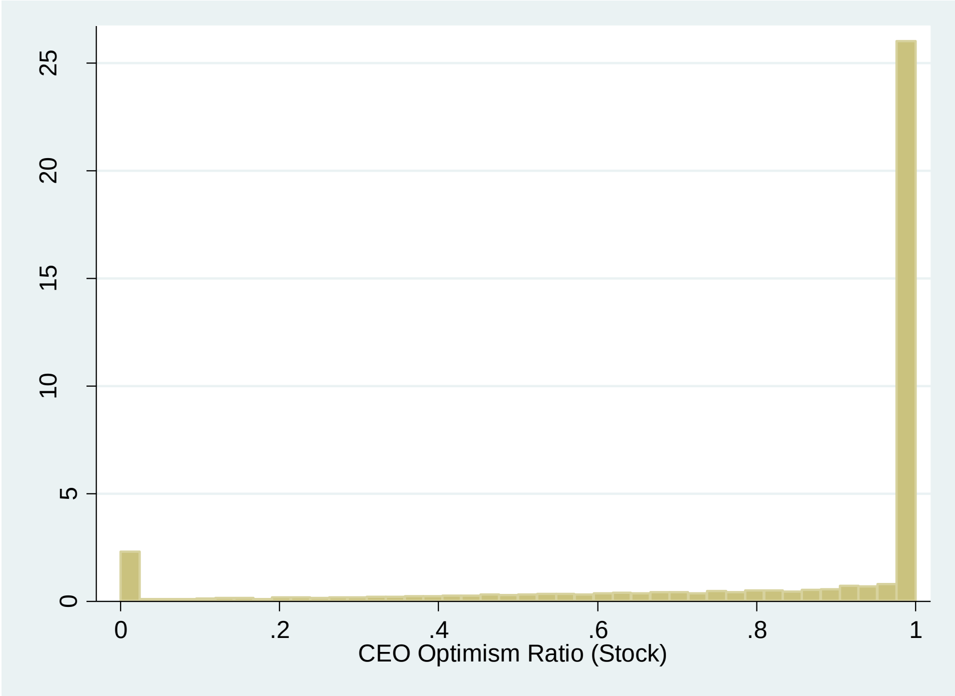


Figure 1.C

Distribution of CFO optimism ratio

(exercisable option delta / total option delta)

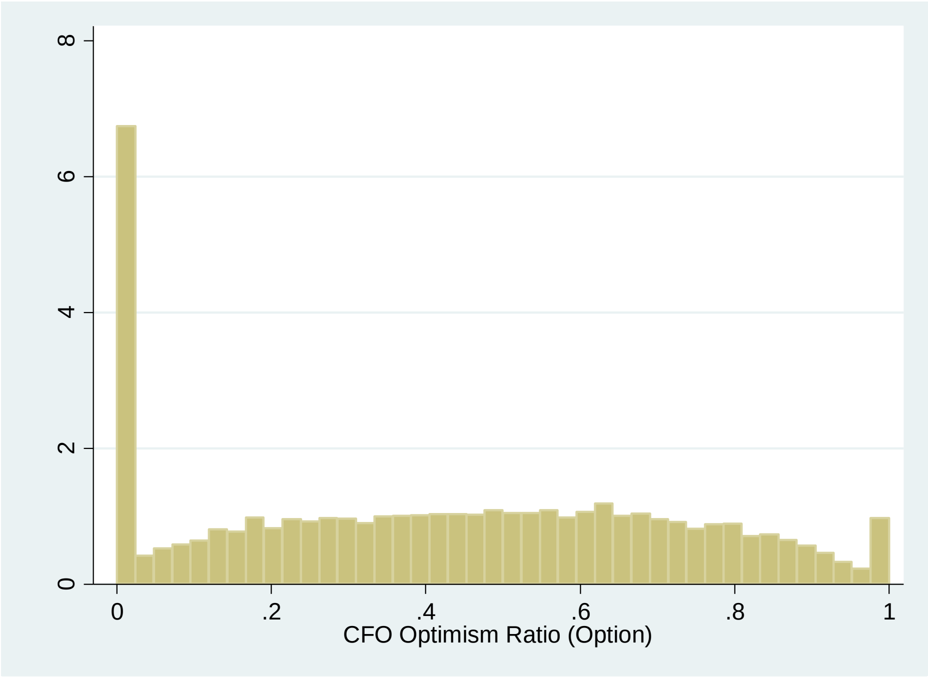


Figure 1.D

Distribution of CFO optimism ratio (Stock)

(unrestricted stock delta / total stock delta)

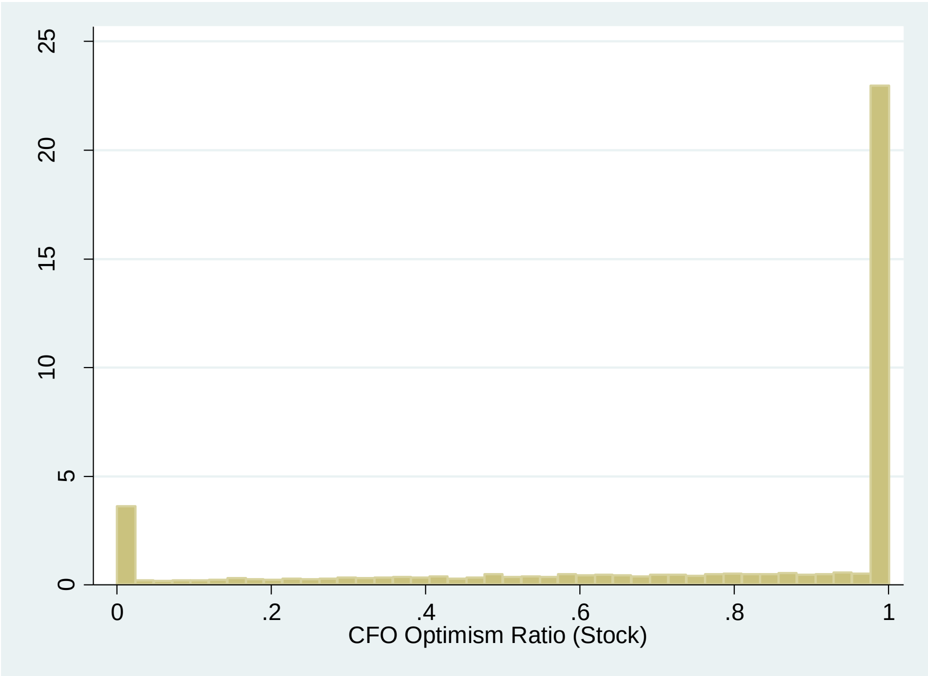


Figure 2.A

Distribution of CEO optimism ratio before 2002

(exercisable option delta / total option delta)

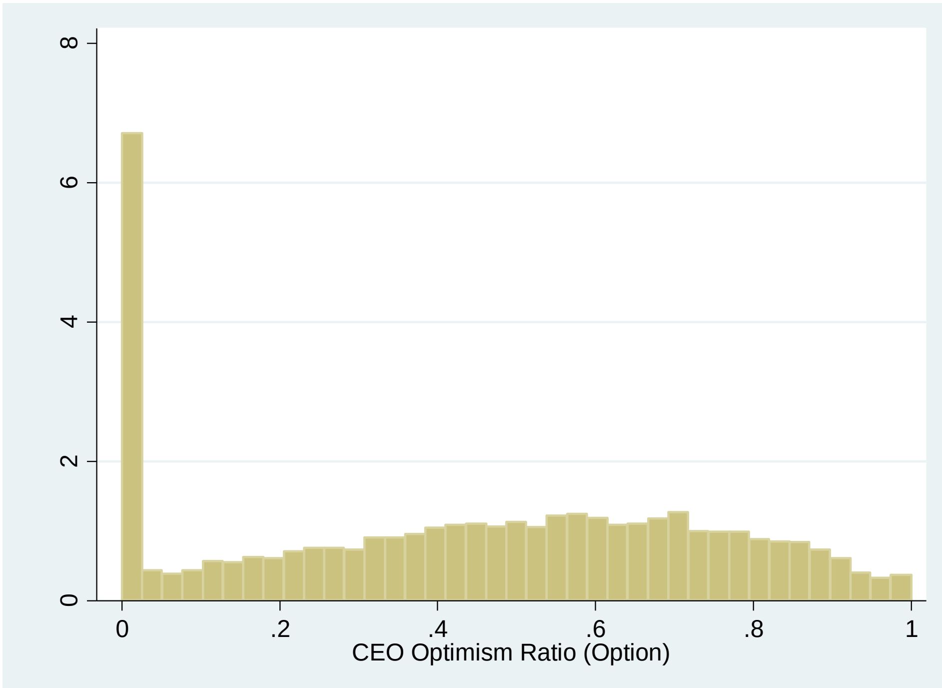
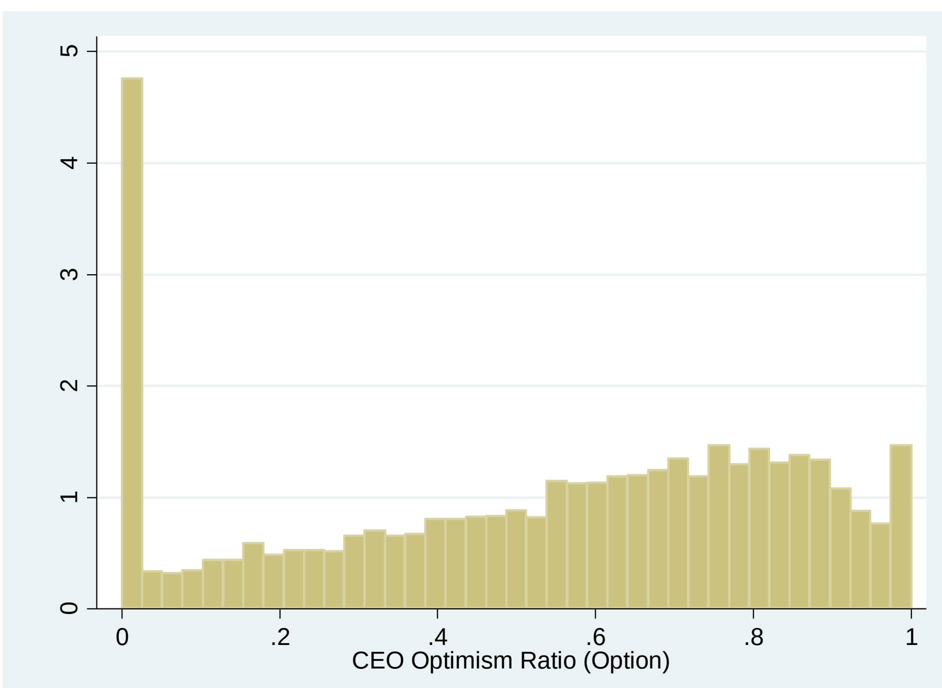


Figure 2.B

Distribution of CEO optimism ratio after 2002

(exercisable option delta / total option delta)



Chapter 3

How Important are Risk-Taking Incentives in Executive Compensation?[1]

We consider a model in which shareholders provide a risk-averse CEO with risk-taking incentives in addition to effort incentives. We show that the optimal contract protects the CEO from losses for bad outcomes, is convex for medium outcomes, and concave for good outcomes. We calibrate the model to data on 727 CEOs and show that it can explain observed contracts much better than the standard model without risk-taking incentives. Moreover, we propose a new measure of risk-taking (dis)incentives that measures the required probability an additional risky project must exceed in order to be adopted by the CEO.

[1]This chapter is based on Dittmann and Yu (2011).

3.1 Introduction

This paper addresses the question to what extent the inclusion of risk-taking incentives in the standard model of executive compensation helps to rationalize observed compensation practice qualitatively and quantitatively. Our point of departure is the Holmström (1979) model, where shareholders wish to provide incentives to a risk-averse and effort-averse CEO to induce him to work hard. This model fails to rationalize observed compensation practice as Hall and Murphy (2002) and Dittmann and Maug (2007) demonstrate, because it cannot explain convex contracts. In this paper, we augment the standard model by assuming that shareholders take into account not only effort incentives but also risk-taking incentives when designing the compensation contract. We show that the augmented model predicts a contract that is flat for poor performance, convex for medium performance, and concave for high performance. We calibrate the optimal contract shape to the data and find that the augmented model approximates observed contracts much better than the model without risk-taking incentives.

The notion that shareholders might want to provide risk-taking incentives in addition to effort incentives goes back at least to Smith and Stulz (1985) and Haugen and Senbet (1981). CEOs not only exert effort and thereby shift the stock price distribution to the right, but they also make decisions that affect firm value and firm risk (i.e. location and dispersion of the stock price distribution). Accordingly, there is ample empirical evidence that risk-taking incentives matter for CEOs' actual risk-taking. Low (2009), for instance, investigates an exogenous increase in takeover protection. In a differences-in-differences analysis, she finds that those firms with little CEO risk-taking incentives experienced a sharp decline in firm risk and firm value.[2]

[2] Tufano (1996) and Knopf, Nam and Thornton (2002) show that CEOs respond to risk-taking incentives for hedging decisions, Rajgopal and Shevlin (2002) for investment decisions, Coles, Daniel and Naveen (2006) and Tchistyi, Yermack and Yun (2010) for capital structure decisions, and May (1995), Smith and Swan (2007), and Acharya, Amihud and Litov (2008) for corporate acquisitions. DeFusco, Johnson and Zorn (1990) and Billett, Mauer and Zhang (2010) investigate the reaction of stock and bond prices to first time equity grants and find that investors expect that these grants affect firm risk.

Hirshleifer and Suh (1992) and Feltham and Wu (2001) show that optimal contracts are convex if they are designed to also provide risk-taking incentives. Therefore, the obvious way to fix the standard model and to introduce convexity into the optimal contract is the inclusion of risk-taking considerations.[3]

The CEO in our model not only exerts costly effort but also determines the firm's strategy, i.e. he makes decisions on issues like project choice, mergers and acquisitions, capital structure, or financial transactions. The CEO is risk-averse and holds firm equity that provides him with effort incentives. If the contract does not provide sufficient risk-taking incentives, the CEO therefore chooses a strategy that avoids risk and depresses firm value. He might, for instance, pass up a profitable but very risky project, or might hedge his firm's risk at some cost. Shareholders can mitigate this inefficiency by providing risk-taking incentives such as rewarding the manager for extreme outcomes, but they must be careful not to impair effort incentives at the same time. While high stock price realizations are an unmistakably good signal, low stock price realizations are ambiguous: they can be indicative of low effort (which is bad) or of extensive risk-taking (which is good, given that the CEO leans towards inefficiently low risk). The best way to provide effort and risk-taking incentives therefore is to reward good outcomes and not to punish bad outcomes, i.e. the optimal contract features a limited downside.

The optimal contract in our model differs markedly from the one in the standard model without risk-taking incentives. As marginal utility rapidly declines with CEO wealth, the standard model predicts that the CEO is punished severely for bad outcomes while he effectively receives a fixed wage for medium and good outcomes. In our model, however, firms pay a flat

[3]There are several alternative explanations for the convexity in CEO contracts. Oyer (2004) models options as a device to retain employees when recontracting is expensive. Inderst and Müller (2005) explain options as instruments that provide outside shareholders with better liquidation incentives. Edmans and Gabaix (2009) and Edmans et al. (2009) show that convex contracts can arise in dynamic contracting models. Peng and Röell (2009) analyze stock price manipulations in a model with multiplicative CEO preferences and find convex contracts for some parameterizations. Dittmann, Maug, and Spalt (2010) show that optimal contracts are convex if the CEO is loss-averse. Hemmer, Kim, and Verrecchia (1999) assume gamma distributed stock prices and find convex contracts, but Dittmann and Maug (2007) show that these results are not robust.

wage for bad outcomes and provide incentives only for medium and high outcomes. Due to decreasing marginal utility, the payout function is convex for medium and concave for high outcomes.

We calibrate both models to the data on 727 U.S. CEOs and for each generate predictions about the optimal payout function. We then compare the optimal with the observed payout function and find that our model can explain observed contracts much better than the standard model without risk-taking incentives. In particular, the average distance between observed contract and optimal contract is 8.0% for our model compared to 28.8% for the model without risk-taking incentives.

Our calibration approach bridges the gap between theoretical and empirical research on executive compensation and allows us to test the quantitative (and not just the qualitative) implications of different models. Moreover, this approach contributes to the empirical literature on CEO compensation as it circumvents the endogeneity problem that shareholders simultaneously determine firm risk and managerial incentives when they design the compensation contract. We model this endogeneity and test the predictions of the model. Under the assumptions that contracting is efficient and that CEOs are effort-averse and risk-averse, our results imply that the provision of risk-taking incentives is a major objective in executive compensation practice. We can reject the hypothesis that risk-taking incentives in observed contracts are a mere by-product of effort incentives.

Another contribution to the empirical literature is a new measure of risk-taking (dis-)incentives that combines the manager's risk preferences with the shape of his compensation contract and that we call *risk-avoidance*. It measures the required profitability an additional risky project must exceed in order to be adopted by the CEO. The median risk avoidance in our sample is 1.25 for a risk-aversion parameter of 2. Hence, the median CEO will adopt a project that increases firm risk by one percentage point if and only if it increases firm value by at least 1.25%. The standard measure for risk-taking incentives in the empirical literature is the vega of the CEO's option portfolio (see, e.g., Guay, 1999) or the utility-adjusted vega (see Lambert, Larcker, and Verrecchia (1991)). We argue that risk-taking incentives not only depend on the (utility-adjusted) vega but also on the (utility-adjusted) delta. While a negative utility-adjusted vega suggests that the CEO will pass up risky, positive-NPV projects, this effect is mitigated if the CEO has high (utility-adjusted) delta as this means that he gains from taking positive-NPV actions. Consequently, our proposed measure of risk-taking incentives is related to the ratio of utility-adjusted vega over utility-adjusted delta.

There are a few theory papers that also consider both effort-aversion and risk-taking incentives in models of executive compensation.[4] To our knowledge, this paper is the first, however, to calibrate such a model and to test its quantitative implications. In this way, we also contribute to recent literature on calibrations of contracting models.[5]

We attribute the convexity in observed contracts to the provision of risk-taking incentives in this paper, and we acknowledge that there are alternative explanations for the use of options in executive compensation (see Footnote 3 above). The only alternative model that can be readily calibrated to the data is Dittmann, Maug, and Spalt (2011) where the CEO is assumed to be loss averse. We also calibrate this model to our data and find that its fit is comparable to the fit of our model. In addition, we show that the loss-aversion model does

[4] Lambert (1986) and Core and Qian (2002) consider discrete volatility choices, where the agent must exert effort to gather information about investment projects. Feltham and Wu (2001) and Lambert and Larcker (2004) assume that the agent's choice of effort simultaneously affects mean and variance of the firm value distribution, so they reduce the two-dimensional problem to a one-dimensional problem. Two other papers (and our model) work with continuous effort and volatility choice: Hirshleifer and Suh (1992) analyze a rather stylized principal-agent model and solve it for special cases. Flor, Frimor and Munk (2011) consider a similar model to ours but they work with the assumption that stock prices are normally distributed while we work with the lognormal distribution. Hellwig (2009) and Sung (1995) solve models with continuous effort and volatility choice, but Hellwig (2009) assumes that the agent is risk-neutral and Sung (1995) that the principal can observe (and effectively set) volatility. In a different type of model, Manso (2010) also establishes that optimal contracts must not punish bad outcomes when risk-taking (innovation) needs to be encouraged.

[5] See Dittmann and Maug (2007), Gabaix and Landier (2008), Edmans, Gabaix, and Landier (2008), Dittmann, Maug, and Spalt (2010), and Dittmann, Maug and, Zhang (2011)

not improve much when shareholders take risk-taking incentives into account. The reason is that the standard loss-aversion model already predicts convex contracts with similar risk-taking incentives as the observed contract.

Our analysis proceeds as follows. In the next section, we present our model and derive the shape of the optimal contract. Section 3 describes the construction of the dataset, and Section 4 derives and empirically analyzes our proposed measure of CEO risk-taking incentives. In Section 5, we present our calibration method and our main results. In a nutshell, we numerically search for the cheapest contract with a given shape that provides the manager with the same incentives and the same utility as the observed contract. Section 6 provides robustness checks. Section 7 contains our analysis for the loss-aversion model, and Section 8 concludes. The appendix collects some technical material.

3.2 Optimal contracting with risk-taking incentives

3.2.1 Model

We consider two points in time. At time $t = 0$ the contract between a risk-neutral principal (the shareholders) and a risk-averse agent (CEO) is signed, and at time $t = T$ the contract period ends. The market value of the firm at time $t = 0$ (after the contract details have been disclosed) is $P_0 = E(P_T)\exp\{-r_f T\}$, where r_f is the appropriate rate of return. At some point during the contract period $(0, T)$, the agent makes two choices. First, he chooses effort $e \in [0, \infty)$ that results in private costs $C(e)$ to the agent and that affects the firm's expected value $E(P_T)$. Second, he chooses a strategy s that affects the firm's expected value $E(P_T)$ and the firm's stock return volatility σ. We will refer to σ interchangeably as 'firm risk'. We can therefore write $E(P_T) = P_0(e, s)\exp\{r_f T\}$ and $\sigma = \sigma(s)$.[6]

[6] In our model, effort only affects expected value but not firm risk whereas strategy affects both value and risk. Other models (e.g. Feltham and Wu, 2001) assume that the agent only chooses effort and that effort affects value

Our model is in the spirit of Holmström (1979). The agent can costlessly destroy output or inflate volatility σ, and the principal cannot observe the agent's actions. As a consequence, the manager's wealth $W_T = w(P_T)$ only depends on the end-of-period stock price P_T, and the wage scheme $w(.)$ is non-decreasing.

We think of the strategy s as a feasible combination of many different actions that affect, among other things, project choice, mergers and acquisitions, capital structure, or financial transactions. Part of the strategy could be, for instance, an R&D project that increases value and risk. Another part could be financial hedging of some input factor which would reduce value and risk. Due to its richness, we do not model the agent's choice of strategy in detail. Instead we assume that the contract chosen by the firm does not make the CEO risk-seeking, and we show in our empirical analysis below that this assumption always holds.[7] Therefore, the CEO chooses an action that minimizes firm risk σ given expected value $E(P_T)$, or equivalently that maximizes expected value $E(P_T)$ given risk σ. Let $\widetilde{s}(e, \sigma)$ denote the strategy that maximizes expected value $E(P_T)$ given effort e and volatility σ. Then the agent's choice of effort e and strategy s is equivalent to a choice of effort e and volatility σ: $E(P_T) = P_0(e, \widetilde{s}(e, \sigma)) \exp\{r_f T\} = P_0(e, \sigma) \exp\{r_f T\}$. In the remainder of this paper, we therefore work with the reduced form of our model where the agent chooses effort e and volatility σ.

We assume that there is a first-best firm strategy $s^*(e)$ that maximizes firm value (given effort e). Let $\sigma^*(e) := \sigma(s^*(e))$ denote the (minimum) firm risk that is associated with this strategy. If the agent wants to reduce risk to some value below $\sigma^*(e)$, he can do so in two

and risk. The main difference between Feltham and Wu (2001) and our model in this respect is that our model allows the CEO to affect value and risk independently of each other.

[7]More formally, we assume that the CEO's expected utility declines when volatility σ increases. This assumption is intuitive: A risk-averse CEO whose wealth is linked to firm-value is averse to an increase in firm risk σ. Providing risk-taking incentives by making the contract more convex (while keeping effort incentives and the CEO's utility constant) is costly. Therefore, firms will never increase risk-taking incentives beyond the optimal point where the CEO is indifferent to firm risk.

While this assumption is intuitive, we cannot show it formally. The reason is that the costs of an increase in risk-taking incentives given that effort incentives and utility are held constant cannot be written in closed-form. However, our empirical results below are consistent with this assumption. In particular, we find that risk-taking incentives are always costly.

ways. Either he drops some risky but profitable projects (e.g., an R&D project), or he takes an additional action that reduces risk but also profits (e.g., costly hedging). In both cases, a reduction in volatility σ leads to a reduction in firm value $E(P_T)$. We therefore assume that $P_0(e,\sigma)$ is increasing and concave in σ as long as $\sigma < \sigma^*(e)$. In the region above $\sigma^*(e)$, firm value $P_0(e,\sigma)$ is weakly decreasing in σ; it is flat if the agent can take additional risk at no costs (e.g., with financial transactions). Finally, we assume that the stock price $P_0(e,\sigma)$ is increasing and concave in e (given volatility σ).

We assume that the end-of-period stock price P_T is lognormally distributed:

$$P_T(u|e,\sigma) = P_0(e,\sigma)\exp\left\{\left(r_f - \frac{\sigma^2}{2}\right)T + u\sqrt{T}\sigma\right\}\ , \quad u \sim N(0,1)\,. \tag{3.2.1}$$

Here, r_f is the risk-free rate, and $P_0(e,\sigma) = E(P_T(u|e,\sigma))\exp\{-r_f T\}$ is the expected present value of the end-of-period stock price P_T.[8]

The manager's utility is additively separable in wealth and effort and has constant relative risk aversion with parameter γ with respect to wealth W_T:

$$U(W_T,e) = V(W_T) - C(e) = \frac{W_T^{1-\gamma}}{1-\gamma} - C(e)\,. \tag{3.2.2}$$

If $\gamma = 1$, we define $V(W_T) = \ln(W_T)$. Costs of effort are assumed to be increasing and convex in effort, i.e. $C'(e) > 0$ and $C''(e) > 0$. We normalize $C(0) = 0$. There is no direct cost associated with the manager's choice of volatility. Volatility σ affects the manager's utility indirectly via the stock price distribution and the utility function $V(.)$. Finally, we assume that the manager has outside employment opportunities that give him expected utility $\underline{U}$.

[8] We follow Dittmann and Maug (2007) and assume that either there is no premium for systematic risk or that the firm has no exposure to systematic risk, so that the risk-free rate r_f is the appropriate stock return. This assumption allows us to abstract from the agent's portfolio problem, because in our model the only alternative to an investment in the own firm is an investment at the risk-free rate. If we allowed the agent to earn a risk-premium on the shares of his firm, he could value these above their actual market price, because investing into his own firm is then the only way to earn the risk-premium. Our assumption effectively means that all risk in the model is firm-specific.

3.2.2 Optimal contract

In order to implement a given effort e^* and level of volatility σ^*, shareholders solve the following optimization problem:

$$\min_{W_T} E\left[W_T(P_T)|e^*, \sigma^*\right] \tag{3.2.3}$$

$$\text{subject to } \frac{dW_T(P_T)}{dP_T} \geq 0 \text{ for all } P_T \tag{3.2.4}$$

$$E\left[V(W_T(P_T))|e^*, \sigma^*\right] - C(e^*) \geq \underline{U} \tag{3.2.5}$$

$$\{e^*, \sigma^*\} \in \text{argmax } \{E\left[V(W_T(P_T))|e, \sigma\right] - C(e)\} \tag{3.2.6}$$

Hence, shareholders choose the wage schedule $W_T(P_T)$ that minimizes contracting costs subject to three constraints: The monotonicity constraint (3.2.4), the participation constraint (4.2.4), and the incentive compatibility constraint (4.2.5). We replace (4.2.5) with its first-order conditions

$$\frac{dE\left[V(W_T(P_T))|e, \sigma\right]}{de} - \frac{dC}{de} = 0, \tag{3.2.7}$$

$$\frac{dE\left[V(W_T(P_T))|e, \sigma\right]}{d\sigma} = 0. \tag{3.2.8}$$

We discuss the validity of the first-order approach (i.e. that (4.2.5) can indeed be replaced by (4.2.6) and (4.2.7)) in detail in Appendix A. We call condition (4.2.6) the effort incentive constraint and (4.2.7) the volatility incentive constraint.

Proposition 1 ***(Optimal contract):*** *The optimal contract that solves the shareholders' problem (4.2.3), (3.2.4), (4.2.4), (4.2.6), and (4.2.7) has the following functional form:*

$$\frac{dV(W_T^*)}{dW_T} = \begin{cases} c_0 + c_1 \ln P_T + c_2(\ln P_T)^2 & \text{if } ln(P_T) > -\frac{c_1}{2c_2} \\ c_0 - \frac{c_1^2}{4c_2} & \text{if } ln(P_T) \leq -\frac{c_1}{2c_2} \end{cases} \tag{3.2.9}$$

where c_0, c_1, and c_2 depend on the distribution of P_T and the Lagrange multipliers of the optimization problem, with $c_2 > 0$. For constant relative risk aversion, we obtain

$$W_T^* = \begin{cases} \left[c_0 + c_1 \ln P_T + c_2 (\ln P_T)^2\right]^{1/\gamma} & \text{if } ln(P_T) > -\frac{c_1}{2c_2} \\ \left[c_0 - \frac{c_1^2}{4c_2}\right]^{1/\gamma} & \text{if } ln(P_T) \leq -\frac{c_1}{2c_2} \end{cases} \tag{3.2.10}$$

The proof of Proposition 1 and full expressions for the parameters c_0, c_1, and c_2 can be found in Appendix B. To develop an intuition for the optimal contract (3.2.10) it is instructive to look first at the optimal contract without risk-taking incentives. This contract has the form $W_T^\gamma = c_0 + c_1 \ln P_T$ and is globally concave as long as $\gamma \geq 1$ (see Dittmann and Maug, 2007). The comparison shows that risk-taking incentives are provided by the additional quadratic term $c_2(\ln P_T)^2$. This term makes the contract more convex and limits its downside, two features that make risk-taking more attractive for a risk-averse agent. To satisfy the monotonicity constraint, the downward sloping part of the wage function due to the quadratic term is replaced by a flat wage. The resulting contract (3.2.10) is flat below some threshold $\widetilde{P} = \exp\{-\frac{c_1}{2c_2}\}$, convex and increasing for some region above this threshold, and finally concave, because the concavity of the logarithm dominates the convexity of the quadratic term asymptotically.

3.3 Data set

We use the ExecuComp database to construct approximate CEO contracts at the beginning of the 2006 fiscal year.[9] We first identify all persons in the database who were CEO during the full year 2006 and executive of the same company in 2005. We calculate the base salary ϕ (which is the sum of salary, bonus, and "other compensation" from ExecuComp) from 2006 data, and take information on stock and option holdings from the end of the 2005 fiscal year. We subsume

[9] We do not perform our analysis for a more recent year for two reasons. First, we cannot construct our sample consistently for 2007, because there was a significant change in the reporting standard in 2006; some firms reported according to the new standard while other firms still used the old standard. Second, we did not choose 2008 or 2009 to avoid using data from the financial crisis.

bonus payments under base salary, because previous research has shown that bonus payments are only weakly related to firm performance (see Hall and Liebman, 1998).[10]

We estimate each CEO's option portfolio with the method proposed by Core and Guay (2002) and then aggregate this portfolio into one representative option. This aggregation is necessary to arrive at a parsimonious wage function that can be calibrated to the data. Our model is static and therefore cannot accommodate option grants with different maturities. The representative option is determined so that it has a similar effect as the actual option portfolio on the agent's utility, his effort incentives, and his risk-taking incentives. More precisely, we numerically calculate the number of options n_O, the strike price K, and the maturity T so that the representative option has the same Black-Scholes value, the same option delta, and the same option vega as the estimated option portfolio.[11] In this step, we lose five CEOs for whom we cannot numerically solve this system of three equations in three unknowns.

We take the firm's market capitalization P_0 from the end of the 2005 fiscal year. While our formulae above abstract from dividend payments for the sake of simplicity, we take dividends into account in our empirical work and use the dividend rate d from 2005. We estimate the firm's stock return volatility σ from daily CRSP stock returns over the fiscal year 2006 and drop all firms with fewer than 220 daily stock returns on CRSP. We use the CRSP/Compustat Merged Database to link ExecuComp with CRSP data. The risk-free rate is set to the U.S. government bond yield with five-year maturity from January 2006.

We estimate the non-firm wealth W_0 of each CEO from the ExecuComp database by

[10] We do not take into account pension benefits, because they are difficult to compile and because there is no role for pensions in a one-period model. Pensions can be regarded as negative risk-taking incentives (see Sundaram and Yermack, 2007, and Edmans and Liu, 2010), so that we overestimate risk-taking incentives in observed contracts.

[11] Appendix F contains more details about this algorithm. We take into account the fact that most CEOs exercise their stock options before maturity by multiplying the maturities of the individual option grants by 0.7 before calculating the representative option (see Huddart and Lang, 1996, and Carpenter, 1998). In these calculations, we use the stock return volatility from ExecuComp and, for the risk-free rate, the U.S. government bond yield with 5-year maturity from January 2006. Data on risk-free rates have been obtained from the Federal Reserve Board's website. For CEOs who do not have any options, we set $K = P_0$ and $T = 10$ (multiplied by 0.7) as these are typical values for newly granted options.

assuming that all historic cash inflows from salary and the sale of shares minus the costs of exercising options have been accumulated and invested year after year at the one-year risk-free rate. We assume that the CEO had zero wealth when he entered the database (which biases our estimate downward) and that he did not consume since then (which biases our estimate upward).[12] To arrive at meaningful wealth estimates, we discard all CEOs who do not have a history of at least five years (from 2001 to 2005) on ExecuComp. During this period, they need not be CEO. This procedure results in a data set with 727 CEOs.

Table 1 provides an overview of our data set. The median CEO owns 0.32% of the stock of his company and has options on an additional 0.92% of the company's stock. The median base salary is \$1.04m, and the median non-firm wealth is \$12.0m. The representative option has a median maturity of 4.4 years and is well in the money with a moneyness (K/P_0) of 72%. Most stock options are granted at the money in the United States (see Murphy, 1999), but after a few years they are likely to be in the money. This is the reason why the representative option grant is in the money for 90% of the CEOs in our sample. In the interest of readability, we call an option with a strike price K that is close to the observed strike price K^d an "at-the-money option." Consequently, we call an option grant "in-the-money" only if its strike price K is lower than the observed strike price K^d.

We require that all CEOs in our data set are included in the ExecuComp database for the years 2001 to 2006, and this requirement is likely to bias our data set towards surviving CEOs, namely those who are older and richer and who work in bigger and more successful firms. Table 1 Panel B describes the full ExecuComp universe of CEOs in 2006. Compared to this larger sample, our CEOs are, on average, one year older and work in bigger firms (+\$450m) with better past performance (1.3% higher return during the past five years). In a robustness

[12]These wealth estimates can be downloaded for all years and all executives in ExecuComp from http://people.few.eur.nl/dittmann/data.htm. They have also been used by Dittmann and Maug (2007) and Dittmann, Maug, and Spalt (2010).

check below, we analyze in how far this selection bias affects our results.

The only parameter in our model that we cannot estimate from the data is the manager's coefficient of relative risk aversion γ. We use $\gamma = 3$ in most of our analysis and provide robustness checks for $\gamma = 0.5$ and $\gamma = 6$. This range includes the risk-aversion parameters used in previous research.[13]

3.4 Measuring Risk-taking Incentives

In the empirical literature on executive compensation, risk-taking incentives are usually measured by the vega of the manager's equity portfolio, i.e. by the partial derivative of the manager's wealth with respect to his own firm's stock return volatility.[14] An exception are Lambert, Larcker and Verrecchia (1991) who work with what we call the "utility adjusted vega", i.e. the partial derivative of the manager's expected *utility* with respect to stock return volatility. However, there is another effect of volatility on managerial utility that - to the best of our knowledge - has been ignored in the empirical literature on risk-taking incentives. Depending on whether or not the CEO has too little or too much incentives to take risk, a rise in volatility respectively increases or decreases firm value and, due to the CEO's equity portfolio, managerial utility. In this subsection, we derive this result formally from our model and propose a new measure of risk-taking incentives that combines the two effects.

In our model, risk-taking incentives are described in the volatility incentive constraint (4.2.7). This constraint can be rewritten as

$$E\left[\frac{dV(W_T)}{dW_T}\frac{dW_T}{dP_T}\frac{dP_T}{d\sigma}\right| e, \sigma\Bigg] = 0 \tag{3.4.1}$$

Substituting in the derivative of the stock price P_T with respect to volatility σ from (4.2.1)

[13] Lambert, Larcker, and Verrecchia (1991) use values between 0.5 and 4. Carpenter (1998) and Hall and Murphy (2000) use $\gamma = 2$. Hall and Murphy (2002) use $\gamma = 2$ and 3.

[14] See, among others, Guay (1999), Rajgopal and Shevlin (2002), Knopf, Nam and Thornton (2002), Habib and Ljungqvist (2005), and Coles, Daniel and Naveen (2006).

yields

$$\Leftrightarrow E\left[\frac{dV(W_T)}{dW_T}\frac{dW_T}{dP_T}\left(\frac{dP_0}{d\sigma}\frac{P_T}{P_0}+P_T\left(-\sigma T+u\sqrt{T}\right)\right)\middle|\, e,\sigma\right]=0. \tag{3.4.2}$$

As $dP_0/d\sigma$ is not random, we can rearrange (3.4.2) as

$$PPS^{ua}\frac{dP_0}{d\sigma}=-\nu^{ua}, \tag{3.4.3}$$

$$\text{where } PPS^{ua}:=E\left[\frac{dV(W_T)}{dW_T}\frac{dW_T}{dP_0}\middle|\, e,\sigma\right]=E\left[\frac{dV(W_T)}{dW_T}\frac{dW_T}{dP_T}\frac{P_T}{P_0}\middle|\, e,\sigma\right] \tag{3.4.4}$$

$$\text{and} \qquad \nu^{ua}:=E\left[\frac{dV(W_T)}{dW_T}\frac{dW_T}{dP_T}P_T\left(-\sigma T+u\sqrt{T}\right)\middle|\, e,\sigma\right]. \tag{3.4.5}$$

Here, PPS^{ua} is the utility adjusted pay-for-performance sensitivity, or the utility adjusted delta, which measures how much the manager's expected utility rises for a marginal stock price increase. Likewise, ν^{ua} is the utility adjusted vega, i.e. the marginal increase in the manager's expected utility for a marginal increase in volatility - assuming that firm value P_0 stays constant.

The first order condition (3.4.3) equates marginal benefits to marginal costs of an increase in volatility from the agent's point of view. The benefits stem from an increase in firm value $dP_0/d\sigma$ in which the manager participates via his incentive pay PPS^{ua}. The costs are given by the decrease of the manager's utility $-\nu^{ua}$ due to higher volatility. Hence, the agent will take an action if only if its benefits exceed its cost, i.e if

$$PPS^{ua}\frac{dP_0}{d\sigma}>-\nu^{ua}\Leftrightarrow\frac{dP_0}{d\sigma}\frac{1}{P_0}>-\frac{\nu^{ua}}{PPS^{ua}}\frac{1}{P_0}. \tag{3.4.6}$$

We therefore define the incentives to avoid risk as

$$\rho:=-\frac{\nu^{ua}}{PPS^{ua}}\frac{1}{P_0}. \tag{3.4.7}$$

Appendix F contains a step by step user's guide on how to numerically calculate risk avoidance ρ.

Equation (3.4.7) defines a hurdle rate: ρ is the required increase in firm value per increase in firm risk that any new project must fulfill in order to be adopted by the CEO.

Consider a project that would increase firm risk by one percentage point, e.g., from 30% to 31%, and let $\rho = 2$. Then the agent takes this project only if it increases firm value by at least 2%. All positive NPV projects that generate less than 2% increase in firm value for each percent of additional risk will be passed up. On the other hand if $\rho < 0$, the agent has incentives to take on risky projects with negative NPV. In the above example of a project that increases firm risk by one percentage point, $\rho = -2$ means that the agent is willing to undertake this project as long as it does not destroy more than 2% of firm value. If $\rho = 0$, the CEO is indifferent to firm risk and will therefore implement all profitable projects irrespective of their riskyness. We refer to ρ as incentives to avoid risk or risk avoidance, and to $-\rho$ as risk-taking incentives.

Our main conceptual result is that the utility adjusted vega alone is not the best measure of risk taking incentives, but that it should be scaled by the utility adjusted delta. To understand why this scaling is necessary, first consider the case where vega is negative, and so the manager wishes to avoid risky, positive-NPV projects. However, this effect is mitigated if the CEO has a high delta as this means that he gains from taking positive-NPV actions. Second, consider the case where vega is positive, and so the manager has an incentive to take risky projects even if they are negative-NPV. Again, this effect is mitigated if the CEO has a high delta as it means that he is hurt by taking negative-NPV actions. Regardless of the sign of vega, the incentives to take too little or too much risk are offset by a high delta, so the measure of risk-taking incentives depends on the ratio of vega to delta.

Table 2, Panel A displays descriptive statistics for the incentives to avoid risk ρ in the observed contract for five values of risk aversion γ. In all cases, risk avoidance ρ is positive for most CEOs; for $\gamma \geq 3$ it is positive for virtually all CEOs. The results in Table 2 are therefore consistent with our assumption that the contracts chosen by the firm do not make CEOs risk-seeking. For $\gamma = 3$, the average ρ is 1.87 and the median is 1.75. This implies that the average

CEO in our sample passes up risky positive NPV projects if they increase fim value by less than 1.87% per percentage point of additional volatility. For lower values of risk aversion γ, risk-avoidance is lower. For $\gamma = 0.5$, the average and median ρ are 0.19.

While risk-avoidance ρ is zero in the first-best optimum, it is positive in the second-best optimum as risk-taking incentives are costly. It is difficult to judge, however, what a plausible optimal level for ρ is, because the optimal level depends on the availability of risky projects: a firm that has only few risky projects will not benefit much from an increase in risk-taking incentives. Nevertheless, a median ρ of 1.75 for $\gamma = 3$ appears large when taking into account that CEO pay typically makes up only about 1% of firm value (see the median of 'value of contract' and 'firm value' in Table 1). A potential reason is that CEOs are less risk averse (see Graham, Harvey, and Puri, 2009), so that $\gamma < 3$. We still use $\gamma = 3$ as the base case in this paper because it is a conservative choice; the fit of our model to the data improves as γ decreases. Another reason why risk avoidance ρ is high in Table 2, Panel A is that major shareholders might not be well diversified and therefore want to take inefficiently low risk (see Faccio, Marchica, and Mura, 2010).

3.5 Empirical Results

In this section, we calibrate the optimal contract (3.2.10) to the data and evaluate how well it approximates observed contracts. We assume that shareholders want to implement a certain action $\{e^*, \sigma^*\}$ and that they have done so in the observed contract.[15] Under this assumption, we can reformulate the shareholder's optimization problem (4.2.3) to (4.2.5) as follows (see

[15]This calibration method has first been used by Dittmann and Maug (2007). It is the first stage of the two-stage procedure in Grossman and Hart for the effort/volatility level implemented by the observed contract. We cannot repeat this task for alternative effort/volatility levels, because this would require knowledge of the production and the cost function. Therefore we cannot analyze the optimal level of effort or volatility (i.e., the second stage in Grossman and Hart, 1983).

Appendix D for the derivation):

$$\min_{c_0,c_1,c_2} E\left[W_T^*(P_T|c_0,c_1,c_2)\right] \tag{3.5.1}$$

$$\text{subject to } E\left[V(W_T^*(P_T|c_0,c_1,c_2))\right] = E\left[V(W_T^d(P_T))\right] \tag{3.5.2}$$

$$PPS^{ua}(W_T^*(P_T|c_0,c_1,c_2)) = PPS^{ua}(W_T^d(P_T)) \tag{3.5.3}$$

$$\rho(W_T^*(P_T|c_0,c_1,c_2)) = \rho(W_T^d(P_T)), \tag{3.5.4}$$

where $W_T^d(P_T) = \phi^d + n_S^d P_T + n_O^d \max\{P_T - K^d, 0\}$ is the observed contract (d for "data") that we construct from the data as described in Section 3.3. Intuitively, we search for the contract $W_T(P_T|c_0,c_1,c_2)$ with shape (3.2.10) that achieves three objectives. First it provides the same effort and risk-taking incentives to the agent as the observed contract (conditions (3.5.3) and (3.5.4)). Second it provides the agent with the same utility as the observed contract (condition (3.5.2)), and third it is as cheap as possible for the firm (objective (3.5.1)).[16] If our model is correct and descriptive of the data, the cheapest contract found in this optimization will be identical to the observed contract. If the new contract differs substantially, the observed contract is not efficient according to the model: it is possible to find a cheaper contract that implements the same effort and the same strategy as the observed contract. In this case, either compensation practice is inefficient or the model is incorrect. In both cases, the model is not descriptive of the data.

Figure 3.5.1 shows our calibration results for a representative CEO.[17] The solid line represents the optimal contract W_T^* that solves the optimization problem (3.5.1) to (3.5.4), and the dotted line is the observed contract W_T^d. The figure shows the CEO's end-of-period

[16]Note that we have as many constraints in problem (3.5.1) to (3.5.4) as we have parameters, so that there are no degrees of freedom left to minimize costs. Therefore, we solve a system of three equations (3.5.2) to (3.5.4) in three unknowns for every CEO in our sample. The resulting contract has the optimal shape and therefore must be cheaper than the observed contract.

[17]For each parameter (observed salary ϕ^d, observed stock holdings n_S^d, observed option holdings n_O^d, wealth W_0, firm size P_0, stock return volatility σ, time to maturity T, and moneyness K/P_0) and each CEO we calculate the absolute percentage difference between individual and median value. Then we calculate the maximum difference for each CEO and select the CEO for whom this maximum difference is smallest.

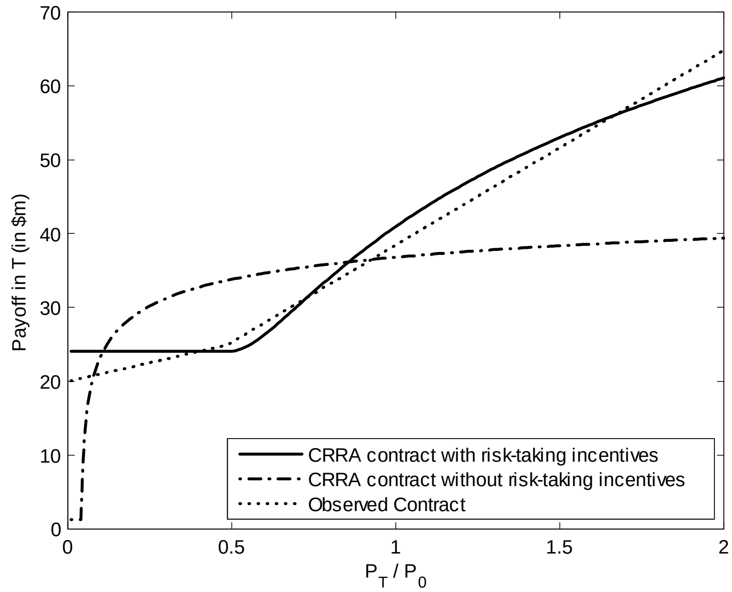


Figure 3.5.1: The figure shows end of period wealth W_T for the observed contract (dotted line), the optimal CRRA contract with risk-taking incentives (solid line), and the optimal CRRA contract without risk-taking incentives (dashed line) for a representative CEO whose parameters are close to the median of the sample. The parameters are $\phi = \$1.1$m, $n_S = 0.33\%$, $n_O = 0.57\%$ for the observed contract. Initial non-firm wealth is $W_0 = \$15.6$m. $P_0 = \$2.8$bn, $\sigma = 27.9\%$, and $K/P_0 = 49\%$, $T = 4.2$ years, $r_f = 4.4\%$, $d = 1.8\%$. All calculations are for $\gamma = 3$.

wealth W_T as a function of end-of-period stock price P_T which we express as a multiple of the beginning-of-period stock price P_0. The optimal contract with risk-taking incentives protects the CEO from losses. It provides the CEO with a flat wealth of \$24m if the stock price falls below 49% of the initial stock price. Intuitively, limiting the downside for bad outcomes provides better (i.e., cheaper) risk-taking incentives than rewarding good outcomes. In the region between 49% and 70% of the initial stock price, the contract is increasing and convex. For larger stock prices, the contract is concave. The reason for the concavity is the CEO's decreasing marginal utility: the richer the CEO is, the less interested he is in additional wealth.

As a benchmark, we also calibrate the optimal contract without risk-taking incentives from Dittmann and Maug (2007); it is the broken line in Figure 3.5.1. For this purpose, we solve the optimization problem (3.5.1) to (3.5.3) without the volatility incentive constraint (3.5.4) and use the contract shape $W_T^*(P_T|c_0, c_1) = (c_0 + c_1 \ln P_T)^{1/\gamma}$. We call this contract the *benchmark contract* or the *CRRA-contract* while we refer to the contract from the full model as the *RTI contract* or, more precisely, the *CRRA-RTI contract*. Figure 3.5.1 shows that the benchmark contract is globally concave and puts the agent's entire wealth at risk. As a consequence, it makes the agent extremely averse to taking additional risk. For the full sample, Table 2, Panel B shows descriptive statistics for the incentives to avoid risk, ρ, for the benchmark contract. For $\gamma = 3$, average ρ is 9.43 compared to 1.87 in the observed contract.[18] With the benchmark contract, the agent will therefore be willing to increase firm risk by one percentage point only if the additional project increases firm value by at least 9.43%. Note that by construction the RTI contract has the same ρ as the observed contract.

The figure suggests that the model with risk-taking incentives (solid line) fits the observed contract (dotted line) much better than the model without risk-taking incentives (broken line). To quantify this visual impression, we calculate for both models the average distance between the contract W_T^* predicted by the model and the observed contract W_T^d:

$$D_1 = E\left(\frac{\left|W_T^*(P_T) - W_T^d(P_T)\right|}{W_T^d(P_T)}\right). \tag{3.5.5}$$

We recognize that the observed contract we construct in Section 3.3 is a stark simplification of the contracts used in practice, especially because typical contracts contain several grants of stock options with different maturities and different strike prices. Contracts are therefore in general not piecewise linear with just one kink but have a more complicated shape. To address

[18]For 94% of all CEO-γ combinations, risk-avoidance ρ is higher in the RTI contract than in the observed contract (not shown in the table). The remaining 6% mostly occur for $\gamma = 6$ and are very likely due to to numerical problems, because the benchmark contract is much steeper for small values of P_T for $\gamma = 6$ than it is for $\gamma = 3$. When the contract approaches zero, differences between very small and very large numbers occur in the numerical routines that cannot be handled well numerically. This is also the reason why the 90% quantile of ρ is lower for $\gamma = 6$ than for $\gamma = 0.5$ or $\gamma = 3$. We therefore conclude that risk-taking incentives are always costly in our model and that firms will never choose a contract that makes the CEO risk-seeking.

this caveat, we consider a second distance metric

$$D_2 = E\left(\frac{\left|W_T^*(P_T) - W_T^{smth}(P_T)\right|}{W_T^{smth}(P_T)}\right), \tag{3.5.6}$$

where $W_T^{smth}(P_T)$ sums up the expected value of all option grants held by the CEO. For a grant that has a maturity larger than T, this is just the Black Scholes value for the remaining maturity given P_T. For a grant that has a maturity smaller than T, we calculate the expected value of the option at maturity given P_0 and P_T and assume that this amount is invested at the risk-free rate for the remaining time between maturity and T. In this way, we obtain a smooth contract for all CEOs who have at least two different option grants. For CEOs with only one option grant, $W_T^{smth}(P_T) = W_T^d(P_T)$. We explain the construction and calculation of W_T^{smth} in more detail in Appendix E. For the representative CEO shown in Figure 1, the distance is 5.2% for the contract with risk-taking incentives and 22.2% for the contract without risk-taking incentives. The representative CEO has only one option grant, so both distance measures have the same value in this case.

Table 3, Panel A shows the results for all CEOs in our sample. The left part of the table describes the optimal contract with risk-taking incentives for three values of constant relative risk-aversion γ. We do not tabulate the parameters c_0, c_1, and c_2, as they cannot be interpreted independently from each other. Instead, the table shows mean and median of a few key variables that describe the contract. These variables include the two distance measures D_1 and D_2 from (3.5.5) and (3.5.6) and the manager's minimum wealth ($\min W_T^*(P_T)$) scaled by non-firm wealth W_0. In addition, the table shows two probabilities. First, the kink quantile is the probability that the contract pays out the minimum wage in the flat region of the contract; formally, this is $\Pr(\mathrm{P}_T \leq -\frac{c_1}{2c_2})$ from equation (3.2.10). Second, the inflection quantile is the probability mass below the point where the contract curvature changes from convex to concave.

Table 3 demonstrates that the optimal contract provides the agent with comprehensive downside protection. For $\gamma = 3$, the median minimum wealth is 1.4 times the initial wealth W_0. Only for 0.1% of the CEOs in our sample is the minimum wealth lower than their observed non-firm wealth W_0. The contract pays out the minimum wage for the worst outcomes with a median probability of 16.1%. The median inflection quantile is 32.5%, so that the contract is convex for mediocre performance between the 16.1% quantile and the 32.5% quantile and concave for good performance above the 32.5% quantile.

Table 3, Panel A also shows the savings firms could realize when they switch from the observed contract to the optimal contract. These savings are defined as

$$savings = \left[E\left(W_T^d(P_T)\right) - E\left(W_T^*(P_T)\right)\right] / E\left(W_T^d(P_T)\right).$$

For $\gamma = 3$, mean (median) savings are 10.4% (6.9%). The mean distance D_1 between observed contract and optimal contract is 8.0%, and the mean distance D_2 is 8.6%. For lower values of risk aversion γ, we obtain a better fit: For $\gamma = 0.5$, the average distance D_1 is only 2.5%. Contracts are then convex over a larger range of stock prices from the 1.7% quantile to the 77.7% quantile for the median CEO. Savings from recontracting are smaller for lower values of risk aversion γ, because savings are generated by efficient risk sharing which is less important if the CEO is less risk averse. Conversely, we find a worse fit for higher values of risk aversion γ. The region of convexity shrinks relative to our benchmark case $\gamma = 3$ and the distance to the observed contract increases according to all measures.

The right part of Table 3 displays the results for the benchmark model without risk-taking incentives. This contract does not contain any downside protection, so the CEO can potentially lose all her wealth. Moreover, it is globally concave for all CEOs if $\gamma > 1$, so that the kink quantile and the inflection quantile are both zero. Due to convergence problems, the sample for the two sets of results in Table 3, Panel A is not the same. We therefore report the numbers again in Panel B for the subsample of CEOs for whom we obtain convergence for both models. This panel shows that the model with risk-taking incentives approximates observed contracts much better than the benchmark model. For $\gamma = 3$, the average distance D_1 is 28.3% for the benchmark model compared to 8.0% for the RTI model. The savings from recontracting are also much higher for the benchmark model than for the RTI model. The benchmark model suggests that shareholders leave 34.5% of contracting costs on the table while the RTI model puts this number at 10.4% only. These numbers suggest that risk-taking incentives play an important role in observed compensation contracts. Observed contracts appear markedly less inefficient when risk-taking incentives are taken into account.

3.6 Robustness checks

3.6.1 Constant absolute risk aversion

The CEO's attitude to risk is central to our model. So far we have assumed that the CEO's preferences exhibit constant relative risk aversion (CRRA). To see whether our results are robust to alternative assumptions on CEO risk aversion, we repeat our analysis from Table 3 with constant absolute risk aversion (CARA), so that $V^{CARA}(W_T) = -\exp(-\eta W_T)$ replaces $V(W_T)$ in equation (4.2.2). Taking the first derivative and plugging the result into equation (3.2.9) from Proposition 1 yields the following corollary:

Corollary 1 *(Optimal CARA contract): If the agent exhibits constant absolute risk aversion with parameter η, the optimal contract has the following functional form:*

$$W_T^* = \begin{cases} \frac{1}{\eta}\log\left\{\eta\left[c_0 + c_1 \ln P_T + c_2(\ln P_T)^2\right]\right\} & \text{if } ln(P_T) > -\frac{c_1}{2c_2} \\ \frac{1}{\eta}\log\left\{\eta\left[c_0 - \frac{c_1^2}{4c_2}\right]\right\} & \text{if } ln(P_T) \leq -\frac{c_1}{2c_2} \end{cases} \tag{3.6.1}$$

To maintain comparability with our previous results, we calculate the coefficient of absolute risk aversion η from γ so that both utility functions exhibit the same risk-aversion at the expected end-of-period wealth. More precisely, we set $\eta = \gamma/(W_0 \exp(r_f T) + \pi_0)$, where π_0 is the market value of the manager's contract. Results are shown in Table 4.

Table 4 demonstrates that all our results continue to hold with CARA utility. In particular, the CARA-RTI model generates a much better fit than the CARA model, it guarantees a minimum payout that is always higher than the CEO's nonfirm wealth, and it is convex for intermediate payouts and concave for good payouts.

3.6.2 Sample selection bias

Our data set is subject to a moderate survivorship bias, as we require that CEOs are covered by the ExecuComp database for at least five years. Table 1 demonstrates that younger and less successful CEOs are underrepresented in our data set. We therefore divide our sample in quintiles according to four variables: CEOs' non-firm wealth W_0, CEO age, firm value P_0, and the past five years' stock return. Table 5 displays for these subsamples the average distance D_1, and, in the last line, the p-value of the Wilcoxon test that the average distance is identical in the first and the fifth quintile. This analysis is done for $\gamma = 3$.

The table shows that the model fit is worse for younger and less wealthy CEOs. For the 20% youngest and the 20% least wealthy CEOs, we find an average distance of 11.7% and, respectively, 11.4% compared to 8.0% for the full sample (see Table 3). Given that our sample is biased towards older and more wealthy CEOs, the average distance in the unbiased sample would be somewhat higher than shown in Table 3. We find the opposite effect, however, for past performance: the 20% best-performing firms have an average distance of 10.6%. As we oversample firms with good performance, the average distance in Table 3 should be adjusted downwards. Altogether, the effect of the sample bias on our results is therefore small.

3.7 Optimal contracts when CEOs are loss averse

Our analysis in Section 3.5 shows that the RTI model can explain observed contracts reasonably well and certainly much better than the benchmark model without risk-taking incentives. Dittmann, Maug, and Spalt (2010) propose an alternative model without risk-taking incentives where the manager is loss averse. They also calibrate the model to the data and show that it fits the data reasonably well. In this section, we therefore compare the CRRA-RTI model and the loss-aversion model (henceforth: LA model) and investigate whether the LA model can be further improved by taking into account risk-taking incentives.

3.7.1 The standard loss-aversion model

Loss-aversion preferences are given by (see Tversky and Kahneman, 1992)

$$V^{LA}\left(W_T\right)=\begin{cases}\left(W_T-W^R\right)^{\alpha} & if \quad W_T\geq W^R\\ -\lambda\left(W^R-W_T\right)^{\beta} & if \quad W_T<W^R\end{cases}, \text{ where } 0<\alpha,\beta<1 \text{ and } \lambda\geq 1. \quad (3.7.1)$$

Here, W^R is the agent's reference wealth level. Payouts above this level are coded as gains, while payouts below are coded as losses. The agent is risk-averse over gains and risk-seeking over losses, and losses receive a higher weight ($\lambda > 1$) than gains. The utility $U^{LA}(W_T, e) = V^{LA}(W_T) - C(e)$ then replaces equation (4.2.2). Following Dittmann, Maug, and Spalt (2010), we use $\alpha = \beta = 0.88$ and $\lambda = 2.25$ and parameterize reference wealth W^R by

$$W^R_{2006} = W_0 + \phi_{2005} + \theta \cdot MV(n^S_{2005}, n^O_{2005}, P_{2006}),$$

where $MV(.)$ denotes the market value of last year's stock and option portfolio evaluated at this year's market price. Reference wealth therefore equals the sum of nonfirm wealth W_0, last year's fixed salary ϕ, and a portion θ of today's market value of the stock and options held last

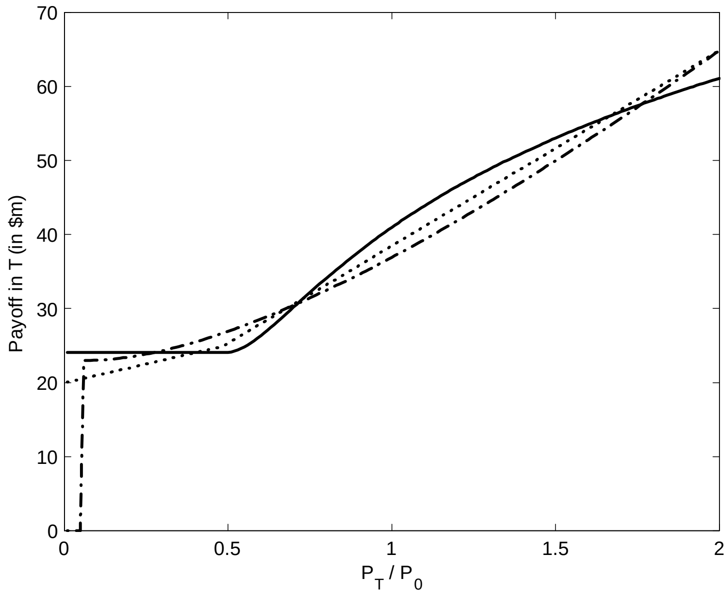


Figure 3.7.1: The figure shows end-of-period wealth W_T of three different contracts for the same representative CEO as Figure 1. The dotted line shows the observed contract; the solid line displays the optimal CRRA contract with risk-taking incentives for $\gamma = 3$; and the dashed line shows the optimal LA contract for $\theta = 0.1$.

period. Dittmann, Maug, and Spalt (2010) show that the model fits the data best for $\theta = 0.1$ and we therefore consider three values of θ: 0.1, 0.5, and 0.9.

Figure 3.7.1 shows the LA contract for $\theta = 0.1$ together with the CRRA-RTI contract for $\gamma = 3$ and the observed contract for the representative CEO. Visual inspection shows that both models fit the observed contract reasonably well. However, there are two important differences: First, while the LA contract is convex over all realistic stock price outcomes, the CRRA-RTI contract is concave for medium and large stock prices. Second, the LA contract features a discontinous jump for very low stock prices from a payout just above the reference point to the lowest possible payout of zero. As a consequence, the LA model approximates the observed contract poorly for very small stock prices, but seems to do a better job than the CRRA-RTI model for high stock prices.

Table 6 displays our results for the LA model for three different values of reference wealth as parameterized by θ. In addition to mean and median of the two distance metrics D_1 and D_2, and the savings, the table shows the average probability that the terminal payout is zero (the "jump quantile") and the inflection quantile where the contract changes from convex to concave. We find that the LA model with $\theta = 0.1$ approximates the observed contract better than the CRRA-RTI model with $\gamma = 3$. The median distance D_1 is 4.3% for the LA model compared with 6.9% for the CRRA-RTI model (see Table 3).[19] For higher reference wealth, however, the LA model is considerably worse than the RTI model for any of the risk-aversion parameters considered ($\gamma = 0.5$, 3, and 6). The reason is that the probability that the CEO ends up with zero wealth is low only for very low reference wealth. For $\theta = 0.5$, the average jump quantile is 3.47% and for $\theta = 0.9$ it is 9.36%. We therefore conclude that the LA model is superior only for a rather specific choice of parameterization. In contrast, the CRRA-RTI model offers a reasonable approximation of the observed contract that is more robust to changes in the preference parameter.

3.7.2 Risk-taking incentives in the loss-aversion model

CEO preferences are different in the loss-aversion model compared to the CRRA model. Hence, risk-taking incentives differ between the two models. Table 8, Panel A displays descriptive statistics of risk avoidance ρ in the LA model for the observed contract. A comparison with Table 2, Panel A shows that risk avoidance in the observed contract is considerably lower if the CEO is loss-averse than if he exhibits constant relative risk aversion. In the LA-model with $\theta = 0.1$, mean and median ρ are both close to zero, and 48.7% of the CEOs have negative ρ, i.e. incentives to take on too much risk. For larger values of θ, ρ increases somewhat but is always much lower than the average 1.87 we find for the CRRA-model with $\gamma = 3$.

[19] Across all models and all specifications, the CRRA-RTI model with $\gamma = 0.5$ has the best fit. However, we do not regard the CRRA model with $\gamma = 0.5$ as reasonable, because the model then implies unrealistic portfolio decisions. A CEO with $\gamma = 0.5$ would borrow heavily and invest much more than his entire wealth into the market portfolio.

Table 7, Panel B shows similar statistics for ρ in the LA contract. Risk-taking incentives do not differ much between observed contracts and optimal contracts in the LA model. On average, ρ decreases somewhat for $\theta = 0.1$ and $\theta = 0.5$, and increases slightly for $\theta = 0.9$. This is in stark contrast to the CRRA model, where the optimal contract generates severely higher ρ compared to the observed contract (see Table 2). The reason is that the cost effective way to provide effort incentives in the CRRA-model is to punish the agent for very low outcomes, and this policy severely increases risk avoidance. In the LA model, on the other hand, cost effective effort incentives consist not only of sticks but also of carrots in the form of convex payouts for medium and high outcomes. While the sticks reduce effort incentives, the carrots increase them, and the overall effect can go in both directions. As a consequence, our assumption that the contract chosen by the firm does not make the CEO risk-seeking does not hold in general for the LA model.

To analyze risk-taking incentives in the loss-aversion model in more detail, we distinguish six cases, depending on whether or not risk-avoidance is higher in the LA model than in the observed contract and on whether one or both of the risk-avoidance measures are positive. Table 7, Panel C defines these six cases and displays how often each of them applies for the three different values of θ. There are only two cases (cases 1 and 4) where risk-taking incentives are unambiguously worse in the LA model than in the observed contract, so that augmenting the model with risk-taking incentives might improve its fit. In cases 2 and 5, risk-taking incentives are better (i.e. ρ is closer to zero) in the LA model than in the observed contract, so there is no room for improvements.

The only case that is consistent with our assumptions is case 1. Note that for the CRRA model with $\gamma = 3$, 99.3% of all CEOs fall into this category (see Table 2). For this case, we derive the shape of the optimal LA-RTI contract in Appendix C and then calibrate it to the observed contract for those CEOs where case 1 applies. The results are shown in Table 8 which is structured similarly to Table 3. The table shows that the probability that the CEO ends up with zero wealth is much lower for the LA-RTI model compared to the LA model. For $\theta = 0.5$, this probability decreases from 6.7% to 3.1% on average. Removing the punishment for poor outcomes increases risk-taking incentives, and the LA-RTI model has a slightly better fit than the LA model if $\theta \leq 0.5$. For $\theta = 0.9$, however, the average distance metrics are higher for the LA-RTI model compared to the LA model. In many cases, the optimal LA-RTI contract has a poor fit, because it is flat at the reference wealth for small and intermediate payouts and takes off with strong convexity only for high payouts. Altogether we therefore conclude that the LA-RTI model does not yield any significant improvements over the LA model. We conclude that risk-taking incentives are less of an issue if managers are loss-averse, because the LA model does not reduce risk-taking incentives nearly as much as the CRRA model.

3.8 Conclusions

In this paper we analyze a principal-agent model in which the agent not only exerts effort but also determines the firm's strategy and thereby its stock return volatility. In this model, the choice of a more risky firm strategy has two effects on the manager's compensation. The first, obvious effect is that higher volatility makes future payoffs more risky, so that the utility a risk-averse manager derives from restricted stock drops. This effect has already been analyzed extensively in the literature (see Lambert, Larcker and Verrecchia, 1991; Guay, 1999; Carpenter, 2000; Ross, 2004). The second effect that has so far been neglected by the empirical literature is that a more risky firm strategy also affects expected firm value. In a situation where the firm takes inefficiently low risk, risk-taking increases firm value and therefore, via the CEO's equity portfolio, CEO wealth. While this is the relevant situation in equilibrium when the

CEO is risk-averse, there is another case that might apply out of equilibrium or for alternative preference specifications, like loss-aversion. Then the firm takes inefficiently high risk and risk-taking reduces firm value and CEO wealth. Therefore, it is not enough to just look at the direct impact of an increase in risk on a manager's compensation package (vega) in order to determine his attitude towards an increase in risk. The indirect effect via a change in firm value and the manager's equity portfolio (delta) must also be taken into account. Our paper provides - to the best of our knowledge - the first empirical analysis of a full principal agent model that takes both effects into account. We also propose a new measure of risk-taking incentives that combines the CEO's preferences and the curvature of the contract and predicts which risky projects the CEO will adopt.

Our model predicts an optimal contract that has a limited downside and a steep slope for intermediate outcomes. It is flat for low performance, increasing and convex for intermediate performance, and increasing and concave for high performance. The optimal contract is therefore reminiscent of a standard bonus scheme that is capped from below as well as from above (see Murphy, 2001, and Healy, 1985). Our calibration results show that the model contract approximates the observed contract well. Across all CEOs, the average distance between the two contracts is 8.0% for a CRRA parameter of 3. In contrast, a model that does not take into account risk-taking incentives differs from the observed contract by 28.8%.

We also calibrate the loss-aversion (LA) model from Dittmann, Maug, and Spalt (2010) to our data and find an average distance of 5.8% for a low reference point. For higher reference points, however, the model is considerably worse than the risk-aversion model with risk-taking incentives (CRRA-RTI). Altogether, it is therefore unclear which model is more successful. The main difference between the two models is that the LA model predicts a discontinuous jump to the lowest possible payout for poor performance while the CRRA–RTI model predicts a flat payout. On the other hand, the LA model is convex over all realistic outcomes whereas the CRRA–RTI model becomes concave for high outcomes. Note that observed contracts are linear for high outcomes, so both models necessarily have an approximation error. We also show that the fit of the LA model does not improve much (and sometimes even gets worse) when risk-taking incentives are taken into account. While risk-taking incentives are neccessary to explain observed contracts in the risk-aversion model, they are not needed in the loss-aversion model.

A limitation of our analysis is that our model is static and considers only two points in time: the time of contract negotiation and the time when the final stock price is realized. Realistically, a bad or unlucky CEO is likely to be replaced if the stock price drops by more than 50%.[20] Such a dismissal has two consequences. First it might affect firm performance if the new CEO is more skilled than the ousted CEO. This effect is beyond the scope of our model, as at least two periods are necessary to describe it. Second, dismissals negatively affect the payout of the ousted CEO, mainly because it reduces the CEO's future employment opportunities. Our model predicts a flat pay for low levels of stock price, so this negative effect of a dismissal is undesirable. Consequently, our analysis can also be interpreted as a justification of severance pay that compensates the manager for his loss in human capital (see Yermack, 2006).

3.9 Tables and Figures

[20] Coughlan and Schmidt (1985), Kaplan (1994), and Jenter and Kanaan (2010), among others, analyze the sensitivity of dismissals to past stock price performance.

Table 1: Description of the dataset

This table displays mean, median, standard deviation, and the 10% and 90% quantile of the variables in our dataset. Stock holdings n_S and option holdings n_O are expressed as a percentage of all outstanding shares. Panel A describes our sample of 727 CEOs from 2006. Panel B describes all 1,490 executives in the ExecuComp universe who are CEO in 2006.

Panel A: Data set with 727 U.S. CEOs

Variable		Mean	Std. Dev.	10% Quantile	Median	90% Quantile
Stock (%)	n_S	1.83%	4.94%	0.04%	0.32%	4.68%
Options (%)	n_O	1.37%	1.62%	0.14%	0.92%	3.17%
Base Salary ($m)	ϕ	1.64	4.47	0.51	1.04	2.43
Value of Contract ($m)	π_0	159.63	1,700.06	4.58	24.97	172.74
Non-firm Wealth ($m)	W_0	62.8	667.0	2.5	12.0	72.2
Firm Value ($m)	P_0	9,294	22,777	377	2,387	20,880
Strike Price ($m)	K	6,829	19,803	269	1,539	13,799
Moneyness (%)	K/P_0	70.1%	21.7%	41.2%	72.0%	100.0%
Maturity (years)	T	4.6	1.4	2.8	4.4	6.4
Stock Volatility (%)	σ	30.0%	13.4%	16.4%	28.3%	45.5%
Dividend Rate (%)	d	1.24%	2.25%	0.00%	0.63%	3.30%
CEO Age (years)		56.0	6.8	47	56	64
Stock Return 2001-5 (%)		11.8%	15.6%	-5.7%	11.4%	28.7%

Panel B: All 1,490 ExecuComp CEOs in 2006

Variable		Mean	Std. Dev.	10% Quantile	Median	90% Quantile
Stock (%)	n_S	1.95%	6.26%	0.02%	0.28%	4.22%
Options (%)	n_O	1.26%	1.57%	0.08%	0.79%	2.88%
Base Salary ($m)	ϕ	1.68	4.01	0.48	1.02	2.63
Firm Value ($m)	P_0	8,840	24,760	339	2,091	17,796
CEO Age (years)		55.1	7.1	46	55	64
Stock Return 2001-5 (%)		10.5%	23.2%	-13.8%	9.8%	34.1%

Table 2: Risk avoidance with Constant Relative Risk Aversion (CRRA)

This table displays descriptive statistics for risk avoidance ρ from equation (3.4.7) for five different values of the CRRA-parameter γ. Panel A shows results for the observed contract. Panel B displays results for the optimal CRRA-contract that does not take risk-taking into account.

Panel A: Observed contract

γ	Obs.	Mean	Standard Deviation	10% Quantile	Median	90% Quantile	Proportion with $\rho > 0$
0.5	727	0.19	0.39	-0.30	0.19	0.64	70.2%
1	727	0.62	0.56	-0.08	0.59	1.31	87.5%
2	727	1.33	0.86	0.30	1.25	2.43	96.8%
3	727	1.87	1.07	0.60	1.75	3.38	99.3%
6	727	2.91	1.50	1.13	2.68	4.88	99.7%

Panel B: Optimal CRRA-contract without risk-taking incentives

γ	Obs.	Mean	Standard Deviation	10% Quantile	Median	90% Quantile	Proportion with $\rho > 0$
0.5	727	1.32	0.63	0.62	1.26	2.11	99.9%
1	726	2.40	1.12	0.99	2.40	3.71	100.0%
2	727	5.74	18.92	3.64	6.71	8.58	99.9%
3	726	9.43	17.21	6.75	10.34	13.02	99.7%
6	652	12.04	7.25	0.02	15.02	18.77	99.4%

Table 3: Optimal CRRA contracts with and without risk-taking incentives

This table describes the optimal contracts according to the CRRA-RTI model from equation (10) and the CRRA model from Dittmann and Maug (2007) for three different values of the CRRA parameter γ. The table displays mean and median of six measures that describe the optimal contract. The two distance metrics D_1 and D_2 are defined in equations (3.5.5) and (3.5.6). *Savings* are the difference in compensation costs between observed contract and optimal contract expressed as a percentage of costs of the observed contract, $(\pi_0^d - \pi_0^*)/\pi_0^d$. *Minimum wealth* is the lowest possible payout of the contract expressed as a multiple of the CEO's non-firm wealth W_0. The *kink quantile* is the probability that the end-of-period stock price P_T is smaller than the point where the wage schedule $W(P_T)$ starts to increase. The *inflection quantile* is the probability that the end-of-period stock price P_T is smaller than the point where the wage scheme turns from convex to concave. Panel A displays these statistics for all CEOs in our sample. The number of observations varies across different values of γ and across the two models due to numerical problems and because we exclude all CEO-γ-combinations for the CRRA-RTI model for which the observed contract implies negative risk-avoidance ρ from equation (3.4.7). Panel B shows results for those CEO-γ-combinations where we obtain convergence for both models.

Panel A: All results

		CRRA-RTI-Model			CRRA-Model		
		$\gamma = 0.5$	$\gamma = 3$	$\gamma = 6$	$\gamma = 0.5$	$\gamma = 3$	$\gamma = 6$
Distance D_1	mean	2.5%	8.0%	13.1%	14.2%	28.8%	36.5%
	median	1.9%	6.9%	10.2%	12.1%	27.9%	30.9%
Distance D_2	mean	5.8%	8.6%	13.1%	12.7%	26.2%	35.6%
	median	4.0%	7.4%	9.7%	10.9%	25.2%	30.3%
Savings	mean	0.1%	10.4%	30.6%	2.1%	34.7%	53.7%
	median	0.0%	6.9%	27.1%	1.1%	32.7%	54.3%
Minimum wealth	mean	3.1	1.7	1.3	0.0	0.0	0.0
	median	1.3	1.4	1.2	0.0	0.0	0.0
	Prop < 1	11.9%	0.1%	0.8%	100.0%	100.0%	100.0%
Kink quantile	mean	4.8%	19.6%	22.4%	0.0%	0.0%	0.0%
	median	1.7%	16.1%	19.5%	0.0%	0.0%	0.0%
Inflection quantile	mean	78.1%	34.9%	31.4%	2.1%	0.0%	0.0%
	median	77.7%	32.5%	29.3%	0.0%	0.0%	0.0%
Observations		388	688	373	727	726	652

Panel B: Results where numerical routine converges for both models

		CRRA-RTI-Model			CRRA-Model		
		$\gamma = 0.5$	$\gamma = 3$	$\gamma = 6$	$\gamma = 0.5$	$\gamma = 3$	$\gamma = 6$
Distance D_1	mean	2.5%	8.0%	13.5%	13.8%	28.3%	27.0%
	median	1.9%	6.9%	10.7%	11.9%	27.5%	25.0%
Distance D_2	mean	5.8%	8.6%	13.5%	13.0%	25.7%	26.7%
	median	4.0%	7.4%	10.2%	11.1%	24.8%	24.8%
Savings	mean	0.1%	10.4%	31.2%	1.7%	34.5%	54.0%
	median	0.0%	6.9%	28.2%	1.0%	32.1%	55.3%
Observations		388	688	334	388	688	334

Table 4: Optimal contracts for CARA utility

This table contains the results from repeating our analysis from Table 3 under the assumption that the CEO has CARA utility. For three different values of γ, we calculate the CEO's coefficient of absolute risk aversion ρ as $\rho = \gamma / (W_0 \exp(r_f T) + \pi_0)$, where π_0 is the market value of his observed compensation package and W_0 is his initial non-firm wealth. The table displays mean and median of six measures that describe the optimal contract. The two distance metrics D_1 and D_2 are defined in equations (22) and (23). *Savings* are the difference in compensation costs between observed contract and optimal contract expressed as a percentage of costs of the observed contract, $(\pi_0^d - \pi_0^*)/\pi_0^d$. *Minimum wealth* is the lowest possible payout of the contract expressed as a multiple of the CEO's nonfirm wealth W_0. The *kink quantile* is the probability that the end-of-period stock price P_T is smaller than the point where the wage schedule $W(P_T)$ starts to increase. The *inflection quantile* is the probability that the end-of-period stock price P_T is smaller than the point where the wage scheme turns from convex to concave. The number of observations varies across different values of γ due to numerical problems and because we exclude all CEO-γ-combinations for the CARA-RTI model for which the observed contract implies negative risk-avoidance ρ from equation (17). Results are shown for those CEO-γ-combinations only where we obtain convergence for both models.

		CARA-RTI-Model			**CARA-Model**		
		γ = 0.5	**γ = 3**	**γ = 6**	**γ = 0.5**	**γ = 3**	**γ = 6**
Distance D_1	mean	6.8%	9.3%	12.7%	22.2%	23.1%	24.6%
	median	5.7%	8.9%	12.4%	19.7%	22.6%	24.3%
Distance D_2	mean	9.2%	9.8%	12.8%	20.5%	20.4%	23.1%
	median	7.7%	9.1%	11.9%	18.1%	19.5%	22.7%
Savings	mean	2.4%	15.1%	25.8%	6.3%	27.4%	39.9%
	median	0.9%	12.1%	24.8%	3.7%	26.0%	40.2%
Minimum wealth	mean	2.9	2.2	2.0	0.0	0.0	0.0
	median	1.5	1.4	1.4	0.0	0.0	0.0
	Prop < 1	0.0%	0.0%	0.0%	100.0%	100.0%	100.0%
Kink quantile	mean	20.7%	22.9%	18.2%	0.0%	0.0%	0.0%
	median	17.2%	19.3%	14.7%	0.0%	0.0%	0.0%
Inflection quantile	mean	54.6%	36.6%	26.1%	0.0%	0.0%	0.0%
	median	52.6%	33.7%	22.8%	0.0%	0.0%	0.0%
Observations		279	419	594	279	419	594

Table 5: Model fit for subsamples

This table shows mean distance D_1 from equation (22) for quintiles formed according to four variables: initial non-firm wealth W_0, CEO age, firm value P_0, and the past five year stock return (from the start of 2001 to the end of 2005). The risk-aversion parameter γ is set equal to 3. The last row shows the p-value of the two-sample Wilcoxon signed rank test that the average D_1 is identical in Quintile 1 and Quintile 5.

Quin-tile	Wealth W_0 (in \$m)		CEO Age		Firm Value P_0 (in \$m)		Stock return 2001-2005	
	Mean	**D_1**	**Mean**	**D_1**	**Mean**	**D_1**	**Mean**	**D_1**
1	2.6	11.4%	41.9	11.7%	386	8.7%	-18.8%	7.5%
2	6.6	7.8%	48.1	9.4%	1,135	8.5%	3.6%	6.8%
3	12.3	7.5%	52.5	8.1%	2,358	8.1%	11.3%	7.5%
4	26.1	6.8%	57.0	7.0%	5,648	7.2%	18.9%	8.5%
5	270.1	6.8%	64.6	7.6%	32,685	7.8%	43.5%	10.6%
P-Value Q1-Q5		0.0000		0.0040		0.9583		0.0001

Table 6:
Optimal loss aversion contracts without risk-taking incentives

This table describes the optimal contract according to the LA model from Dittmann, Maug, and Spalt (2010) for three different levels of reference wealth W^R parameterized by θ. The table displays mean and median of five measures that describe the optimal contract. The two distance metrics D_1 and D_2 are defined in equations (3.5.5) and (3.5.6). *Savings* are the difference in compensation costs between observed contract and optimal contract expressed as a percentage of costs of the observed contract, $(\pi_0^d - \pi_0^*)/\pi_0^d$. The *jump quantile* is the probability that the end-of-period stock price P_T is smaller than the point where the contract jumps from the lowest possible payout to some payout above the reference wealth. The *inflection quantile* is the probability that the end-of-period stock price P_T is smaller than the point where the wage scheme turns from convex to concave. The number of observations varies across different values of θ due to numerical problems.

		θ = 0.1	**θ = 0.5**	**θ = 0.9**
Distance D_1	mean	5.8%	19.0%	31.7%
	median	4.3%	15.9%	29.0%
Distance D_2	mean	6.4%	17.6%	28.6%
	median	4.5%	15.4%	26.3%
Savings	mean	0.8%	4.8%	9.5%
	median	0.1%	3.8%	8.4%
Jump quantile	mean	0.25%	3.47%	9.36%
	median	0.00%	1.80%	7.79%
Inflection quantile	mean	100%	100%	100%
	median	100%	100%	100%
Observations		715	676	586

Table 7: Risk avoidance when managers are loss averse

This table displays descriptive statistics for risk avoidance ρ from equation (17) for three different levels of reference wealth W^R parameterized by θ. Panel A shows results for the observed contract. Panel B displays results for the optimal LA contract that does not take risk-taking into account. Panel C defines six cases for changes in risk avoidance from the observed contract to the optimal LA contract and reports the relative frequency with which these cases apply for each of the three levels of reference wealth.

Panel A: Observed contract

θ	Obs.	Mean	Standard Deviation	10% Quantile	Median	90% Quantile	Proportion with $\rho > 0$
0.1	727	-0.04	0.28	-0.44	0.01	0.27	51.3%
0.5	727	0.27	0.37	-0.24	0.31	0.72	76.2%
0.9	727	0.41	0.38	-0.12	0.46	0.87	84.6%

Panel B: Optimal LA contract

θ	Obs.	Mean	Standard Deviation	10% Quantile	Median	90% Quantile	Proportion with $\rho > 0$
0.1	715	-0.16	0.63	-0.67	-0.22	0.25	30.8%
0.5	676	-0.13	1.01	-1.06	-0.34	0.88	34.0%
0.9	586	0.55	1.38	-1.30	0.62	2.21	71.8%

Panel C: Changes in risk avoidance

θ	Obs.	Case 1: $\rho^{obs} > 0$ $\rho^{LA} \geq \rho^{obs}$	Case 2: $\rho^{obs} > 0$ $\rho^{LA} \in [0, \rho^{obs})$	Case 3: $\rho^{obs} > 0$ $\rho^{LA} < 0$	Case 4: $\rho^{obs} < 0$ $\rho^{LA} \leq \rho^{obs}$	Case 5: $\rho^{obs} < 0$ $\rho^{LA} \in (\rho^{obs}, 0]$	Case 6: $\rho^{obs} < 0$ $\rho^{LA} > 0$
0.1	715	13.0%	10.5%	27.6%	29.5%	12.2%	7.3%
0.5	676	15.2%	11.2%	50.7%	12.9%	2.4%	7.5%
0.9	586	44.0%	17.6%	24.2%	2.7%	1.2%	10.2%

Table 8: Optimal LA contracts with and without risk-taking incentives

This table describes the optimal contracts according to the LA-RTI model from Appendix C and the LA model from Dittmann, Maug, and Spalt (2010) for three different levels of reference wealth W^R parameterized by θ. The table displays mean and median of five measures that describe the optimal contract. The two distance metrics D_1 and D_2 are defined in equations (3.5.5) and (3.5.6). *Savings* are the difference in compensation costs between observed contract and optimal contract expressed as a percentage of costs of the observed contract, $(\pi_0^d - \pi_0^*)/\pi_0^d$. The *jump quantile* is the probability that the end-of-period stock price P_T is smaller than the point where the contract jumps from the lowest possible payout to some payout above the reference wealth. The *inflection quantile* is the probability that the end-of-period stock price P_T is smaller than the point where the wage scheme turns from convex to concave. The number of observations is small and varies across different values of θ, because we only consider the CEOs from Case 1 in Table 2, Panel C. In the other cases, either our model assumptions are violated or the optimal LA and LA-RTI contracts are identical. We also lose some observations due to numerical problems.

		LA-RTI-Model			**LA-Model**		
		θ = 0.1	**θ = 0.5**	**θ = 0.9**	**θ = 0.1**	**θ = 0.5**	**θ = 0.9**
Distance D_1	mean	2.1%	20.6%	43.0%	2.2%	21.8%	37.3%
	median	0.7%	17.4%	37.7%	1.0%	19.4%	37.1%
Distance D_2	mean	2.2%	18.9%	37.4%	2.2%	20.0%	33.5%
	median	0.8%	15.3%	32.3%	1.3%	17.5%	32.8%
Savings	mean	0.4%	7.3%	8.7%	1.1%	8.3%	11.2%
	median	0.0%	7.5%	8.8%	0.0%	8.0%	10.4%
Jump quantile	mean	0.1%	3.1%	5.3%	0.3%	6.7%	14.3%
	median	0.0%	0.0%	0.1%	0.0%	5.4%	13.5%
Inflection quantile	mean	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%
	median	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%
Observations		75	85	182	75	85	182

3.10 Appendix

Appendix A: First Order Approach

Note that the monotonicity constraint (3.2.4) must hold for every P_T, so that it is actually a continuum of infinitely many restrictions. We first rewrite the restriction as a function of W_T. Let $h(.)$ be the function that maps P_T into W_T: $W_T = h(P_T)$. Then $P_T = h^{-1}(W_T)$, and $\frac{dW_T}{dP_T}(P_T) = h'(h^{-1}(W_T))$. Hence, (3.2.4) can be rewritten as

Like most of the theoretical literature on executive compensation, we work with the first order approach: we replace the incentive compatibility constraint (4.2.5) by the two first-order conditions (4.2.6) and (4.2.7). This approach is only valid if the utility which the agent maximizes has exactly one optimum, and a sufficient condition is that this utility is globally concave. In our model, this sufficient condition does not hold, and it is possible that the first-order approach is violated.

A violation of the first-order approach has two potential consequences. First, the agent might choose a different combination of effort e and volatility σ than under the observed contract. The reason is that our optimization routine only ensures that the pair $\{e^d, \sigma^d\}$ (which is implemented by the observed contract) remains a *local* optimum under the new contract, but we do not require it to be the global optimum (see Lambert and Larcker (2004) and especially the discussion of their Figure 1). Second, a violation of the first-order approach implies that there might be more than one solution to the optimization problem. We tackle the second problem by repeating our numerical optimizations with different starting values, but we do not find any indication that there are multiple solutions for any CEO in our sample. In this appendix, we therefore concentrate on the first problem. In particular, we analyze whether the agent has an incentive under the optimal contract $W^*(P_T)$ to shirk, i.e., to choose effort

$e \neq e^d$ or volatility $\sigma \neq \sigma^d$ such that $P_0(e, \sigma) < P_0^d = P_0(e^d, \sigma^d)$. We ignore deviations that lead to an increase of firm value as shareholders are not likely to worry about this case. For expositional convenience, we say that the first-order approach is violated if the agent shirks under the optimal contract $W^*(P_T)$. In the remaining part of this appendix, we derive two conditions under which the first-order approach is not violated. To simplify the argument, we normalize $P_0(e = 0, \sigma) = P_0(e, \sigma = 0) = 0$ and $C(e = 0) = 0$.

Condition 1 *The agent has no incentives to choose $e = 0$ or $\sigma = 0$, i.e., $E(V(W_T^*)|P_0 = 0) < E(V(W_T^*)|P_0 = P_0^d) - C(e^d) = \underline{U}$.*

The optimal contract W_T^* from (3.2.10) features a lower bound on the payout to the agent. If this lower bound is higher than the agent's outside option $\underline{U}$, the agent will not exert any effort and will choose the lowest feasible volatility. Consequently, the first-order approach is violated. Our first condition therefore states that this is not the case. This assumption appears reasonable, because for the median CEO the minimum payout (\$1.4m, from Table 3, Panel A for $\gamma = 3$) is only 5.6% of the expected payout (\$25.0m, from Table 1). The strong rise in executive compensation during the past three decades has been attributed to a higher outside option or higher rents, but not to an increase in the costs of effort. Therefore, Condition 1 is plausible: No CEO will stop working when he gets a minimum payment of 5.6% of what he can expect with normal effort.

Next, we consider more general (and less extreme) deviations from the target values of effort e^d and volatility σ^d. We show that these deviations are not profitable for the agent when Condition 1 and the following condition hold:

Condition 2 *The production function $P_0(e, \sigma)$ is concave enough, i.e., it is steep enough in e and σ for $e < e^d$ and $\sigma < \sigma^d$ and it is not too steep in e and σ for $e > e^d$ and $\sigma > \sigma^d$.*

We distinguish three cases. First, consider a choice $e \leq e^d$ and $\sigma \leq \sigma^d$, where $e < e^d$ or $\sigma < \sigma^d$. The agent will not deviate in this way if

$$E(V(W_T^*)|e, \sigma) - C(e) < E(V(W_T^*)|e^d, \sigma^d) - C(e^d).$$

This inequality holds if the firm value $P_0(e, \sigma)$ associated with the deviation to (e, σ) is low enough to render this choice unattractive. This is the case if Condition 1 holds and if $P_0(e, \sigma)$ is steep enough in e and σ.

The second case obtains if $e < e^d$ and $\sigma > \sigma^d$. To rule out such a deviation, the punishment for the downward deviation in e must not be fully compensated by the reward for the upward deviation in σ. This is achieved if $P_0(e, \sigma)$ is steep enough in e for $e < e^d$ and not too steep in σ for $\sigma > \sigma^d$. A similar argument applies to the third case if $e > e^d$, $\sigma < \sigma^d$.

Appendix B: Proof of Proposition 1

Note that the monotonicity constraint (3.2.4) must hold for every P_T, so that it is actually a continuum of infinitely many restrictions. We first rewrite the restriction as a function of W_T. Let $h(.)$ be the function that maps P_T into W_T: $W_T = h(P_T)$. Then $P_T = h^{-1}(W_T)$, and $\frac{dW_T}{dP_T}(P_T) = h'(h^{-1}(W_T))$. Hence, (3.2.4) can be rewritten as

$$h'(h^{-1}(W_T)) \geq 0. \tag{3.10.1}$$

For every W_T, (3.2.4) provides one restriction, so the Lagrangian for the differentiation at W_T is:

$$
\begin{aligned}
L_{W_T} = &\int_0^\infty [P_T - W_T]\, g(P_T|e,\sigma)dP_T + \lambda_{PC}\left(\int_0^\infty V(W_T,e)g(P_T|e,\sigma)dP_T - C(e) - \underline{U}\right)\\
&+ \lambda_e\left(\int_0^\infty V(W_T)g_e(P_T|e,\sigma)dP_T - \frac{dC}{de}\right) + \lambda_\sigma \int_0^\infty V(W_T)g_\sigma(P_T|e,\sigma)dP_T\\
&+ \lambda_{W_T} h'(h^{-1}(W_T)),
\end{aligned}
$$

where $g(P_T|e,\sigma)$ is the (lognormal) density function of end-of-period stock price P_T:

$$
g(P_T|e,\sigma) = \frac{1}{P_T\sqrt{2\pi\sigma^2 T}} \exp[-\frac{(\ln P_T - \mu(e,\sigma))^2}{2\sigma^2 T}] \tag{3.10.2}
$$

with

$$
\mu(e,\sigma) = \ln P_0(e,\sigma) + (r_f - \sigma^2/2)T. \tag{3.10.3}
$$

g_e and g_σ are the derivatives of $g(.)$ with respect to e and σ. The first-order condition then is

$$
\begin{aligned}
g(P_T|e,\sigma) = &\lambda_{PC} V_{W_T} g(P_T|e,\sigma) + \lambda_e V_{W_T} g_e(P_T|e,\sigma) + \lambda_\sigma V_{W_T} g_\sigma(P_T|e,\sigma) \\
&+ \lambda_{W_T} \frac{h''(h^{-1}(W_T))}{h'(h^{-1}(W_T))}.
\end{aligned} \tag{3.10.4}
$$

While there is one multiplier λ_{W_T} for each value of W_T, the other three multipliers λ_{PC}, λ_e, and λ_σ are the same across all values of W_T. If the constraint (3.10.1) is binding, equation (3.10.4) defines the Lagrange multiplier λ_{W_T}, and the solution is determined by the binding monotonicity constraint. If (3.10.1) is not binding, λ_{W_T} is zero and the first-order condition (3.10.4) simplifies with some rearranging to

$$
\frac{1}{V_{W_T}(W_T)} = \lambda_{PC} + \lambda_e \frac{g_e}{g} + \lambda_\sigma \frac{g_\sigma}{g}. \tag{3.10.5}
$$

Consequently, the solution is given by (3.10.5) as long as it is monotonically increasing, and flat otherwise.

For the log-normal distribution (3.10.2) we get:

$$g_e = g \cdot \frac{\ln P_T - \mu(e,\sigma)}{\sigma^2 T} \cdot \mu_e(e,\sigma) \tag{3.10.6}$$

$$\begin{aligned} g_\sigma &= g \cdot \frac{[\ln P_T - \mu(e,\sigma)] \cdot \mu_\sigma(e,\sigma) \cdot \sigma^2 T + [\ln P_T - \mu(e,\sigma)]^2 \sigma T}{(\sigma^2 T)^2} - \frac{g}{\sigma} \\ &= g \cdot \frac{[\ln P_T - \mu] \cdot \mu_\sigma \cdot \sigma + [\ln P_T - \mu]^2}{\sigma^3 T} - \frac{g}{\sigma}. \end{aligned} \tag{3.10.7}$$

Substituting this into the first-order condition (3.10.5) yields:

$$\frac{1}{V_{W_T}(W_T)} = \lambda_{PC} + \lambda_e \frac{[\ln P_T - \mu] \cdot \mu_e}{\sigma^2 T} + \lambda_\sigma \left(\frac{[\ln P_T - \mu] \cdot \mu_\sigma \cdot \sigma + [\ln P_T - \mu]^2}{\sigma^3 T} - \frac{1}{\sigma} \right).$$

From inspection, the optimal wage contract can be written as (3.2.9) with parameters c_0, c_1, and c_2:

$$\begin{aligned} c_0 &= \lambda_{PC} - \lambda_e \frac{\mu_e \cdot \mu}{\sigma^2 T} - \lambda_\sigma \left(\frac{\mu \cdot \mu_\sigma}{\sigma^2 T} - \frac{\mu^2}{\sigma^3 T} + \frac{1}{\sigma} \right), \\ c_1 &= \lambda_e \frac{\mu_e}{\sigma^2 T} + \lambda_\sigma \left(\frac{\mu_\sigma}{\sigma^2 T} - \frac{2\mu}{\sigma^3 T} \right), \\ c_2 &= \lambda_\sigma \frac{1}{\sigma^3 T} \geq 0. \end{aligned}$$

Equation (3.2.10) then follows immediately with $V(W_T) = \frac{W_T^{1-\gamma}}{1-\gamma}$.■

Appendix C: Optimal loss aversion contract

Proposition 3 ***(Optimal LA contract):*** *Under the assumptions that (i) the agent is loss-averse as described in (4.2.2) and (3.7.1) and (ii) the stock price P_T is lognormally distributed as described in (4.2.1), the optimal contract $W^*(P_T)$ that solves the shareholders' problem (4.2.3), (3.2.4), (4.2.4), (4.2.6), and (4.2.7) is:*

$$W_T^{*,LA} = \begin{cases} W^R + [\widetilde{w}(P_T)]^{\frac{1}{1-\alpha}} & \text{if } P_T > \widehat{P} \\ 0 & \text{if } P_T \leq \widehat{P} \end{cases}, \tag{3.10.8}$$

where $\widetilde{w}(P_T) := c_0 + c_1 \ln P_T + c_2 (\ln P_T)^2$ and $\widehat{P}$ is the largest solution to

$$\alpha W^R = \widetilde{w}(P_T) \lambda \left(W^R\right)^\beta + (1-\alpha) \left(\widetilde{w}(P_T)\right)^{\frac{1}{1-\alpha}}. \tag{3.10.9}$$

If no solution for $\widehat{P}$ exists to (3.10.9), the optimal contract is

$$W_T^{*,LA} = \begin{cases} W^R + [\widetilde{w}(P_T)]^{\frac{1}{1-\alpha}} & \text{if } ln(P_T) > -\frac{c_1}{2c_2} \\ W^R + \left(c_0 - \frac{c_1^2}{4c_2}\right)^{\frac{1}{1-\alpha}} & \text{if } ln(P_T) \leq -\frac{c_1}{2c_2} \end{cases}. \tag{3.10.10}$$

The parameters c_0, c_1, and c_2 depend on the distribution of P_T and the Lagrange multipliers of the optimization problem, with $c_2 > 0$.

Lemma 1 in Appendix A in Dittmann, Maug and Spalt (2010) continues to hold. This lemma states that the optimal contract never pays off in the interior of the loss space. Together with the assumption that the optimal contract is monotonically increasing, this immediately implies that either the contract pays out in the gain space only or there exists a cut-off value $\widehat{P}$ such that the optimal contract pays out in the gain space for all $P_T > \widehat{P}$ and 0 for all $P_T < \widehat{P}$. We can therefore rewrite the optimization problem as:

$$\min_{\widehat{P}, W_T \geq W^R} \int_{\widehat{P}}^{\infty} W_T g(P_T|e,\sigma) dP_T \tag{3.10.11}$$

$$s.t. \int_{\widehat{P}}^{\infty} V\left(W_T\right) g(P_T|e,\sigma) dP_T + V(0) G(\widehat{P}|e,\sigma) \geq \underline{U} + C\left(e\right), \tag{3.10.12}$$

$$\int_{\widehat{P}}^{\infty} V\left(W_T\right) g_e(P_T|e,\sigma) dP_T + V(0) G_e(\widehat{P}|e,\sigma) \geq C'\left(e\right), \tag{3.10.13}$$

$$\int_{\widehat{P}}^{\infty} V\left(W_T\right) g_\sigma(P_T|e,\sigma) dP_T + V(0) G_\sigma(\widehat{P}|e,\sigma) \geq 0. \tag{3.10.14}$$

Here, $G(P_T)$ is the cumulative distribution function of the lognormal stock price distribution. To keep the proof simple, we do not add the monotonicity constraint to the program at this point. Further below, we check whether the solution to this program satisfies the monotonicity constraint.

The derivative of the Lagrangian with respect to W_T at each point $P_T \geq \widehat{P}$ is:

$$\begin{aligned} \frac{\partial \mathcal{L}}{\partial W_T} =& g(P_T|e,\sigma) - \lambda_{PC} V'\left(W_T\right) g(P_T|e,\sigma) - \lambda_e V'\left(W_T\right) g_e(P_T|e,\sigma) \\ & - \lambda_\sigma V'\left(W_T\right) g_\sigma(P_T|e,\sigma) \end{aligned} \tag{3.10.15}$$

Setting (3.10.15) to zero and solving gives the optimal contract in the gain space as:

$$V'\left(W_T\right) = \left[\lambda_{PC} + \lambda_e \frac{g_e\left(P_T|e,\sigma\right)}{g\left(P_T|e,\sigma\right)} + \lambda_\sigma \frac{g_\sigma\left(P_T|e,\sigma\right)}{g\left(P_T|e,\sigma\right)}\right]^{-1}. \tag{3.10.16}$$

For the Tversky and Kahneman (1992) preferences (3.7.1) we can rewrite (3.10.16) as:

$$W_T = W^R + \left[\alpha\left(\lambda_{PC} + \lambda_e \frac{g_e\left(P_T|e,\sigma\right)}{g\left(P_T|e,\sigma\right)} + \lambda_\sigma \frac{g_\sigma\left(P_T|e,\sigma\right)}{g\left(P_T|e,\sigma\right)}\right)\right]^{\frac{1}{1-\alpha}}. \tag{3.10.17}$$

Substituting the relevant expressions for the lognormal distribution from (3.10.6) and (3.10.7) and rearranging yields

$$W_T = W^R + \left[c_0 + c_1 \ln P_T + c_2 (\ln P_T)^2\right]^{\frac{1}{1-\alpha}}, \tag{3.10.18}$$

where

$$c_0 = \alpha\lambda_{PC} - \alpha\lambda_e \frac{\mu_e \cdot \mu}{\sigma^2 T} - \alpha\lambda_\sigma \left(\frac{\mu \cdot \mu_\sigma}{\sigma^2 T} - \frac{\mu^2}{\sigma^3 T} + \frac{1}{\sigma}\right), \tag{3.10.19}$$

$$c_1 = \alpha\lambda_e \frac{\mu_e}{\sigma^2 T} + \alpha\lambda_\sigma \left(\frac{\mu_\sigma}{\sigma^2 T} - \frac{2\mu}{\sigma^3 T}\right), \tag{3.10.20}$$

$$c_2 = \frac{\alpha\lambda_\sigma}{\sigma^3 T} \geq 0. \tag{3.10.21}$$

Equation (3.10.18) provides the shape of the optimal contract for $P \geq \widehat{P}$ - provided that it is monotonic.

The optimal cut-off point $\widehat{P}$. To find $\widehat{P}$ we take the derivative of the Lagrangian with respect to $\widehat{P}$:

$$\begin{aligned}
\frac{\partial \mathcal{L}}{\partial \widehat{P}} &= \left(-W(\widehat{P})\right) g(\widehat{P}|e,\sigma) + \lambda_{PC} \left(V(W(\widehat{P})) - V(0)\right) g(\widehat{P}|e,\sigma) \\
&\quad + \lambda_e \left(V(W(\widehat{P})) - V(0)\right) g_e(\widehat{P}|e,\sigma) + \lambda_\sigma \left(V(W(\widehat{P})) - V(0)\right) g_\sigma(\widehat{P}|e,\sigma) \qquad (3.10.22)\\
&= -\left(V(W(\widehat{P})) - V(0)\right) g(\widehat{P}|e,\sigma) \left[\frac{W(\widehat{P})}{V(W(\widehat{P})) - V(0)} - \lambda_{PC} - \lambda_e \frac{g_e\left(\widehat{P}|e,\sigma\right)}{g\left(\widehat{P}|e,\sigma\right)} - \lambda_\sigma \frac{g_\sigma\left(\widehat{P}|e,\sigma\right)}{g\left(\widehat{P}|e,\sigma\right)}\right].
\end{aligned}$$

(3.10.23)

This derivative of the Lagrangian is zero if the term in squared brackets in (3.10.23) is zero. Substituting equation (3.10.16) and rearranging yields:

$$\frac{\partial \mathcal{L}}{\partial \widehat{P}} = 0 \Leftrightarrow V(W(\widehat{P})) - V(0) - V'\left(W\left(\widehat{P}\right)\right) W(\widehat{P}) = 0. \tag{3.10.24}$$

With Tversky and Kahneman (1992) preferences (3.7.1) we obtain:

$$\alpha W(\widehat{P}) - \lambda \left(W^R\right)^\beta \left(W(\widehat{P}) - W^R\right)^{1-\alpha} - \left(W(\widehat{P}) - W^R\right) = 0. \tag{3.10.25}$$

With (3.10.18) equation (3.10.25) becomes:

$$\alpha W^R = \left(c_0 + c_1 \ln \widehat{P} + c_2(\ln \widehat{P})^2\right) \lambda \left(W^R\right)^\beta + (1-\alpha) \left(c_0 + c_1 \ln \widehat{P} + c_2(\ln \widehat{P})^2\right)^{\frac{1}{1-\alpha}} . \quad (3.10.26)$$

This equation defines the threshold $\widehat{P}$.

As the wage function W_T from (3.10.18) is quadratic, the solution to condition (3.10.26) is not unique and might even not exist at all. If no solution exists, the contract always pays off in the gain space, because paying off only in the loss space (i.e. always the minimum wealth 0) violates the participation constraint. With the same argument as the one put forth in the proof of Proposition 1, the optimal contract is then given by (3.10.18) as long as this function is monotone increasing. Otherwise, the optimal contract is constant. This proves (3.10.10).

Condition (3.10.26) might have exactly one solution, but this is a non-generic case. Generically, if there is one solution, there is also a second solution. Then the general LA contract pays out in the gain space for very low and very high stock prices, while it pays the minimum wage for an intermediate range. Due to the monotonicity constraint, however, the contract is forced to pay out the minimum wage for all stock prices below the bigger of the two solutions to (3.10.26), and this proves (3.10.8). ■

Appendix D: Calibration method

This appendix shows how the original optimization problem (4.2.3), (3.2.4), (4.2.6), and (4.2.7) can be transformed into (3.5.1) to (3.5.4) which can be calibrated to the data. Our derivations are analogue to those in Dittmann and Maug (2007). We start by rewriting the effort incentive constraint (4.2.6) so that the LHS of the equation does not contain any quantities that we cannot compute while the RHS does not contain the wage function (see Jenter (2002)):

$$PPS^{ua}(W_T(P_T)) = E\left[\frac{dV(W_T)}{dW_T}\frac{dW_T}{dP_0}\right] = \frac{C'(e)}{\frac{dP_0}{de}} \quad (3.10.27)$$

Under the null hypothesis that the model is correct, the observed contract fulfills this equation, so that the effort incentive constraint in our calibration problem can be written as (3.5.3). For the volatility incentive constraint (4.2.7), equations (3.4.3) and (3.4.7) imply

$$\rho(W_T(P_T)) = \frac{dP_0}{d\sigma}\frac{1}{P_0}. \tag{3.10.28}$$

Note that this equation again separates quantities that we cannot compute ($dP_0/d\sigma$) from quantities that depend on the shape of the optimal contract (ρ). Under our null hypothesis, we therefore obtain (3.5.4). For the participation constraint (4.2.4), we first note that it must be binding as CEO utility is not downward restricted. If the constraint does not bind, we can shift the wage function downward until it binds. Under the null hypothesis the participation constraint can then be written as (3.5.2).

Appendix E: Representing the observed contract

Let N be the number of option grants. Each grant i is characterized by the strike price K^i, the maturity T^i, and the number of options n_O^i. We define

$$W_T^{smth}(P_T) := \phi e^{r_f T} + n_S P_T e^{dT} + \sum_{i=1}^{N} n_O^i V(T^i, K^i, P_T) e^{r_f (T-T^i)}, \tag{3.10.29}$$

where $V(T^i, K^i, P_T) = E\left(\max\left\{P_{T^i} - K^i, 0\right\}|P_T\right)$. If $T^i > T$, this is simply the Black-Scholes value of the option i over the remaining maturity $T^i - T$. If $T^i < T$, we assume that the option is exercised at time T^i if it is in the money and that the proceeds are invested at the risk-free rate until time T. The proceed at time T^i from exercising the option is then $V(T^i, K^i, P_T) = E\left(\max\left\{P_{T^i} - K^i, 0\right\}|P_T, P_0\right)$.

Note that, for each option grant i with $T^i < T$, $W_T^{smth}(P_T)$ contains a separate integral with respect to the stock price at T^i conditional on P_T . Therefore, D_2 is an $(m+1)$-dimensional integral, where m is the number of option grants with $T^i < T$. As we cannot solve this numerically, we approximate D_2 by a sum over 1,001 equally spaced stock prices P_T over the range of stock prices that covers 99.9% of the probability mass.

Appendix F: User's guide on how to calculate risk avoidance ρ

This Appendix contains formulae for our measure of risk avoidance ρ from (3.4.7) that can be readily implemented in a computer program. We start with a few definitions:

$$
\begin{aligned}
PC &= P_0 \exp\left\{\left(r_f - d - \frac{\sigma^2}{2}\right)T\right\}, \\
CV &= \sigma\sqrt{T}, \\
TW &= (\phi + W_0)\exp\{r_f T\}, \\
MD2 &= \frac{\ln(K) - \ln(PC)}{CV},
\end{aligned}
$$

With these definitions, we can calculate PPS^{ua} and ν^{ua} as follows:

$$
\begin{aligned}
PPS^{ua} =& \frac{PC}{P_0}\left[\int_{-\infty}^{MD2} (TW + n_S \exp\{dT\} PC \exp\{CVu\})^{-\gamma} n_S \exp\{dT + CVu\} f(u)du\right. \\
&+ \int_{MD2}^{\infty} (TW + (n_S \exp\{dT\} + n_O) PC \exp\{CVu\} - n_O K)^{-\gamma} \\
&(n_S \exp\{dT\} + n_O)\exp\{CVu\} f(u)du] \\
\nu^{ua} =& \int_{-\infty}^{MD2} (TW + n_S \exp\{dT\} PC \exp\{CVu\})^{-\gamma} n_S \exp\{dT + CVu\} \\
&PC\left(-\sigma T + u\sqrt{T}\right) f(u)du \\
&+ \int_{MD2}^{\infty} (TW + (n_S \exp\{dT\} + n_O) PC \exp\{CVu\} - n_O K)^{-\gamma} (n_S \exp\{dT\} + n_O) \\
&PC \exp\{CVu\}\left(-\sigma T + u\sqrt{T}\right) f(u)du,
\end{aligned}
$$

where $f(u)$ is the standard normal density function. Our measure of risk avoidance then follows from (3.4.7).

For a CEO with more than one option grant, the option portfolio must first be aggregated into one representative option. We therefore numerically calculate the number of options

n_O, the strike price K, and the maturity T so that the representative option has the same Black-Scholes value, the same option delta, and the same option vega as the estimated option portfolio. Hence, we solved the following system of three equations in three variables:

$$n_O \cdot BS(P_0, K, T, \sigma, r_f) = \sum_i n_O^i \cdot BS(P_0, K^i, 0.7T^i, \sigma, r_f)$$

$$n_O \cdot delta(P_0, K, T, \sigma, r_f) = \sum_i n_O^i \cdot delta(P_0, K^i, 0.7T^i, \sigma, r_f)$$

$$n_O \cdot vega(P_0, K, T, \sigma, r_f) = \sum_i n_O^i \cdot vega(P_0, K^i, 0.7T^i, \sigma, r_f),$$

where n_O^i, K^i, and T^i are the number, the strike price, and the maturity of the ith option in the CEO's option portfolio. We multiply T^i by 0.7 to correct for early exercise (see Footnote 11 above).

Chapter 4

Should Options be Issued in the Money? Evidence from Model Calibrations with Risk-Taking Incentives[1]

This paper investigates the optimal structure of CEO compensation contracts. We consider a stylized principal-agent model that captures the interdependence between firm risk and mangerial incentives. We calibrate the model to individual CEO data and show that the optimal compensation structure looks strikingly different from observed contracts. Specifically we show that the optimal compensation package should replace at-the-money options and stocks by in-the-money options. If the tax discrimination against in-the-money options are taken into account, the model is then consistent with the almost uniform use of at-the-money stock options.

4.1 Introduction

The paper evaluates the optimal structure for CEO compensation, specifically the optimal balance among base pay, stock, and options. Standard agency theory suggests equity pay – including stock and options – as one of the mechanisms to reduce agency costs. However, stock and options are different in their implications of incentives. While options are cheaper in that they provide high-power incentives with less cost to shareholders, risk-averse CEOs subjectively also view them as less valuable.[2] Our paper shows that options are indeed part of an optimal

[1]This chapter is based upon Dittmann and Yu (2008).

[2]Dittmann and Maug (2007) offers a nice illustration of comparing subjective and objective values of stock and options in their introduction.

contract. They can be detrimental to risk-taking incentives, but wreak less havoc than stock. Having neither stock nor options is not an alternative, because such a contract would not provide any effort incentives. We also show that the optimal contract consists of fixed salary and in-the-money options barring any tax disadvantages against issuing in-the-money options. After we factor into the tax disadvantages, the contracts predicted by the model perfectly fits to the data.

There is an ongoing debate in the literature on whether executive stock options do provide risk-taking incentives. Intuitively, this seems obvious as the value of an option increases with the volatility of the underlying asset (see, e.g., Haugen and Senbet (1981) or Smith and Stulz (1985)). However, Carpenter (2000), Ross (2004), and Lewellen (2006) argue that stock options can make managers more averse to increases in firm risk, so that stock options might be counter-productive if risk-taking incentives need to be provided.

We approach this question with a new calibration method that incoporates standardized building blocks from principal-agent theory. We assume that an effort-averse and risk-averse agent chooses his effort and the firm's strategy, and where the strategy affects firm value and risk. This model incorporates not only the notion that the CEO's actions can affect firm risk but also firm value. We calibrate this model to the data on 727 U.S. CEOs and for each generate predictions about the optimal compensation structure, i.e. the optimal mix of base salary, stock, and options, and the optimal strike price.[3]

Our calibrations predict contracts with large option holdings and little or no stock. The optimal strike price is lower than the observed strike price which indicates that options

[3]There is an ongoing debate in the literature on whether executive stock options do provide risk-taking incentives. Intuitively, this seems obvious as the value of an option increases with the volatility of the underlying asset (see, e.g., Haugen and Senbet (1981) or Smith and Stulz (1985)). However, Carpenter (2000), Ross (2004), and Lewellen (2006) argue that stock options can make managers more averse to increases in firm risk, so that stock options might be counter-productive if risk-taking incentives need to be provided. Our paper shows that options are indeed part of an optimal contract. They can be detrimental to risk-taking incentives, but wreak less havoc than stock. Having neither stock nor options is not an alternative, because such a contract would not provide any effort incentives.

should be issued in the money according to the model. In-the-money options provide incentives for intermediate and high outcomes and they avoid punishing the CEO for bad outcomes. Hence they provide effort and risk-taking incentives at the same time. Our model also predicts higher base salaries than observed, because these must rise as stock is replaced by less valuable options to guarantee the CEO's reservation utility. The savings that can be expected when firms switch from the observed contract to the optimal contract are low and average only 5.3% of total compensation costs.

The U.S. tax system strongly discriminates against in-the-money options.[4] In our calibrations, the savings from recontracting are much smaller than the additional tax penalties most firms and executives would have to pay if in-the-money options were used. If we include these tax penalties in our model, observed contracts turn out to be optimal for 76% to 94% of all CEOs in our sample (depending on assumptions), so our model is broadly consistent with compensation practice. In this context, our analysis suggests that the current U.S. tax system forces firms to resort to inefficient contract arrangements, because most firms - and especially small firms with poor past performance - could benefit from granting in-the-money options. Moreover, our analysis shows that the universal use of at-the-money options, that is often seen as evidence for managerial rent-extraction (see Bebchuk and Fried (2004)), is perfectly consistent with efficient contracting.

In our model, CEOs are poorly diversified because a large part of their wealth is linked to the company's share price to provide effort incentives. In the absence of proper risk-taking incentives, CEOs therefore prefer low firm risk and tend to choose a firm strategy that results in inefficiently low risk. They might, for instance, pass up a profitable but very risky project,

[4] According to IRC Section 162(m), in-the-money stock options are not considered as performance-based compensation, so that the "one-million-dollar" rule applies and only up to $1m (including base salary) are deductible on corporate tax returns. Moreover, Section 409A requires that the difference between the stock price and the strike price be recognized as income at the time of vesting, rather than on exercise. Thus this rule accelerates income recognition from the exercise date to the vesting date. In addition, Section 409A imposes an additional 20% tax on this income (see Alexander, Hirschey, and Scholz (2007)).

or they might hedge their firm's risk at some cost. Shareholders can reduce this inefficiency by providing risk-taking incentives. The challenge is to provide risk-taking incentives without impairing effort incentives. While high stock price realizations are an unmistakably good signal, low stock price realizations are ambiguous: they can be indicative of low effort (which is bad) or of extensive risk-taking (which is good, given that the CEO leans towards inefficiently low risk). The best way to provide effort and risk-taking incentives together therefore is to reward good outcomes and not to punish bad ones, i.e. the optimal contract resembles a call option on the firm's stock.

We also contribute to the discussion on whether executive stock options do provide risk-taking incentives. Intuitively, this seems obvious as the value of an option increases with the volatility of the underlying asset (see, e.g., Haugen and Senbet (1981) or Smith and Stulz (1985)). However, Carpenter (2000), Ross (2004), and Lewellen (2006) argue that stock options can make managers more averse to increases in firm risk, so that stock options might be counter-productive if risk-taking incentives need to be provided. Our paper shows that options are indeed part of an optimal contract. They can be detrimental to risk-taking incentives, but wreak less havoc than stock. Having neither stock nor options is not an alternative, because such a contract would not provide any effort incentives. While we attribute the existence of options to the provision of risk-taking incentives in this paper, we acknowledge that there are alternative explanations for the use of options in executive compensation.[5]

In the next section, we present our model in which the manager must choose effort

[5] Oyer (2004) models options as a device to retain employees when recontracting is expensive, and Inderst and Müller (2005) explain options as instruments that provide outside shareholders with better liquidation incentives. Edmans and Gabaix (2009) and Edmans et al. (2009) show that convex contracts can arise in dynamic contracting models. Peng and Röell (2009) analyze stock price manipulations in a model with multiplicative CEO preferences and find convex contracts for some parameterizations. Hemmer, Kim, and Verrecchia (1999) assume gamma distributed stock prices and find convex contracts, but Dittmann and Maug (2007) show that these results are not robust. Dittmann, Maug and Spalt (2010) show that options can be explained if managers are loss-averse. With the exception of Dittmann, Maug and Spalt (2010), none of these models has been calibrated to data, and some models are too stylized to be calibrated at all.

and the firm's strategy. We explain our calibration approach and describe our data construction approach in Section 2 In a nutshell, we numerically search for the cheapest contract with a given shape that provides the manager with the same incentives and the same utility as the observed contract. In Section 3, we present our main results on optimal piecewise linear contracts consisting of base salary, stock, and an option grant. Section 4 discusses reasons why in-the-money options are rarely used in practice. In particular, we analyze the impact of U.S. taxes on our calibration results here. Section 5 contains robustness checks, and Section 6 concludes.

4.2 The model and its calibration

4.2.1 Model

We consider two points in time. At time $t = 0$ the contract between a risk-neutral principal (the shareholders) and a risk-averse agent (CEO) is signed, and at time $t = T$ the contract period ends. The market value of the firm at time $t = 0$ (after the contract details have been disclosed) is $P_0 = E(P_T)\exp\{-r_f T\}$, where r_f is the appropriate rate of return. At some point during the contract period $(0, T)$, the agent makes two choices. First, he chooses effort $e \in [0, \infty)$ that results in private costs $C(e)$ to the agent and that affects the firm's expected value $E(P_T)$. Second, he chooses a strategy s that affects the firm's expected value $E(P_T)$ and the firm's stock return volatility σ. We will refer to σ interchangeably as 'firm risk'. We can therefore write $E(P_T) = P_0(e, s)\exp\{r_f T\}$ and $\sigma = \sigma(s)$.[6]

We think of the strategy s as a feasible combination of many different actions that affect, among other things, project choice, mergers and acquisitions, capital structure, or financial transactions. Part of the strategy could be, for instance, an R&D project that increases value and risk. Another part could be financial hedging of some input factor which would reduce value and

[6] In our model, effort only affects expected value but not firm risk whereas strategy affects both value and risk. Other models (e.g. Feltham and Wu, 2001) assume that the agent only chooses effort and that effort affects value *and* risk. The main difference between Feltham and Wu (2001) and our model in this respect is that our model allows the CEO to affect value and risk independently of each other.

risk, etc. Due to its richness, we do not model the agent's choice of strategy in detail. Instead we recognize that a risk-averse agent with a wage contract $w(P_T)$ that is increasing in P_T will always choose an action that minimizes firm risk σ given expected value $E(P_T)$, or equivalently that maximizes expected value $E(P_T)$ given risk σ. Let $\widetilde{s}(e,\sigma)$ denote the strategy that maximizes expected value $E(P_T)$ given effort e and volatility σ. Then the agent's choice of effort e and strategy s is equivalent to a choice of effort e and volatility σ: $E(P_T) = P_0(e, \widetilde{s}(e,\sigma)) \exp\{r_f T\} = P_0(e,\sigma)\exp\{r_f T\}$. In the remainder of this paper, we therefore work with the reduced form of our model where the agent chooses effort e and volatility σ.

We assume that there is a first-best firm strategy $s^*(e)$ that maximizes firm value (given effort e). Let $\sigma^*(e) := \sigma(s^*(e))$ denote the firm risk that is associated with this strategy. If the agent wants to reduce risk to some value below $\sigma^*(e)$, he can do so in two ways. Either he drops some risky but profitable projects (e.g. an R&D project), or he takes an additional action that reduces risk but also profits (e.g. costly hedging). In both cases, a reduction in volatility σ leads to a reduction in firm value $E(P_T)$. We therefore assume that $P_0(e,\sigma)$ is increasing and concave in σ as long as $\sigma < \sigma^*(e)$. In the region above $\sigma^*(e)$, firm value $P_0(e,\sigma)$ is weakly decreasing: if the agent can costlessly take on more risk in financial markets, it is flat; otherwise, a higher value of σ also leads to a distortion of the agent's actions and thereby to a lower firm value. Finally, we assume that the stock price $P_0(e,\sigma)$ is increasing and concave in e (given volatility σ).

Our model is in the spirit of Holmström (1979): The principal cannot observe the agent's actions e and σ, so the manager's wage W_T only depends on the end-or-period stock price P_T.[7] We use risk-neutral pricing and assume that the end-of-period stock price P_T is

[7] The ex-post volatility can obviously be estimated from stock returns, but these are only realizations of the ex-ante distribution whose volatility the CEO selects. Moreover, volatility is not exclusively determined by the CEO's management strategy. If the CEO has other means to drive up volatility (e.g. by frequent contradictory announcements), total observed volatility can be manipulated and can be higher than the fundamental volatility the CEO selects in our model.

lognormally distributed:

$$P_T(u,e,\sigma) = P_0(e,\sigma)\exp\left\{\left(r_f - \frac{\sigma^2}{2}\right)T + u\sqrt{T}\sigma\right\}\ ,\quad u \sim N(0,1)\,. \tag{4.2.1}$$

Here, r_f is the risk-free rate, and $P_0(e,\sigma) = E(P_T(u,e,\sigma))\exp\{-r_f T\}$ is the expected present value of the end-of-period stock price P_T.[8]

The manager's utility is additively separable in wealth and effort and has constant relative risk aversion with parameter γ with respect to wealth:

$$U(W_T,e) = V(W_T) - C(e) = \frac{W_T^{1-\gamma}}{1-\gamma} - C(e)\,. \tag{4.2.2}$$

If $\gamma = 1$, we define $V(W_T) = \ln(W_T)$. Costs of effort are assumed to be increasing and convex in effort, i.e. $C'(e) > 0$ and $C''(e) > 0$. There is no direct cost associated with the manager's choice of volatility. Volatility σ affects the manager's utility indirectly via the stock price distribution and the utility function $V(.)$. Finally, we assume that the manager has outside employment opportunities that give him expected utility $\overline{U}$. The shareholders' optimization problem then is:

$$\underset{W_T,e,\sigma}{max}\, E\left[P_T - W_T(P_T)|e,\sigma\right] \tag{4.2.3}$$

$$\text{subject to}\quad E\left[V(W_T(P_T))|e,\sigma\right] - C(e) \geq \overline{U} \tag{4.2.4}$$

$$\text{and}\qquad \{e,\sigma\} \in \text{argmax}\ \left\{E\left[V(W_T(P_T))|e,\sigma\right] - C(e)\right\} \tag{4.2.5}$$

We replace the incentive compatibility constraint (4.2.5) with its first-order conditions:

$$\frac{dE\left[V(W_T(P_T))|e,\sigma\right]}{de} - \frac{dC}{de} = 0 \tag{4.2.6}$$

$$\frac{dE\left[V(W_T(P_T))|e,\sigma\right]}{d\sigma} = 0, \tag{4.2.7}$$

We call condition (4.2.6) the effort incentive constraint and (4.2.7) the volatility incentive constraint.

[8] Risk-neutral pricing allows us to abstract from the agent's portfolio problem, because in our model the only alternative to an investment in the own firm is an investment at the risk-free rate. If we allowed the agent to earn a risk-premium on the shares of his firm, he could value these above their actual market price, because investing into his own firm is then the only way to earn the risk-premium. Our assumption effectively means that all risk in the model is firm-specific.

4.2.2 Calibration method

We cannot calibrate the full optimization problem to the data, because this requires knowledge (or estimates) of the production function $P_0(e, \sigma)$ and of the cost function $C(e)$. We therefore resort to the subproblem of finding a new contract with a given shape that achieves three objectives. Firstly it provides the same effort and risk-taking incentives to the agent as the observed contract. Secondly it provides the agent with the same utility as the observed contract, and thirdly it is as cheap as possible for the firm. This subproblem is the first stage of the two-stage procedure in Grossman and Hart (1983), where they search for the cheapest contract that implements a given level of effort. In our case, this is the level of effort that is implemented by the observed contract. If our model is correct and descriptive of the data, the cheapest contract found in this optimization will be identical to the observed contract. If the new contract differs substantially, the observed contract is not efficient according to the model: it is possible to find a cheaper contract that implements the same effort and the same investment choices as the observed contract. In this case, either compensation practice is inefficient or the model is incorrect. In both cases, the model is not descriptive of the data.

We only calculate the cost-effective contract for the effort/volatility level implemented by the observed contract. We cannot repeat this task for alternative effort/volatility levels, because this would require knowledge of the production and the cost function. Therefore we cannot analyze the optimal level of effort or volatility (i.e., the second stage in Grossman and Hart (1983)). Our method analyzes the optimal structure of compensation only.

We start by rewriting the effort incentive constraint (4.2.6) so that the LHS of the equation does not contain any quantities that we cannot compute while the RHS does not contain the wage function (see Jenter (2002)):

$$PPS^{ua}(W_T(P_T), e, \sigma, \gamma) = E\left[\frac{dV(W_T)}{dW_T}\frac{dW_T}{dP_0}\middle| e, \sigma\right] = \frac{C'(e)}{\frac{dP_0}{de}} \tag{4.2.8}$$

Under the null hypothesis that the model is correct, the observed contract fulfills this equation, so that the effort incentive constraint in our calibration problem becomes:

$$PPS^{ua}(W_T^*(P_T), e, \sigma, \gamma) = PPS^{ua}(W_T^d(P_T), e, \sigma, \gamma) \tag{4.2.9}$$

Here W_T^* denotes the new (cost minimizing) contract and W_T^d denotes the observed contract (d for "data").

We can reformulate the participation constraint (4.2.4) and the volatility incentive constraint (4.2.7) in a similar way:

$$E\left[V(W_T^*(P_T))|e, \sigma, \gamma\right] \geq E\left[V(W_T^d(P_T))|e, \sigma, \gamma\right], \tag{4.2.10}$$

$$RTI(W_T^*(P_T), e, \sigma, \gamma) = RTI(W_T^d(P_T), e, \sigma, \gamma). \tag{4.2.11}$$

For our calibration approach to work, we also need to restrict the shape of the optimal contract, so that it depends on only a few parameters. In Section **??**, we derive the optimal contract shape which depends on three parameters and we calibrate this to the data. In the next section, we calibrate a piecewise linear contract that consists of fixed salary ϕ, the number of shares n_S, and the number of options n_O with strike price K:

$$W_T^{lin}(P_T) = (W_0 + \phi)\exp\{r_f T\} + n_S P_T + n_O \max\{P_T - K, 0\}. \tag{4.2.12}$$

With W_0 we denote the manager's initial non-firm wealth, i.e. all wealth that is not invested in stock or options of his own firm. We express the number of shares n_S and the number of options n_O as a percentage of outstanding shares, so that $0 \leq n_S \leq 1$. Our numerical optimization problem is to minimize the costs of the new contract, $E\left(W_T^{lin}(P_T)|e^d, \sigma^d\right)$, subject to the constraints (4.2.9), (4.2.10), and (4.2.11). We have four parameters to minimize costs over: ϕ, n_S, n_O, and K.

4.2.3 Construction of Data

We use the ExecuComp database to construct approximate CEO contracts at the beginning of the 2006 fiscal year. We first identify all persons in the database who were CEO during the full year 2006 and executive of the same company in 2005. We calculate the base salary ϕ (which is the sum of salary, bonus, and "other compensation" from ExecuComp) from 2006 data, and take information on stock and option holdings from the end of the 2005 fiscal year. We subsume bonus payments under base salary, because previous research has shown that bonus payments are only weakly related to firm performance (see Hall and Liebman (1998)).[9]

We estimate each CEO's option portfolio with the method proposed by Core and Guay (2002) and then aggregate this portfolio into one representative option. This aggregation is necessary to arrive at a parsimonious wage function (in fact at (4.2.12)) that can be calibrated to the data. Our model is static and therefore cannot accommodate option grants with different maturities. The representative option is determined so that it has a similar effect as the actual option portfolio on the agent's utility, his effort incentives, and his risk-taking incentives. More precisely, we numerically calculate the number of options n_O, the strike price K, and the maturity T so that the representative option has the same Black-Scholes value, the same option delta, and the same option vega as the estimated option portfolio.[10] In this step, we lose five CEOs for whom we cannot numerically solve this system of three equations in three unknowns.

We take the firm's market capitalization P_0 from the end of 2005. While our formulae above abstract from dividend payments for the sake of simplicity, we take dividends into account

[9]We do not take into account pension benefits, because they are difficult to compile and because there is no role for pensions in a one-period model. Pensions can be regarded as negative risk-taking incentives (see Sundaram and Yermack (2007)), so that we overestimate risk-taking incentives in observed contracts.

[10]We take into account the fact that most CEOs exercise their stock options before maturity by multiplying the maturities of the individual option grants by 0.7 before calculating the representative option (see Huddart and Lang (1996) and Carpenter (1998)). In these calculations, we use the stock return volatility from ExecuComp and, for the risk-free rate, the U.S. government bond yield with 5-year maturity from January 2006. Data on risk-free rates have been obtained from the Federal Reserve Board's website. For CEOs who do not have any options, we set $K = P_0$ and $T = 10$ as these are typical values for newly granted options.

in our empirical work and use the dividend rate d from 2005. We estimate the firm's stock return volatility σ from daily CRSP stock returns over the fiscal year 2006 and drop all firms with fewer than 220 daily stock returns on CRSP. We use the CRSP/Compustat Merged Database to link ExecuComp with CRSP data. The risk-free rate is set to the U.S. government bond yield with five-year maturity from January 2006.

We estimate the non-firm wealth W_0 of each CEO from the ExecuComp database by assuming that all historic cash inflows from salary and the sale of shares minus the costs of exercising options have been accumulated and invested year after year at the one-year risk-free rate. We assume that the CEO had zero wealth when he entered the database (which biases our estimate downward) and that he did not consume since then (which biases our estimate upward). To arrive at meaningful wealth estimates, we discard all CEOs who do not have a history of at least five years (from 2001 to 2005) on ExecuComp. During this period, they need not be CEO. This procedure results in a data set with 737 CEOs.

Table 1 Panel A provides an overview of our data set. The median CEO owns 0.3% of the stock of his company and has options on an additional 1% of the company's stock. The median base salary is \$1.1m, and the median non-firm wealth is \$11.1m. The representative option has a median maturity of five years and is well in the money with a moneyness (K/P_0) of 72%. Most stock options are granted at the money in the United States (see Murphy (1999)), but after a few years they are likely to be in the money. This is the reason why the representative option grant is in the money for 90% of the CEOs in our sample. In the interest of readability, we call an option with a strike price K that is close to the observed strike price K^d an "at-the-money option". Consequently, we call an option grant "in-the-money" only if its strike price K is lower than the observed strike price K^d.

We require that all CEOs in our data set are included in the ExecuComp database for the years 2001 to 2006, and this requirement is likely to bias our data set towards surviving CEOs, namely those who are older and richer and who work in bigger and more successful firms. Table 1 Panel B describes the full ExecuComp universe of CEOs in 2006. Compared to this larger sample, our CEOs are, on average, one year older and own somewhat more options (+0.1%). They work in bigger firms (+$500m) with better past performance (1.25% higher return during the past five years). We conclude that our sample is subject to a moderate survivorship bias. We investigate this bias by separately analyzing subsamples with more successful and less successful CEOs in Section 4.5.

The only parameter in our model that we cannot estimate from the data is the manager's coefficient of relative risk aversion γ. We therefore repeat our analysis for six different risk-aversion parameters ranging from $\gamma = 0.5$ (low risk-aversion) to $\gamma = 8$ (strong risk-aversion). This range includes the risk-aversion parameters used in previous research. We regard values of γ below 1 as unrealistically low as they imply implausible private portfolio decisions: with $\gamma < 1$, the CEO would like to borrow heavily and invest much more than his entire wealth in the stock market.

4.3 Optimal Compensation Structure

In this section we present our main empirical results. For each CEO in our sample, we numerically calculate the cheapest piecewise linear contract that provides the manager with the same utility and the same incentives as the observed contract. We call this cheaper contract the "optimal contract" and compare it with the observed contract.

More formally, we minimize $E\left(W_T^{lin}(P_T)\right)$ subject to the participation constraint (4.2.10) and the two incentive compatibility constraints (4.2.9) and (4.2.11). We need a few additional restrictions, so that the problem is well-defined. First, we assume that the number of shares n_S is non-negative. We allow for negative option holdings n_O and negative salaries ϕ, but we require that $n_O > -n_S \exp\{dT\}$ and $\phi > -W_0$ to prevent negative payouts. Negative option holdings or negative salaries are rarely seen in practice, but they are certainly possible. A negative salary would imply that the firm requires the CEO to invest this amount of his private wealth in firm equity. We argue that a good model should not *assume* but rather *generate* positive option holdings and positive salaries.[11]

We also need to restrict the strike price K, because options and shares become indistinguishable if K approaches zero, and the problem becomes poorly identified if K is small. We work with two lower bounds for K. We first solve the numerical problem with the restriction $K/P_0 \geq 20\%$. If we find a corner solution with $K/P_0 = 20\%$, we repeat the calibration with a lower bound $K/P_0 \geq 10\%$. If the second calibration does not converge, we use the (corner) solution from the first step.[12]

Table 2, Panel A contains our calibration results for six values of the risk-aversion parameter γ, ranging from 0.5 to 8. For low values of risk-aversion we lose some of our 737 observations, because risk-taking incentives from (3.4.7) are positive.[13] The column *Observations* displays the remaining observations after CEOs with positive ν^{ua} have been deleted, and the column *Converged* shows the number of CEOs for which our numerical routine was successful. In addition, the table describes the four contract parameters ϕ, n_S, n_O, and K of the calibrated optimal contract, and the percentage savings the firm could realize by switching from

[11]We do not allow for negative stockholdings, because compensation could then become non-monotonic in stock price.

[12]In many cases, the objective function in our problem is rather flat around the optimal solution. In order to check whether an interior solution with $n_S^* > 0$ is indeed the optimal solution (in most cases we find $n_S^* = 0$, as we discuss shortly), we repeat our calibration with the additional restriction $n_S = 0$ whenever we obtain a solution with $n_S^* > 0$ in the original problem. In almost all cases, the contract with $n_S = 0$ is slightly cheaper than the initially found contract with $n_S^* > 0$. This shows that interior solutions with $n_S^* > 0$ are a numerical artifact. For our empirical analysis we always use the solution with the lowest costs.

[13]As long as the agent is risk-averse, our model predicts negative RTI in equilibrium (see the discussion at the end of Section 2.2). Therefore, a positive RTI directly rejects our model assumptions. We interpret the fact that $RTI > 0$ for many CEOs for $\gamma \leq 1$ as a confirmation that these levels of risk-aversion are unrealistically low. Note that, for the more reasonable value $\gamma = 3$, virtually all the CEOs in our sample have negative RTI.

the observed contract W_T^d to the optimal contract W_T^* , i.e.

$$savings = \left[E\left(W_T^d(P_T)\right) - E\left(W_T^*(P_T)\right)\right]/E\left(W_T^d(P_T)\right). \tag{4.3.1}$$

Optimal contracts differ systematically from observed contracts regarding the CEO's stock holdings. While observed contracts nearly always contain stock holdings, 99% of all CEOs would not receive any shares according to the optimal contract for $\gamma = 3$. Instead, the strike price of their option holdings would be much lower: the median strike price is 51% of the share price compared to 72% for the observed contract. While average and median option holdings are higher for the optimal contract with $\gamma = 3$, this is not uniformly so for all CEOs. Instead, we find that the *sum* of stock and options is always smaller in the optimal contract than in the observed contract (not shown in the table). Therefore, the optimal contract is less steep than the observed contract in the best states of the world.

The general picture is that the stock and option holdings in the observed contract are replaced by option holdings that are considerably deeper in the money. As options are less valuable than shares, this exchange is accompanied by an increase in base salary, so that the new contract provides the same expected utility to the agent as the observed contract. The model predicts that median base salaries (for $\gamma = 3$) should nearly triple from \$1.1m to \$3.2m. For $\gamma \geq 1$, optimal base salaries and option holdings are virtually always positive. Hence, a model with effort and risk-taking incentives can explain these stylized facts far better than models that account for effort incentives only. In those models, at least 25% of the CEOs should receive no options or a negative fixed salary (see Dittmann and Maug (2007) and Dittmann, Maug and Spalt (2010)).

Figure 4.3.1 illustrates our main results. It shows the payout function $W_T(P_T)$ of the observed contract and the optimal contract for one CEO in our sample. This CEO is not representative for our sample; for a typical CEO the two contracts are more difficult to

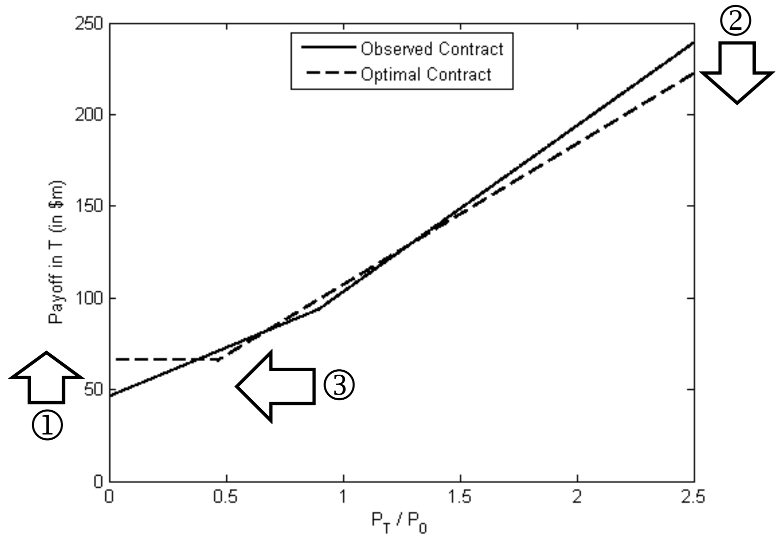


Figure 4.3.1: The figure shows end-of-period wealth W_T as a function of end-of-period stock price P_T for the observed contract (solid line) and the optimal piecewise linear contract (dashed line) for one CEO in our sample. The arrows indicate the three main features of the optimal contract relative to the observed contract: (1) it punishes very bad outcomes less, (2) it rewards very good outcomes less, and (3) the strike price of the option grant is lower. The parameters for this CEO are $\phi = \$6.3$m, $n_S = 5.97\%$, $n_O = 4.44\%$ for the observed contract. Initial non-firm wealth is $W_0 = \$32.1$m. $P_0 = \$853$m, $\sigma = 25.7\%$, and $K/P_0 = 90\%$, $T = 4.4$ years, $r_f = 4.4\%$, $d = 0.9\%$, and $\gamma = 3$.

distinguish visually. The three arrows in Figure 1 indicate the main features of the optimal contract and help to develop an intuition for our main result that in-the-money options are a cheaper way to provide incentives than a portfolio of stock and at-the-money options. The first feature of the optimal contract is that it provides for less punishment in the bad states of the world than the observed contract, which improves risk-taking incentives. On the other hand, the optimal contract also gives fewer rewards in the best states of the world (feature 2), which reduces risk-taking incentives. These two effects offset each other, so that the optimal contract provides the same risk-taking incentives as the observed contract. Effort incentives, on the other hand, are reduced by both features (1) and (2). Moving the strike price more into the money (feature 3), however, increases effort incentives and offsets the effect of features (1) and (2). Therefore, the optimal contract also generates the same effort incentives as the observed contract; it merely moves some of the effort incentives from the tails of the distribution to its center. Finally observe that features (1) and (2) make the optimal contract less risky than the observed contract. Therefore the agent demands a lower risk-premium for the optimal contract than for the observed contract, and the optimal contract is cheaper for shareholders.

However, the savings generated by switching to the optimal contract are limited. For $\gamma = 3$, the median firm would just save 2.6% of its compensation costs (the average is 5.3%, see Table 2, Panel A). The savings in the case shown in Figure 1 are 2.8%. This is hardly a savings potential that would trigger shareholder activism or takeovers. The comparatively small savings imply that a portfolio of stock and at-the-money options is a good substitute for in-the-money options. The numerical flip side of low savings is that the objective function (after taking into account the constraints) is rather flat. While this is certainly a complication when it comes to solving the model numerically (see Footnote 12), it is not a *problem* of our model but rather a *result*.

While 98.8% of the CEOs in our sample would not receive any stock if firms implemented the optimal contract, there are still 1.2% who would. A more detailed analysis (not shown in the tables) shows that there are two reasons for these positive stockholdings. A few CEOs have no options in their observed contract, so that it is not possible to construct an alternative contract with all the three features highlighted in Figure 1. For other CEOs, our optimization routine hits the boundary $K/P_0 = 20\%$ or $K/P_0 = 10\%$, so that we have a corner solution with positive stock holdings. Beyond these two cases, we find no true interior solutions with $n_S^* > 0$, except for $\gamma = 0.5$. We therefore conclude that, within our model, in-the-money options are generally preferable to a portfolio of at-the-money options and stock.

Table 2, Panel B reproduces the results from Panel A for those 282 CEOs for which our algorithm converges for all $\gamma \geq 1$. This table shows that, as γ increases, the optimal contract features fewer stock options, lower strike prices, and lower base salaries. Therefore, the contract becomes flatter and less convex as γ increases. Savings are considerable for high levels of risk-aversion and negligible for $\gamma = 1$. This finding is not surprising as savings stem from improved risk-sharing, which is more important if CEOs are more risk-averse.

4.4 Taxes and the popularity of at-the-money options

The low savings from recontracting shown in Table 2 imply that observed compensation practice is consistent with our model if there is an effect (possibly even small) in favor of shareholdings or at-the-money options that we did not account for in our model. In this section, we review a few potential reasons why at-the-money options are so popular in compensation practice.

The U.S. tax system strongly discriminates against in-the-money options (see Footnote 4). According to IRC Section 409A, income from in-the-money options is subject to a 20% penalty tax that has to be paid by the executive at the time of vesting. Shares, at-the-money options, or out-of-the-money options are not subject to this additional tax. Walker (2009) argues that this rule "is probably the measure that most strongly discourages explicit grants of in-the-money options." Moreover, in-the-money options (like restricted stock) do not automatically qualify as performance based pay under IRC Section 162(m) and therefore count towards the $1 million per executive that are tax deductible at firm level. However, this rule can be easily circumvented by subjecting in-the-money options to specific performance criteria. We therefore concentrate on the 20% penalty tax from Section 409A and neglect the potential effects of Section 162(m) in the following analysis.[14]

To illustrate the effect of taxes, we first consider a representative CEO whose para-

[14] Another potential reason why we do not see in-the-money options in the U.S. are the U.S. accounting rules. In-the-money options always had to be expensed while at-the-money options did not need to be expensed prior to 2006. These accounting reasons probably explain the absence of in-the-money options before 2004, the year in which Section 409A was enacted.

meters are closest to the median values shown in Table 1.[15] The observed contract of this representative CEO consists of \$1.1m base salary, \$7.9m stock, and at-the-money options with a Black-Scholes value of \$12.1m. Our model proposes instead \$3.9m base salary, no stock, and in-the-money options with a value of \$17.0m. This contract would generate savings of \$0.2m or 1% of total compensation costs, but the CEO would have to pay additional taxes of \$3.4m ($= 20\% \cdot \$17$m) in expectation, so that a portfolio of stock and at-the-money options is cheaper than in-the-money options if taxes are taken into account.

In order to investigate this tax effect more systematically, we repeat our numerical analysis for $\gamma = 3$ with the 20% tax penalty on in-the-money options. We assume that this tax must be paid if and only if the strike price is lower than the observed strike price, so we effectively assume that all options in the observed contract have been issued at-the-money. We find that in this setting the observed contract turns out to be optimal for 93.7% of all CEOs for whom our algorithm converges (not shown in the tables).

This tax analysis does not take into account that part of the shares held by an executive might not be restricted but held voluntarily. If these are replaced by in-the-money options, the executive would have to sell them and buy in-the-money options from the proceeds. As these options are bought from private wealth, they would not be subject to the 20% penalty tax.[16] In the above example, all the shares held by the representative CEO are unrestricted. If he sells them and invests the proceeds of \$7.9m into options, only \$9.1m ($= \$17$m $- \$7.9$m) are subject to the penalty tax, resulting in a penalty of \$1.82m which still exceeds the benefits from recontracting (\$0.2m). For the full sample, we find that the optimal contract remains optimal

[15] For each parameter (observed salary ϕ^d, observed stock holdings n_S^d, observed option holdings n_O^d, wealth W_0, firm size P_0, stock return volatility σ, time to maturity T, and moneyness K/P_0) and each CEO we calculate the absolute percentage difference between individual and median value. Then we calculate the maximum relative difference for each CEO and select the CEO for whom this maximum difference is smallest.

[16] It is not obvious that this second way to include taxes in our model is necessarily the more accurate one. Unrestricted shares can also be seen as the result of restricted stock awarded in previous periods. If in-the-money options instead of restricted stock had been issued in the previous periods, the tax penalty would have applied.

for 75.5% of all CEOs under these assumptions. For the remaining 24.5% the optimal contract is identical to the optimal contract without taxes (see Table 2), except that more options are awarded to compensate the CEO for the tax payment.

Many other countries (including the U.K., Canada, Germany, and France) discourage the use of in-the-money options, so the United States is not an exception (see Walker, 2009).[17] A potential reason is that the rest of the world generally tends to follow the U.S. when it comes to executive compensation and especially executive stock options. Alternatively, one can argue that in-the-money options cause some costs that are not included in our model and that justify government intervention. Our results in Table 2 show that the use of in-the-money options is associated with large increases in base salary. These might be difficult to explain to shareholders and the general public, and might cause social unrest and higher wage demands. Alternatively, there might be concerns that executives try to influence the strike price of the option grants just as some appear to have done in the recent backdating scandal. A commitment to using only at-the-money options could reduce this rent-seeking activity, and our analysis shows that the costs of such a commitment are low.

4.5 Robustness Checks

Sample selection bias Our data set is subject to a moderate survivorship bias, as we require that CEOs are covered by the ExecuComp database for at least five years. Table 1 demonstrates that younger and less successful CEOs are underrepresented in our data set. We therefore divide our sample in quintiles according to four variables: CEOs' non-firm wealth W_0, CEO age, firm value P_0, and the past five years' stock return. Table 3 displays for these subsamples the average savings as a percentage of pay that firms could realize by switching to the optimal piecewise linear contract. The last line shows the p-value of the Wilcoxon test that average savings are

[17] Australia is the only country for which we could find evidence that in-the-money options are commonly used. See Rosser and Canil (2004).

identical in the first and the fifth quintile.

The table shows that savings are considerably higher for younger and especially less wealthy CEOs. With constant relative risk-aversion, higher wealth implies lower absolute risk-aversion and consequently fewer gains from efficient risk-sharing. The table also demonstrates that smaller firms and those with poor past performance would benefit more from recontracting. Their CEOs typically have options that are less in-the-money or even out-of-the-money. Therefore, the payout pattern of their options differs more from that of their stock holdings than it does for more successful CEOs. In our model, savings are generated by replacing the portfolio of stock and options with an option grant that is "intermediate" in the sense that its strike price lies between the strike price of the original option and zero, which is the "strike price" of stock. The scope for these savings is larger, if stock and options in the observed contract differ more from one another, i.e. if the strike price of the original option is high. This suggests that our full sample results are biased downwards and that the average savings in the unbiased sample would be somewhat higher than the 5.3% shown in Table 2.

Wealth robustness check CEO wealth is not observable and we can therefore work only with a rough approximation. In order to see to what extent our results depend on our wealth estimates, we repeat our analysis after multiplying the wealth estimate of all CEOs by a factor M that ranges from 0.5 to 2. Table 4 displays the results for $\gamma = 3$.

A comparison of Table 2, Panel A and Table 4 shows that an increase in wealth W_0 has a similar effect as a decrease in the risk aversion parameter γ. With constant relative risk-aversion, higher wealth implies lower absolute risk-aversion. This leads to more options, a higher strike price, and lower savings. In absolute terms, however, the variation of our results across different wealth multipliers M is small. We therefore conclude that the imprecision in our wealth estimates is unlikely to bias our results significantly. Our qualitative results are certainly not affected.

CEO preferences The CEO's attitude to risk is central to our model. So far we have assumed that the CEO's preferences exhibit constant relative risk aversion (CRRA). In order to see whether our results are robust to alternative assumptions on CEO risk aversion, we repeat our analysis from Table 2 with constant absolute risk aversion (CARA), so that $V^{CARA}(W_T) = -\exp(-\rho W_T)$ replaces $V(W_T)$ in equation (4.2.2). To maintain comparability with our previous results, we calculate the coefficient of absolute risk aversion ρ from γ so that both utility functions exhibit the same risk-aversion at the expected end-of-period wealth, i.e. we set $\rho = \gamma/(W_0 + \pi_0)$, where π_0 is the market value of the manager's contract (i.e., the costs of the contract to the firm). Table 5 displays the results for six different values of γ.

The results are quite similar to those for CRRA in Table 2, Panel A. With CARA preferences, the strike price is somewhat higher than with CRRA preferences: for $\gamma = 3$ the strike price averages 52.1% for CARA instead of 50.5% for CRRA. Savings from recontracting are higher for CARA than for CRRA for low values of risk-aversion ($\gamma < 3$) while the opposite holds for high values of risk-aversion ($\gamma > 3$). We conclude that our results continue to hold for CARA utility.

4.6 Conclusions

In this paper we analyze the optimal stock/option mix using a principal-agent model. We find optimal contracts that look very different from observed compensation practice. According to the model, managers should not receive any stock but instead in-the-money options and higher fixed salary. However, the savings generated by switching to this optimal contract are low and average only 5.3%. This suggests that observed compensation practice is close to the optimum and that a slight preference of shareholders for stock, for at-the-money options, or against an increase in base salary renders observed compensation practice efficient. One such effect included in our model in a robustness check is the extra tax that must be paid by the firm and the CEO if options are issued in the money. These tax penalties are prohibitive for most firms, i.e. they render the observed contract efficient if they are taken into account. But even in the absence of such taxes, the observed contract can easily be optimal if firms have a preference not to increase base salaries and are willing to forgo the 5.3% savings. In times of an increasingly hot public debate on executive compensation, such an upward restriction on base salaries appears plausible.[18]

In the principal-agent model, the agent does not only exert effort but also determines the firm's strategy and thereby its stock return volatility. The choice of a more risky strategy has two effects on the manager's compensation. The first, obvious effect is that higher volatility makes future payoffs more risky, so that the utility a risk-averse manager derives from restricted stock drops. This effect has already been analyzed extensively in the literature (see Lambert, Larcker and Verrecchia, 1991; Guay, 1999; Carpenter, 2000; Ross, 2004). The second effect that has so far been neglected by the empirical literature is that a more risky firm strategy also increases expected firm value. The reason is that the first-best solution, where the optimal

[18]See Hall and Murphy (2000) for an alternative justification of at-the-money strike prices.

management strategy is chosen irrespective of its risk, is not achievable. In the second-best solution, the manager passes up some profitable but risky projects as these would reduce his utility, or he adopts some unprofitable but safe projects that increase his utility. If the firm's strategy is adjusted and becomes more risky in this second-best environment, more profitable and less unprofitable projects will be adopted and firm value increases. Therefore, it is not sufficient to only consider the direct impact of an increase in risk on a manager's compensation package (vega) to determine his attitude towards an increase in risk. The indirect effect via an increase in firm value and the manager's equity incentives (delta) must also be taken into account. Our paper provides - to the best of our knowledge - the first empirical analysis of a full principal agent model that takes both effects into account.

A limitation of our main analysis is its restriction to a single option grant (with a single strike price). In order to understand optimal contracts with more than one option grant, we derive and estimate the general monotonic contract that is not restricted to be piecewise linear. Any piecewise linear contract with a given number of option grants will be an approximation to this general monotonic contract. We find that the optimal monotonic contract pays a flat wage for low outcomes and is increasing and eventually concave over medium and high outcomes. Therefore, it can be implemented by a high fixed salary (twice the observed salary for the median CEO), long option holdings with low, in-the-money strike price, and short option holdings with higher strike prices. Alternatively, it can be approximated by fixed salary and a linear bonus scheme with an upper bound on the bonus payout (see Healy, 1985). Such a contract would save up to 12.9% for the average firm.

Another limitation of our analysis is that our model is static and considers only two points in time: the time of contract negotiation and the time when the final stock price is realized. Realistically, a bad or unlucky CEO is likely to be replaced if the stock price drops by more than

50%.[19] Such a dismissal has two consequences. First it might affect firm performance if the new CEO is more skilled than the ousted CEO. This effect is beyond the scope of our model, as at least two periods are necessary to describe it. Second, dismissals negatively affect the payout of the ousted CEO, mainly because it reduces the CEO's future employment opportunities. Our model predicts a flat pay for low levels of stock price, so this negative effect of a dismissal is undesirable. Consequently, our analysis can also be interpreted as a justification of severance pay that compensates the manager for his loss in human capital (see Yermack (2006)).

4.7 Tables and Figures

[19] Coughlan and Schmidt (1985), Kaplan (1994), and Jenter and Kanaan (2006), among others, analyze the sensitivity of dismissals to past stock price performance.

Table 1: Description of the dataset

This table displays mean, median, standard deviation, and the 10% and 90% quantile of the variables in our dataset. Stock holdings n_S and option holdings n_O are expressed as a percentage of all outstanding shares. Panel A describes our sample of 737 CEOs from 2006. Panel B describes all 1,490 executives in the ExecuComp universe who are CEO in 2006.

Panel A: Data set with 737 U.S. CEOs

Variable		Mean	Std. Dev.	10% Quantile	Median	90% Quantile
Stock (%)	n_S	1.76%	4.85%	0.04%	0.31%	3.96%
Options (%)	n_O	1.40%	1.62%	0.15%	0.96%	3.19%
Base Salary ($m)	ϕ	1.60	4.29	0.50	1.07	2.43
Non-firm Wealth ($m)	W_0	64.9	671.5	2.3	11.1	64.1
Firm Value ($m)	P_0	9,347	23,296	366	2,418	19,614
Strike Price ($m)	K	6,929	20,209	236	1,556	12,853
Moneyness (%)	K/P_0	70.6%	21.1%	42.1%	71.8%	99.9%
Maturity (years)	T	5.2	1.6	3.6	5.0	6.6
Stock Volatility (%)	σ	30.3%	13.6%	16.5%	28.5%	45.8%
Dividend Rate (%)	d	1.37%	3.96%	0.00%	0.66%	3.38%
CEO Age (years)		55.9	6.8	47	56	64
Stock Return 2001-5 (%)		11.8%	15.5%	-5.7%	11.5%	28.8%

Panel B: All 1,490 ExecuComp CEOs in 2006

Variable		Mean	Std. Dev.	10% Quantile	Median	90% Quantile
Stock (%)	n_S	1.95%	6.26%	0.02%	0.28%	4.22%
Options (%)	n_O	1.26%	1.57%	0.08%	0.79%	2.88%
Base Salary ($m)	ϕ	1.68	4.01	0.48	1.02	2.63
Firm Value ($m)	P_0	8,840	24,760	339	2,091	17,796
CEO Age (years)		55.1	7.1	46	55	64
Stock Return 2001-5 (%)		10.5%	23.2%	-13.8%	9.8%	34.1%

Table 2: Optimal piecewise linear contracts

This table describes the optimal piecewise linear contract. The table displays mean and median of the four contract parameters: base salary ϕ^*, stock holdings n_S^*, option holdings n_O^*, and the moneyness, i.e. the option strike price K^* scaled by the stock price P_0. In addition, it shows the fraction of CEOs with non-positive salaries ($\phi^* \leq 0$), the fraction of CEOs with zero stock holdings ($n_S^* = 0$), and the fraction of CEOs with non-positive option holdings ($n_O^* \leq 0$). Savings are the difference in compensation costs between observed contracts and optimal contracts as a percentage of total (observed) pay: $(\pi_0^d - \pi_0^*)/\pi_0^d$. The last row shows the corresponding values of the observed contract. Panel A shows the results for six different values of the parameter of risk aversion γ. The number of observations varies across different values of γ because we exclude all CEO-γ-combinations for which the observed contract implies positive risk-taking incentives *RTI* Panel B displays the results for those 282 CEOs for whom our numerical routine converges for all γ between 1 and 8.

Panel A: Results for all 737 CEOs

Risk Aversion	Obs.	Con-verged	Base Salary ϕ^* ($m)			Stock n_S^*			Options n_O^*			Moneyness K^*/P_0		Savings	
			Mean	Median	Prop≤0	Mean	Median	Prop=0	Mean	Median	Prop≤0	Mean	Median	Mean	Median
0.5	537	120	1.44	1.22	13.3%	0.62%	0.00%	80.8%	2.39%	1.60%	5.83%	55.7%	57.5%	0.11%	0.04%
1.0	665	394	4.73	2.46	0.0%	0.02%	0.00%	98.5%	2.49%	1.55%	1.52%	54.4%	54.5%	0.41%	0.16%
2.0	720	613	7.90	3.21	0.0%	0.04%	0.00%	98.9%	2.51%	1.39%	0.82%	53.2%	54.2%	2.09%	0.86%
3.0	735	654	7.68	3.15	0.0%	0.10%	0.00%	98.8%	2.15%	1.33%	0.46%	50.5%	50.9%	5.32%	2.56%
5.0	735	604	6.56	2.81	0.0%	0.26%	0.00%	95.9%	1.60%	1.14%	0.00%	44.7%	44.8%	14.01%	9.31%
8.0	737	442	4.66	2.08	0.2%	0.28%	0.00%	88.0%	1.14%	0.86%	0.23%	39.8%	39.8%	26.46%	22.20%
Data	737	N/A	1.60	1.07	0.0%	1.76%	0.31%	1.2%	1.40%	0.96%	5.16%	70.6%	71.8%	N/A	N/A

Panel B: Results for 282 CEOs with numerical results for all levels of risk-aversion

Risk Aversion	Fixed Salary ϕ^* ($m)			Stock n_S^*			Options n_O^*			Moneyness K^*/P_0		Savings	
	Mean	Median	Prop≤0	Mean	Median	Prop=0	Mean	Median	Prop≤0	Mean	Median	Mean	Median
1.0	4.08	2.18	0.0%	0.00%	0.00%	100.0%	2.54%	1.86%	0.00%	54.1%	55.0%	0.48%	0.20%
2.0	3.85	2.11	0.0%	0.00%	0.00%	100.0%	2.38%	1.77%	0.00%	50.6%	51.1%	3.16%	1.61%
3.0	3.64	2.03	0.0%	0.00%	0.00%	100.0%	2.16%	1.65%	0.00%	47.0%	47.3%	8.12%	5.15%
5.0	3.27	1.83	0.0%	0.15%	0.00%	97.5%	1.60%	1.23%	0.00%	40.6%	41.1%	20.05%	17.37%
8.0	2.76	1.65	0.4%	0.23%	0.00%	87.2%	1.11%	0.86%	0.00%	34.4%	32.9%	33.97%	35.44%
Data	1.27	0.94	0.0%	0.70%	0.31%	1.8%	1.92%	1.47%	0.00%	68.2%	68.3%	N/A	N/A

Table 3: Savings from recontracting for subsamples

This table shows average savings for quintiles formed according to four variables: initial non-firm wealth W_0, CEO age, firm value P_0, and the past five year stock return (from the start of 2001 to the end of 2005). The risk-aversion parameter γ is set equal to 3. Savings are the difference in compensation costs between observed contract and optimal piecewise linear contract expressed as a percentage of costs of the observed contract, $(\pi_0^d - \pi_0^*)/\pi_0^d$. The last row shows the p-value of the two-sample Wilcoxon signed rank test that the average savings are identical in Quintile 1 and Quintile 5.

Quin-tile	**Wealth W_0 (in \$m)**		**CEO Age**		**Firm Value P_0 (in \$m)**		**Stock return 2001-2005**	
	Mean	**Savings**	**Mean**	**Savings**	**Mean**	**Savings**	**Mean**	**Savings**
1	2.2	10.0%	46.2	7.3%	381	8.7%	-9.1%	9.7%
2	5.4	5.7%	51.5	5.3%	1,122	5.5%	4.9%	5.0%
3	10.3	4.6%	55.1	4.5%	2,462	4.3%	11.2%	4.0%
4	21.5	4.4%	57.9	5.7%	6,406	4.0%	17.2%	3.9%
5	246.3	2.0%	63.4	4.1%	33,935	4.1%	32.8%	4.0%
P-Value Q1-Q5		0.0000		0.0001		0.0001		0.0000

Table 4: Wealth robustness check

This table contains the results from repeating our analysis from Table 2 when we multiply our wealth estimates by the factor M, for $M \in \{0.5, 0.75, 1.5, 2.0\}$. The risk-aversion parameter γ is set equal to 3. The table displays mean and median of the four contract parameters: base salary ϕ^*, stock holdings n_S^*, option holdings n_O^*, and the moneyness, i.e. the option strike price K^* scaled by the stock price P_0. In addition, it shows the fraction of CEOs with non-positive salaries ($\phi^* \leq 0$), the fraction of CEOs with zero stock holdings ($n_S^* = 0$), and the fraction of CEOs with non-positive option holdings ($n_O^* \leq 0$). Savings are the difference in compensation costs between observed contracts and optimal contracts as a percentage of total (observed) pay: $(\pi_0^d - \pi_0^*)/\pi_0^d$. The number of observations varies across different values of the multiplier M because we exclude all CEO-M-combinations for which the observed contract implies positive risk-taking incentives *RTI*.

Multipl. *M*	Obs.	Con-verged	Base Salary ϕ^* (\$m)			Stock n_S^*			Options n_O^*			Moneyness K^*/P_0		Savings	
			Mean	Median	Prop≤0	Mean	Median	Prop=0	Mean	Median	Prop≤0	Mean	Median	Mean	Median
0.50	735	650	7.21	3.00	0.00%	0.18%	0.00%	96.3%	2.05%	1.25%	0.77%	47.9%	48.3%	8.43%	4.59%
0.75	735	650	7.98	3.09	0.00%	0.20%	0.00%	97.4%	2.14%	1.30%	0.77%	49.5%	49.9%	6.56%	3.37%
1.00	735	654	7.68	3.15	0.00%	0.10%	0.00%	98.8%	2.15%	1.33%	0.46%	50.5%	50.9%	5.32%	2.56%
1.50	729	625	7.30	3.21	0.00%	0.18%	0.00%	97.4%	2.13%	1.36%	0.64%	52.1%	53.0%	3.92%	1.81%
2.00	721	608	7.83	3.20	0.00%	0.09%	0.00%	98.2%	2.25%	1.41%	0.49%	52.5%	53.5%	3.22%	1.43%

Table 5: Piecewise linear contracts when CEOs have CARA utility

This table contains the results from repeating our analysis from Table 2 under the assumption that the CEO has CARA utility. For six different values of γ, we calculate the CEO's coefficient of absolute risk aversion ρ as $\rho = \gamma / (W_0 + \pi_0)$, where π_0 is the market value of his observed compensation package and W_0 is his initial non-firm wealth. The table displays mean and median of the four contract parameters: base salary ϕ^*, stock holdings n_S^*, option holdings n_O^*, and the moneyness, i.e. the option strike price K^* scaled by the stock price P_0. In addition, it shows the fraction of CEOs with non-positive salaries ($\phi^* \leq 0$), the fraction of CEOs with zero stock holdings ($n_S^* = 0$), and the fraction of CEOs with non-positive option holdings ($n_O^* \leq 0$). Savings are the difference in compensation costs between observed contracts and optimal contracts as a percentage of total (observed) pay: $(\pi_0^d - \pi_0^*)/\pi_0^d$. The number of observations varies across different values of γ because we exclude all CEO-γ-combinations for which the observed contract implies positive risk-taking incentives *RTI*.

Risk Aversion	Obs.	Con-verged	Base Salary ϕ^* (\$m)			Stock n_S^*			Options n_O^*			Moneyness K^*/P_0		Savings	
			Mean	Median	Prop≤0	Mean	Median	Prop=0	Mean	Median	Prop≤0	Mean	Median	Mean	Median
0.5	626	422	5.46	2.71	0.00%	0.19%	0.00%	98.1%	2.31%	1.51%	1.90%	55.1%	56.3%	0.54%	0.17%
1.0	705	572	6.61	3.15	0.00%	0.02%	0.00%	98.8%	2.26%	1.40%	1.05%	55.6%	56.5%	1.15%	0.45%
2.0	733	640	6.98	3.20	0.00%	0.29%	0.00%	97.3%	2.13%	1.32%	2.03%	54.1%	55.2%	2.99%	1.34%
3.0	735	639	7.09	3.15	0.00%	0.15%	0.00%	98.1%	2.04%	1.24%	1.25%	52.1%	53.1%	5.34%	2.96%
5.0	735	627	7.06	3.04	0.00%	0.25%	0.00%	96.2%	1.79%	1.12%	0.80%	48.6%	49.3%	10.37%	6.92%
8.0	737	556	5.85	2.57	0.00%	0.42%	0.00%	93.4%	1.44%	0.89%	0.72%	45.3%	45.5%	18.56%	16.11%

Chapter 5

Conclusion

The dissertation studies both theoretical and empirical components in executive compensation. The next section will give a short summary of the main findings of the three chapters followed by implications and suggestions for future research.

5.1 Summary of the Main Findings

Chapter 2 constructs a novel measure of executive optimism by separating incentives that CEOs receive and the incentives CEOs can and should get rid of as a risk-averse agent. The optimistic ratio measure is based on executives' relative portfolio compositions in unrestricted and restricted parts. We show that CEO optimistic ratios are positively and signficantly related to firm-specific price crash risk. Optimistic CEOs tend to spend more on R&D projects while producing less innovation output in return. The paper provides new evidence that CEO personal portfolio decisions are related to firm performance. The results are robust to various empirical specifications and various previously identified factors of stock price crash risk.

In Chapter 3, we consider a model in which shareholders provide a risk-averse CEO with risk-taking incentives in addition to effort incentives. We show that the optimal contract protects the CEO from losses for bad outcomes, is convex for medium outcomes, and concave for good outcomes. We calibrate the model to data on 727 CEOs and show that it can explain observed contracts much better than the standard model without risk-taking incentives. Under the assumptions that contracting is efficient and that CEOs are effort-averse and risk-averse, our results imply that the provision of risk-taking incentives is a major objective in executive compensation practice. We can reject the hypothesis that risk-taking incentives in observed contracts are a mere by-product of effort incentives. A new measure of risk-taking (dis)incentives that measures the required probability an additional risky project must exceed in order to be adopted by the CEO is proposed. Subsequently in Chapter 4, we apply the same model to contracts that consist of base salary, stock, and options yields that options should be issued in the money. If the tax discrimination against in-the-money options are taken into account, the model is then consistent with the almost uniform use of at-the-money stock options. We conclude that risk-taking incentives are important in provisions

5.2 Implications and Suggestions for Future Research

The relationship we document between CEO optimism and stock price crash is quite strong and more robust than regular incentive alignment measures. In particular, we show that the incentives CEOs should get rid of, not the incentives CEOs receive, play a more significant role in stock price crashes. This suggests that closer attention should be paid to managerial portfolio *decisions* in addition to managerial portofolio *compositions*. Traditionally in the literature, the attention is on how much incentives are contracted to the executives, without taking how much incentives executives can get rid of into account. While there is another strand of literature that considers executive option expensing behavior[1], there is hardly any paper that considers both aspects in the dynamics of incentive evolution. Our findings have important implications in combining both aspects in executive compensation: the incentives CEOs receive and the incentives CEOs get rid of.

In Chapter 3 and Chapter 4, a unique calibration approach[2] that requires a minimum

[1] See Klein and Maug (2009) for examples of the literature.

[2] For detailed implementation methods, one can refer to Dittmann, Maug, Spalt, and Zhang (2011).

set of parameter assumptions and enables model fitting for each CEO in the sample, not simply the average, is employed. In comparison with regular empirical studies, our calibration approach circumvents the endogeneity problem by specifically modeling the likely simultaneous relationship between corporate risk-taking policies and executive risk-taking incentives. In comparison with regular theoretical research, the approach incorporates more information in the calibration, and allows us to test the quantitative (not just the qualitative) implications of different models.

One of the possible extension to the already complicated model in Chapter 3 and 4 is to consider the dynamics of incentive revolution as suggested in Chapter 2. In Chapter 2, we show that not only the incentives that CEOs receive, but also the incentives that CEOs should get rid of play a role in corporate policies. It would be interesting to consider this in a model that incorporates both aspects in incentives and study the implications on evolution of executive pay and corporate policies.

Chapter 6

Samenvatting (Summary in Dutch)

In de afgelopen 20 jaar stonden vergoedingen voor topmanagement centraal in zowel academische discussies, als in de kranten van Wall Street. Hebben aandeelhouders te veel betaald aan CEO's? Zijn de vergoedingen nodig voor het werven en behouden van leidinggevend talent? Is de manier waarop de vergoedingen zijn opgebouwd redelijk? Of bevordert de manier waarop beloond wordt dat CEO's gaan manipuleren?

Het debat tussen het zogenaamde "rent-seeking" idee, waarbij leidinggevenden steeds geld onttrekken van hun aandeelhouders, en het "efficient contracting" idee, waar de beloning voor de leidinggevenden wordt bepaald door rationele economische overwegingen van de aandeelhouders, lijkt op korte termijn geen definitieve conclusie op te leveren. Dit proefschrift draagt bij aan het debat door in de eerste twee hoofdstukken een economische verklaring te geven voor de huidige beloningssystemen. Vervolgens zal ik in hoofdstuk vier beschrijven hoe bedrijven, wiens CEO's meer aandelen en opties hebben dan nodig, een grotere kans hebben op een plotselinge daling van de beurskoers. Een te groot optimisme van de CEO's kan hiervan de oorzaak zijn.

Hoofdstuk 2 "CEO Optimism en Stock Crashes" onderzoekt wat er gebeurt als CEO's meer bedrijfsaandelen bezitten dan nodig is. De standaard agency-theorie gaat uit van een belangenconflict wat de risico's betreft zoals geïllustreerd in de laatste twee hoofdstukken. Leidinggevenden zijn meer risicomijdend omdat hun rijkdom sterk verbonden is met het bedrijf, en ze de risico's niet kunnen afdekken zoals algemene aandeelhouders dat kunnen. Waarom blijven ze vasthouden aan de aandelen en opties wanneer ze deze eigenlijk niet nodig hebben? Het hoofdstuk onderzoekt een aantal mogelijke redenen. Ik construeer een manier om dit optimisme te kunnen meten gebaseerd op de relatieve mix van beperkte en onbeperkte prikkels en toon aan dat CEO's met een hogere ratio optimisme - een ratio van onbeperkte stimuli loon en totale prikkel loon, meer kans hebben om meer uit te geven aan R & D-projecten, maar minder effectief zijn in innovatieve resultaten. En hun bedrijven hebben meer kans op grote koersdalingen. De resultaten zijn robuust voor tal van empirische "settings" en overtreffen de bestaande voorspellers van aandelenkoers-crashes.

In hoofdstuk 3, getiteld " How Important are Risk Taking Incentive in Executive Compensation?" onderzoeken we een model waarin aandeelhouders een risico mijdende CEO extra beloningen geven die aanzetten om risico's te nemen, in aanvulling op de normale belondingen. We laten zien dat een optimale contract de CEO beschermt tegen verliezen vanwege slechte resultaten, convex is voor gemiddelde resultaten, en concaaf voor goede resultaten. We kalibreren het model met gegevens over 727 CEO's en laten zien dat het de beoordeelde contracten beter verklaart dan het standaard model zonder prikkels die aanzetten tot het nemen van risico's. Uit het toepassen hiervan op contracten die bestaan uit een basissalaris, aandelen en opties blijkt dat opties als geld uitgekeerd moeten worden. Bovendien stellen wij voor een nieuwe maatregel te nemen rondom (anti) prikkels die de benodigde "kans" meet, die een extra risicovol project moet overschrijden om te kunnen worden uitgevoerd door de CEO.

Hoofdstuk 4 " Should Options be Issued in the Money? Evidence from Model Calibrations with Risk-Taking Incentives" onderzoekt de optimale structuur van CEO-vergoedingen, met name veelgebruikte compensatiemechanismen zoals: een vast salaris, aandelen en opties. We passen hetzelfde model toe uit hoofdstuk 2 op de individuele CEO gegevens en laten zien dat het optimale compensatie pakket at-the-money opties en aandelen vervangen door in-the-money opties. Het blijkt dat het model de praktijk van vergoedingen verrassend goed kan verklaren. Als men rekening houdt met de fiscale discriminatie van in-the-money opties, dan is het model consistent met het bijna uniform gebruik van at-the-money aandeel opties.

In hoofdstuk 3 en hoofdstuk 4, gebruiken we een unieke kalibratie aanpak die een minimale aantal parameter aannamen nodig heeft en maakt het model passend voor elke CEO in de steekproef - en niet alleen de gemiddelde. De kalibratie aanpak overbrugt de kloof tussen theoretisch en empirisch onderzoek naar de beloning van bestuurders en stelt ons in staat om de kwantitatieve (en niet alleen de kwalitatieve) implicaties van de verschillende modellen te testen. Bovendien draagt deze aanpak bij aan de empirische literatuur over vergoedingen voor de CEO's omdat dit het endogeniteit probleem omzeilt dat aandeelhouders tegelijkertijd stevige risico en management prikkels bepalen wanneer zij de vergoedingen in contracten ontwerpen, wiens endogeniteit we modelleren en de voorspellingen van dit model testen. Een andere bijdrage aan de empirische literatuur is een nieuwe maatregel van (anti) prikkels die de risico voorkeuren van managers combineert met de vorm van zijn vergoedingencontract en datgene wat we noemen "risico vermijdend". Het meet de gewenste winstgevendheid welke een extra risicovol project moet overschrijden, om te worden aangenomen door de CEO. De mediaan risicovermijding is in onze steekproef is 1,25 voor een risico-mijdende parameter van 2.

Bibliography

[1] Acharya, Viral V., Yakov Amihud, and Lubomir Litov, 2008. Creditor rights and corporate risk-taking, discussion paper, New York University.

[2] Alexander, Raquel Meyer, Mark Hirschey, and Susan Scholz, 2007. Backdating employee stock options: Tax implications, *CPA Journal* 77(10), 24-28.

[3] Athanasakou, Vasiliki, Lisa Goh, and Daniel Ferreira. 2011. Excessive Risk-taking and the Structure of Executive Compensation, working paper.

[4] Ali, Ashiq, Kelsey D. Wei, and Yibin Zhou. 2011. Insider Trading and Option Grant Timing in Response to Fire Sales (and Purchases) of Stocks by Mutual Funds. *Journal of Accounting Research* 49(3): 595-632.

[5] Armstrong, Christopher S., David F. Larcker, and Che-Lin Su, 2007. Stock options and chief executive officer compensation, discussion paper, Stanford University.

[6] Arping, Stefan, Zacharius Sautner. 2010. Did the Sarbanes-Oxley Act of 2002 Make Firms Less Opaque? Evidence from Analyst Earnings Forecasts, working paper.

[7] Bebchuk, Lucien Arye, and Jesse M. Fried, 2004, *Pay without performance - the unfulfilled promise of executive compensation* (Harvard University Press, Cambridge (MA) and London).

[8] Bebchuk, Lucian Arye, Martijn Cremers, and Urs Peyer. 2011. The CEO pay slice. *Journal of Financial Economics* forthcoming.

[9] Ben-david, Itzhak, John R Graham, and Campbell R Harvey. 2010. Managerial miscalibration, NBER working paper.

[10] Bereskin, Frederick L., and Po-Hsuan Hsu. 2011. New dogs new tricks: CEO turnover, CEO-related factors, and innovation performance, working paper, University of Connecticut.

[11] Billett, Matthew T., David C. Mauer, and Yilei Zhang. 2010. Stockholder and Bondholder Wealth Effects of CEO Incentive Grants. *Financial Management* 39(2): 463-487.

[12] Brisley, Neil. 2006. Executive Stock Options: Early Exercise Provisions and Risk-taking Incentives. *Journal of Finance* 61(5): 2487-2509.

[13] Campbell, T. Colin, Michael Gallmeyer, Shane a. Johnson, Jessica Rutherford, et al. 2011. CEO optimism and forced turnover. *Journal of Financial Economics* 101(3): 695-712.

[14] Carpenter, Jennifer N. 2000. Does Option Compensation Increase Managerial Risk Appetites? *Journal of Finance* 50(5): 2311-2331.

[15] Carpenter, Jennifer N. 1998. The exercise and valuation of executive stock options. *Journal of Financial Economics* 48(2): 127-158.

[16] Carpenter, Jennifer N., Richard Stanton, and Nancy Wallace. 2010. Optimal exercise of executive stock options and implications for firm cost. *Journal of Financial Economics* 98(2): 315-337.

[17] Chen, Joseph S., Harrison Hong, and Jeremy C. Stein. 2001. Forecasting crashes: trading volume, past returns, and conditional skewness in stock prices. *Journal of Financial Economics* 61(3): 345-381.

[18] Coles, Jeffrey L., Naveen D. Daniel and Lalitha Naveen, 2006, Managerial incentives and risk-taking, *Journal of Financial Economics* 79, 431-468.

[19] Core, John E., and Wayne R. Guay, 2002, Estimating the value of stock option portfolios and their sensitivities to price and volatility, *Journal of Accounting Research* 40, 613-640.

[20] Core, John E. and Qian, Jun, 2002, Project selection, production, uncertainty, and incentives, Working paper, University of Pennsylvania.

[21] Coughlan, Anne T., and Ronald M. Schmidt, 1985, Executive compensation, management turnover, and firm performance: An empirical investigation, *Journal of Accounting and Economics* 17, 43-66.

[22] DeFusco, Richard A., Robert R. Johnson, and Thomas S. Zorn, 1990, The effect of executive stock option plans on stockholders and bondholders, *Journal of Finance* 45, 617-627.

[23] Dittmann, Ingolf, and Ernst Maug, 2007, Lower salaries and no options? On the optimal structure of executive pay, *Journal of Finance* 62, 303-343.

[24] Dittmann, Ingolf, Ernst Maug, and Oliver Spalt. 2010. Sticks or Carrots? Optimal CEO Compensation when Managers Are Loss Averse. *Journal of Finance* 65(6).

[25] Dittmann, Ingolf, Ernst Maug, Oliver Spalt, and Dan Zhang. 2011. Note on the Calibration of Executive Compensation Models. working paper.

[26] Dittmann, Ingolf, and Ko-Chia Yu. 2011. How Important are Risk-Taking Incentives in Executive Compensation?, working paper.

[27] Dittmann, Ingolf, and Ko-Chia Yu. 2008. Should Options be Issued in the Money? Evidence from Model Calibrations with Risk-Taking Incentives, working paper.

[28] Dittmann, Ingolf, Ernst Maug, and Dan Zhang. 2011. Restricting CEO Pay. *Journal of Corporate Finance*, Forthcoming

[29] Edmans, Alex, and Qi Liu. 2010. "Inside Debt." Review of Finance 15(1): 75-102

[30] Edmans, Alex, and Xavier Gabaix, 2009, Tractability and detail-neutrality in incentive contracting, discussion paper, Wharton School.

[31] Edmans, Alex, Xavier Gabaix, and Augustin Landier, 2009. A multiplicative model of optimal CEO incentives in market equilibrium, *Review of Financial Studies* 22(12): 4881-4917.

[32] Edmans, Alex, Xavier Gabaix, Tomasz Sadzik, and Yuliy Sannikov, 2009, Dynamic incentive accounts, discussion paper, New York University.

[33] Faccio, Mara, Maria-Teresa Marchica, and Roberto Mura. 2010. Large shareholder diversification and corporate risk-taking, working paper.

[34] Feltham, Gerald A. and Martin G. H. Wu, 2001, Incentive efficiency of stock versus options, *Review of Accounting Studies* 6, 7-28.

[35] Flor, Christian Riis, Hans Frimor, and Claus Munk. 2011, Options in compensation: promises and pitfalls, working paper.

[36] Gabaix, Xavier, and Augustin Landier, 2008, Why has CEO pay increased so much?, *Quarterly Journal of Economics* 123, 49-100.

[37] Gervais, Simon, JB Heaton, and Terrance Odean. 2011. Overconfidence, compensation contracts, and capital budgeting. *Journal of Finance* forthcoming.

[38] Gopalan, Radhakrishnan, Todd Milbourn, Fenghua Song, and Anjan V. Thakor. 2011. The Optimal Duration of Executive Compensation : Theory and Evidence, working paper.

[39] Grossman, Sanford J., and Oliver D. Hart, 1983, An analysis of the principal-agent problem, *Econometrica* 51, 7-45.

[40] Guay, Wayne R., 1999, The sensitivity of CEO wealth to equity risk: An analysis of the magnitude and determinants, *Journal of Financial Economics* 53, 43-71.

[41] Habib, Michel A., and Alexander Ljungqvist, 2005, Firm value and managerial incentives: A stochastic frontier approach, *Journal of Business* 78, 2053-2093.

[42] Hall, Brian J., and Jeffrey B. Liebman, 1998, Are CEOs really paid like bureaucrats?, *Quarterly Journal of Economics* 113, 653-691.

[43] Hall, Brian J., and Kevin J. Murphy, 2000, Optimal exercise prices for executive stock options, *American Economic Review* 90, 209-214.

[44] Hribar, Paul, and Holly Yang. 2010. Does CEO Overconfidence Affect Management Forecasting and Subsequent Earnings Management?, working paper, University of Pennsylvania

[45] Haugen, Robert A., and Lemma W. Senbet, 1981, Resolving the agency problems of external capital through options, *Journal of Finance* 36, 629-647.

[46] Healy, Paul M., 1985, The effect of bonus schemes on accounting decisions, *Journal of Accounting and Economics* 7, 85-107.

[47] Hellwig, Martin F. 2009. A reconsideration of the Jensen-Meckling model of outside finance, *Journal of Financial Intermediation* 18(4): 495-525.

[48] Hemmer, Thomas, Oliver Kim, and Robert E. Verrecchia, 1999, Introducing Convexity into Optimal Compensation Contracts, *Journal of Accounting and Economics* 28, 307-327.

[49] Henderson, M Todd. 2011. Insider Trading and CEO Pay. Vanderbilt Law Review (64) : 505-555.

[50] Hirshleifer, David and Yoon Suh, 1992, Risk, managerial effort and project choice, *Journal of Financial Intermediation* 2, 308-345.

[51] Hirshleifer, DA, Angie Low and Siew Hong Teoh. 2010. Are Overconfident CEOs Better Innovators? working paper.

[52] Holmström, Bengt, 1979, Moral hazard and observability, *Bell Journal of Economics* 10, 74-91.

[53] Huddart, Steven J., and Mark Lang, 1996, Employee stock option exercises - an empirical analysis, *Journal of Accounting and Economics* 21, 5-43.

[54] Hutton, Amy P., Alan J. Marcus, and Hassan Tehranian. 2009. Opaque financial reports, R2, and crash risk. *Journal of Financial Economics* 94(1): 67-86.

[55] Inderst, Roman, and Holger M. Müller, 2005, Benefits of Broad-Based Option Pay, CEPR Discussion Paper no. 4878.

[56] Jenter, Dirk, 2002, Executive compensation, incentives, and risk, working paper, MIT Sloan School of Management.

[57] Jenter, Dirk, and Fadi Kanaan. 2010. CEO Turnover and Relative Performance Evaluation. *Journal of Finance* forthcoming.

[58] Jewitt, Ian, 1988, Justifying the First-Order Approach to Principal-Agent Problems, *Econometrica* 56, 1177-1190.

[59] Kaplan, Steven N., 1994, Top executive rewards and firm performance: A comparison of Japan and the United States, *Journal of Political Economy* 102, 510-546.

[60] Kale, Jayant R., Ebru Reis, and Anand Venkateswaran. 2009. "Rank-Order Tournaments

and Incentive Alignment: The Effect on Firm Performance." *Journal of Finance* 64(3): 1479-1512.

[61] Kim, Jeong-bon, Yinghua Li, and Liandong Zhang. 2011. CFOs versus CEOs: Equity incentives and crashes. *Journal of Financial Economics* (1993): 1-18.

[62] Klein, Daniel, and Ernst Maug. 2009. How do Executives Exercise Their Stock Options?, working paper.

[63] Knopf, John D., Jouahn Nam and John H. Thornton, Jr., 2002, The volatility and price sensitivities of managerial stock option portfolios and corporate hedging, *Journal of Finance* 57, 801-813.

[64] Lambert, Richard A., 1986, Executive effort and selection of risky projects, *Rand Journal of Economics* 17, 77-88.

[65] Lambert, Richard A., and David F. Larcker, 2004, Stock options, restricted stock, and incentives, discussion paper, Wharton School.

[66] Lambert, Richard A., David F. Larcker, and Robert Verrecchia, 1991, Portfolio considerations in valuing executive compensation, *Journal of Accounting Research* 29, 129-149.

[67] Lewellen, Katharina, 2006, Financing decisions when managers are risk averse, *Journal of Financial Economics* 82, 551-589.

[68] Low, Angie, 2009, Managerial risk-taking behavior and equity-based compensation, *Journal of Financial Economics* 92, 470-490.

[69] Malmendier, Ulrike, and Geoffrey Tate. 2005a. CEO overconfidence and corporate investment." *Journal of Finance* 22(1): 2661–2700.

[70] Malmendier, Ulrike, and Geoffrey Tate. 2005b. Does Overconfidence Affect Corporate Investment? CEO Overconfidence Measures Revisited." *European Financial Management* 11(5): 649-659.

[71] Malmendier, Ulrike, and Geoffrey Tate. 2008. Who makes acquisitions? CEO overconfidence and the market's reaction." *Journal of Financial Economics* 89(1): 20-43.

[72] Malmendier, Ulrike, and Geoffrey Tate. 2011. Overconfidence and Early-life Experiences : The Effect of Managerial Traits on Corporate Financial Policies." *Journal of Finance* forthcoming.

[73] Manso, Gustavo. 2011. Motivating Innovation. *Journal of Finance* forthcoming.

[74] May, Don O., 1995, Do managerial motives influence firm risk reduction strategies?, *Journal of Finance* 50, 1291-1308.

[75] Murphy, Kevin J., 1999, Executive compensation, in O. Ashenfelter and D. Cards, eds.: *Handbook of Labor Economics* 3 (North Holland, Amsterdam).

[76] Odean, Terrance, Jonathan Berk, and Domenico Cuoco. 2002. "The Positive Role of Overconfidence and Optimism in Investment Policy." working paper.

[77] Otto, Clemens A. 2011. "CEO optimism and incentive compensation." working paper, London Business School.

[78] Oyer, Paul, 2004, Why do firms use incentives that have no incentive effects?, *Journal of Finance* 59, 1619-1650.

[79] Peng, Lin, and Ailsa Röell, 2009, Managerial incentives and stock price manipulation, discussion paper, Columbia University.

[80] Prendergast, Canice, 2002, The tenuous trade-off between risk and incentives, *Journal of Political Economy* 110, 1071-1102.

[81] Rajgopal, Shivaram, and Terry Shevlin, 2002, Empirical evidence on the relation between stock option compensation and risk taking, *Journal of Accounting and Economics* 33, 145-171.

[82] Rogerson, William P., 1985, The First-Order Approach to Principal-Agent Problems, *Econometrica* 53, 1357-1367.

[83] Ross, Stephen A., 2004, Compensation, incentives, and the duality of risk aversion and riskiness, *Journal of Finance* 60, 207-225.

[84] Rosser, Bruce A., and Jean M. Canil, 2004, Executive stock options: Evidence that premium and discount awards do matter, discussion paper, University of Adelaide.

[85] Smith, Gavin S., and Peter L. Swan, 2007, The incentive to 'bet the farm': CEO compensation and major investments, discussion paper, University of New South Wales.

[86] Smith, Clifford W., and René M. Stulz, 1985, The determinants of firms' hedging policies, *Journal of Financial and Quantitative Analysis* 20, 391-405.

[87] Sautner, Zacharias, Martin Weber, and Markus Glaser. 2010. "What determines how top managers value their stock options?" 1-34.

[88] Sundaram, Rangarajan K., and David Yermack, 2007, Pay me later: Inside debt and its role in managerial compensation, *Journal of Finance* 62, 1551-1588.

[89] Sung, Jaeyoung, 1995, Linearity with project selection and controllable diffusion rate in continuous-time principal-agent problems, *RAND Journal of Economics* 26, 720-743.

[90] Tchistyi, Alexei, David Yermack, and Hayong Yun, 2011, Negative hedging: Performance sensitive debt and CEO's equity incentives. *Journal of Financial and Quantitative Analysis*, 46, 657-686

[91] Thompson, Samuel B. 2011. Simple formulas for standard errors that cluster by both firm and time. *Journal of Financial Economics* 99(1): 1-10.

[92] Tufano, Peter, 1996, Who Manages Risk? An Examination of Risk Management Practices in the gold mining industry, *Journal of Finance* 51, 197-1137

[93] Tumarkin, Robert. 2010. How Much Do CEO Incentives Matter? working paper.

[94] Walker, David I., 2009, The Non-Option: Understanding the dearth of discounted employee stock options, *Boston University Law Review*, (08).

[95] Yermack, David, 2006, Golden handshakes: Separation pay for retired and dismissed CEOs, *Journal of Accounting and Economics* 41, 237-256.

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