

研發效用年限與高階主管獎酬

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摘要

本研究探討研發投資的效用年限對高階主管獎酬之影響，研究結果顯示高階主管獎酬契約的設計會將研發投資的效用年限納入考慮。首先，本研究發現研發效用年限較長的公司，傾向於向上調整CEO的現金獎酬與研發支出變動的關聯性，以避免CEO的現金獎酬受到研發支出對盈餘有負面效果之影響，並補償CEO因為研發投資所面臨之風險增加；同時，也增加股票選擇權的獎酬與研發支出的敏感度以促使CEO將研發支出投入在較佳的研發案上。另一方面，研發效用年限較短的公司，在決定CEO獎酬時，傾向於將研發支出當作費用。此外，結果顯示，當研發的效用年限較長時，CEO獎酬對會計績效的敏感度降低，說明了研發的效用年限降低了會計報酬率在績效衡量上的適當性。最後，本研究發現對新任的CEO，獎酬委員會增強研發效用年限與CEO獎酬對研發支出敏感度之影響，以鼓勵面臨高度不確定性的新上任CEO投資於具長期性質的研發支出，並降低研發效用年限與CEO獎酬對會計報酬率的敏感度之關連，因為繼任CEO任期中早期階段的會計績效很可能反映的是前任CEO對研發的投入。

關鍵詞：研發效用年限、高階主管獎酬、管理激勵誘因、研發不確定性

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R&D Horizon and CEO Compensation*

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Abstract

This study investigates the impact of the long-lived nature of R&D investment on CEO compensation, and provides evidence that the R&D horizon is contract-relevant. First, this study documents that firms with a longer R&D payoff period tend to adjust the association between CEO cash compensation and changes in R&D expenditures upward to shield CEO cash compensation from the negative earnings impact of R&D expenses as well as to provide compensation for the risks embedded in such R&D investment, while increasing option compensation to induce R&D investment in good projects. On the other hand, firms with a short R&D payoff period tend to treat R&D expenditures as an expense when rewarding CEOs. In addition, the results show that CEO compensation is less sensitive to accounting returns when R&D has a longer horizon, suggesting that the R&D horizon reduces the desirability of accounting return as a performance measure. Finally, I find that, for new CEOs, compensation committees tend to strengthen the association between R&D horizon and the sensitivity of CEO compensation to R&D expenditure in order to encourage new CEOs to invest in long-lived R&D and reduce the association between R&D horizon and the sensitivity of CEO cash compensation to accounting returns since accounting performance in the earlier stage of the successor's tenure is more likely to reflect the R&D effort of the predecessor CEO when R&D has a long horizon.

Keywords: *R&D horizon, CEO compensation, Managerial incentives, R&D uncertainty.*

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1. INTRODUCTION

Unlike other capital expenditures, R&D investments usually require a longer payoff period; yet, R&D expenditures are not capitalized in the financial statements and stock prices do not fully incorporate the value of off-balance assets (Hall 1993; Lev and Sougiannis 1996; Chan, Lakonishok and Sougiannis 2001).¹ Thus, while accounting numbers and stock prices are most frequently observed as performance measures in executive compensation contracts (Murphy 2000), they do not fully reflect managerial efforts in regard to investing and managing R&D capital. However, managers are endowed with private information about the value and opportunities of the firm's investment in R&D; in addition, their efforts in managing R&D capital are not directly observable to the shareholders. Most importantly, the R&D horizon is usually longer than the average CEO tenure and the risks inherent in R&D activities may magnify the agency problem.² As a result, the design of managerial compensation contracts plays an important role in inducing managers to optimize the investment and management of R&D. The purpose of this study is to investigate whether and how compensation committees consider the long-lived nature of R&D investment when designing compensation contracts.

Prior research on R&D and executive compensation has focused on the flow of R&D investments, and uses annual R&D spending as proxy for information asymmetry or managerial efforts related to R&D management (e.g. Clinch 1991; Gaver 1992; Cheng 2004). However, solely looking at how much a firm spends on R&D treats the risks and the future benefit of one dollar of R&D investment as being homogeneous across industries and across firms. Studies by Lev and Sougiannis (1996), Lev, Nissim and Thomas (2008), and Amir, Guan and Livne (2007) show that the payoff period of R&D is different across industries; Shi (2003) shows that the risk and uncertainty of R&D is higher for R&D investment with a longer R&D useful life span. While Shi (2003) points out that valuation research tends to overstate the future benefits of R&D and overlook its related riskiness, overlooking risks associated with R&D investments in incentive contract design has a real impact on a firm's value because it reduces contract efficiency and, more importantly, hampers managerial incentives to make optimal R&D decisions for the shareholders' benefit.^{3,4} Thus, considering the trade-off between risk and incentives, R&D horizon is

¹ Some observers suggest that investors overestimate the benefits from R&D and thus the valuations attached to R&D –intensive technology stocks are excessive. See detailed discussion in Chan, Lakonishok and Sougiannis (2001).

² Lev and Sougiannis (1996) and Lev et al. (2008) document that there are variations in the economic useful life spans of R&D across industries and that the useful life ranges from 4 to 8 years; yet, the median CEO tenure in my sample of R&D intensive firms is 68 months (5.6 years), comparable to the statistics documented in prior studies (e.g. Antia, Pantzalis and Park 2010).

³ The basic premise in the literature is that shareholders are risk-neutral since they can diversify their portfolio and the managers are risk-adverse since their human capital endowment in the firms cannot be fully diversified.

used herein as a proxy for risks associated with R&D activities and to examine whether the association between changes in R&D expenditure and changes in CEO compensation, as documented in Cheng (2004), differs among firms with different R&D gestation periods/horizons.

Lev et al. (2008) estimate the economic life of R&D spending and its impact on future earnings across a variety of industries. Based on the estimated useful life of R&D by Lev et al. (2008), this study provides evidence that firms with a longer R&D horizon tend to adjust the association between changes in CEO compensation and changes in R&D expenditure upward (positively) to encourage CEOs to create future R&D capital and to compensate for the risks imposed on the executives. I also find a greater increase in option compensation to be associated with changes in R&D spending when the R&D horizon is longer, suggesting that firms use more option compensation to match the CEO's planning horizon with that of the shareholders, and to induce managers to invest in good projects when R&D requires a long payoff period. However, when a firm has a short R&D payoff period, the compensation committees of these firms treat R&D expenditures more like other expenses since the problem of overinvestment from tying CEO compensation positively with an increase in R&D spending dominates the benefits of shielding CEOs from the risks of R&D.

In addition, considering the long-lived nature of R&D investment, the way that the relative weights of accounting return and stock return in CEO compensation vary with R&D horizon is examined. Overall, it is clear that there is a strong downward association between R&D horizon and the strength of the implicit relation between accounting return and CEO cash, options and total compensation. Specifically, the slope coefficients from regressing CEO compensation on accounting return decrease in relation to the R&D horizon. Thus, firms with a long R&D horizon appear to tie compensation awards less closely to accounting-based performance measures than do short R&D horizon firms. Besides, the evidence shows that such attenuating effect is more evident for CEOs who have just taken office. For new CEOs, firms strengthen the sensitivity of CEO compensation to R&D expenditure when R&D has longer horizon to avoid conservative R&D investment behavior. However, I found no evidence that the R&D horizon weakens the association between changes in CEO compensation and stock return.

The contribution of this study is two-fold. First, this study sheds light on the impact of R&D horizon on the relation between executive compensation and R&D spending, and reconciles the inconclusive findings in the literature. Prior research on the relation between R&D spending and executive compensation finds mixed evidence. Bizjak, Brickley and

⁴ Gjesdal (1981) shows that information system rankings for decision making and stewardship do not generally coincide. Christensen, Feltham and Sabac (2005) show that while earning quality is desirable for valuation, it is not necessarily so for contracting.

Coles (1993) find a negative association between R&D spending and CEO cash and total compensation, while Matsunaga (1995) and Yermack (1995) find no association between R&D spending and option compensation. A recent study by Cheng (2004) finds a positive association between R&D spending and CEO compensation when opportunistic reductions in R&D spending are more likely to happen, but no association otherwise. These studies use R&D spending measures, such as ratios of annual R&D expenditures to sales, assets or equity, as a proxy for information asymmetry or growth opportunity. The evidence in this study extends Cheng (2004) and Clinch (1991) and shows that R&D horizon has implications beyond the naïve R&D spending measures in explaining CEO compensation. Specifically, this study shows that the relation between CEO compensation and R&D spending is affected by the R&D horizon. The reason is that R&D horizon captures the risks associated with the future payoff of R&D investment. Thus, when facing the trade-off between risks and incentives, compensation committees adjust the relation between CEO compensation and R&D spending according to the payoff period of R&D investment. In addition, R&D horizon also has an impact on the relative sensitivity of CEO compensation to accounting returns versus stock returns.

Second, prior research on the CEO horizon problem tends to focus on the situation when CEOs approach retirement (e.g. Dechow and Sloan (1991), Baber, Janakiraman and Kang (1996), and Cheng (2004)); although this helps to sharpen the predictions, CEO turnover threats actually occur at any CEO age and CEO planning horizon would continue longer than CEO tenure. For example, Campbell and Marino (1994) show that managers select myopic investments to show their superior abilities to labor markets and hope to move before their poor choices become apparent. Thus, the myopia problem would exist even when there is no expected CEO retirement. The long-lived nature of R&D spending enables this study to examine how compensation contract design copes with the horizon problem across different stages of CEO tenure. In addition, the evidence in this study sheds light on the compensation contract designs for CEOs in the earlier years of their tenure. Specifically, for CEOs who have just taken office, the sensitivity of cash compensation to accounting return is reduced when firms have a longer R&D horizon. Besides, to provide new CEOs with sufficient incentives to invest in R&D with a long payoff period, compensation committees strengthen the positive association between CEO compensation and such R&D expenditures. The evidence documented in the study also helps to explain how firms encourage managers to create intangible assets with long-lived nature and avoid misallocation of managerial efforts on managing intangible assets.

The next section of the paper summarizes relevant previous research and develops hypotheses. Section 3 explains the sample and the research design. Section 4 summarizes the results, and Section 5 provides additional tests. Section 6 concludes with a discussion of the study's implications.

2. LITERATURE REVIEW AND HYPOTHESIS DEVELOPMENT

Agency theory suggests that optimal contracts relate executive compensation directly with performance measures presumed to be correlated with management's actions. The strength of the relation between compensation and performance measure is partly determined by the relative informativeness of the performance measures. Specifically, the sensitivity of executive compensation to a given performance measure is increasing in the "signal-to-noise" ratio of the performance measure in evaluating management's efforts (Lambert and Larcker 1987; Banker and Datar 1989; Sloan 1993).

While accounting numbers and stock prices are most frequently observed as performance measures in executive compensation contracts (Murphy 2000),⁵ they do not fully capture managers' efforts in regard to R&D investment or in utilizing a firm's R&D capital to maximize firm value. The mandated full expensing of R&D results in a negative impact of R&D expenditures on current accounting earnings. Thus, when managerial compensation is tied to the aggregate accounting measures, such as ROA, ROE or EPS, managers have an incentive to boost current accounting earnings by reducing R&D expenditures. For example, Baber, Fairfield and Haggard (1991) show that managers are more likely to consider current-period income effects when making R&D decisions than when making capital-spending decisions, as the costs of the latter are amortized over a number of accounting periods.

Much of the accounting literature has tried to identify the weights on alternative measures of earnings, or components of earnings (e.g. Clinch and Magliolo 1993; Dechow, Huson and Sloan 1994; Healy, Kang and Palepu 1987; Gaver and Gaver 1998; Natarajan 1996). Along this line of research, Cheng (2004) studies the relation between changes in CEO compensation and changes in R&D expenditure to investigate how CEO compensation plans mitigate the undesirable managerial opportunistic behavior in regard to R&D spending. He predicts that as R&D spending is generally desirable to shareholders, compensation committees seek to prevent any opportunistic reduction in R&D spending by relating CEO compensation positively with R&D spending. However, naïvely linking CEO compensation positively with R&D spending potentially encourages overinvestment in R&D.

In addition, although Cheng (2004) claims that focusing on situations where opportunistic reductions in R&D expenditure are more likely to happen helps to sharpen predictions about the relation between R&D expenditures and CEO compensation, his study provides little implication on how opportunistic behavior in R&D investment can be

⁵ Much of the literature examines how compensation contracts substitute toward accounting- and market-based performance measures when such measures are better indicators of managerial performance (e.g. Engel, Hayes and Wang 2003).

addressed in a more general setting. Particularly, the CEO horizon problem may occur even when there is no expected CEO retirement, and the myopia problem may exist at any level of performance threshold. For example, Campbell and Marino (1994) show that managers select myopic investments to show their superior abilities in regard to labor markets, and hope to move before their poor choices become apparent.

As CEO turnover is difficult to anticipate and the average CEO tenure is relatively short, this study posits that compensation committees address this issue according to the R&D horizon of a firm. Prior research shows that the payoff period and the risks associated with R&D expenditures differ across industries (Lev and Sougiannis 1996; Lev et al. 2008; Amir et al. 2007). The estimation in Lev et al. (2008) shows that the payoff period of R&D investments ranges from 4 to 8 years across different industries. As the R&D horizon is often longer than the average CEO tenure of 5.6 years in our sample of R&D intensive firms, compensation contracts must address the horizon problem to avoid managerial opportunism even when there is no expected CEO retirement.

This study posits that the moral hazard problem becomes more severe when a firm's R&D investment requires a longer payoff. First, managers are risk-averse while shareholders are risk-neutral. To ensure that managers pursue risky projects to maximize shareholders' interests, compensation contracts have to be designed in a way that encourages risk taking and to compensate the managers for the risks imposed on them. As argued in Shi (2003), the longer the payoff period of R&D, the riskier the future benefits of R&D investment. Thus, when R&D requires a longer payoff period, firms need to strengthen the association between changes in CEO compensation and changes in R&D expense to encourage CEOs to invest for future R&D capital and to compensate the CEOs for the risks embedded in such R&D investments.

Second, under current accounting treatment, R&D expenditures are fully expensed and thus have a negative impact on earnings and, consequently, on the executives' accounting-based compensation. Yet, as average CEO tenure is shorter than the general payoff period of R&D, the future benefits of current R&D investment become more uncertain to be fully or partially realized during the CEO's tenure. Thus, as R&D expenditures take a longer payoff period, the executives would be more reluctant to invest in R&D and tying CEO compensation more positively related to R&D expenditure helps to avoid myopia R&D underinvestment.

The discussion above leads to the following testable hypothesis:

H1: The sensitivity of CEO compensation to R&D expenditures increases with the R&D horizon.

In addition to identifying the weights on alternative measures of earnings, or components of earnings, another line of literature evaluates the relative weights placed on earnings and stock return in compensation plans (e.g. Clinch and Magliolo 1993; Dechow et al. 1994; Healy et al. 1987; Gaver and Gaver 1998; Natarajan 1996; Baber, Kang and Kumar 1998, 1999). Specifically, boards of directors may adjust the weights that compensation contracts placed on accounting returns and stock returns to mitigate the potential problems derived from evaluating managerial performance based on these typical performance measures. Prior research has looked into the possible adjustments that the board of directors would make to mitigate the undesirable managerial opportunistic behaviors. Based on the assumption that stock prices will immediately reflect the market perception of R&D efforts, Clinch (1991) argues that compensation has a stronger association with stock return than with accounting earnings when *R&D intensity* increases, but he provides inconclusive empirical evidence. The inconclusive results can be partly explained by later studies that document market mispricing of R&D capital in R&D intensive companies.

Specifically, although stock price is forward-looking and reflects market perceptions of R&D investment, it may not be a sufficient statistic for contracting purposes (Bushman and Indjejikian 1993; Feltham and Wu 2000). First, a firm's stock price is a function of the managers' actions and some exogenous noise factors that are beyond the managers' control (Sloan 1993); thus it is a noisy indicator of managerial R&D efforts. Second, prior studies document that stock prices do not fully incorporate the value of off-balance assets because of the information asymmetry which exists between the manager and shareholders and the uncertainty of realized benefits from current R&D spending. For example, Lev and Sougiannis (1996) document that R&D capital does not appear to be fully reflected contemporaneously in stock prices. Their finding suggests investor's under-reaction to R&D information or an extra-market risk factor associated with R&D capital. Chan et al. (2001) find that market prices on average incorporate the future benefits from R&D, while the lack of accounting information on R&D capital increases stock volatility.⁶ Aggarwal and Samwick (1999) find that the variance of a performance measure is an important determinant of pay-performance sensitivity. As R&D capital increases stock volatility, it decreases the contracting quality of stock return. In addition, Hall (1993) suggests that investors have short time horizons and fail to anticipate the rewards from long-term investments such as R&D. Thus, the R&D horizon may decrease the desirability of using stock returns as a performance measure in the compensation contract design. However, despite the possibility that R&D accumulated from prior years may increase the noise in

⁶ There are also observers who suggest that investors overestimate the benefits from R&D and thus valuations attached to R&D intensive technology stocks are excessive. See detailed discussion in Chan et al. (2001).

stock return, current accounting treatment on R&D investment is still likely to make stock returns more informative about the managerial effort relative to accounting earnings. Thus, how R&D horizon affects the absolute sensitivity of CEO compensation to stock returns is less clear.

However, R&D expenditures are not capitalized under generally accepted accounting principles. When R&D has a longer payoff period, firms tend to carry a greater magnitude of off-balance sheet assets, i.e. R&D capital, which is the accumulation of R&D investment in previous years. Thus, traditional accounting measures, such as ROA or ROE, that deflate earnings by total assets or equity obtained from the balance sheet may overstate the profitability and efficiency of a firm in utilizing its assets on hand or investment by the shareholders.⁷ This would become more of a problem when a CEO has just taken office because such off-balance sheet assets were created by the predecessor and pays off with a time lag.

To increase contract efficiency and to provide managers with sufficient incentives to optimize R&D management, this study expects the weight on accounting return to decrease in relation to R&D horizon. In addition, the literature indicates the importance of examining the relative weights when multiple performance measures are considered (e.g. Lambert and Larcker 1987; Baber et al. 1996). Thus, following Baber et al. (1996), this study examines whether the relative weight on accounting performance versus market return decreases with increased R&D horizon. The discussion above leads to the following testable hypothesis:

H2: The relative sensitivity of CEO compensation to accounting returns, versus stock returns, decreases with the R&D horizon.

Past accounting literature on the managerial horizon problem tends to focus on the situation when CEO is approaching retirement (e.g. Murphy and Zimmerman 1993; Dechow and Sloan 1991; Cheng 2004); compensation contract design for newly-appointed CEOs has been relatively less discussed in the literature. Recent studies have started to recognize that when a firm hires a new CEO, it enters into a complex relationship that has significant long-term implications, such as organizational strategies and performance, for the stockholders; while the CEO faces a tremendous amount of uncertainty that incurs agency costs and contracting costs (e.g. Gillan, Hartzell and Parrino 2009).

Gillan et al. (2009) point out that a new CEO who faces more uncertainty might also be more likely to avoid risky positive net present value projects or to pursue

⁷ I follow the procedures in Lev et al. (2008) and calculate the proportion of past spending that is still productive in a given year, i.e. stock of R&D capital. In my sample, the average ratio of R&D capital to book value of equity is 14.2 percent, indicating that that R&D capital is nontrivial.

overly-conservative policies. Thus, to avoid such conservative behaviors on R&D investment, the board of directors ought to provide CEOs with sufficient incentives to invest in R&D, particularly when the R&D requires a longer horizon.

Besides, if the R&D horizon reduces the informativeness of accounting return as a performance measure, one would expect to see this attenuating effect to be more consequential when a new CEO has just taken office. The reason is that accounting performance in the earlier years of the successor's tenure would, to a certain extent, come from the payoff of R&D investment cumulated from prior years during the predecessor CEO's tenure. Thus, I expect that the impact of R&D horizon on the relation of CEO compensation to R&D expenditures (H1) and to accounting returns versus stock returns (H2) to be stronger for newly-appointed CEOs.

The discussion above leads to the following testable hypotheses:

H3a: The impact of R&D horizon on the sensitivity of CEO compensation to R&D expenditure is stronger for new CEOs.

H3b: The negative impact of R&D horizon on the relative sensitivity of CEO compensation to accounting returns, versus stock returns, is stronger for new CEOs.

3. EMPIRICAL DESIGN

3.1 SAMPLE AND DATA

The sample selection procedure starts from S&P 500 firms during 1993-2004 with sufficient data from ExecuComp for the compensation and stock return data and Compustat for the accounting data. Similar to prior studies (Dechow and Sloan 1991; Murphy and Zimmerman 1993; Cheng 2004), this study examines large firms as agency problems with innovation are more severe in these firms. Following Shi (2003), Chan et al. (2001) and Cheng (2004), the focus here is on R&D-intensive industries with two-digit SIC codes of 28, 34, 35, 36, 37, and 38. The sample period starts from 1993 because the data in ExecuComp start from 1992 and lagged compensation data are required to compute the changes in bonuses. The firm-year observations with CEO turnover during the year are deleted. To reduce the effects of extreme observations, the observations for which any of the variables used in the regression lie outside the top and bottom 1 percent range of its sample distribution are deleted. These selection criteria result in a sample of 1,016 firm-year observations. All monetary items are restated to the dollar value in 2000, using the Consumer Price Index.

3.2 MEASUREMENT OF THE MAIN VARIABLES

R&D Horizon

Lev and Sougiannis (1996) and Lev et al. (2008) estimate the impact of current and past R&D spending on earnings across R&D intensive industries. The estimates from these studies are frequently adopted in the literature, for example, Shi (2003) and Chan et al. (2001). This study also relies on the estimates on the industry-specific useful life of R&D investment by Lev et al. (2008). Specifically, the value equals to 4 in the Machinery and Computer Hardware industries (SIC: 35) and the Scientific Instruments industry (SIC: 38), 5 in the Fabricated metal industries (SIC: 34), 6 in the Transportation Vehicles industries (SIC: 37), and 8 in the Chemical and Pharmaceuticals industry (SIC: 28) and the Electrical and Electronics industry (SIC: 36).⁸

CEO Compensation

Following prior studies (e.g. Cheng 2004; Davila and Venkatachalam 2004), three measures of CEO compensation are used: cash compensation, option compensation, and total compensation. CEO cash compensation is the sum of CEO salary and annual bonus. Option compensation is the Black and Scholes value of option grants in the fiscal year. CEO total compensation is the sum of salary, bonus, other annual, value of stock options granted, value of restricted stock granted, long-term incentive payouts, and all other.

Performance Variables

ROE is measured as earnings before extraordinary items and discontinued operation and before R&D expenditures divided by the average common stockholders' equity. Stock return is measured using the sum of capital gains and dividends divided by the stock price at the beginning of the year. R&D expenditure includes internal R&D spending and acquired in-progress R&D.

3.2 EMPIRICAL MODEL

The extant literature suggests various compensation-performance specifications. Similar to Lambert and Larcker (1987), Jensen and Murphy (1990), and Babe et al. (1996), the basic model specification in this study regresses changes in CEO compensation on changes in ROE and stock returns. This basic model examines the sensitivity of CEO compensation to the accounting performance, measured as changes in ROE, and stock returns.

To test my first hypothesis, I rely on the useful life estimates provided by Lev et al. (2008) and assign an indicator variable, *R&D horizon*, with value equal to the specific payoff period of R&D as reported in Lev et al. (2008). The specific amortization period

⁸ See Lev et al. (2008) for further details.

ranges from 4 years in the Scientific Instruments industry (SIC: 38) and the Machinery and Computer Hardware industry (SIC: 35) to 8 years in the Chemical and Pharmaceuticals industry (SIC: 28) and the Electrical and Electronics industry (SIC: 36).⁹ I then estimate the following regression model to test the first hypothesis:

$$\begin{aligned} \Delta COMP_{i,t} = & \alpha_0 + \alpha_1 \Delta ROE_{i,t} + \alpha_2 \Delta ROE_{i,t} \times RD Horizon_i + \alpha_3 RET_{i,t} \\ & + \alpha_4 RET_{i,t} \times RD Horizon_i + \alpha_5 \Delta RD_{i,t} + \alpha_6 \Delta RD_{i,t} \times RD Horizon_i \\ & + \alpha_7 RD Horizon_i + \varepsilon_{i,t} \end{aligned} \quad (1)$$

where, for each firm i and year t :

- $\Delta COMP$ = change in the natural log of CEO compensation;
- ΔROE = change in earnings before extraordinary items before R&D expenditure, deflated by average book value of common equity;
- RET = one-year stock return (dividend reinvested);
- ΔRD = change in R&D expenditures, deflated by average book value of common equity;
- $RD Horizon$ = indicator variable with value equals to the estimated useful life of R&D spending as reported in Lev et al. (2008).

H1 predicts that $\alpha_6 < 0$, i.e. the association between changes in CEO compensation and changes in R&D expenditures is adjusted upward when R&D expenditures have a longer gestation period. Generally, I expect $\alpha_1 > 0$ and $\alpha_3 > 0$ for a positive pay-performance sensitivity. The interaction terms, $\Delta ROE_{i,t} \times RD Horizon_i$ and $\Delta RET_{i,t} \times RD Horizon_i$, indicate how *R&D horizon* impacts the sensitivity of CEO compensation to the accounting returns and market returns, respectively, and are the main focus of investigation for H2. The discussion in Section 2 posits α_2 to be negative, while making no clear prediction on α_4 . H2 predicts that the relative sensitivity of CEO compensation to accounting earnings numbers, versus market performance, is lower when firms have longer *R&D horizon*. Because accounting returns and market returns are scaled differently, the magnitude of α_2 cannot be compared with the magnitude of α_4 . Thus H2 is supported only when $\alpha_2 < 0$ and $\alpha_4 \geq 0$.¹⁰

To test H3a and H3b, I expand regression model (1) to include a dummy variable, *NEW*, to indicate whether CEO tenure is below the 1st tenure quartile, 36.67 months,¹¹ of the sample CEOs and interact *NEW* with $\Delta ROE_{i,t} \times RD Horizon_i$, $\Delta RET_{i,t} \times RD Horizon_i$, and $\Delta RT_{i,t} \times RD Horizon_i$. The model is specified as follow:

⁹ See Lev et al. (2008) for further details.

¹⁰ Baber et al. (1996) also examine the relative compensation weights on accounting returns versus stock returns and provide a detailed discussion on the hypothesis testing of the relative weights.

¹¹ 36.67 months is comparable to the average duration of explicit CEO employment agreement of 3.41 years (median, 3 years) documented in Gillan et al. (2009)

$$\begin{aligned}
\Delta COMP_{i,t} = & \beta_0 + \beta_1 \Delta ROE_{i,t} + \beta_2 \Delta ROE_{i,t} \times RD Horizon_i + \beta_3 \Delta ROE_{i,t} \times NEW \\
& + \beta_4 RET + \beta_5 RET_{i,t} \times RD Horizon_i + \beta_6 RET_{i,t} \times RD Horizon_i \times NEW \\
& + \beta_7 \Delta RD_i + \beta_8 \Delta RD_{i,t} \times RD Horizon_i + \beta_9 \Delta RD_{i,t} \times RD Horizon_i \times NEW \\
& + \beta_{10} RD Horizon_i + \beta_{11} NEW + \varepsilon_{i,t}
\end{aligned} \tag{2}$$

H3a predicts the coefficient on $\Delta RD_{i,t} \times RD Horizon_i \times NEW$ to be positive, i.e. the impact of *R&D horizon* on the sensitivity of CEO compensation to R&D expenditure is stronger for new CEOs. H3b predicts that compensation committees reduce the relative weight on accounting returns, versus stock returns, for new CEO when the *R&D horizon* is longer and is supported when $\beta_3 < 0$ and $\beta_6 \geq 0$.

4. RESULTS

4.1 DESCRIPTIVE STATISTICS

Panel A of Table 1 presents the industry composition of the sample firms, industry *R&D horizon*, and the average of firm characteristics, including return on equity, one-year stock return, and market-to-book ratio.

Panel B of Table 1 presents the descriptive statistics for major components of CEO compensation for the 1,016 observations in the sample.¹² The median total compensation is \$4,855,230 and the median cash compensation is \$1,833,280. At the median, the bonus represents 53% of CEO cash compensation and stock options represent 40% of total compensation. More than 50% of the CEOs in our sample do not receive restricted stocks. Similarly, more than 50% of the sample firms do not have long-term incentive plans (LTIP). At the mean, the sum of salary, bonus, option, restricted stock, and long-term incentive payment represents 96% of CEO total compensation.¹³

Panel C of Table 1 reports the descriptive statistics for variables in the regression model. The statistics in this table show that the volatility of CEO option compensation changes (Std. Dev. = 0.77) is greater than the volatility of CEO cash compensation changes (Std. Dev. = 0.30) and that of total compensation changes (Std. Dev. = 0.55). Besides, the median CEO tenure of the sample firms is 68 months (5.6 years), which is relatively short compared to the *R&D horizon* that ranges from 4 to 8 years across different industries. Table 2 reports the correlation between CEO cash/total compensation, ROE, stock returns,

¹² Most executive pay packages contain four basic components: a base salary, an annual bonus tied to accounting performance, stock options, and long-term incentive plan (including restricted stock plans). For a detailed discussion, see Murphy (1999).

¹³ Other compensation components include perquisites, payments to cover executive's taxes, preferential earnings payable but deferred at executive's election, company contributions to benefit plans, split-dollar insurance payments, etc.

and R&D variables. Consistent with prior studies, both CEO cash compensation and total compensation are positively related to accounting returns and stock returns; yet, CEO option compensation is not strongly correlated with accounting returns.

TABLE 1 Descriptive Statistics (N=1,016, 1993-2004)

Panel A: Sample composition and averages of some key variables by industry						
Industry (2-digit SIC)	No. of Obs.	<i>R&D Horizon</i>	<i>ROE</i>	<i>RET</i>	<i>M/B ratio</i>	
Chemicals and Pharmaceuticals (28)	240	8	0.26	0.18	6.09	
Fabricated Metal Industries (34)	26	5	0.13	0.12	2.19	
Machinery and Computer Hardware (35)	388	4	0.20	0.33	4.62	
Electrical and Electronics (36)	125	8	0.17	0.35	4.82	
Transportation Vehicles (37)	92	6	0.18	0.19	2.99	
Scientific Instruments (38)	145	4	0.18	0.27	5.26	
Panel B: Descriptive statistics for CEO compensation (in thousands of \$)						
Variable	No. of Obs.	<i>Mean</i>	<i>Std Dev</i>	<i>Lower Quartile</i>	<i>Median</i>	<i>Upper Quartile</i>
Salary	1,016	884.25	324.42	692.145	856.00	1,019.63
Bonus	1,016	1,142.24	926.31	571.55	970.90	1,440.00
Option	1,016	3,533.05	6,426.55	802.67	1,940.32	4,103.72
RSTK	1,016	458.00	1,444.65	0	0	19.14
LTIP	1,016	496.37	1,546.90	0	0	432.23
Cash comp	1,016	2,026.49	1,080.70	1,365.21	1,833.28	2,464.80
Total comp	1,016	6,780.16	7,317.03	3,112.88	4,855.23	7,714.55
Panel C: Descriptive statistics for variables in the regression models						
Variable	No. of Obs.	<i>Mean</i>	<i>Std Dev</i>	<i>Lower Quartile</i>	<i>Median</i>	<i>Upper Quartile</i>
$\Delta LnCash$	1,016	0.0851	0.2998	-0.0288	0.0836	0.2415
$\Delta LnOption$	816	0.1969	0.7703	-0.1734	0.2010	0.5250
$\Delta LnTotal$	1,016	0.1279	0.5477	-0.1306	0.1523	0.4259
ΔROE	1,016	0.0006	0.1204	-0.0598	-0.0009	0.0542
RET	1,016	0.2690	0.4541	-0.0112	0.1979	0.4173
ΔRD	1,016	-0.0043	0.0290	-0.0118	-0.0026	0.0050
$RD Intensity$	1,016	0.0580	0.0469	0.0241	0.0421	0.0812
Tenure	1,016	91.1380	73.7150	36.6667	68.0000	120.3333
Age	967	55.886	6.5895	52	57	61

Variable definitions:

- Option* = aggregate Black-Scholes value of stock options granted;
- RSTK* = value of restricted stock granted;
- LTIP* = long-term incentive plan payouts;
- Cash comp* = salary and bonus;
- Total comp* = sum of salary, bonus, other annual, value of stock options granted, value of restricted stock granted, long-term incentive payouts, and all other;
- $\Delta \ln \text{Cash}$ = change in the natural log of CEO's cash compensation (salary and bonus);
- $\Delta \ln \text{Option}$ = change in the natural log of the value of CEO annual option grants;
- $\Delta \ln \text{Total}$ = change in the natural log of CEO's total compensation (salary, bonus, other annual, restricted stock granted, stock options granted, long-term incentive payouts, and all other total);
- RET* = one-year stock return (dividend reinvested);
- ΔROE = change in earnings before extraordinary items before R&D expenditure, deflated by average book value of common equity;
- ΔRD = change in R&D expenditures, deflated by average book value of common equity;
- RD Intensity*= R&D expense divided by sales;
- Tenure* = CEO tenure (in months); and
- Age* = CEO age.

4.2 REGRESSION RESULTS

Table 3 presents the impact of *R&D horizon* on the association between changes in CEO compensation and the performance measures, i.e. stock return, changes in ROE, and changes in R&D spending. The results based on CEO cash compensation, reported in Column (1), show that changes in CEO cash compensation are, on average, positively associated with changes in ROE and stock returns, and negatively associated with changes in R&D expenditure. In addition to the general positive pay-performance sensitivities, this result suggests that, on average, firms do not place a positive weight on R&D spending as it may induce overinvestment.

The estimated coefficient on the interaction term between changes in R&D spending and *RD horizon* is significantly positive (0.477, $t=2.96$), consistent with H1. This suggests that compensation committees adjust the association between changes in R&D expenditure and changes in CEO cash compensation upward to shield CEOs from the negative earnings impact of R&D spending when R&D spending has a longer gestation period to encourage investment in creating long-term intangible assets, R&D capital. As Shi (2003) suggests, the longer the payoff period of R&D expenditure, the longer it takes to derive R&D benefits, and thus the more risky the future benefits of R&D. Thus, by adjusting the association between changes in R&D expenditure and changes in CEO cash compensation upward, compensation contracts, to some extent, also shield CEOs from the risks associated with R&D investment.

The estimated coefficient on $\Delta ROE \times RD horizon$ (-0.078, $t=-1.99$), is significantly negative, indicating that if a firm's R&D investment has a longer payoff period, CEO cash compensation places a lower weight on accounting return, suggesting that the long-lived nature of R&D investment makes accounting return an undesirable performance measure for CEO efforts. On the other hand, the coefficients on the interaction term between stock return and the estimated R&D capital are insignificantly positive (0.013, $t=1.26$), suggesting that the sensitivity between CEO compensation and stock return is not reduced by firms' *R&D horizon*. I interpret the results as signifying that while stock price undervalues a firm's R&D capital (eg. Chan et al. 2001), it still impounds a greater extent of market perceptions of R&D performance and serves as an acceptable performance measure or a better performance measure than accounting returns when a firm has longer *R&D horizon*. This trade-off then leads to the result of insignificant coefficient on the interaction term between stock returns and *R&D horizon*. The result from interacting accounting return and stock return with *R&D horizon* contrasts to the puzzling finding in Clinch (1991) that both slope coefficients from a regression of compensation on stock return and accounting return on equity increase systematically with *R&D intensity*.¹⁴ My

¹⁴ This result from Clinch (1991) appears puzzling because prior studies, such as Lambert and Larcker

results suggest that the impact of *R&D horizon* on the pay-performance sensitivity differs from that of *R&D intensity*.

Overall, the negative estimated coefficients on $\Delta ROE \times RD Horizon$ ($\alpha_2 < 0$) and the insignificant (different from zero) estimated coefficients on $RET \times RDC$ ($\alpha_4 = 0$) support H2 that the relative compensation weights on accounting return, versus stock return, are reduced when R&D has a longer horizon. In other words, *R&D horizon* creates a disparity between the informativeness of accounting return and stock return in the evaluation of CEO performance.

Column (2) of Table 3 reports the results for CEO option compensation. The estimated coefficient on ΔROE remains significantly positive (2.239, $t=2.97$) and the coefficient on ΔRD remains significantly negative (-8.542, $t=-2.77$). When interacting with *R&D horizon*, the estimated coefficient on $\Delta ROE \times RD horizon$ turns significantly negative (-0.362, $t=-2.82$), suggesting that, when R&D has a longer payoff period, the board then adjusts the sensitivity of option compensation to accounting performance downward to preclude the CEO from focusing on short term performance. The estimated coefficient on $RET \times RD horizon$ remains insignificant. The results support the hypothesis that *R&D horizon* reduces the weight on accounting performance relative to the weight on stock return.

It is worth noting that the magnitude of the estimated coefficient on $\Delta RD \times RD horizon$ (1.359, $t=2.71$) is about three times of that in the cash compensation regression. This is consistent with Cheng (2004) that stock option grants tied to R&D spending to help enhance the chance that only “good” R&D investments are induced. The result is also consistent with the argument by Smith and Watts (1982) and Gaver (1992) that stock options reduce the horizon problem by equating the manager’s decision horizon with that of the shareholders.

The results for CEO total compensation are reported in Column (3) of Table 4. Similar to prior studies (Sloan 1993; Baber et al. 1998), the coefficients on changes in return on equity (1.236, $t=2.58$) and stock return (0.240, $t=2.05$) are both significantly positive, suggesting a strong positive pay-performance sensitivity on CEO total compensation. The coefficient on $\Delta ROE \times RD horizon$ (-0.147, $t=-1.84$) is significantly negative, while the coefficient on $RET \times RD horizon$ (-0.02, $t=-0.97$) is insignificantly different from zero, indicating that, overall, compensation committees recognize that accounting returns are noisy performance measures for managerial efforts when R&D expenditures have a longer payoff period.

(1987), Sloan (1993), and Bushman and Indjejikian (1993), show that compensation contracts substitute toward market- and accounting-based measures when such measures better capture managerial efforts.

TABLE 2
Pearson Correlation among the Variables in the Regression (N=1,016, 1993-2004)

	$\Delta LnOption$	$\Delta LnTotal$	RET	ΔROE	ΔRD	$Rdintensity$	$Tenure$	Age
$\Delta LnCash$	-0.03915 (0.2640)	0.2468 (<0.0001)	0.2474 (<0.0001)	0.3801 (<0.0001)	-0.0376 (0.2312)	0.0298 (0.3432)	0.0655 (0.0369)	-0.0557 (0.0834)
$\Delta LnOption$		0.7240 (<0.0001)	0.0750 (0.0322)	0.0330 (0.3471)	-0.0214 (0.5446)	-0.0005 (0.9893)	0.0304 (0.3866)	-0.0149 (0.6792)
$\Delta LnTotal$			0.1694 (<0.0001)	0.1206 (0.0001)	0.0256 (0.4150)	0.0173 (0.5820)	0.0567 (0.0708)	-0.0822 (0.0106)
RET				0.1638 (<0.0001)	0.0485 (0.1220)	0.1570 (<0.0001)	0.1228 (<0.0001)	-0.1874 (<0.0001)
ΔROE					0.2837 (<0.0001)	-0.0659 (0.0357)	0.0216 (0.4925)	-0.0763 (0.0177)
ΔRD						-0.0042 (0.8949)	0.0205 (0.5131)	0.0147 (0.6481)
$Rdintensity$							0.1298 (<0.0001)	-0.0538 (0.0944)
$Tenure$								0.2212 (<0.0001)

Variable definitions:

$\Delta LnCash$ = change in the natural log of CEO's cash compensation (salary and bonus);

$\Delta LnOption$ = change in the natural log of the value of CEO annual option grants;

$\Delta LnTotal$ = change in the natural log of CEO's total compensation (salary, bonus, other annual, restricted stock granted, stock options granted, long-term incentive payouts, and all other total);

RET = one-year stock return (dividend reinvested);

ΔROE = change in earnings before extraordinary items before R&D expenditure, deflated by average

TABLE 3
Analysis of the Impact of R&D Horizon on the Sensitivities of CEO Compensation to Accounting Return, Stock Return, and R&D Spending

	Predicted Signs	(1) ΔLnCash	(2) $\Delta \text{LnOption}$	(3) $\Delta \text{LnTotal}$
Intercept	?	0.1051 (2.25)***	0.149 (1.02)	0.045 (0.47)
ΔROE	+	1.377 (5.83)***	2.239 (2.97)***	1.236 (2.58)***
$\Delta \text{ROE} \times \text{Rdhorizon}$	-	-0.078 (-1.99)***	-0.362 (-2.82)***	-0.147 (-1.84)**
RET	+	0.089 (1.55)*	-0.005 (-0.03)	0.240 (2.05)**
$\text{RET} \times \text{Rdhorizon}$?	0.013 (1.26)	0.002 (0.07)	-0.020 (-0.97)
ΔRD	?	-4.373 (-4.49)***	-8.542 (-2.77)***	-0.925 (-0.47)
$\Delta \text{RD} \times \text{Rdhorizon}$	+	0.477 (2.96)***	1.359 (2.71)***	0.161 (0.49)
Rdhorizon		-0.004 (-0.70)	-0.002 (-0.10)	0.003 (0.25)
N		1,016	1,016	1,016
Adj. R^2		0.2352	0.0718	0.0577

t-statistics are presented in parenthesis.
***, **, * indicate significance at the 1%, 5% and 10% level respectively (one-tailed when the coefficient sign is predicted, two-tailed otherwise).

ΔLnCash = change in the natural log of CEO's cash compensation (salary and bonus);
 $\Delta \text{LnOption}$ = change in the natural log of the value of CEO annual option grants;
 $\Delta \text{LnTotal}$ = change in the natural log of CEO's total compensation (salary, bonus, other annual, restricted stock granted, stock options granted, long-term incentive payouts, and all other total);
 RET = one-year stock return (dividend reinvested);
 ΔROE = change in earnings before extraordinary items before R&D expenditure, deflated by average book value of common equity;
 ΔRD = change in R&D expenditures, deflated by average book value of common equity;
 Rdhorizon = indicator variable with value equals to the estimated useful life of R&D spending as reported in Lev et al. (2008).
Year dummies are included, but not reported.

TABLE 4
Analysis of the Impact of R&D Horizon on the Sensitivities of CEO Compensation to Accounting Return, Stock Return, and R&D Expenditure, Distinguishing Observations Where the CEO Is New to the Company

	Predicted Signs	(1) $\Delta \ln \text{Cash}$	(2) $\Delta \ln \text{Option}$	(3) $\Delta \ln \text{Total}$
Intercept	?	0.113 (2.45)**	0.157 (1.08)	0.058 (0.62)
ΔROE	+	1.359 (5.80)***	2.206 (2.94)***	1.212 (2.56)***
$\Delta ROE \times RDH$	-	-0.064 (-1.63)*	-0.364 (-2.82)**	-0.134 (-1.68)**
$\Delta ROE \times RDH \times NEW$	-	-0.0632** (-2.12)	0.071 (0.75)	-0.029 (-0.48)
RET	+	0.101 (1.77)**	0.011 (0.06)	0.267 (2.31)**
$RET \times RDH$?	0.006 (0.63)	0.004 (0.12)	-0.024 (-1.18)
$RET \times RDH \times NEW$?	0.031*** (3.32)	-0.052 (-1.65)*	-0.029 (-0.48)
ΔRD	?	-4.351 (-4.50)***	-9.119 (-2.96)***	-1.646 (-0.84)
$\Delta RD \times RDH$	+	0.387 (2.39)***	1.187 (2.32)**	-0.014 (-0.04)
$\Delta RD \times RDH \times NEW$	+	0.272*** (2.56)	0.830*** (2.57)	0.923*** (4.28)
RDH_{horizon}		-0.002 (-0.56)	-0.001 (-0.07)	0.004 (0.40)
New		-0.082*** (-3.53)	0.016 (0.22)	-0.081* (-1.73)
N		1,016	816	1,016
Adj. R^2		0.2508	0.0801	0.0791

t -statistics are presented in parenthesis.
***, **, * indicate significance at the 1, 5 and 10% level respectively (one-tailed when the coefficient sign is predicted, two-tailed otherwise).

$\Delta \ln \text{Cash}$ = change in the natural log of CEO's cash compensation (salary and bonus);
 $\Delta \ln \text{Option}$ = change in the natural log of the value of CEO annual option grants;
 $\Delta \ln \text{Total}$ = change in the natural log of CEO's total compensation (salary, bonus, other annual, restricted stock granted, stock options granted, long-term incentive payouts, and all other total);
 RET = one-year stock return (dividend reinvested);
 ΔROE = change in earnings before extraordinary items before R&D expenditure, deflated by average book value of common equity;
 ΔRD = change in R&D expenditures, deflated by average book value of common equity;
 RDC = R&D capital estimated by Lev et al. (2008), deflated by average book value of common equity;
 New = dummy with value equals to 1 if CEO tenure is less than the first tenure quarter of all sample CEOs, 36.67 months.

Year dummies are included, but not reported.

Consistent with Cheng (2004), the coefficient on ΔRD is insignificant, indicating no direct association between changes in CEO total compensation and changes in R&D spending. In other words, compensation committees shield CEO total compensation from R&D expenses. I also do not find the association between CEO total compensation and R&D expenditure to be adjusted according to the *R&D horizon* of the firm, in contrast with the finding on cash compensation and option compensation regression. One possible explanation is that, at the mean, the sum of CEO cash compensation and option compensation only represents 82% of CEO total compensation. Thus, the inclusion of long-term compensation and other compensation components in total compensation introduces noises to the regression model, and thus total compensation is influenced by more factors than cash compensation or option compensation is. Compared with the adjusted *R*-square of 23.52 percent for cash compensation regression and 7.18 percent for option compensation regression, the adjusted *R*-square of 5.77 percent for total compensation regression also reflects that the explanatory power of the model is relatively low.

Most importantly, the results taken together suggest that compensation contract design is a more complicated task than just deciding how much to pay in total to the CEOs. Each compensation component of the total pay is structured for certain purposes, such as retaining talent CEOs from the competitive labor market, providing appropriate incentives for CEOs to take desirable actions, balancing CEOs' risk exposure, etc. Thus, a compensation package comprises different components that work together to align managers' incentive and to maximize firm value.

Table 4 reports the regression results for Hypotheses 3a and 3b (Eq. 2). Similar to the results in Table 3, the estimated coefficients on ΔRD is significantly negative for CEO cash compensation (-4.351, $t=-4.50$) and for CEO option compensation (-9.119, $t=-2.96$). When interacting ΔRD with *RDhorizon*, the estimated coefficients on $\Delta RD \times RDhorizon$ are significantly positive for both cash compensation (0.387, $t=2.39$), and option compensation (1.187, $t=2.32$), suggesting that the sensitivity of CEO cash and option pay to R&D expenditure is adjusted upward when the *R&D horizon* is longer.

The estimated coefficients on $\Delta RD \times RDH \times NEW$ are significantly positively for CEO cash compensation (0.272, $t=2.56$), option compensation (0.830, $t=2.57$), and total compensation (0.923, $t=4.28$), consistent with H3a. The results suggest that in the earlier years of CEO tenure, firms with longer *R&D horizon* are more likely to provide CEOs with incentives to invest in R&D activities and reduce CEO's exposure to the related R&D uncertainties.

However, regarding the impact of *R&D horizon* on the relative weights of accounting return versus stock return for new CEOs, I only find the result to support H3b in CEO cash

compensation. Column (1) of Table 4 reports that the estimated coefficient on $\Delta ROE \times RDH \times NEW$ is significantly negative (-0.0632, $t=-2.12$), suggesting that the attenuating influence of *R&D horizon* on the use of accounting return for evaluating CEO performance is more evident for CEOs who are in the earlier years of their tenure. The statistically significant positive estimate on the interaction $RET \times RDH \times NEW$ (0.031, $t=3.32$) indicates that market-based performance measures then receive a greater weight in rewarding new CEOs of firms with longer *R&D horizon*.

I do not find CEO option compensation to exhibit similar pattern for new CEOs. A possible reason is that the option grants during the earlier year of the CEO tenure are more likely to be aimed to reach optimal managerial ownership than just paying for performance. Consequently, the results based on CEO total compensation are weak as well.

5. ADDITIONAL TESTS

5.1 THE IMPACT OF SHORT R&D HORIZON ON THE PAY-PERFORMANCE SENSITIVITIES

To make it convenient to interpret the coefficients when the *R&D horizon* is short, I assign a dummy variable, *SHORT*, with value equal to one if the firm's R&D investment has the shortest payoff period of 4 years, i.e. firms in the Scientific Instruments industry (SIC: 38) and the Machinery and Computer Hardware industry (SIC: 35), and 0 otherwise and estimate the following model:

$$\begin{aligned} \Delta COMP_{i,t} = & \gamma_0 + \beta_1 \Delta ROE_{i,t} \times SHORT_i + \gamma_3 RET_{i,t} \\ & + \gamma_4 RET_{i,t} \times SHORT_i + \gamma_5 \Delta RD_{i,t} + \gamma_6 \Delta RD_{i,t} \times SHORT_i + \varepsilon_{i,t} \end{aligned} \quad (3)$$

Table 5 presents the impact of a short R&D payoff period on the association between changes in CEO compensation and the performance measures, ΔROE , RET , and ΔRD . In the cash compensation regression, as reported in Column (1) of Table 5, the estimated coefficients on ΔROE and RET are significantly positive, consistent with the general positive pay-performance relation. The coefficient on $\Delta ROE \times SHORT$ (0.167, $t=1.15$) is positive, but insignificant, and the coefficient on $RET \times SHORT$ (-0.058, $t=-1.50$) is significantly negative at a marginal level, suggesting that when R&D expenditure has a short payoff period, the relative weight on stock return decreases and the relative weight on accounting return increases.

TABLE 5
Analysis of the Impact of Short R&D Horizon on the Sensitivities of CEO Compensation to Accounting Return, Stock Return, and R&D Spending

	Predicted Signs	(1) $\Delta \ln \text{Cash}$	(2) $\Delta \ln \text{Option}$	(3) $\Delta \ln \text{Total}$
Intercept	?	0.077 (2.24)**	0.146 (1.35)	0.058 (0.83)
ΔROE	+	0.847 (8.06)***	-0.492 (-1.44)*	0.137 (0.64)
$\Delta ROE \times \text{Short}$?	0.167 (1.15)	1.356 (2.92)***	0.529 (1.80)*
RET	+	0.194 (6.32)***	0.013 (0.13)	0.112 (1.81)**
$RET \times \text{Short}$?	-0.058 (-1.50)*	0.005 (-0.08)	0.031 (0.40)
ΔRD	?	-0.900 (-2.13)**	1.911 (1.51)	0.263 (0.31)
$\Delta RD \times \text{Short}$	-	-1.446 (-2.43)***	-5.377 (-2.90)***	-0.512 (-0.42)
Short		0.020 (1.01)	0.004 (0.07)	0.013 (0.34)
N		1,016	816	1,016
Adj. R^2		0.2328	0.0731	0.0569

t-statistics are presented in parenthesis.

***, **, * indicate significance at the 1%, 5% and 10% level respectively (one-tailed when the coefficient sign is predicted, two-tailed otherwise).

$\Delta \ln \text{Cash}$ = change in the natural log of CEO's cash compensation (salary and bonus);

$\Delta \ln \text{Option}$ = change in the natural log of the value of CEO annual option grants;

$\Delta \ln \text{Total}$ = change in the natural log of CEO's total compensation (salary, bonus, other annual, restricted stock granted, stock options granted, long-term incentive payouts, and all other total);

RET = one-year stock return (dividend reinvested);

ΔROE = change in earnings before extraordinary items before R&D expenditure, deflated by average book value of common equity;

ΔRD = change in R&D expenditures, deflated by average book value of common equity;

Short = dummy variable with value equals to one if the firm's R&D investment has the shortest payoff period of 4 years, i.e. firms in the Scientific Instruments industry (SIC: 38) and the Machinery and Computer Hardware industry (SIC: 35), and 0 otherwise.

Year dummies are included, but not reported.

The estimated coefficient on ΔRD is significantly negative (-0.900, $t=-2.13$), consistent with the result in Table 5 that, on average, firms tie CEO cash compensation negatively related to R&D expenditure. The estimated coefficient is significantly negative when ΔRD interacts with SHORT (-1.446, $t=-2.43$). This suggests that when R&D has a short horizon, such short-lived R&D expenditures are treated as an expense in CEO cash compensation to avoid over-investment on R&D.

The results for CEO option compensation are reported in Column (2), Table 5. Compared with the regression results in Column (2), Table 3, the estimated coefficient on

ΔRD now turns insignificant (1.911, $t=1.51$) and the coefficient on $\Delta RD \times SHORT$ is significantly negative (-5.377, $t=-2.90$), suggesting that on average, CEO option compensation is shielded from R&D expenditure, consistent with Cheng (2004), but short-lived R&D expenditures are treated as an expense in CEO option compensation to avoid over-investment in R&D. The results for CEO total compensation, reported in Column (3), Table 5, are generally in similar directions, but are not statistically significant as total compensation possibly contains other strategic consideration and may introduce more noises to the regression.

5.2 CONTROLLING FOR *R&D INTENSITY*

Although the results in Clinch (1991) are inconclusive, he documents an indirect effect of *R&D intensity* on CEO compensation in some model specifications. Thus to control for the effect of *R&D intensity*, I conduct a sensitivity test to control for *R&D intensity* in the regression models.

The results, presented in Table 6, remain qualitatively the same across different compensation components after controlling for *R&D intensity*. Similar to the results in Table 3, the estimated coefficients on $\Delta RD \times RDHorizon$ are significant for CEO cash compensation (0.472, $t=2.92$) and for CEO option compensation (0.472, $t=2.92$), but not for CEO total compensation. The coefficients on $\Delta ROE \times RDHorizon$ remain significantly negative; the coefficients on $RET \times RDHorizon$ are insignificantly different from zero across columns (1) – (3).

Overall, the results suggest that the coefficient on *R&D intensity* is insignificant in the model specification with *R&D horizon* and the results of the impact of *R&D horizon* on the sensitivities of CEO compensation to accounting return, stock return, and R&D expenditures holds after controlling for *R&D intensity*.

5.3 CEO AGE

Cheng (2004) shows that changes in CEO compensation spending are more strongly positively associated with changes in CEO compensation when the CEO approaches retirement, i.e. CEO horizon problem. It is possible that the results in Table 3 are driven by the sample observations with CEOs approach retirement. To rule out this possibility, I then conduct the analyses based on the subsample of firms with no expected CEO retirement.

Table 7 presents the results when 61, the 3rd quartile of the age distribution of the sample CEOs, is used as the cut-off. The results remain qualitatively the same when alternative cut-offs are applied, e.g. 62 and 63. Overall, the results from the subsamples of firms with no expected CEO retirement show that the coefficients on the interaction term between ΔRD and *R&D horizon* remain positive for both cash compensation and option compensation, indicating that the result on the adjustment for *R&D horizon* holds even

when there is no expected CEO retirement. The result suggests that compensation committees adjust the weight on R&D spending according to the expected R&D payoff period in order to overcome the horizon problem in a more general setting.

TABLE 6
Analysis of the Impact of R&D Horizon on the Sensitivities of CEO Compensation to Accounting Return, Stock Return, and R&D Spending

	Predicted Signs	(1) $\Delta \ln \text{Cash}$	(2) $\Delta \ln \text{Option}$	(3) $\Delta \ln \text{Total}$
Intercept	?	0.102 (2.18)**	0.146 (1.00)	0.040 (0.42)
ΔROE	+	1.38 (5.84)***	2.245 (2.97)**	1.246 (2.60)***
$\Delta ROE \times RDhorizon$	-	-0.078 (-1.99)**	-0.362 (-2.82)***	-0.147 (-1.85)**
RET	+	0.085 (1.47)*	-0.008 (-0.05)	0.233 (1.98)**
$RET \times RDhorizon$?	0.013 (1.28)	0.002 (0.07)	-0.019 (-0.95)
ΔRD	?	-4.347 (-4.46)***	-8.519 (-2.76)***	-0.881 (-0.45)
$\Delta RD \times RDhorizon$	+	0.472 (2.92)***	1.355 (2.70)***	0.153 (0.47)
$RDhorizon$		-0.004 (-0.79)	-0.002 (-0.13)	0.002 (0.17)
$RDintensity$		0.110 (0.60)	0.112 (0.20)	0.186 (0.50)
N		1,016	816	1,016
Adj. R^2		0.2347	0.0707	0.0570

t-statistics are presented in parenthesis.

***, **, * indicate significance at the 1%, 5% and 10% level respectively (one-tailed when the coefficient sign is predicted, two-tailed otherwise).

$\Delta \ln \text{Cash}$ = change in the natural log of CEO's cash compensation (salary and bonus);
 $\Delta \ln \text{Option}$ = change in the natural log of the value of CEO annual option grants;
 $\Delta \ln \text{Total}$ = change in the natural log of CEO's total compensation (salary, bonus, other annual, restricted stock granted, stock options granted, long-term incentive payouts, and all other total);
 RET = one-year stock return (dividend reinvested);
 ΔROE = change in earnings before extraordinary items before R&D expenditure, deflated by average book value of common equity;
 ΔRD = change in R&D expenditures, deflated by average book value of common equity;
 $RDhorizon$ = indicator variable with value equals to the estimated useful life of R&D spending as reported in Lev et al. (2008).
 $RDintensity$ = R&D intensity, measured as annual R&D spending divided by sales.

Year dummies are included, but not reported.

TABLE 7
Sensitivity Test: Analysis of the Association of Changes in CEO Compensation on Changes in R&D Expenditures When There Is No Expected CEO Retirement (Subsamples of CEOs with Age Less than 61)

	Predicted Signs	(1) ΔLnCash	(2) $\Delta \text{LnOption}$	(3) $\Delta \text{LnTotal}$
Intercept	?	0.096 (1.82)*	0.096 (0.58)	0.041 (0.38)
ΔROE	+	1.042 (3.94)***	2.744 (3.20)***	1.425 (2.68)***
$\Delta \text{ROE} \times \text{RDhorizon}$	-	-0.022 (-0.50)	-0.448 (-3.08)***	-0.172 (-1.93)**
RET	+	0.099 (1.60)*	0.082 (0.42)	0.256 (2.06)**
$\text{RET} \times \text{RDhorizon}$?	0.009 (0.88)	-0.013 (-0.35)	-0.023 (-1.07)
ΔRD	?	-4.115 (-3.87)***	-7.938 (-2.30)**	-0.541 (-0.25)
$\Delta \text{RD} \times \text{RDhorizon}$	+	0.441 (2.52)***	1.333 (2.42)***	0.132 (0.38)
RDhorizon		-0.003 (-0.55)	0.015 (0.76)	0.010 (0.81)
N		831	676	831
Adj. R^2		0.2327	0.0708	0.0687

t-statistics are presented in parenthesis.

***, **, * indicate significance at the 1%, 5% and 10% level respectively (one-tailed when the coefficient sign is predicted, two-tailed otherwise).

ΔLnCash = change in the natural log of CEO's cash compensation (salary and bonus);
 $\Delta \text{LnOption}$ = change in the natural log of the value of CEO annual option grants;
 $\Delta \text{LnTotal}$ = change in the natural log of CEO's total compensation (salary, bonus, other annual, restricted stock granted, stock options granted, long-term incentive payouts, and all other total);
 RET = one-year stock return (dividend reinvested);
 ΔROE = change in earnings before extraordinary items before R&D expenditure, deflated by average book value of common equity;
 ΔRD = change in R&D expenditures, deflated by average book value of common equity;

Year dummies are included, but not reported.

6. CONCLUSION

Prior studies on the relation between R&D and executive compensation mainly focus on annual R&D expenditure. However, simply looking at how much a firm spends on R&D treats the future benefit of one dollar R&D expenditure as homogeneous across industries and across firms. As studies by Lev and Sougiannis (1996), Shi (2003), Lev et al. (2008) show that the payoff period and the risks associated with R&D are different across industries, I investigate whether compensation committees consider the payoff period of R&D expenditures, i.e. *R&D horizon*, and adjust (1) the association between changes in R&D expenditures and changes in CEO compensation accordingly and (2) the relative sensitivity of CEO compensation to accounting returns versus stock returns.

The results show that firms with long R&D payoff period tend to adjust the association between changes in CEO cash compensation and changes in R&D expenditures upward (positively) to encourage investment in R&D with longer horizon, while firms with short R&D payoff period tend to treat R&D expenditure as an expense when rewarding CEOs. This study also finds evidence that the sensitivity of changes in CEO option compensation to changes in R&D expenditures is greater when R&D expenditures has a long-lived nature, suggesting that compensation committees adjust CEO incentive arrangement by tying CEOs wealth to long-term performance of the firm and inducing CEO to invest in “good” project, rather than simply boosting R&D spending. However, when examining CEO total compensation, I do not find CEO total compensation to be associated with R&D spending, consistent with Cheng (2004), and *R&D horizon*. Taken together, the results show that compensation committees consider the importance of *R&D horizon* beyond the naïve magnitude of R&D spending when determining the association of CEO compensation to R&D spending and the relative sensitivity of CEO compensation to accounting returns versus stock returns. The evidence also provides implication that compensation contract design needs to consider the attributes of each compensation component, rather than simply deciding how much to pay CEOs in total. In particular, compensation committees consider the long-term incentive effects of option compensation and increase the sensitivity of CEO option compensation to R&D expenditure when R&D investment has a longer horizon. The use of option compensation, in contrast with that of cash compensation, helps to equate CEO planning horizon with shareholder horizon and to induce managers to invest in good projects when R&D takes a longer payoff period.

This study also provides evidence that *R&D horizon* reduces the weight of accounting performance in CEO cash, option, and total compensation as such long-term R&D capital is not reflected in the book value of assets. Specifically, I find that the sensitivity between changes in CEO compensation and changes in ROE is adjusted downward when R&D has a longer horizon in response to the noise in accounting returns in capturing managerial

R&D efforts. This result is in contrast with the result in Clinch (1991) that both slope coefficients from a regression of estimated compensation numbers on stock return and accounting return on equity increase systematically with R&D expenditure. In addition, this study does not find the decrease in the relative weight on accounting return to increase the absolute weight on stock return. This is consistent with the evidence documented in Chan et al. (2001) that R&D capital increases the return volatility and that stock price undervalues a firm's R&D capital, which in turn decreases the signal-to-noise ratio of stock return as a performance measure.

The results also show that the attenuating impact of *R&D horizon* on the sensitivity of CEO compensation to accounting returns is more consequential when the new CEO just takes the office. Besides, when CEOs are newly appointed, firms tend to strengthen the association between *R&D horizon* and the sensitivity of CEO compensation to R&D expenditure to avoid new CEOs' conservative investment behavior when facing uncertainties. In contrast to prior studies (e.g. Cheng 2004; Dechow and Sloan 1991) that focus on horizon problem when CEOs approach retirement, the evidence in this study contributes to the literature by showing how compensation contract is designed for CEOs in the earlier years of the tenure.

There are also important limitations to the study. First, the test variable, RD horizon, in Lev and Sougiannis (1996) and Lev et al. (2008), is estimated at the industry level and thus does not allow *R&D horizon* to vary across firms in the same industry. Second, CEO compensation contracts are not directly observable. Thus, like prior studies (e.g. Gaver and Gaver 1998; Cheng 2004; Sloan 1993), it is necessary to rely on realized compensation to infer the sensitivity of CEO compensation to accounting return, stock return, and R&D expenditures. These issues present research opportunities for future research.

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