THE INNOVATION GAME

A STUDY OF THE RELATIONSHIP BETWEEN CEO COMPENSATION AND R&D SPENDING

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Abstract:

While previous research has examined how CEO compensation influences managerial behavior, little is known about whether and how compensation influences R&D spending decisions. Because theoretical models predict that CEOs are disincentivized to undertake projects with uncertain long-term payoffs, scholars argue that CEO compensation should be linked to long-term performance. To investigate this in the context of R&D spending, we examine the relationship between the fraction of long-term compensation awarded to CEOs and R&D intensity. We find that the level of CEO long-term compensation relative to total compensation is associated with the level of R&D intensity. However, we find no clear evidence that changes in the fraction of long-term compensation is followed by changes in R&D intensity. Nonetheless, when separating the different components of long-term compensation, we see that changes in stock option awards relative to total compensation is positively associated with changes in subsequent R&D intensity. Our study contributes to an understanding of the role of compensation design in aligning the incentives of CEOs with the firm's strategic goals for R&D spending.

Keywords:

CEO, Compensation, Risk-taking, Research & Development, Options

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1. Introduction

“If you pick the right people and give them the opportunity to spread their wings and put compensation as a carrier behind it you almost don’t have to manage them.” - Jack Welch[1]

Executive compensation is widely recognized as a critical element in aligning the interest of managers with those of shareholders. Since Jensen and Murphy (1990) argued that “it is not how much you pay, but how you pay”, discussions about the appropriate structure of executive compensation have received increasing attention. In this regard, scholars have investigated how executive compensation structure impacts firm and manager behavior. For example, research has shown that excessive short-term compensation may lead to short-termism and managerial myopia (e.g., Bebchuk and Fried, 2010). Accordingly, one important factor to consider when designing compensation packages is how to incentivize executives to invest in projects where payoffs are uncertain and long term.

One area that involves such projects is investments in research & development (R&D). CEOs may hesitate to invest in such activities due to their high level of uncertainty and long-term nature (Rosenberg, 2009). Building on such argumentation, Manso (2011) proposes that for managers to invest in innovation, compensation must be designed to incentivize long-term thinking. Research shows that firms with longer-term projects, like R&D, tend to have more long-term compensation (Gopalan et al., 2014) and that companies use stock options or incentive payment plans to align agent’s interests with those of principals (Hayes et al., 2012). This renders two critical questions. Firstly, does the utilization of long-term compensation as a means to incentivize R&D spending yield the desired behavior? Secondly, are any specific types of long-term compensation more effective than others in stimulating such behavior?

To address these questions, we examine whether CEO compensation structure is associated with the level of R&D intensity. Specifically, we investigate if and how the

[1] Jack Welch Quotes. BrainyQuote.com, BrainyMedia Inc, 2023. https://www.brainyquote.com/quotes/jack_welch_130691, accessed May 8, 2023.

fraction of long-term compensation relative to total compensation is associated with R&D spending as a fraction of sales and how this relationship varies across different components of long-term compensation. Accordingly, this paper aims to provide an empirical analysis that considers compensation structure as a determinant of R&D spending. Our results suggest a positive relationship between the fraction of total CEO compensation that is long-term and the level of R&D intensity in firms. However, while we find no clear evidence that increases in the fraction of long-term compensation overall is associated with subsequent changes in R&D intensity, when investigating the effect of separate components, we find that increases in the fraction of stock option awarded to CEOs have a positive effect on R&D intensity in the following year.

The contribution of this paper is three-fold. Firstly, while previous research has extensively investigated the impact of executive compensation on executive actions and decision-making in the context of short-term undertakings (e.g., Sanders and Carpenter, 2003; Sanders, 2001, Bergstresser and Philippon, 2006; Burns and Kedia, 2006), we find that little research has examined the relationship in a more long-term oriented context such as R&D spending. Secondly, researchers often group different types of long-term compensation into a single measure (Devers et al., 2007). However, as suggested by the behavioral agency model developed by Wiseman and Gomez-Mejia (1998), different individual elements of compensation may have distinct implications for risk-taking. Expanding on this argument, researchers show that because different forms of pay have unique risk properties, each component can influence executive behavior differently (e.g., Sanders, 2001; Larraza-Kintana et al., 2007). Accordingly, a more thorough understanding of how different forms of pay motivate behavior is essential (Devers et al., 2007). Our study sheds light on this discussion as it, to the best of our knowledge, is the first paper to investigate how different individual components of long-term compensation affect R&D decisions.

Thirdly, the practical implications of this research contribute to the existing literature on how firms can work with compensation design. Specifically, this could facilitate informed decisions among stakeholders that seek to construct compensation packages that align CEOs' incentives with their strategic goals for R&D spending.

1.1. Scope and Definitions

Within the scope of our study are listed firms included in the S&P 1500. The study is limited to S&P 1500 because of the extensive data available on executive compensation for firms included in this index. Additionally, the S&P 1500 is representative of a broad range of companies and industries. We have limited the research to include the years between 2013-2021. We choose this period to increase the relevance and accuracy of our findings in reflecting the current state of executive compensation and R&D spending.

Key definitions

R&D intensity: R&D expenditures as a fraction of sales in a given year.

Long-term compensation: The sum of option awards, stock awards, and non-equity incentive plans scaled by total compensation in a given year

1.2. Disposition

Our thesis is structured as follows. First, we explore existing research and theories on executive compensation and its effect on various firm outcomes and managerial behavior. This theoretical framework then serves as the foundation on which we develop our hypotheses. After establishing our hypotheses, we present our data collection process and the statistical methodology used to conduct our analysis. Thereafter, we present our results and analyze them thoroughly, followed by a discussion of our findings. Finally, we discuss the limitations of this study and provide suggestions for future research.

2. Literature review

Our literature review is divided into four sections. First, we take a broader perspective and present the general theories relevant to our study. Thereafter, we examine theories and previous research on executive compensation. We then investigate the relationship between executive compensation and firm outcomes in general and the link to R&D spending in particular. Lastly, we summarize the key takeaways from the previous research that are of particular importance for the rest of this paper.

2.1. Central theories and problems

Central to our study are the problems outlined by principal-agent theory. As explained by Ross (1973), problems arise when a principal employs an agent to act on their behalf but cannot fully ensure that the agent's actions align with their own interests due to incomplete contracts. Consequently, the agent might pursue actions that are not in the principal's best interest. To mitigate such behavior, effective contractual arrangements that align the incentives of both parties are needed (Holmstrom, 1989).

A typical situation in which principal-agent issues may arise is when a CEO is appointed to manage a firm on behalf of the shareholders. If congruence in incentives is not achieved, CEOs may prioritize their own interest over those of the shareholders, leading to adverse outcomes such as managerial myopia, empire-building, or excessive risk-taking (Berk and DeMarzo, 2017). One key mechanism for avoiding such situations is the design of appropriate compensation packages, for example, to ensure long-term commitment and protection from failure (Holmstrom, 1989). Accordingly, to mitigate agency problems, many companies use compensation components such as stock options, incentive payment plans, or restricted stock awards (Hayes et al., 2012). For example, stock options create convex pay-offs, encourage risk-taking behavior, and have lengthy expiration periods, ensuring long-term commitment (Manso, 2017). This relates to the behavioral agency model outlined by Wiseman and Gomez-Mejia (1998) that integrates behavioral decision theory views on risk with agency theory. They examine the influence of various compensation designs on executive risk-bearing and risk-taking and conclude that different forms of compensation have unique risk properties and can incentivize different types of behavior.

2.2. Executive compensation

Although executive compensation is a frequently discussed topic in academia and popular media, it is often with an emphasis on how much executives are paid (Murphy, 1999). While the level of compensation awarded to top executives has increased significantly over time, it is also clear that the structure of pay is changing (Edmans et al., 2017). Therefore, it is important to assess the implications of this in business. For example, Frydman and Saks (2010) conclude that awarding top executives with stock options has become an increasingly popular approach.

There is considerable debate on what causes the changing trends in the level and structure of executive compensation. Edmans et al. (2017) observe several perspectives from various scholars on the topic of pay, one being the “shareholder value” view. The “shareholder value” view argues that compensation contracts are chosen to maximize shareholder value while considering the competitive market for executives and the necessity of providing adequate incentives. In light of this view, Jensen and Murphy (1990) assert that the key consideration when providing adequate incentives and aligning managers with shareholder interests is not how much they are compensated but rather how they are compensated. While an executive’s compensation package can take many forms, Edmans et al. (2017) state that it mainly consists of five components: salary, annual bonus, payouts from long-term incentive plans (LTIPs), option grants, and stock grants. Further, they establish that these five components have different implications for how managers act and how firms subsequently perform.

Harris and Raviv (1979), substantiate this by arguing that the allocation between different forms of pay is a fundamental issue in compensation design. This relates to the debate in the literature over the influence of incentive alignment structures on agent behavior (Gomez-Mejia, 1994). As Wiseman and Gomez-Mejia (1998) outline in their paper, this debate revolves around the relative importance of the risk and incentive properties of variable compensation. On the one hand, Larcker (1983) proposes that performance-based pay reduces the natural tendency of risk-averse managers to avoid risk-increasing projects. This view suggests that when agent wealth is closely linked to firm performance, and because agents are inclined to maximize wealth, they will pursue riskier strategic options that align with the risk preferences of the principals (Coffee, 1988; Mehran, 1995). On the contrary, when compensation is not tied to firm performance, executives lack incentives to take on risk when selecting which strategic options to pursue (Hill and Snell, 1989). Accordingly, contingent compensation contractually promotes agent self-regulation, ultimately benefiting the principal (Welbourne et al., 1995). In contrast to this view, the normative agency perspective contends that excessive risk-bearing by managers increases their risk aversion (Holmstrom and Milgrom, 1987). Because of the noisy relationship between the actions of managers and firm outcome, this perspective argues that, as the link between their compensation and firm performance increase, managers increasingly seek to reduce uncertainty in firm performance (Amihud and Lev, 1981; Lewellen et al., 1987; Sloan, 1993)

Many scholars have examined the effect of different forms of executive compensation on firm outcomes. For example, Mehran (1995) find that the percentage of an executive's equity-based compensation, as well as the percentage of equity held by managers is positively related to firm performance. Extensive research has also been done on the influence of compensation structure on certain executive actions (Devers et al., 2007). Bergstresser and Philippon (2006) find that compensation design affects earnings management, specifically that more incentivized CEOs (with more equity-based compensation) lead firms with more earnings management. Furthermore, Burns and Kedia (2006) assert that the sensitivity of a CEO's option portfolio to the stock price is positively related to the propensity to misreport, while Carpenter (2000) finds that option compensation increases managerial risk appetite. A body of research has proposed that compensating risk-averse managers with stock options could encourage them to take risks due to the positive relationship between the expected payoff of an option and the volatility of the underlying stock's return (e.g., Smith and Stulz, 1985; Haugen and Senbet, 1981). On the other hand, later studies have shown that executives will value options subjectively, i.e., not at the market value, if they cannot sell or otherwise hedge the risk related to their options. Thus, an executive's risk appetite may not necessarily increase if granted options. In conclusion, it is clear from prior research that the compensation structures of executives can have different implications for firm outcomes.

2.3. Executive compensation and R&D

Some scholars have examined the relationship between compensation structure and innovation as a firm outcome. For example, Balkin et al. (2000) argue that the level of both long- and short-term CEO compensation in high-technology firms is contingent on the level of innovation achieved by the organization. Specifically, because innovation is more easily controlled by principals in high uncertainty and discretionary environments, compensation will be based more on innovation, such as R&D and patents, than firm performance. In addition, Gopalan et al. (2014) assert that firms with longer-duration projects (e.g., due to the nature of their industry) will prefer longer-duration executive compensation. While Gopalan et al. (2014) examine the contextual influence of firms with long-duration projects (measured using proxies like market-to-book ratio, the proportion of long-term assets, and R&D intensity) on compensation design, less research has been devoted to examining how CEO compensation design incentivizes spending on R&D.

Although CEOs may not be directly involved in innovation processes, they oversee the direction of innovation and make crucial decisions regarding the allocation of resources for R&D (Balkin et al. 2000). However, CEOs may hesitate to invest in such activities due to the high level of uncertainty and long-term nature of technological innovations (Rosenberg, 2009). Similarly, Jensen (1993) argues that because managers tend to be more risk-averse than shareholders due to their large portion of personal wealth being tied up in the company and their job security being dependent on firm performance, CEOs may choose to pursue alternative projects less risky projects innovation. Building on this principal-agent problem, Manso (2011) outlines a scenario where a manager faces two alternatives: exploiting actions with known returns or exploring actions with unknown, however potentially greater returns. He argues that the agent's compensation must be linked to long-term performance to motivate the choice of innovation projects, which are generally characterized by long lead times and high uncertainty. If not, there is little or no incentive to pursue actions that yield payoffs only in the long term. On the contrary, if pay is dependent on long-term performance, it incentivizes managers to pursue actions beneficial for the firm in the long term.

Correspondingly, Holmstrom (1989) argues that, for managers to invest in innovation, compensation should be designed to assure long-term commitment and protection from failure. One instrument for achieving this effect is stock options. Stock options create convex payoffs, encourage risk-taking behavior, and have lengthy expiration periods, ensuring long-term commitment (Manso 2017). Accordingly, many companies use stock options or incentive payment plans to mitigate agency problems (Hayes et al., 2012). Manso (2011) proposes that extending vesting periods for stock and option grants may serve as a remedy to managers focusing excessively on short-term performance at the expense of long-term performance, also called managerial "myopia". Furthermore, Edmans et al. (2012) and Marinovic and Varas (2019) highlight the benefits of long vesting horizons in combating myopia as it aligns managers with a more long-term view.

Following the argument by Currim et al. (2012), there are powerful short-term disincentives for top executives to spend on R&D as the benefits of such spending will only materialize several years into the future. Meanwhile, the GAAP-based policies dictate that R&D expenditure should be expensed in the current period, meaning that it negatively impacts short-term profitability. These disincentives become even more pronounced when executives face earnings pressure from analysts and face the likelihood of limited tenure within the firm. Consequently, these disincentives can lead to short-sighted resource management and myopic behavior, where executives prioritize immediate gains through cuts in R&D spending over long-term investments in such projects.

Some scholars have researched how compensation design motivates certain measures of innovation. Lerner and Wulf (2007) examine the relationship between innovation and incentives and show that more long-term incentives (such as stock options and restricted stock) are associated with more heavily cited patents, more frequent awards, and patents of greater originality. In contrast, they see little relation between short-term incentives and measures of innovation. Currim et al. (2012) find that an increase in the equity-to-bonus compensation ratio for a firm's top executives is positively associated with increased in R&D spending as a share of sales. They establish that a longer-term compensation structure can incentivize a longer-term orientation for R&D spending to improve stock return. This way, myopic management of resources can be mitigated. According to research by Hoskisson et al. (1993) and Larcker (1983), managers who receive contingent pay tend to increase capital investment and R&D spending, suggesting the undertaking of riskier projects.

2.4. Takeaways from previous research

To conclude, the principal-agent problem may lead agents to pursue actions that are not in the principal's best interest. To mitigate such behavior, it is argued that compensation design can be used to align the agent's incentives with those of the principal. Executive compensation packages can consist of various components with unique properties that incentivize different types of managerial behavior. Due to the high uncertainty and long-term horizon of R&D, CEOs may hesitate to invest in such projects. Accordingly, to motivate such investments, many scholars argue that compensation should be linked to long-term performance. On this topic, some studies have shown that executives are more inclined to pursue innovation if awarded more long-term incentivizing compensation.

3. Hypotheses

As addressed previously, agency theory suggests that a firm's management team may prioritize its own interests over those of shareholders, resulting in suboptimal decision-making. A key issue is managerial myopia, i.e., that executives are excessively focused on boosting short-term performance at the expense of long-term value-creating initiatives (e.g., Bebchuk and Fried, 2010). If compensation is heavily weighted on short-term performance, such as a large portion being short-term cash bonuses, there is a substantial risk that executives deprioritize projects where rewards are harvested many years into the future, potentially hurting the long-term competitiveness of the firm (Manso, 2011). To mitigate this risk, executive compensation contracts often incorporate long-term incentives (Hayes et al. 2012). However, Gopalan et al. (2014) suggest that short-term weighted compensation only poses a problem if a firm’s optimal projects are primarily long-term. Put differently, there could be significant long-term consequences if there is a mismatch between the structure of compensation packages and the nature of the firm’s optimal projects.

As such, we expect this principal-agent issue to become especially prevalent in firms where long-term projects, such as innovation and R&D, are essential. As outlined in the literature review, R&D projects are inherently risky, and there is considerable uncertainty about the timing and magnitude of the payoffs, and most often, the rewards cannot be harvested until many years into the future. As such, executives with short-term compensation packages might be hesitant to pursue such projects. Correspondingly, firms for which innovation is key for future success are likely more concerned about ensuring that managers are incentivized to make long-term decisions. Based on this argument, we expect that firms with high R&D intensity provide more long-term weighted compensation than other firms. Overall, both existing theory and previous research suggest that firms that have a higher portion of R&D spending will exhibit executive compensation packages that are more long-term weighted. This leads to our first hypothesis:

i. *There is a positive relationship between the fraction of CEO compensation that is long-term and a firm's R&D intensity.*

While the first hypothesis provides insight into whether R&D-intensive firms have more long-term weighted compensation structures, it provides little insight into if and how CEOs are incentivized by increases in long-term compensation when making R&D decisions. As such, it is interesting to investigate this relationship further and see whether changes in compensation structure are associated with subsequent changes in R&D spending. If the predictions that long-term compensation structures make managers more likely to make long-term decisions hold (e.g., Holmstrom, 1989; Manso, 2017; Manso, 2011; Edmans et al., 2012; Marinovic and Varas, 2019), we expect that when firms change the CEO compensation structure to become more long-term weighted, R&D spending should increase in subsequent years. This leads to our second hypothesis:

ii. *There is a positive relationship between increases in the fraction of long-term compensation awarded to CEOs and increased R&D intensity in the subsequent year.*

It is important to consider that not all forms of compensation are equal, as different types of incentives may have different implications for CEO behavior and decision-making (Wiseman and Gomez-Mejia, 1998). By separating long-term compensation into its three constitutive components, we bring light to a discussion of which form of incentive is most effective in incentivizing R&D investments. To exemplify, stock options give CEOs the right, but not the obligation, to purchase a certain number of shares regardless of the current share price. This means that the CEO can choose not to exercise the options and thereby avoid any potential losses. Research has shown that stock options can incentivize CEOs to pursue riskier strategies to increase the value of their options, where, according to Manso (2017), stock options create convex pay-offs, encouraging risk-taking behavior. In contrast, if the CEO is awarded stocks, they are exposed to the entire downside risk of the stock price. Accordingly, by separating stock options as a separate form of compensation, we can control whether the change in R&D intensity is also attributable to changes in downside risk and not only changes in long-term compensation.

As such, by examining the effects of different types of long-term compensation on R&D intensity, we can gain a more nuanced understanding of how different long-term incentives affect R&D. This leads to our third hypothesis:

iii. Changes in the fractions of different types of long-term compensation components relative to total compensation have varying effects on changes in R&D intensity in the subsequent year.

4. Methodology

This section outlines the research design of this paper. First, we describe the process for data collection and how we arrive at our final sample. Second, we present the statistical methods used to test our hypotheses. Third, we provide descriptions of the variables included in our regressions.

4.1. Data

Data on compensation for executives is retrieved from the Execucomp database. The database tracks yearly executive compensation from the companies' annual proxy statements for the top five executives in firms included in the S&P 1500 and their respective pay components per year. The different compensation components include salary, bonus, option awards, stock awards, non-equity incentives, pensions, and other compensation. We screen for data on all executive firm years between 2013 and 2021. We also include firms currently inactive (e.g., acquired or delisted) but were active at the time of measurement to obtain a more accurate representation of the population being studied. This can help to reduce sample bias and increase the generalizability of the results to the entire population of firms that were active during the period of interest in our study while also increasing the sample size.

The initial sample obtained from Execucomp is then merged with financial data extracted from the Compustat database. S&P Capital IQ Compustat provides data on company financials, ownership, transactions, industries, estimates, and private company data. For the scope of this research paper, Compustat is used to gather data on relevant firm metrics such as research and development expenditure, revenue, assets, liabilities, and SIC codes. This data is then integrated with stock market data provided by the Center for Research in Security Prices (CRSP), a historical time series data vendor on securities. From CRSP, we retrieve information on the historical share prices of the firms within our sample.

After consolidating the data from all databases and obtaining a gross sample, the next step involves filtering the data to exclude irrelevant observations. As our study focuses solely on CEO compensation, we exclude any observations pertaining to executives who do not hold the position of CEO. Additionally, we remove observations where total compensation data for the CEO is either missing or equal to zero, as well as observations for firms where data on R&D spending is not available or equal to zero. Furthermore, as we investigate the specific relationship between CEO compensation and R&D as a fraction of sales, we exclude observations for firms with zero or missing sales data. We argue that companies which do not invest in R&D at all in a given year, are unlikely to do so even with changes to their compensation structure. Including such firms could therefore distort our sample and act as noise in our regressions.

Our final sample is an unbalanced panel data set with 2,438 executive firm-year observations for 365 unique firms.

4.2. Statistical method

The hypotheses established in Section 3 are tested cross-sectionally using ordinary least-squares (OLS) regressions. We develop one model for each hypothesis.

The regressions are conducted in three steps. First, we start with a basic regression where only the dependent variable and independent variables of interest are included, showing the direct association between the variables that are the primary focus of our study. In the second step, we also include control variables for CEO and firm characteristics. The control variables are included to account for other potentially relevant factors and mitigate the influence of confounding variables. By controlling for other variables that may impact the results, the regression can more accurately determine the specific impact of our explanatory variables of interest on our dependent variable. In the third step, we also include industry and time fixed. This helps us capture unobserved heterogeneity across these dimensions and ensure trends across industries and time do not influence our results.

When investigating the data, we find that some variables have observations that can be considered extreme outliers. To prevent the possibility of our regression results being heavily driven by such observations, we winsorize all the variables included in our model. When winsorizing, it is essential to select an appropriate threshold that minimizes the impact of outliers while still preserving the integrity of the data. We choose to winsorize at the first and 99th percentile, capping the top and bottom 1% of values in the dataset, in line with Armstrong and Vashishtha (2012).

Furthermore, as will be discussed in Section 6. *Robustness tests*, we find indications of heteroskedasticity in our models. Additionally, as noted by Woolridge (2015), the utilization of panel data poses a considerable risk of the error terms being correlated across time, a phenomenon referred to as autocorrelation. This correlation can introduce a bias in the estimated standard errors in the regression. To address these issues, we employ robust estimation methods and cluster at the firm level, as proposed by Hoechle (2007). This is done for all regression models.

4.2.1. Regression model for Hypothesis 1

To test our first hypothesis, we develop a model that investigates the correlation between R&D as a percentage of sales and the fraction of total compensation that is long-term in a given year t (Equation I).

Equation I:

$$R\&D\ intensity_{it} = \beta_0 + \beta_1 Long\_term\_Compensation_{it} + \beta_2 Age_{it} + \beta_3 Tenure_{it} + \beta_4 Shareholding_{it} + \beta_5 Firm\_Size_{it} + \beta_6 ROA_{it} + \beta_7 Leverage_{it} + \beta_8 Tobin's\_Q_{it} + \beta_9 Share\_Price\_Performance_{i(t-3\ to\ t)} + \beta_{10} Volatility_{i(t-1)} + Industry_{FE} + Time_{FE} + \varepsilon$$

4.2.1. Regression model for Hypothesis 2

To investigate our second hypothesis and capture the relationship between changes in compensation and subsequent changes in R&D intensity, we develop a model where we measure the delta for our key variables. The dependent variable is Delta (R&D intensity), measured as the delta between t and t+1. The explanatory variable of interest is Delta (Long-term compensation – %), measured as the delta between t-1 and t. This approach allows us to examine how changes in compensation in a particular period affect R&D intensity in the following period. Equation II describes the relationship between changes in long-term compensation structure and changes in R&D intensity.

Equation II:

$$Delta(R\&D\ intensity)_{i(t\ to\ t+1)} = \beta_0 + \beta_1 Delta(Long\_term\_Compensation)_{i(t-1\ to\ t)} + \beta_2 Age_{it} + \beta_3 Tenure_{it} + \beta_4 Shareholding_{it} + \beta_5 Firm\_Size_{it} + \beta_6 ROA_{it} + \beta_7 Leverage_{it} + \beta_8 Tobin's\_Q_{it} + \beta_9 Share\_Price\_Performance_{i(t-3\ to\ t)} + \beta_{10} Volatility_{i(t-1)} + Industry_{FE} + Time_{FE} + \varepsilon$$

4.2.1. Regression model for Hypothesis 3

In our third regression model, we want to capture how changes in different individual components of long-term compensation are associated with subsequent changes in R&D intensity. As such, we split long-term compensation into its three constitutive components. As in the second regression model, the dependent variable is Delta (R&D intensity), measured as the delta between t and t+1. The explanatory variables of interest in this model are *Delta (Option awards – %)*, *Delta (Stock awards – %)*, and *Delta (Non-equity incentives – %)*. These are measured as the delta between t-1 and t. We include *Salary (%)* and *Bonus (%)* as control variables, also measured as the delta between t-1 and t. The model is displayed in Equation III.

Equation III:

$$Delta(R\&D\ intensity)_{i(t\ to\ t+1)} = \beta_0 + \beta_1 Delta(Option\_awards)_{i(t-1\ to\ t)} + \beta_2 Delta(Stock\_awards)_{i(t-1\ to\ t)} + \beta_3 Delta(Non\_Equity\_incentives)_{i(t-1\ to\ t)} + \beta_4 Delta(Salary)_{i(t-1\ to\ t)} + \beta_5 Delta(Bonus)_{i(t-1\ to\ t)} + \beta_6 Age_{it} + \beta_7 Tenure_{it} + \beta_8 Shareholding_{it} + \beta_9 Firm\_Size_{it} + \beta_{10} ROA_{it} + \beta_{11} Leverage_{it} + \beta_{12} Tobin's\_Q_{it} + \beta_{13} Share\_Price\_Performance_{i(t-3\ to\ t)} + \beta_{14} Volatility_{i(t-1)} + Industry_{FE} + Time_{FE} + \varepsilon$$

4.3. Description of variables

Table I. Description of variables

Variable	Definition
R&D intensity	R&D expenditure scaled by sales
Long-term compensation (%)	The sum of option awards, stock awards and non-equity incentive plans scaled by total compensation
Option awards (%)	Option awards scaled by total compensation
Stock awards (%)	Stock awards scaled by total compensation
Non-equity incentives (%)	Non-equity incentive plans scaled by total compensation
Salary (%)	Salary scaled by total compensation
Bonus (%)	Cash bonus scaled by total compensation
Age	The age of the CEO
Tenure	The number of years that the CEO has held its position
Shareholding (%)	The percentage of shares owned by the CEO
Firm size	The natural logarithm of annual sales
ROA	Net income scaled by total assets
Leverage	Total liabilities scaled by total assets
Tobin's Q	Market value of equity divided by book value of equity
Share price performance	Accumulated stock return over the last three years
Volatility	Annualized volatility of monthly stock returns in the previous year

The dependent variable is R&D intensity. Long-term compensation (%), Option awards (%), Stock awards (%) and Non-equity incentives (%) are the independent variables of interest. In regression models 2 and 3 we use the delta change in the dependent and independent variables.

Dependent variable: The dependent variable in our regression model is R&D intensity. In line with previous research, we measure R&D intensity by scaling R&D expenditure with annual sales for each firm. We measure R&D scaled to sales rather than assets in line with Currim et al. (2012). However, to ensure the robustness of our results, we also conduct a sensitivity test by using R&D expenditure scaled by total assets as an alternative measure for R&D intensity.

Independent variables: Similar to other studies that have investigated various effects of different executive compensation structures (e.g., Benston and Evan (2006), Ang et al. (2002), Abrokwah et al. (2018)), we choose to define our independent variable as the fraction of long-term compensation to total compensation. We calculate long-term compensation by summing the following components of executive compensation; option awards at grant date fair value (using the Black & Scholes formula), stock awards at grant date fair value and, non-equity incentive plan compensation. Despite being a long-term benefit, we exclude pensions from our definition of long-term compensation. This is because pensions are not likely to influence the CEO's decision-making process when pursuing long-term actions. The reason for this is that the value of the pension awards is not directly contingent on the firm's future success. Additionally, we exclude other compensation from our definition of long-term compensation because the item can have varying definitions across different companies, resulting in limited use of the variable in the regressions and difficulties in interpretation. We calculate total compensation using salary, bonus, non-equity incentive plan compensation, other compensation, pensions, stock grants at grant date fair value, and option grants at grant date fair value using the Black & Scholes formula.

In the third regression, where we separate the different components of long-term compensation, Option awards (%), Stock awards (%) and Non-equity incentives (%) are the independent variables. These are calculated by dividing the respective component by total compensation.

Control variables: We include control variables in our regression models. By controlling for the influence of confounding variables, we can more accurately estimate the relationship between independent and dependent variables.

Tenure and Age: To control for the impact of changes in the risk preferences and behavioral tendencies of CEOs that occur with age and tenure, we have included the control variable *Age* and *Tenure*. Previous research has indicated that executives nearing retirement are less inclined to engage in actions that are long-term in nature (e.g., Gibbons and Murphy, 1992; Dechow and Sloan, 1991).

Shareholding (%): The objectives of a CEO may become more aligned with those of the shareholders if the CEO holds more equity in the firm (Berk and Demarzo, 2017). As such, the effect of the choice of compensation structure might have a less pronounced impact on the decisions of CEOs who own a large share of the company's shares. The awarded compensation may not be a significant source of wealth for CEOs who already hold significant equity in the firm. In such cases, CEOs may not be incentivized enough by additional long-term compensation grants to invest in additional R&D. *Shareholding (%)* is calculated as the shares owned by the CEO divided by the total shares outstanding in each observation year.

Share price performance: Share performance can indicate a firm's underlying operational performance which can affect the financial resources available for R&D spending. Bhagat and Welch (1995) find a positive relationship between current R&D expenditure and stock return in prior years for US firms. In addition, CEOs with a proven ability to perform may be awarded more long-term compensation for firms to retain their abilities (Gopalan et al. 2014). Furthermore, if a company's past performance has been poor, the CEO may be pressured to improve performance and may be more inclined to prioritize short-term performance over long-term investment. We calculate *Share price performance* as accumulated stock return for the three previous years.

ROA: Similarly, the level of ROA may affect the financial resources available for R&D investment. Also, ROA can be an indicator of a CEO's performance, and CEOs who have been successful in generating profits may be more likely to receive long-term compensation to retain their abilities (Gopalan et al., 2014). We calculate *ROA* as net income scaled by total assets.

Volatility: Share price volatility may impact incentives for R&D investment and compensation structure. Based on principal-agent theory, it is argued that firms with higher output risk choose less performance-sensitive compensation contracts (Holmstrom, 1979). If a company's share is highly volatile, the CEO may be pressured to focus on short-term performance. Furthermore, share price volatility may be associated with a CEO's risk preferences. CEOs in firms with high share price volatility may be more risk-averse and less likely to invest in long-term projects such as R&D. We calculate *Volatility* as stock return volatility using the annualized volatility of monthly stock returns in the previous year.

Leverage: Leverage may impact the level of R&D intensity and compensation structure in several ways. For example, in highly levered firms, a larger portion of cash flows may be allocated towards debt servicing, leaving fewer resources available for R&D. In addition, leverage and greater financial risk may impact the will to take on additional risk associated with R&D. Support for this argument is found in the study by Bhagat and Welch (1995), who find a negative correlation between current R&D expenditure and last year's debt levels for US firms. Furthermore, more levered firms may choose to offer different forms of compensation to align the interest of the CEO with those of the firm's shareholders. We calculate *Leverage* by dividing total liabilities by total assets.

***Tobin's Q*:** Tobin's Q can indicate growth opportunities and future earnings potential. Therefore, firms with high Tobin's Q values may be more likely to invest in R&D. Guay (1999) supports the argument that a positive relationship exists between a firm's growth and investment opportunity sets and the risk-taking of managers. Furthermore, he argues that firms with abundant investment opportunities are the ones that will suffer the most if managers are too risk-averse and underinvest in projects that are risky yet value-adding. Thus, such firms incentivize risk-taking by providing more equity-based compensation. To control for these effects, we include Tobin's Q as an indicator of a firm's growth opportunities. We use a simplified measure of *Tobin's Q* by dividing the market value of equity by the book value of equity.

Firm size: Previous literature has shown that firm size impacts compensation structure (e.g., Guay, 1999, Coles et al., 2006). Furthermore, Currim et al. (2012) show that the effect of compensation incentives on managerial behavior is larger in smaller firms. Therefore, we include firm size as a control variable in our model. We measure *Firm size* as the natural logarithm of annual sales.

Industry and year fixed effects: We control for industry and year fixed effects in all our regression models to ensure that our results are not influenced by trends across industries and time. Overall, the inclusion of fixed effects enhances the precision of our model and helps ensure that we accurately capture the intended effects.

Salary and bonus: In our third regression, *Salary (%)* and *Bonus* (%) are included as control variables as they can influence the risk-taking behavior of CEOs and, therefore, investments in R&D. For example, according to Guay (1999), higher total cash compensation can make CEOs less risk averse because such CEOs are better diversified.

4.4. Descriptive statistics

In this section, we present descriptive statistics for the data used in our analysis and its implications. First, we summarize the data on compensation and the various compensation components (Table II). Then, we present the data on CEO and firm characteristics (Table III). Lastly, we show the distribution of the firm-year observations in our sample across industries and time (Table IV).

Table II. Descriptive statistics - Compensation data

Variable	Mean	Median	Std. Deviation	Min	Max
Total compensation (USDm)	9,403.2	7,465.3	7,269.4	537.6	35,728.8
Long-term compensation (%)	72.4%	78.5%	20.2%	0%	96.5%
Salary (%)	17.6%	12.8%	15.5%	2.4%	97.3%
Bonus (%)	1.3%	0%	4.8%	0%	29.2%
Option awards (%)	15.5%	11.8%	18.3%	0%	72.3%
Stock awards (%)	38.2%	39.8%	24.8%	0%	90.1%
Non-equity incentives (%)	18.4%	16.9%	14.1%	0%	65.7%
Pension (%)	5.1%	0%	9.8%	0%	42.3%
Other compensation (%)	3.3%	1.9%	5.0%	0%	34.6%

The total sample consists of 2,438 firm-year observations from 365 unique firms in the time period 2013-2021. Total compensation is displayed in USDm and the other variables are presented as fractions of total compensation. All variables are winsorized at the first and 99th percentile.

On average, long-term compensation (option awards, stock awards, and non-equity incentives) constitutes the majority of compensation paid to CEOs in our sample, with almost three-quarters of total compensation being long-term. Stock awards is the most prevalent individual compensation element, amounting to almost 40% of total compensation paid. Contrary, bonuses constitute a relatively small share of total compensation for firms in our sample. The median value of 0% for cash bonuses indicates that half of the observations in our sample do not include cash bonuses at all. We generally observe a wide range of values and relatively large standard deviations across all variables. This suggests that there is significant variation in executive compensation practices across companies.

Table III. Descriptive statistics – CEO & Firm characteristics

Variable	Mean	Median	Std. Deviation	Min	Max
R&D intensity	6.13%	2.99%	7.60%	0.06%	38.53%
Age	57.15	57	6.02	43	76
Tenure	7.27	5.63	6.56	0.64	42.03
Shareholding (%)	0.97%	0.33%	1.94%	0%	13.41%
Sales (USDm)	13,949	3,000	30,104	70	181,265
ROA	5.62%	5.98%	7.56%	(26.78%)	26.63%
Leverage	55.78%	56.10%	22.13%	8.66%	124.16%
Tobin's Q	4.78	3.23	7.56	(21.28)	50.75
Share price performance	46.09%	32.14%	76.47%	(76.17%)	411.10%
Volatility	29.25%	25.56%	14.98%	9.83%	88.97%

The total sample consists of 2,438 firm-year observations from 365 unique firms in the time period 2013-2021. All variables are winsorized at the first and 99th percentile.

In Table III, we can see that the mean R&D intensity is higher than the median, indicating the presence of outliers towards the right tail of the distribution. The presence of outliers is also true for other variables. Accordingly, we winsorize our variables to ensure that our results are not primarily driven by outliers in the data.

The fact that the firms in our sample tend to have high values for Tobin’s Q, past stock return, and stock volatility, could indicate that our sample is somewhat biased toward certain types of firms that exhibit such characteristics. This could partly be an effect of excluding firms with zero R&D spending from our sample and is important to consider when interpreting our results.

Table IV. Descriptive statistics – Distribution across Industry and Time

Industry classification	Observations
Mining and Construction	63
Manufacturing	2,111
Transportation, Communications, Electric, Gas and Sanitary service	9
Wholesale Trade and Retail Trade	19
Finance, Insurance and Real Estate	15
Services	203
Non-Classifiable	18
Year	**Observations**
2013	313
2014	299
2015	294
2016	283
2017	274
2018	254
2019	250
2020	250
2021	221

The total sample consists of 2,438 firm-year observations from 365 unique firms in the time period 2013-2021.

From Table IV, we observe that most firms operate in the manufacturing industry. It should be noted that this is a very broad category and includes firms in various sectors, from traditional industrial manufacturing to high-technology firms. Additionally, the firm-year observations demonstrate a relatively even distribution where the number of observations across specific years is not significantly deviating from other years.

5. Results and analysis

In this section, we present the results from the regressions used to test our hypotheses. Furthermore, in light of previous research and theories presented on executive compensation, we discuss these results and their possible interpretations.

5.1. Regression results for Hypothesis 1

In our first hypothesis, we test the relationship between the fraction of long-term compensation awarded to CEOs and the R&D intensity in firms. Based on theory and previous literature, we expect a positive relationship between the two variables. We present the results from the regression used to investigate this hypothesis (Equation I) in Table V.

Table V. Regression results for Hypothesis 1

R&D intensity	Regression 1	Regression 2	Regression 3
Constant	0.0372	0.1196	-0.0019
	(2.90)***	(2.91)***	(0.05)
Long-term compensation (%)	0.0332	0.0648	0.0640
	(1.84)*	(4.09)***	(5.00)***
Age		-0.0011	-0.0003
		(1.72)*	(0.64)
Tenure		0.0012	0.0013
		(1.66)*	(2.06)**
Shareholding (%)		0.1753	-0.2379
		(0.80)	(1.24)
Firm size		-0.0031	-0.0004
		(1.14)	(0.18)
ROA		-0.1857	-0.2106
		(3.64)***	(4.37)***
Leverage		-0.0674	-0.0812
		(3.60)***	(4.26)***
Tobin's Q		0.0012	0.0011
		3.26***	(3.05)***
Share price performance		0.0100	0.0077
		2.99***	(2.60)**
Volatility		0.0252	0.0665
		(1.56)	(3.33)***
Industry fixed effects	No	No	Yes
Year fixed effects	No	No	Yes
Adjusted R-squared	0.0074	0.1215	0.2566
Number of observations	2,438	2,438	2,438

All regressions are conducted using robust standard errors, clustering on firm level. The dependent variable is R&D intensity, and the explanatory variable of interest is Long-term compensation (%). All variables are measured in time t except for Share price performance which is the accumulated stock return between t-3 and t, and Volatility which is the share price volatility in the previous year. The t-stat for the respective variable is presented in parenthesis under each coefficient.

*Note: * p<0.1; ** p<0.05; *** p<0.01*

In the first step of the regression, where control variables and fixed effects are not included, the estimated coefficient for *Long-term compensation (%)* is positive and significant at the 10% significance level. When adding control variables and fixed effects, the statistical significance increases, and the positive relationship between our dependent and independent variable is significant at the 1% significance level. Hence, this model suggests a positive relationship between the R&D intensity in firms and the share of CEO compensation that is long-term, in line with our expectations. Important to note here is that we do not try to establish any causal relationship between our variables of interest in this regression, and the results should not be interpreted as such. Instead, the positive correlation solely indicates that firms that spend large amounts of R&D in relation to sales tend to award more long-term weighted compensation packages to their CEOs. This result is consistent with the aforementioned literature in this domain (e.g., Gopalan et al., 2014).

Other variables that exhibit positive coefficients that are statistically significant at the 5% significance level or less in the full model are *Tenure*, *Tobins' Q*, *Share price performance,* and *Volatility*. As such, these results indicate that all these variables are positively associated with *R&D intensity*. Contrarily, the variables *ROA* and *Leverage* have statistically significant negative coefficients, indicating that these firm characteristics are negatively associated with *R&D intensity*. A negative coefficient for *Leverage* is in line with our expectations. However, a negative coefficient for *ROA* is contrary to our predictions. One potential explanation for the negative relationship between *ROA* and *R&D intensity* could be that firms that invest much in R&D might be at an earlier stage on the maturity curve and thus have not yet reached the point where they can harvest their markets with high profitability.

As expected, the adjusted R-squared value increases as we add control variables and fixed effects. The complete model has an adjusted R-squared value of 0.26, indicating that the model has relatively high explanatory power. However, the R-squared is of relatively low relevance in this study as it is not the aim of the study to fully predict the R&D intensity of firms.

5.2. Regression results for Hypothesis 2

For our second hypothesis, we investigate whether a delta change in the fraction of CEO long-term compensation to total compensation is associated with a delta change in the R&D intensity in subsequent years. Specifically, we hypothesize that there is a positive relationship between increases in the fraction of long-term compensation in a given year and increased R&D intensity in the following year. The results are presented in Table VI.

Table VI. Regression results for Hypothesis 2

Delta (R&D intensity)	Regression 1	Regression 2	Regression 3
Constant	-0.0001	-0.0040	-0.0056
	(0.54)	(1.25)	(1.70)*
Delta (Long-term compensation - %)	0.0039	0.0033	0.0039
	(1.61)	(1.36)	(1.57)
Age		0.0000	0.0000
		(0.60)	(0.85)
Tenure		-0.0001	-0.0000
		(1.02)	(0.85)
Shareholding		0.0074	0.0062
		(0.30)	(0.24)
Firm size		0.0003	0.0004
		(1.79)*	(2.07)**
ROA		0.0183	0.0200
		(2.13)**	(2.18)**
Leverage		-0.0038	-0.0042
		(1.82)*	(1.93)*
Tobin's Q		0.0000	0.0000
		(0.51)	(0.68)
Share price performance		-0.0006	-0.0007
		(1.06)	(1.09)
Volatility		0.0036	0.0066
		(1.49)	(2.27)**
Industry fixed effects	No	No	Yes
Year fixed effects	No	No	Yes
Adjusted R-squared	0.0014	0.0089	0.0143
Number of observations	2,438	2,438	2,438

All regressions are conducted using robust standard errors, clustering on firm level. The dependent variable is Delta (R&D intensity) which is measured as the delta between t and t+1. The explanatory variable of interest is Delta (Long-term compensation - %), which is measured as the delta between t-1 and t. All control variables are measured in time t except for Share price performance which is the accumulated stock return between t-3 and t, and Volatility which is the share price volatility in the previous year. Year t is the basis for year fixed effects. The t-stat for the respective variable is presented in parenthesis under each coefficient.

*Note: * $p<0.1$; ** $p<0.05$; *** $p<0.01$*

The estimated coefficient for *Delta (Long-term compensation - %)* is positive. It is relatively close to being significant at the 10% significance level for the full regression (p-value = 0.117 with control variables and fixed effects included). While this indicates a positive relationship between our dependent and independent variable, the lack of statistical significance means that we cannot draw such conclusions for certain. As such, we find no convincing support for our second hypothesis. We observe statistically significant positive relationships at the 5% significance level for *Firm size, ROA,* and *Volatility* when including fixed effects. We see a negative coefficient for *Leverage* at the 10% significance level.

We generally observe relatively small coefficients for many of our explanatory variables, including our variable of interest *Delta (Long-term compensation - %)*. This means that every unit increase in these variables is associated with a quite small increase in our dependent variable, indicating that the economic significance of these variables is small. Furthermore, the R-squared of this model is low at 1.43% when including control variables and fixed effects, indicating low predictive power. While this does not render the model invalid, it shows that there is a lot of unexplained variation in the dependent variable. This is not unique to our study. Similar studies that have investigated the relationship between changes in compensation and firm outcomes (e.g., Currim et al. 2012) also exhibit low values for R-squared. Low explanatory power could indicate that changes in R&D intensity are driven by factors that are difficult to control for.

Our result of no significant relationship between changes in the fraction of long-term compensation and changes in subsequent R&D intensity is non-conforming to the conclusions drawn by (Currim et al. 2012). They find a significantly positive relationship between increases in the equity-to-bonus ratio and changes in R&D intensity. However, it is important to note that our study differs from that of Currim et al. (2012) in the measurement of compensation variables. While they examined the relationship using changes in equity-to-bonus ratio for all top executives, we define our measure as a fraction of long-term compensation to total compensation. Furthermore, our measure includes all long-term compensation, including non-equity incentive plans, and is limited to the compensation of CEOs. Our result also deviates from previous research that has found a positive relationship between equity-based compensation and managerial risk-taking (Coffee, 1988; Mehran, 1995). Given that R&D investments can be risky endeavors (Rosenberg, 2009), a stronger relationship between increases in long-term compensation and subsequent R&D intensity would be more in line with these findings.

The result of no significant relationship in our regression can have several interpretations. One possible interpretation could be that factors other than compensation structure are more influential in motivating CEOs to undertake long-term investments in R&D. Additionally, while CEO compensation can play a role in influencing subsequent R&D spending, other factors may be more influential in driving R&D expenditures. While a body of research suggests that long-term compensation incentivizes R&D, there are several reasons why this may not be the case. First, equity compensation, which we consider long-term, may not necessarily motivate CEOs to take a long-term view. For example, if the vesting period for equity grants is short, CEOs may still prioritize short-term financial performance over long-term investments such as R&D. This argument is indirectly supported by Manso (2011), who proposes that extending vesting periods for stock and option grants may serve as a remedy to managers focusing excessively on short-term performance. Another interpretation could be that, while the second regression groups the different types of long-term compensation into a single measure, Wiseman and Gomez-Mejia (1998) suggest that different individual compensation elements have different implications for managerial behavior. As such, a consolidated measure of long-term compensation might be a noisy measure that fails to highlight the unique properties of different sub-elements of compensation.

5.3. Regression results for Hypothesis 3

In our third hypothesis, we investigate the relationship between changes in the individual sub-components of compensation and subsequent changes in R&D intensity. We separate long-term compensation into its three constitutive components (option awards, stock awards, and non-equity incentive plans) to see how different types of compensation affect R&D intensity. The results are presented in Table VII.

Table VII. Regression results for Hypothesis 3

Delta (R&D intensity)	Regression 1	Regression 2	Regression 3
Constant	-0.0001	-0.0041	-0.0054
	(0.27)	(1.26)	(1.61)
Delta (Options - %)	0.0093	0.0074	0.0093
	(2.05)**	(1.72)*	(2.06)**
Delta (Stock awards - %)	0.0035	0.0018	0.0031
	(1.39)	(0.72)	(1.09)
Delta (Non-equity incentives - %)	0.0014	-0.0012	0.0010
	(0.54)	(0.43)	(0.35)
Delta (Salary - %)		-0.0013	0.0001
		(0.31)	(0.03)
Delta (Bonus - %)		-0.0083	-0.0066
		(1.24)	(0.98)
Age		0.0000	0.0000
		(0.64)	(0.90)
Tenure		-0.0001	-0.0001
		(1.14)	(0.95)
Shareholding		0.0072	0.0052
		(0.29)	(0.21)
Firm size		0.0003	0.0004
		(1.74)*	(1.93)*
ROA		0.0185	0.0200
		(2.13)**	(2.16)**
Leverage		-0.0039	-0.0042
		(1.87)*	(1.98)**
Tobin's Q		0.0000	0.0000
		(0.56)	(0.72)
Share price performance		-0.0006	-0.0007
		(1.01)	(1.05)
Volatility		0.0038	0.0066
		(1.55)	(2.24)**
Industry fixed effects	No	No	Yes
Year fixed effects	No	No	Yes
Adjusted R-squared	0.0030	0.0104	0.0157
Number of observations	2,438	2,438	2,438

All regressions are conducted using robust standard errors, clustering on firm level. The dependent variable is Delta (R&D intensity) which is measured as the delta between t and t+1. The explanatory variables of interest are the Delta changes of the different components of long-term compensation (option awards, stock awards and non-equity incentives). These are measured as the delta between t-1 and t. Salary and bonus are included as control variables and are also measured as the delta between t-1 and t. All control variables are measured in time t except for Share price performance which is the accumulated stock return between t-3 and t, and Volatility which is the share price volatility in the previous year. Year t is the basis for year fixed effects. The t-stat for the respective variable is presented in parenthesis under each coefficient.

*Note: * p<0.1; ** p<0.05; *** p<0.01*

The result from our third regression model indicates that different compensation components have different effects on R&D intensity in subsequent years. The argument that different forms of pay have unique risk properties, and can influence executive behavior differently (e.g., Sanders, 2001; Larraza-Kintana et al., 2007), is further substantiated by our finding that this applies to the context of R&D spending decisions as well.

Interestingly, option awards is the only type of compensation that exhibits a statistically significant coefficient. The positive coefficient suggests that increasing the fraction of option awards to total compensation is associated with subsequent increases in R&D intensity. While the other types of long-term compensation (stock awards and non-equity incentives) also have positive coefficients in the full model, as we expected, none display any significant relationship with R&D intensity. This indicates that the positive coefficient for *Delta (Long-term compensation - %)* in regression 2, which is relatively close to being statistically significant, is mainly driven by the effect of option awards. Bonus is the only compensation type with a negative coefficient in the full model. However, it is not statistically significant.

These results show the importance of treating different types of long-term compensation elements separately, as emphasized by Wiseman and Gomez-Mejia (1998). Aggregating compensation elements and examining their combined effect on executives can miss nuances in how long-term compensation incentivizes managerial risk-taking. Our findings suggest that the positive relationship between long-term compensation and risk-taking in other studies (e.g., Coffee, 1988; Mehran, 1995) is potentially driven by certain subcomponents of long-term compensation rather than long-term compensation in general. This has strategic implications for companies that prioritize investment in R&D, particularly with regard to the role of compensation committees in determining CEO pay. Specifically, our finding suggests that compensation committees may want to consider increasing the fraction of stock options in CEO compensation if aiming to incentivize R&D investment.

Previous research has shown that option compensation increases managerial risk appetite (e.g., Carpenter 2000). While our finding may thus not be entirely unexpected given the uncertain nature of R&D projects, it provides valuable insights to see that only increases in the share of option awards are associated with increases in R&D intensity. One could expect that all forms of long-term compensation should incentivize CEOs to invest more in long-term projects such as R&D. However, building on the argument of Wiseman and Gomez-Mejia (1998), this may be explained by the unique properties of options. Holmstrom (1989) argues that, for managers to invest in innovation, compensation should be designed to assure long-term commitment and protection from failure. While both stock awards and stock options ensure long-term commitment in the sense that their values depend on the firm’s long-term performance, options differ in that they limit the downside, thus offering protection from failure. Furthermore, stock options create convex pay-offs, meaning that the potential upside of risk-taking is greater (Manso, 2017). Accordingly, CEOs may be more inclined to pursue R&D projects if their compensation structure is more heavily weighted toward stock options.

The R-squared of this model is relatively low at 1.57%, meaning there is a large amount of unexplained variation in the dependent variable. It is also important to note that the coefficients for the variables of interest are small. This implies that a unit increase in, for instance, the fraction of option awards is associated with small increases in subsequent R&D intensity, indicating low economic significance. As such, while our results show a statistically significant positive relationship between increases in the fraction of option awards and subsequent R&D intensity, it is important to be cautious about drawing overly conclusive interpretations from our results.

6. Robustness tests

To validate our findings and ensure the robustness of our regression models, we performed a series of additional tests that are outlined below.

6.1. Heteroskedasticity

One of the fundamental assumptions of the OLS regression is homoscedasticity, meaning that the error term's variance remains constant. Any inconsistency or variation in the error term's variance leads to biased variances of the estimated coefficients, which renders the regression results invalid. Failure to recognize this issue could increase the risk of type 1 errors, as observed by Rosopa et al. (2013). To address this concern, we perform the Whites-T test (White, 1980) to test for heteroscedasticity in our OLS regression models. For all our models, the test rejects the null hypothesis of the model exhibiting homoscedasticity at a significance level of 10%.

Additionally, we plot the fitted values against the residuals and observe indications of heteroskedasticity. Together, these findings indicates that our models suffer from heteroskedasticity. Accordingly, we employ robust estimation methods and cluster at the firm level in our models. This approach helps to control for the aforementioned concerns and increase the reliability of our results.

6.2. Multicollinearity

Multicollinearity is a problem that occurs when there is a high correlation among independent variables in a regression model. This does not necessarily make the model invalid. However, it lowers the validity as it becomes challenging to interpret the regression results due to the difficulty in determining the contribution effect of each variable (Farrar and Glauber, 1967). To detect multicollinearity, we conduct a VIF (Variance Inflation Factor) test for all variables in our models. The results from the VIF test show that the VIF factor is below the commonly accepted threshold value of 4 (O'Brien, 2007), indicating that none of our models suffer from multicollinearity. Appendix 1 provides detailed results of the VIF test.

6.3. Alternative measure for R&D intensity

As a robustness test, we run regressions on all three hypotheses using R&D to assets as our dependent variable instead of R&D to sales. Our regressions using R&D to assets as the dependent variable exhibit similar results for the dependent and independent variables as the regressions using R&D to sales (see regression results in Appendix 2). Although, there are some minor differences regarding the statistical significance of the coefficients. For the first hypothesis, the t-value is lower yet still significant at the 1% level. For the second hypothesis, the t-value is lower and still insignificant. For the third hypothesis, the t-value of options as a share of total compensation is slightly higher. In conclusion, the results for the relationship between the dependent and independent variables in our model hold when using an alternative measure of R&D intensity. However, it is important to acknowledge that some of our control variables exhibit different significance levels and magnitudes of coefficients when using R&D to assets as an alternative to R&D to sales when measuring R&D intensity.

7. Conclusion

This study aims to investigate whether CEO compensation structure is associated with R&D intensity and whether compensation design can effectively align incentives and stimulate innovation. In light of this, we hypothesize that the fraction of a CEO’s total compensation that is long-term is positively related to a firm’s R&D intensity. Furthermore, we predict that increases in the fraction of long-term compensation relative to total compensation are followed by subsequent increases in R&D intensity. Finally, we investigate how the fractions of separate components of long-term compensation relative to total compensation are associated with subsequent R&D intensity.

We find a positive relationship between the fraction of total CEO compensation that is long-term and the level of R&D intensity in a firm. However, we find no clear evidence that an increase in the fraction of total long-term compensation is followed by an increase in R&D intensity. Nonetheless, when separating the different components of long-term compensation, we find that an increase in option awards relative to total compensation is positively associated with a subsequent change in R&D intensity. This indicates that different elements of long-term compensation influence executive behavior differently and shows the importance of not treating all forms of long-term compensation equally, both in academic and practical contexts.

This paper makes three main contributions. Firstly, our study is among the few to examine the impact of executive compensation on decision-making in a long-term context, such as R&D spending. Secondly, our research highlights the importance of considering individual compensation elements and contributes to the understanding of how different forms of pay motivate executive behavior. Lastly, our study has practical implications as it contributes to an understanding of how firms can work with compensation design to align the incentives of top executives with the firm’s strategic goals for R&D spending.

Overall, our findings suggest that compensation design can motivate CEOs to invest in R&D. This study provides valuable insights for stakeholders involved in constructing compensation packages and determining CEO pay, particularly for firms that prioritize innovation and long-term growth.

7.1. Limitations

In the following section, we discuss limitations that could affect the validity and reliability of our findings.

One limitation of our study is the potential for bias within our sample. If our sample is not fully representative of the general population, it is important to be cautious when interpreting our results and drawing general conclusions from them. Dropped observations due to missing data may not be missing at random, and their exclusion could introduce bias in our results. Additionally, as we observe from the descriptive statistics, there are indications of our sample being biased towards certain types of firms, most likely growth firms. Firms in our sample exhibit high values for Tobin’s Q, past stock return, and stock volatility, which can be typical characteristics of such firms. This could partly be an effect of excluding firms with zero R&D spending from our sample.

Another potential limitation is that CEO successions are not accounted for in our model, i.e., in some cases, there might have been a change in CEO during the period for which we measure the delta in compensation and R&D intensity. In such cases, the subjective preferences of the new CEO may influence R&D spending decisions. Moreover, we only measure changes in R&D intensity following changes in compensation structure over one year. Therefore, we cannot conclude what happens over a more extended period of time. It could be that the impact of changes in compensation structure may not be fully reflected in R&D intensity until later years. Additionally, our measure of long-term compensation does not quantify to what extent the compensation is long-term. For example, it does not consider the timing of payments, vesting periods, or cliff vesting, which can affect the executive's incentive to pursue long-term actions. As argued by Manso (2011), option and stock awards that vest over a longer time horizon provide more incentive to invest long-term than option and stock awards that vest over shorter time horizons. This effect is not accounted for in our measure. Also, as the fraction of long-term compensation relative to total compensation is measured in a given year, the CEO’s accumulated long-term incentives are not considered. This can lead to a skewed perception of the CEO's actual long-term stake in the company. Even though our shareholding control variable can be a proxy for this, it does not consider unexercised options currently held by the CEO.

It is also important to consider the potential endogeneity issue in our study. The interdependence between R&D intensity and long-term compensation means that the direction of causality may be unclear. Additionally, R&D decisions may based on factors that are difficult to incorporate into a model, such as budgeting, innovation strategy, and changes in the competitive landscape. These factors may influence R&D intensity levels, and our model may not capture this effect in its entirety, leading to omitted variable bias.

The scope of our study is limited to firms included in the S&P1500, which may limit the generalizability of our results to other geographies and firm types. Factors such as corporate governance structures and cultural differences could mean that the findings in this study may be different in other geographies and for smaller or privately held firms. Accordingly, generalizing our results to such contexts should be made with caution. Also, our study focuses on the compensation structure for CEOs exclusively. However, it is important to acknowledge that decision-making regarding R&D spending is not limited to CEOs alone. Such decisions can involve multiple executives as well as the board of directors, and the level of discretion that executives have over R&D decisions may vary across firms.

Despite these limitations, we argue that our study contributes to understanding the relationship between CEO compensation structure and R&D intensity, how this relationship differs across different compensation components, and can inform practitioners on considerations within compensation design.

7.2. Future research

While writing this thesis, we have identified several interesting aspects that extend beyond the scope of our study but warrant further in-depth research.

One potential avenue for future research is to extend the time horizon beyond the one-year lag used in our second and third regression when measuring the effect of changes in compensation structures on subsequent changes in R&D spending. As previously stated, the one-year lag may not capture the full effect on R&D intensity as the effect might extend over a longer time horizon. As such, a longer-term analysis could provide more comprehensive insights into the relationship investigated in this study. Secondly, further research could investigate how the effect of individual elements of long-term compensation extends beyond R&D intensity to other areas of firm outcomes. By examining this effect on a wider range of metrics, researchers can better understand how compensation relates to executive behavior. Furthermore, while our study focuses exclusively on the compensation structure for CEOs, future studies could examine if and how the relationship changes if also considering compensation for other executives. Previous research has found that in the context of firm risk-taking, providing outside directors with stock option compensation weakens the effect of the CEO's compensation of the risk-taking on the firm (Deutsch et al., 2011). As such, the results might change if also considering the compensation incentives for other executives and board members.

Additionally, future research could build on our study by examining how R&D investment decisions stemming from various compensation structures translate into firm performance. While our study focuses on the relationship between changes in CEO compensation structure and R&D intensity, it does not consider the impact of these changes on firm performance. Moreover, our study is limited to large firms listed in the US. As such, it would be interesting to investigate whether our findings also hold true in other geographies, which may have significantly different cultural, business, and regulatory environments.

Lastly, we encourage future studies to investigate this relationship from a qualitative perspective. While previous studies predominantly adopt a quantitative approach to examine this relationship, such studies mainly explore whether compensation structure influence firm outcomes. A qualitative study could provide a more comprehensive understanding of the underlying factors that explain the relationships found in this study and capture nuances that are difficult to quantify.

8. References

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9. Appendix

9.1. Appendix 1: Multicollinearity (VIF-test)

Regression Model 1:

Variable	VIF	1/VIF
Long-term compensation (%)	1.24	0.81
Age	1.41	0.71
Tenure	2.12	0.47
Shareholding	1.89	0.53
Firm size	1.98	0.51
ROA	1.53	0.65
Leverage	1.61	0.62
Tobin's Q	1.19	0.84
Share price performance	1.25	0.80
Volatility	1.68	0.60

Regression Model 2:

Variable	VIF	1/VIF
Delta (Long-term compensation - %)	1.04	0.96
Age	1.41	0.71
Tenure	2.13	0.47
Shareholding	1.82	0.55
Firm size	1.95	0.51
ROA	1.53	0.66
Leverage	1.61	0.62
Tobin's Q	1.19	0.84
Share price performance	1.23	0.81
Volatility	1.68	0.60

Regression Model 3:

Variable	VIF	1/VIF
Delta (Options - %)	1.82	0.55
Delta (Stock awards - %)	2.30	0.43
Delta (Non-equity incentives - %)	1.82	0.55
Delta (Salary - %)	1.52	0.66
Delta (Bonus - %)	1.14	0.88
Age	1.41	0.71
Tenure	2.13	0.47
Shareholding	1.83	0.55
Firm size	1.96	0.51
ROA	1.53	0.65
Leverage	1.61	0.62
Tobin's Q	1.19	0.84
Share price performance	1.23	0.81
Volatility	1.69	0.59

9.2. Appendix 2: Alternative measure of R&D

Regression model 1:

R&D share of assets	Coefficients
Constant	0.0284
	(1.10)
Long-term compensation (%)	0.0317
	(3.41)***
Age	-0.0005
	(1.20)
Tenure	0.0012
	(2.37)**
Shareholding (%)	-0.1009
	(0.68)
Firm size	-0.0028
	(1.68)*
ROA	-0.1064
	(2.95)***
Leverage	-0.0308
	(2.12)**
Tobin's Q	0.0009
	(3.06)***
Share price performance	0.0053
	(1.99)**
Volatility	0.0535
	(3.23)***
Industry fixed effects	Yes
Year fixed effects	Yes
Adjusted R-squared	0.2237
Number of observations	2,438

*Note: * $p<0.1$; ** $p<0.05$; *** $p<0.01$*

Regression model 2:

Delta (R&D share of assets)	Coefficients
Constant	0.0009
	(0.32)
Delta (Long-term compensation - %)	0.0020
	(1.18)
Age	-0.0000
	(0.80)
Tenure	0.0000
	(0.57)
Shareholding (%)	-0.0181
	(1.09)
Firm size	0.0001
	(0.71)
ROA	-0.0057
	(1.13)
Leverage	-0.0018
	(1.16)
Tobin's Q	0.0000
	(0.17)
Share price performance	-0.0007
	(1.45)
Volatility	0.0023
	(0.85)
Industry fixed effects	Yes
Year fixed effects	Yes
Adjusted R-squared	0.0054
Number of observations	2,438

Note: $^{*}p<0.1$; $^{**}p<0.05$; $^{***}p<0.01$

Regression model 3:

Delta (R&D share of assets)	Coefficients
Constant	0.0009
	(0.32)
Delta (Options - %)	0.0073
	(2.08)**
Delta (Stock awards - %)	0.0034
	(1.47)
Delta (Non-equity incentives - %)	0.0036
	(1.57)
Delta (Salary - %)	-0.0006
	(0.20)
Delta (Bonus - %)	-0.0052
	(1.01)
Age	-0.0000
	(0.72)
Tenure	0.0000
	(0.61)
Shareholding (%)	-0.0203
	(1.24)
Firm size	0.0001
	(0.59)
ROA	-0.0062
	(1.23)
Leverage	-0.0019
	(1.17)
Tobin's Q	0.0000
	(0.16)
Share price performance	-0.0007
	(1.43)
Volatility	0.0021
	(0.79)
Industry fixed effects	Yes
Year fixed effects	Yes
Adjusted R-squared	0.0089
Number of observations	2,438

*Note: * p<0.1; ** p<0.05; *** p<0.01*