Changes in CEO Stock Option Grants: A Look at the Numbers*

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Abstract

We study changes in the number of CEO stock option grants. Despite some evidence of short-term rigidity, the number of options granted changes frequently over time. CEOs of firms with unusual investment patterns subsequently receive fewer stock options as part of their compensation packages. CEOs who hold exercisable deeply-in-the-money options (overconfident CEOs) also receive fewer stock options in subsequent periods. Our results show that past CEO behavior predicts stock option grants. These insights can inform theoretical discussion on option-granting behavior and, more broadly, on the board's re-contracting process.

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1. Introduction

Recent evidence on the number of CEO option grants shows a high degree of rigidity, with nearly 20% of new option grants containing the same number of options as the previous year's grant (Shue and Townsend 2017a). This degree of rigidity suggests that boards do not always adjust compensation towards a target valuation. Rigidity in the number of option grants has been used as one explanation for the rise in CEO pay since the 1990s (Murphy 2013, Shue and Townsend 2017a), which has attracted significant public and investor criticism.

In light of these facts, in this paper we examine changes in the number of CEO stock option grants. How often do boards revise their option-granting decisions? What variables predict such revisions? To answer these questions, we first provide a detailed description of the main aggregate trends in CEO stock option grants. We then move on to study boards' option-granting behavior by examining factors that predict changes in stock option grants.

The number of stock option grants is central to executive compensation. Under current NYSE listing requirements, companies need to obtain shareholders' approval for the total number of options granted. Despite the importance of the number of option grants in executive pay, we currently know relatively little about boards' option-granting behavior. Most of the literature focuses on the value of options as the outcome variable. This stream of the literature suggests that option pay adjusts to optimal levels over time (Core and Guay 1999) and that such adjustments are more pronounced following periods of aggressive accounting (Cheng and Farber 2008). However, since changes in the value of options may be driven by changes in stock prices rather than the number of options granted, option value alone does not offer clear insights into the board's option-granting decision. Our paper fills a gap in this literature by examining how the number of option grants changes over time. In a sample of large US firms from 1992 to 2020, we measure annual changes in stock option grants as a percentage of total shares outstanding; for simplicity, we refer to this variable as the number of stock option grants. We find that, despite some evidence of short-term rigidity, the number of options granted to CEOs changes significantly over time.

We next examine factors that predict changes in the number of option grants. We focus initially on corporate investment decisions. We define "abnormal investment" as capital expenditures and R&D investments that are not predicted by observable firm characteristics. We find that CEOs that undertake either high or low levels of investment receive fewer stock options in the subsequent period. Our estimated effects are economically large. For example, for the typical firm, being in the top or bottom quintile of the distribution of "abnormal capital expenditures" predicts a subsequent reduction of roughly 10% in the number of options granted to the CEO, compared to all other firms. We document a similar change in the number of options granted when firms undertake high levels of R&D investment.

Our results show that drastic investment decisions are associated with future reductions in the number of stock option grants. One potential explanation for this fact is that firms learn about their CEO from past investment decisions. That is, abnormal levels of corporate investment could indicate the presence of CEO preferences and traits that lead CEOs to make suboptimal decisions. For example, abnormally high levels of corporate investment could be a symptom of CEO short-termism, overconfidence, or empire-building (Bebchuk and Stole 1993; Edmans, Fang and Lewellen 2017; Malmendier and Tate 2005, 2008; Gervais, Heaton, and Odean 2011).[1] Similarly,

[1] There is a literature on CEO compensation that studies the association between stock options, risky outcomes, and corporate investment (Aggrawal and Mandelker 1987; Balachandran, Kogut, and Harnal 2010; Cohen, Hall, and Viceira 2000; Guay 1999; Rajgopal and Shevlin 2002; Sanders and Hambrick 2007). There is also evidence that when option holdings are too high, they may induce managers to invest too much (Coles et al. 2006), undertaking overly risky projects for a given level of return (Core and Guay 1999). Too many stock options may also trigger earnings management incentives and lead CEOs to invest too little, in an attempt to meet earnings targets. In this case, low levels of discretionary investment, in particular R&D, which is fully expensed in the current period, become a means of inflating profitability to meet short-term earnings targets (Dechow and Sloan 1991; Bartov 1993; Baber, Kang, and

abnormally low levels of investment can be a consequence of CEOs' incentives to meet earnings targets (Stein 1989). Alternatively, underinvestment can occur because overconfident CEOs put more weight on their own private information when deciding how much to invest (Gervais et al. 2011). Therefore, abnormal investment activity may indicate a need for reshaping CEO incentives.[2] That is, after observing abnormal investment activity, boards may adjust CEO incentives through option grants.

To investigate whether changes in option grants are related to CEO overconfidence, we extend our empirical model to include a common measure of CEO overconfidence, which is the holding of vested deeply-in-the-money options (Malmendier and Tate 2005). We find that more overconfident CEOs experience larger reductions in option grants. As abnormal investment remains a predictor of option grants even after controlling for direct measures of CEO overconfidence, the evidence does not pin down a single mechanism through which abnormal investment predicts option-granting behavior. Our findings are nevertheless suggestive that boards rely on multiple observable CEO actions, e.g., corporate investment and option holding activity, when revising stock option grants.[3]

We explore the rebalancing of compensation structure further by investigating whether abnormal investment levels predict changes in other components of CEO compensation. We find

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Kumar 1998; Bushee 1998; Bens, Nagar and Wong 2002; Bens Nagar, Skinner, and Wong 2003; Roychowdhury 2006). This research assumes that earnings management survives optimal executive contracts (Dutta and Fan 2014, Goldman and Slezak 2006) and that high stock option holdings are associated with earnings management (Burns and Kedia 2006; Bergstresser and Philippon 2006; Cheng and Warfield 2005; Efendi, Srivastava, and Swanson 2007; Cohen, Dey, and Lys 2008; Grant, Markarian, and Parbonetti 2009). In turn, earnings management has been shown to interfere with investment decisions (Biddle, Hilary, and Verdi 2009).

[2] Consistent with this, some theories predict that rational principals learn about CEO preferences from the decisions that CEOs make and then dynamically adjust compensation parameters accordingly (see, e.g., Gibbons and Murphy 1992).

[3] Cornelli, Kominek, and Ljungqvist (2013) reach a similar conclusion when examining turnover decisions as way of monitoring CEO competence.

limited evidence that unusual levels of investment predict changes in salary, cash bonuses, and restricted share grants.

Our results shed light on boards' option-granting behavior by highlighting dynamic changes in the number of option grants as a function of observable CEO actions. Our goal is to document changes in compensation patterns after periods of unusual investment or option holding behavior. Past investment predicts future option grants presumably because investment contains (or is correlated with) information that is useful for boards to decide on option grants. Thus, exogenous shocks to investment – by definition – would not contain such information. As we do not use a random source of variation for investment decisions, we make no claims about causality. We provide no causal evidence on the determinants of stock option grants; this is beyond the scope of this paper.

Our findings complement recent evidence on the number of option grants (Shue and Townsend 2017a) by showing that, while there is a degree of rigidity in option grants, there is also considerable variation in annual changes in the number of options. We show that this variation is partly predicted by measures of corporate investment and CEO overconfidence.

Another contribution of this paper is to improve our understanding of re-contracting in executive compensation. While efficiency in the design of compensation schemes is a central theme in recent governance debates, there is little empirical evidence of feedback effects from firm outcomes to compensation design. A notable exception is the work of Cheng and Farber (2008), who find that firms revise stock option grants downwards following earnings restatements. However, earnings restatements occur infrequently, thus it is difficult to generalize this finding to the majority of firms, which do not demonstrate significant failures in reporting. Unusual investment patterns, on the other hand, can be more easily and frequently detected. They therefore offer an alternative setting for investigating the dynamics of CEO compensation contracts.

Our work is also related to that of Gopalan, Milbourn, Song, and Thakor (2014). They propose a new measure of CEO pay duration, which measures the extent to which compensation is short-term. They find that pay duration is related to several firm characteristics. As in our paper, they argue that boards make inferences about executive characteristics and change compensation contracts to reflect such characteristics.

The rest of the paper is organized as follows. In Section 2 we discuss our measures of changes in stock option grants, high and low investment, and our empirical models. Section 3 describes our sample and data. Section 4 presents our findings, and Section 5 concludes.

2. Research Design

2.1 Why numbers?

Most of the empirical literature on CEO compensation uses valuation-based measures of equity incentives. For example, in the case of executive stock options, many studies use option valuation models to calculate their variables of interest, which are often the proportion of the value of option holdings over total compensation, or some option "Greeks," such as delta or vega. Valuation-based measures of equity incentives are particularly useful for directly measuring the strength of the incentives provided to CEOs through compensation contracts. The downside in using valuation-based measures is that their value is always endogenously determined; among other things, this value reflects the market's expectations of changes in CEO behavior induced by the compensation scheme.[4]

[4] There is evidence that stock price movements (both price and return volatility) affect the valuation of the options because the market reacts upon the firm's announcement of the grant (see, e.g., DeFusco, et al., 1990; Martin and Thomas 2001; Espahbodi, et al, 2002).

When interested in directly measuring boards' choices of compensation parameters, *valuation-free* measures, such as the number of option and share grants (normalized by the total number of shares), are arguably preferable to valuation-based measures. When granting stock options, the board has two variables within its control: the number of stock options granted and the exercise price. The common practice of granting stock options at the money means that, in practice, the only tool remaining in the control of boards is the number of stock options granted.

As an indicator of boards' choices, the number of options has the advantage of not being contaminated by the stock price reaction to such decisions. Although boards may use a dollar target for option grants, the announcement of a grant may itself affect the stock price and thus disguise the intended direction of the adjustment. For a concrete example, suppose that the board optimally decides to reduce the number of options granted to the CEO. As the market learns about the adjustment, the price goes up. Thus, the final impact on the value of the new option grants is ambiguous. This ambiguity is not an issue for measuring the total incentive effects of the change, but it does confound the inference when one is interested in directly measuring the choices made by the board.

Our goal is not to revisit the extensive literature on CEO incentive provision, but to consider how compensation parameters change as information about CEO decisions become available. That said, with the usual caveats, changes in the number of options can be interpreted as revisions to compensation contracts, with consequences for incentive provision. For example, delta and vega are typically defined as CEO wealth sensitivity to stock price or volatility. In practice, they are measured as the derivative of the Black-Scholes value of one option to either price or volatility, times the number of options (see, e.g., Guay 1999, and Coles, Daniel, and Naveen 2006). Because the number of options does not affect the derivative of one option, all else being held constant, a higher number of options unambiguously leads to higher delta and vega. Because options are usually granted at the money, in practice, the number of options is likely to be the main choice variable for affecting delta and vega.

Prior research largely assumes that executive stock options are granted at the money (Chauvin and Chenoy, 2001; Heron and Lie, 2007, Bebchuk et al., 2010; Murphy, 2013; Shue and Townsend 2017a, 2017b). Until 2006, accounting standards permitted firms to expense stock options at their intrinsic value, which is calculated as zero if the exercise price is set equal to the market price (Accounting Principles Board Opinion 25, 1972). "Under this method, the compensation cost of an employee stock option is assumed to be the excess, if any, of the market price of the stock over the exercise price on the date the option is granted. In the most common situation, in which options are granted with an exercise price equal to the current market price, the intrinsic-value-based method calculates the compensation cost as zero" (Hull and White, 2004, p. 114). Though Statement of Financial Accounting Standard No. 123 (FASB 1995) recommended that firms expense the fair value of stock options and provided a methodology for fair value calculation, almost all companies continued to use the intrinsic value method to record zero stock option expenses until valuation-based expensing was mandated in 2006 by SFAS 123R (FASB 2004). This nil cost was a major contributor to the widespread or near-uniform practice of firms granting stock options at the money (Bebchuk et al., 2002; Murphy, 2013), as they would be "costless" in the financial statements.

While mandatory valuation model-based expensing of options introduced in 2006 with SFAS 123R did contribute to a decrease in the number of options granted (Carter, Lynch, and Tuna 2007, Brown and Lee 2011, Hayes, Lemmon, and Qiu 2012), it also suggests that firms preferred to adjust numbers and type of compensation, rather than adjust exercise prices relative to market prices. Thus, in practice, the relative stickiness of zero-excess price-setting leaves the number of options granted as the cleanest and most direct measure of the choices made by the board.

2.2 Definition of main variables

We define the level of option grants, $\#Option\_Grants_{it}$, as the number of annual option grants divided by total shares outstanding, as follows:

$$\#Option\_Grants_{it} = \left(\frac{Number\ of\ options\ granted\ in\ the\ year}{Number\ of\ shares\ outstanding}\right)_{it} \times 100. \quad (1)$$

The change in option grants, $\Delta\#Option\_Grants_{it}$, is the first difference of equation (1).[5] Other papers that use the number of stock option grants as a key variable include Cheng and Farber (2008), Kedia and Rajgopal (2009), and Call, Kedia, and Rajgopal (2016).

Prior literature examining the association between the design of CEO compensation schemes and CEO investment decisions emphasizes R&D investments (Bryan, Hwang and Lilien 2000; Coles et al. 2006; Cheng and Farber 2008; Kim and Lu 2011).[6] Investment in R&D is more discretionary in nature than investment in physical assets, and has immediate accounting effects, as it is expensed, not capitalized, and therefore directly affects a company's reported profitability. Capital expenditures, while initially capitalized, also affect reported profitability indirectly, through subsequent depreciation expenses. However, unlike investment in R&D, which conveys superior investment information mainly in R&D-intensive industries (Amir, Guan, and Livne 2007), capital expenditure information is available for all industries. Furthermore, investments in physical assets have less uncertain returns, which may facilitate the board in detecting abnormally

[5] Dividing by the number of shares outstanding is common practice both in studies that have also used number of options grants (e.g. Cheng and Farber (2008) for executive options; Kedia and Rajgopal (2009) for options to rank-and-file employees) and in studies examining the sensitivity of option holdings (Core and Guay 1999; Guay 1999).
[6] Stock return volatility has also been used as a proxy for the riskiness of investments (see Cheng and Farber 2008). Stock return volatility may capture risk relating to the firm's operating, financing and reporting decisions. However, it is difficult to normalize and is inevitably affected by stock market anomalies. Stock returns may also be beyond the control of managers as they also reflect changes in the economy or industry-wide circumstances.

high or low levels of investment, given business fundamentals. Accordingly, we examine unusual investment patterns, e.g., high and low investment, in both capital expenditures and R&D.

To capture high and low investment levels in capital expenditures, we identify investments that are substantially higher or lower than the amount that would be justified by business fundamentals, according to an empirical model. We calculate identifiers of high and low capital expenditure (*HCAPEX* and *LCAPEX*) for firms in the top and bottom quintile of abnormal capital expenditures. We follow McNichols and Stubben (2008) to estimate the normal investment level as follows:

$$CAPEX_{it} = \alpha_0 + \alpha_1 CAPEX_{it-1} + \alpha_2 Q_{it-1} + \alpha_3 Q_{it-1} \times QRT2_{it-1} + \alpha_4 Q_{it-1} \times QRT3_{it-1} + \alpha_5 Q_{it-1} \times QRT4_{it-1} + \alpha_6 CF_{it} + \alpha_7 Growth_{it} + e_{it}, \quad (2)$$

where *CAPEX* is total investment in capital expenditures scaled by net property, plant and equipment, *Q* is Tobin's Q, *QRT2* (*QRT3*, *QRT4*) equals 1 if *Q* is in the second (third, fourth) quartile of its industry-year distribution, *CF* is cash flow from operations scaled by net property, plant and equipment, and *Growth* is growth in total assets. The model builds on the premise that investment opportunities and cash flows (because of financial constraints) determine optimal investment. The model also allows for nonlinear effects of *Q*. Lagged capital expenditures control for time-varying firm-specific components of investment decisions not captured by other business fundamentals.[7] The Appendix provides detailed definitions of all variables. Subscripts *i* and *t* indicate firm and year, respectively.

We estimate equation (2) for each of Fama and French (1997)'s 48 industry groups with at least 20 firms in each industry-year combination. Annual cross-sectional estimations of equation (2) yield firm- and year-specific residuals representing abnormal capital expenditure (*ACAPEX*). As we are interested in both high and low levels of investment, we form quintiles by year based

[7] We find qualitatively similar results if we also include lagged *CF* in model (2).

on *ACAPEX*. *HCAPEX* equals 1 for all firm-years in the top quintile of residuals of equation (2) (*ACAPEX*), and 0 otherwise. *LCAPEX* equals 1 for all firm-years in the bottom quintile of the residuals (*ACAPEX*), and 0 otherwise.

To derive a measure of high and low investment in R&D, as with capital expenditures, we calculate identifiers of high and low R&D (*HRD* and *LRD*) for firms in the top and bottom quintile of abnormal R&D (*ARD*), respectively. We define abnormal R&D (*ARD*) as the residuals of an empirical model as in Berger (1993) and Gunny (2010):

$$RD_{it} = \alpha_0 + \alpha_1 RD_{it-1} + \alpha_2 FUNDS_{it} + \alpha_3 CAPEXS_{it} + \alpha_4 Q_{it} + \alpha_5 ROA_{it} + e_{it}, \quad (3)$$

where *RD* is R&D investment, *FUNDS* is pre-R&D cash flow, *CAPEXS* is capital expenditures, *Q* is Tobin's Q as above, and *ROA* is income before extraordinary items divided by average total assets. R&D divided by sales is a common measure of R&D intensity among capital market participants. Lagged R&D intensity, RD_{it-1}, allows for innovation opportunities to be autocorrelated.[8] The level of internal funds, *FUNDS,* may affect R&D expenditure as R&D projects may need to be rationed if external finance cannot be raised. Capital expenditures (*CAPEXS*) controls for the potential competition for resources between capital expenditures and R&D projects. *Q* proxies for investment opportunities. Following the prior literature on abnormal levels of R&D (Athanasakou, Strong, and Walker 2011), we also control for operating performance (*ROA*). Following Berger (1993), we deflate all variables by sales.[9]

R&D levels in certain concentrated industries have been found to be a major element of competition, thus a firm's R&D spending is expected to be influenced by its rivals. We therefore also estimate equation (3) for each of Fama and French (1997)'s 48 industry groups with at least

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[8] Firms that have identified more potentially profitable innovation opportunities may be expected to spend more on R&D each year.
[9] We find qualitatively similar results if we also include lagged *FUNDS* in model (3).

20 firms in each industry-year combination, to ensure efficient parameter estimation. Annual cross-sectional estimations of equation (3) yield abnormal R&D investment levels (*ARD*). *HRD* equals 1 for all firm-year observations in the top quintile of residuals from equation (3) (*ARD*) and 0 otherwise. *LRD* equals 1 for all firm-year observations in the bottom quintile of *ARD* and 0 otherwise.

Since equations (2) and (3) impose some structure on the data, one may wonder whether such a structure is important for the results that follow. As a simple alternative to these models, we also define high and low levels of investment by forming quintiles of total investment levels by industry. In Section 4.4, we show that the results are similar when we use either approach.

2.3 Empirical model of changes in stock option grants

There is a paucity of theoretical work on models that link time-varying information about CEO decisions or characteristics to future revisions of compensation contracts (a notable exception is Gibbons and Murphy 1992). The theoretical literature, thus, offers little guidance on how to specify empirical models of changes in options grants. We thus choose simple reduced-form models with sufficient flexibility to entertain multiple hypotheses.

To understand the intuition behind our empirical model, suppose we tentatively use the following simple model:

$$\#Option\_Grants_{it} = \boldsymbol{z'}_{it-1}\boldsymbol{\alpha} + \boldsymbol{x'}_{it-1}\boldsymbol{\beta} + \boldsymbol{p'}_{t}\ \boldsymbol{\gamma} + e_{it}, \tag{4}$$

where $\boldsymbol{z'}_{it-1}$ is a vector of indicators for abnormal investment (in levels), $\boldsymbol{x'}_{it-1}$are control variables, $\boldsymbol{p'}_{t}$ are year dummies, $\boldsymbol{\alpha}, \boldsymbol{\beta}$, and $\boldsymbol{\gamma}$ are vectors of parameters to be estimated, and e_{it} is the error term.

Although simple, this specification has some undesirable properties. For example, suppose that the abnormal investment indicators remain unchanged from $t-2$ to $t-1$. All else being held constant, according to the model in (4), the expected number of option grants would also not change from $t-1$ to t. But if there is, say, persistent overinvestment in both $t-2$ and $t-1$, and the board wishes to moderate overinvestment by changing the compensation structure, the number of option grants should change from $t-1$ to t. Thus, the model in (4) does not match the economic question we wish to investigate. The problem with this specification is that it assumes that the level of option grants depends on abnormal investment. An alternative is as follows:

$$\#Option\_Grants_{it} = \#Option\_Grants_{it-1} + \boldsymbol{z'}_{it-1}\boldsymbol{\alpha} + \boldsymbol{x'}_{it-1}\boldsymbol{\beta} + \boldsymbol{p'}_{t}\ \boldsymbol{\gamma} + e_{it}, \qquad (5)$$

Under this specification, changes in option grants depend on the level of abnormal investment, which fits the notion that boards learn from observing evidence of abnormal investment. However, the model in (5) now has a different undesirable feature: option grants keep on increasing (or decreasing) forever even when the control variables in $\boldsymbol{x}$ remain constant over time. To fix this issue, we use instead

$$\Delta\#Option\_Grants_{it} = \boldsymbol{z'}_{it-1}\boldsymbol{\alpha} + \Delta\boldsymbol{x'}_{it-1}\boldsymbol{\beta} + \boldsymbol{p'}_{t}\ \boldsymbol{\gamma} + e_{it}, \qquad (6)$$

where $\Delta\#Option\_Grants_{it}$ is the change in the number of stock options granted for firm i in year t and $\Delta\boldsymbol{x}_{it-1}$is a vector of lagged firm characteristics in first differences. The model in (6) is similar to that of Cheng and Farber (2008, p. 1228), who also use a specification in which the change in the number of stock option grants depends on an earnings restatement indicator, changes in firm characteristics, and time dummies.

All right-hand-side variables in equation (6) (except year dummies) are lagged by one year. Our variables of interest are in $\boldsymbol{z}_{it-1}$. The composition of set $\boldsymbol{z}_{it-1}$ varies across different specifications. This set may include high and low capital expenditure indicators (*HCAPEX* and *LCAPEX*), high and low R&D indicators (*HRD* and *LRD*), and an overconfidence indicator (discussed in Section 4.2).

Our set of control variables, $\boldsymbol{x}$, draws upon research on the determinants of equity-based compensation, both at the firm and CEO level. In this set of covariates, we first include the change in capital expenditure (*ΔCAPEX*) and change in R&D (*ΔRD*). We also add a number of key factors known to be correlated with CEO equity holdings, as identified by Core and Guay (1999), Bryan et al. (2000), Hanlon, Rajgopal, and Shevlin (2003), and Cheng and Farber (2008).[10]

First, we include several firm characteristics that may affect boards' stock option grant revisions. Prior research has shown that compensation is increasing with size (Murphy, 2013), as larger firms are more complex, with greater monitoring needs, and require more experience, skills, and talent. However, larger firms may need to rely proportionately less on option-based compensation; for a small firm, the percentage of share capital granted to ensure sufficient incentivization may be higher than that for a large firm, where the same percentage would represent a much higher dollar value in the executive's portfolio. Meanwhile, firms with higher investment opportunities (growth firms) have higher external monitoring costs, thus increasing the efficiency of equity incentives (Smith and Watts, 1992). We therefore include firm size (*ΔSize)* and investment opportunities, measured as *ΔB/M*, in our model. We also control for the level of cash constraints and distress faced by the firm. Firms with operating losses and constrained amounts of cash are more likely to compensate managers with stock options in order to preserve firm liquidity, and the risk of distress is associated with increased incentives for performance (Bryan et al. 2000, Chang, Hayes, and Hillegeist 2015, Feltham and Wu 2001). To control for revisions in option grants associated with changes in these situational incentives, we include *ΔNetOperatingLoss* and *ΔCashShortfall*. We add changes in leverage (*ΔLev*), as debt financing may act as a substitute

[10] Core and Guay (1999) model CEO portfolio holdings of equity incentives, drawing from literature examining the determinants of managerial ownership (Demsetz and Lehn 1985; Jensen 1986; Himmelberg, Hubbard, and Palia 1999). These factors include firm and director characteristics affecting monitoring difficulty and agency costs.

monitoring mechanism to stock options. We also add changes in the structure of CEO compensation induced by stock price performance (Edmans, Gabaix, Sadzik, and Sannikov 2012) by including returns lagged by one and two periods ($\Delta Return_{t-1}$ and $\Delta Return_{t-2}$, respectively). Finally, prior research suggests that firms operating in more noisy and less predictable environments also have higher monitoring costs, and therefore are more likely to use equity incentives, as they more explicitly incentivize the CEO to increase effort and take appropriate actions (Demsetz and Lehn 1985; Core and Guay 1999). We follow this line of prior research and include changes in stock return volatility as proxy for this idiosyncratic risk, or noise (*ΔσReturn*).

Next, we include changes in several CEO-level characteristics to allow for person-specific determinants of option-based compensation. We control for changes in the level of cash compensation received by the CEO (*ΔCashCompensation*), as option compensation may function as a substitute for cash-based compensation (including cash-based incentive plans). We also include changes in the level of existing share ownership (*ΔShares_Own*). Although share ownership has a different risk-reward payoff and therefore provides a different incentive structure compared to stock options alone, shares may play a broadly similar role in the overall compensation mix, in that they provide stock market-based incentives for CEOs to exert effort. Thus, the necessity of granting stock options decreases as share ownership increases. Following the model of Cheng and Farber (2008), we also add changes in CEOs' existing stock option holdings to control for the proportion of the change in stock option grants related to changes in the number of expiring, exercised, and vesting stock options, and changes in ownership (*ΔExercisable_Options*, *ΔUnexercisable_Options*, and *ΔShares_Own*). Controlling for changes in the existing option and share portfolio effectively controls for changes in option grants that are related to maintaining a constant level of equity incentives, and allows for time-series variations in the stock option portfolio. We include an indicator of new CEOs (*ΔNewCEO*) to account for structural changes in the equity/cash mix of newly appointed CEOs. In Section 4.3, we discuss the addition of CEO tenure to the model.

Finally, we add year fixed effects to control for time-specific variation in stock option grants not captured by the other independent variables. More specifically, including year fixed effects controls for inter-temporal changes related to events such as the requirement to expense stock options under SFAS 123R, which induced many firms to reduce the number of stock options granted, or stop issuing options altogether (Hayes et al. 2012).

By considering changes in option grants (and also changes in all non-binary control variables), we control for the impact of time-invariant firm characteristics on CEO compensation structures. As our model is in first differences, we estimate a number of variations of equation (6) using pooled OLS regressions with standard errors clustered by firm.[11] Because we need to consider the information available to boards at the time of the decision to grant options in a given year, we use lagged values for all variables. Using lagged values also mitigates the concern that $\#Option\_Grants_{it}$ may decrease because firms that overinvest may also be more likely to issue more shares, thus diluting the proportion of CEO options over total shares outstanding by inducing denominator-driven changes.

More generally, scaling by the number of shares outstanding makes our measure of stock option grants sensitive to changes in share capital. Increases in share capital are possible for firms undertaking high investment in either R&D or physical assets. To address this concern, we re-estimate equation (6) controlling for changes in the number of shares outstanding from year $t-1$ to year t, and our core findings remain.

[11] Our results are unaffected by clustering standard errors by both firm and year.

3. Sample and summary statistics

3.1 Sample

Our initial sample is composed of an unbalanced panel of CEOs of non-financial firms covered by Execucomp from 1992–2020, which have accounting data from Compustat and market data from *CRSP*. Execucomp covers firms that are members or have been members of the S&P 1500 index. Our use of a first-difference specification with lagged variables causes us to lose two years of observations. Our final sample consists of 29,085 firm-years, and 2,548 unique firms, from 1994–2020.

3.2 Aggregate trends in option grants

We first investigate aggregate trends in stock option grants. Figure 1 plots the frequency of firms that offer no stock options (i.e., zero option grants) over our sample period. This frequency rises steadily from the sample period low of 22% in 2001-2002, reaching 73% in 2019. As firms that use stock-based compensation may, in some years, choose not to grant any options, we also plot the frequency of firms that offer no stock options in both the current and preceding fiscal period, i.e., firms with two consecutive years of zero option grants. This frequency shows a similar trend, peaking at 60% in 2019 and 2020. Despite these trends, however, a substantial fraction of firms still actively grants stock options in 2020.

We next investigate the significance of option grants for these actively-granting firms, i.e., firms that have non-zero option grants in the current and preceding year. Figure 2 plots $\#Option\_Grants_{it}$. Consistent with prior findings on the decrease in use of stock option grants following mandatory accounting recognition of stock option expenses under SFAS 123R (Brown and Lee 2011; Hayes et al. 2012), we observe that stock option grants are declining among actively granting firms, from a period high of 0.37% of shares outstanding in 2001 to 0.22% in 2020.[12]

We then explore evidence of rigidity among option-granting firms. Figure 3 plots the frequency of firms that grant the same number of options as in the previous year and those granting round multiples of the previous year's number (similar to Shue and Townsend's (2017a) measure of rigidity). Over our sample period, only a small fraction of option-granting firms — an average of 8% — grants the same number of options from one year to the next (or round multiples of the same number), with evidence of a declining trend from 2004, reaching a period low of only 3% by 2018 and 2019. Thus, the more recent data show evidence of disappearing rigidity. In Figure 4, among the remaining option-granting firms, the fraction of option granting firms increasing their stock option grants dominates the fraction of firms decreasing their stock option grants, especially towards the end of the sample period.

Taken together, Figures 3 and 4 provide some evidence of rigidity in stock option grants, but which is limited to a small and declining fraction of sample firms. More importantly, there is evidence of inter-temporal changes for actively-granting firms. All in all, it appears that option-granting firms have become more active and sophisticated in revising their option-granting decisions, with very little option rigidity by 2020, and that boards actively revise their option-granting decisions from year to year.

3.3 Descriptive statistics

Table 1 presents the basic descriptive statistics of our sample. The mean number of option grants as a percentage of shares outstanding, $\#Option\_Grants_{it}$, is 0.153%. The mean change in

[12] While there is a sharp decline in option grants in 2006 upon adoption of SFAS 123R (Brown and Lee 2011; Hayes et al. 2012), the declining trend starts earlier, from 2002. Such earlier declines in stock option usage may reflect anticipation of SFAS 123R (Carter et al. 2007; Choudhary, Rajgopal, and Venhkatachalam 2009), or stock option revisions unrelated to accounting cost considerations.

option grants, our dependent variable $\Delta\#Option\_Grants_{it}$, is −0.009, while the median is zero, in line with a gradual decline in option grants over our sample period. Approximately 42% of firm-years display no options in the current period ($\#OptionsZero$). The percentage of firm-years with firms not granting options in the current and preceding period is 31% ($\#OptionsZerotoZero$). The percentage of firm-years with firms granting the same number of options (or round multiples) from one year to the next is 8%.

The average percentage increase in lead salary ($\Delta Salary_{t+1}$) is 5.7%, while the average increase in bonus (*ΔBonus*) is 24% over our sample period. Mean ΔRD_{t-1} and $\Delta CAPEX_{t-1}$ are −0.001 and −0.012, suggesting that investment levels are decreasing over time in our sample.[13] The mean value of *ACAPEX* is also negative, suggesting that the average firm in the final sample reports below-benchmark investment in *CAPEX*. The mean and median change in the number of exercisable options ($\Delta Exercisable\_Options_{t-1}$) held by CEOs is positive, and the change in the number of unexercisable options ($\Delta Unexercisable\_Options_{t-1}$) is negative and close to zero. Over the entire sample, exercisable options are increasing and unexercisable options are decreasing. The positive mean and median change in firm size, $\Delta Size_{t-1}$, show that the sample firms are growing over time. Table 1 also presents the distribution of other control variables, including changes in leverage, stock returns, volatility, and book to market ratio.

Table 2 presents the correlations between some of the key variables used in our analysis. Variables HRD_{t-1} and $HCAPEX_{t-1}$ are only weakly positively correlated with one another, and likewise LRD_{t-1} and $LCAPEX_{t-1}$ are also only weakly correlated. Such pattern of correlations suggests that the investment indicators capture non-overlapping instances of high and low investment. We observe a negative association between $\Delta\#Option\_Grants_t$ and

[13] The average sample firm invests 5%% of revenues on R&D (mean *RD*: 0.051), and 27% of net property, plant and equipment on capital expenditure (mean *CAPEX*: 0.266).

$\Delta CashCompensation_{t-1}$, consistent with the rebalancing properties of the equity/cash mix. We also find a negative correlation between $\Delta Size_{t-1}$ and $\Delta CashCompensation_{t-1}$, consistent with Cheng and Farber (2008).

4. Results

4.1 Changes in CEO option-based compensation and investment levels

Table 3 reports the results of regressing changes in option grants on indicators of high and low investment in capital expenditures ($HCAPEX_{t-1}$ and $LCAPEX_{t-1}$) and R&D (HRD_{t-1} and LRD_{t-1}) and a vector of control variables (equation (6)). Column 1 reports the results for capital expenditure indicators, using a parsimonious specification including only basic control variables, i.e., changes in firm size, book-to-market ratio, and lagged changes in capital expenditures and R&D. Column 2 reports the output of a regression with the full set of control variables. The estimated coefficient on $LCAPEX_{t-1}$ is negative and significant in both specifications. The coefficient on $HCAPEX_{t-1}$ is also negative and significant in the full model. These results suggest that CEOs of firms in either the bottom or the top quintile of abnormal investment in capital expenditure receive fewer stock option grants in the subsequent period than other CEOs. These findings are economically significant: in our sample, the average number of annual option grants as a percentage of shares outstanding is 0.153%. For example, firms in the bottom or top quintile of abnormal capital expenditure reduce subsequent option grants by about 0.015 percentage points (0.016 and 0.013 respectively, in Column 2). Thus, CEOs who seem to invest too little or too much in capital expenditures subsequently experience a reduction of slightly less than 10% in the number of the new options granted to them.[14]

[14] Since we normalize the number of annual option grants by the total number of shares outstanding, the sample average of 0.153% means that, in a typical year, the average CEO receives new options that equal 0.00153 times the number of shares outstanding.

The next two columns repeat the analysis of equation (6) for R&D indicators. Columns 3 and 4 show the results for the parsimonious model and the full model, respectively. In both columns, the coefficients on HRD_{t-1} are negative and statistically significant. The evidence suggests that CEOs of firms in the top quintile of abnormal investment in R&D receive fewer stock option grants in the subsequent period than other CEOs. Firms in the top quintile of abnormal R&D reduce further option grants by about 0.014 percentage points (0.012 in Column 3 and 0.016 in Column 4). Thus, CEOs who invest too much in R&D experience a reduction of about 9% in the number of the new options granted to them.

We obtain similar results when we include all four indicators of high and low investment in Columns 5–6. In this specification, the estimated coefficients on $LCAPEX_{t-1}$, $HCAPEX_{t-1}$ and HRD_{t-1} have similar size and significance levels as those in Columns 2–4. Moreover, the results in Columns 5–6 suggest that the CAPEX and R&D investment have independent predictive ability for changes in option grants.

In terms of control variables, the negative coefficients on ΔRD_{t-1} in Columns 2, 4, and 6 suggest that boards adjust CEO stock option grants down after periods of increasing R&D intensity (this effect is only statistically significant in the full model). Thus, the number of option grants decreases both when firms invest more than their peers (the effect of HRD_{t-1}) and when firms invest more than they did in the past (the effect of ΔRD_{t-1}).[15] Unlike changes in R&D, changes in capital expenditures ($\Delta CAPEX_{t-1}$) do not seem to reliably predict changes in option grants.[16]

[15] We also estimate both the parsimonious and the full model using the differenced variable ΔHRD_{t-1} instead of HRD_{t-1}, so that the model becomes a standard fixed effects model. This procedure amounts to estimating the model in (4) in first differences. The variable ΔHRD_{t-1} reflects movements into and out of the top quintile of abnormal R&D spenders. The coefficients on ΔHRD_{t-1} are significantly negative, with a similar magnitude to those of HRD_{t-1} in Table 3. As discussed in Subsection 2.3, this model has a less natural interpretation than the model in (6). For example, model (4) forces the effect of no changes in HRD_{t-1} to be the same regardless of whether ΔHRD_{t-1} is one or zero.

[16] In further analysis (not tabulated), we introduce an interaction term between ΔRD_{t-1} and HRD_{t-1}; the interaction coefficient is small and not statistically significant.

For the other control variables, we note that the coefficient on $\Delta Size_{t-1}$ is negative and significant, consistent with prior findings of Cheng and Farber (2008, p. 1234) and the supplemental results of Bryan et al. (2000, p. 682). Changes in option grants are negatively related to $\Delta Return_{t-1}$ and positively associated with $\Delta B/M_{t-1}$, suggesting that stock market performance feeds back into stock option grants. There are some arguments which may predict a positive relationship between option grants, firm size, and returns (e.g., increasing complexity, agency conflicts, and more resources). Our findings suggest that the positive compensation-size relation is decreasing in size (i.e., the relationship is concave). There are several possible reasons for this fact. First, concavity suggests that firms with larger share capital need to pay proportionately less equity compensation to ensure incentivization, and thus larger firms need to rely proportionately less on option-based compensation. Second, firms with increasing stock returns (and thus higher share prices) may choose to grant fewer stock options, because the positive returns indicate that fewer incentives are required, or because each stock option granted is more valuable to the manager, even if the strike price is set equal to the market price, because higher returns may be related to higher underlying stock volatility.[17] The effects of most of the other control variables are intuitive. CEOs with increasing amounts of exercisable and unexercisable options receive fewer option grants, as evidenced by the negative and statistically significant coefficients on $\Delta Exercisable\_Options_{t-1}$ and $\Delta Unexercisable\_Options_{t-1}$. This finding suggests a "stock option maintenance effect," or a potential "target" level of stock options that boards expect CEOs to hold.[18] CEO succession also predicts changes in option grants, as there is a negative and

[17] Results for $\Delta Size_{t-1}$, $\Delta Return_{t-1}$, and $\Delta B/M_{t-1}$ are consistent with growth in revenue, stock returns, and market-to-book leading to downward revisions in stock option grants. This evidence suggests that boards may consider additional cues associated with CEO investment style other than corporate investment levels.

[18] While the descriptive statistics show that, at the median, $\Delta Exercisable\_Options_{t-1}$ and $\Delta Unexercisable\_Options_{t-1}$ are positive, an alternative interpretation is that CEOs with decreasing amounts of exercisable and unexercisable stock options receive more new stock options. This effect would be consistent with an adjustment of option grants to replace options that have vested, expired, or been exercised.

statistically significant coefficient on $\Delta NewCEO_{t-1}$.[19] As our first-difference specification requires compensation data for the previous year, this result refers only to new internally-hired CEOs that were promoted in year $t-1$, i.e. cases where $\Delta NewCEO_{t-1}=1$. Our descriptive statistics show that CEOs are likely to receive a large option grant at the time of appointment (year $t-1$) to increase their incentives to an appropriate level for a CEO. However, this is not sustained, leading to a downward adjustment in the subsequent year (t). The coefficients on changes in cash compensation, cash constraints, net operating losses, and stock return volatility are not statistically significant.

Collectively, the results in Table 3 are consistent with high investment in either capital expenditures or R&D being a predictor of fewer stock option grants. With respect to low investment, our results suggest that boards also reduce stock option grants; here the evidence is only statistically significant for capital expenditures.

Overall, the evidence suggests that option grants are revised downwards following both high and low investment levels. Our results suggest that boards tend to temper the flow of options granted to CEOs in firms with unusual investment patterns. While it is not possible to pin down a single explanation for this behavior, we note that such behavior is compatible with boards learning about CEO preferences and traits from past investment behavior. Boards may also view unusual investment patterns as evidence of CEO overconfidence. In the next section, we examine CEO overconfidence more thoroughly.

4.2 CEO overconfidence

Overconfident CEOs are more likely to overinvest, as they tend to overestimate investment returns and their own ability to pick profitable projects. Consistent with this, evidence shows that

[19] Bereskin and Hsu (2014) find that CEO turnover is associated with greater quantity and quality of future innovation (i.e. more patents, citations) and that the innovation is higher for new internal compared to new external CEOs.

overconfident CEOs undertake projects that would have been rejected by rational or less-overconfident CEOs (Malmendier and Tate 2005; 2008), or may invest in projects that are value-destroying (Goel and Thakor 2008). Gervais et al. (2011) propose that overinvestment by overconfident CEOs results from inefficient contracting; high powered incentives may exacerbate the consequences of overconfidence because CEOs are likely to overestimate their own financial returns when making investment decisions. This implies that some revision of compensation contracts may take place when a CEO is identified as (or is believed to be) overconfident.[20] A board may wish to reduce the flow of equity incentives to counter an overconfident CEO's propensity to overinvest.

Overconfident CEOs may also underinvest (or overinvest) relative to their industry peers because they put excessive weight on their own private information (Gervais et al. 2011). More incentivized CEOs will put more effort into acquiring costly private information and will thus have more private information at their disposal. In this context, underinvestment occurs when managers rely too much on their own bearish private information.

The literature acknowledges the possibility that boards may offset the negative effects of CEO overconfidence by properly designing compensation contracts. Malmendier and Tate (2005) make this point explicitly: "*If the board chooses a CEO because of his overconfidence, it should be aware of the "dark sides" of this personality feature (such as distorted investment behavior) and take steps to explicitly address them*" (p. 2664). Gervais et al. (2011) suggest that overinvestment by overconfident CEOs should be moderated by (or factored into) compensation arrangements. Otto (2014) provides evidence consistent with this claim, showing that

[20] In line with this prediction, Malmendier and Tate (2005; 2008) show that overconfident CEOs are more likely to undertake riskier investments than less-overconfident CEOs. Goel and Thakor (2008) provide similar evidence for CEOs that are highly overconfident, supported by Pikulina et al. (2017) in an experimental setting.

overconfident CEOs receive less equity pay and more cash-based compensation. If overconfidence cannot be ascertained at the point of hiring, or if it develops over time, a board can still learn about a CEO's overconfidence progressively by observing her actions. This learning is likely to lead to dynamic adjustments to equity incentives, as episodes of unusual investment activity may be perceived as evidence of CEO overconfidence.

In this subsection, we investigate whether measures of CEO overconfidence predict changes in option grants. Malmendier and Tate (2005; 2008) classify CEOs as overconfident if they hold exercisable options that are deep in-the-money. They find that these CEOs systematically overestimate returns on investment projects (see also Malmendier, Tate, and Yan 2011, and Deshmukh, Goel, and Howe 2013).[21] To assess how boards respond to evidence of CEO overconfidence, we extend our model to include a similar identifier of CEOs with continued holding of exercisable in-the-money stock options. We note that this proxy for CEO overconfidence is time-varying.

Malmendier and Tate (2005) measure CEO optimism by the continued holding of in-the-money stock options, with options that are at least 67% in the money, provided that the CEO has demonstrated this holding behavior at least twice in the sample period. Hirshleifer, Low, and Teoh (2012) also use this 67% threshold. We use instead the more conservative threshold of 100% "moneyness" of Campbell, Gallmeyer, Johnson, Rutherford and Stanley (2011), to capture CEOs that exhibit very high levels of overconfidence.[22] We calculate moneyness using the difference

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[21] A related literature on CEO overconfidence using alternative measures of overconfidence also finds that overconfident CEOs are likely to take bold actions, such as actions that lead to volatile organizational performance (Chatterjee and Hambrick 2007), earnings management, or fraud (Schrand and Zechman 2012). Firms with overconfident CEOs are also more likely to miss voluntary earnings forecasts (Hribar and Yang 2016), use short-term debt, and repurchase shares (Ben-David, Graham, and Harvey 2013).

[22] Malmendier and Tate (2005) rely on a proprietary data set of stock and stock option holdings (from Yermack (1995) and Hall and Liebman (1998)), which provides details about exercise prices, number of underlying shares, and time to maturity for a set of data from 1980–1994. Since we do not have the same data on a per-grant basis, we calculate moneyness using an estimate of the exercise price, similar to Campbell et al. (2011) and Hirshleifer et al. (2012).

between the fiscal year-end stock price (*PRCCF*) and the estimated exercise price of exercisable options.[23] We then calculate the moneyness of the exercisable options as *PRCCF* divided by *Est_Exercise_Price* minus 1. We classify CEO-years in which *Moneyness* >100% as overconfident CEO-years (*OC*), starting with the first time that the holding behavior is observed, provided that the CEO has had *Moneyness*>100% at least twice over the period. Observations where *Moneyness* ≤100% are classified as non-OC years and therefore *OC* may fluctuate between zero and one during a CEO's tenure. As we are interested in board responses to observed option holding behavior, we use *OC* lagged by one period to reflect holding characteristics at the beginning of the period. As *Moneyness* is directly observable, boards are likely to use *OC* (or other evidence correlated with *OC*) as a complement to measures of abnormal investment. Also, *OC* is arguably a more direct measure of CEO traits than the observation of abnormal investment outcomes. Whether *OC* complements or substitutes abnormal investment measures is an empirical question.

To test whether boards respond to CEO overconfidence, we re-estimate equation (6), adding a lagged indicator of overconfidence (OC_{t-1}). Our requirement to examine the exercising or holding behavior of executives limits our sample to firms with CEOs who have exercisable stock options (as in Campbell et al. 2011), which reduces our sample size to 22,902 observations.

Table 4 reports the results. Column 1 presents a model that includes OC_{t-1} and the full set of control variables as in equation (6), without investment variables. Column 1 shows that the overconfidence indicator predicts a reduction in the number of options granted to the CEO. In the years following the observation that the CEO holds options that are more than 100% in the money,

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[23] We use the approximation of Core and Guay (2002), also used by Campbell et al. (2011) and Hirshleifer et al. (2012). We estimate the per-option realizable value by taking the total realizable value of exercisable options and dividing by the number of exercisable options. We then estimate the average exercise price (*Est_Exercise_Price*) by subtracting the per-option realizable value from the fiscal year-end share price (*PRCCF*), where: $Est\_Exercise\_Price = \frac{OPT\_UNEX\_EXR\_EST\_VAL}{OPT\_UNEX\_EXER\_NUM}$. Variable names in capital letters are those used by *Execucomp* on the WRDS platform.

the number of options granted as a proportion of shares outstanding decreases by 0.013 percentage points. For a typical CEO-year in our sample, such a change represents a reduction of roughly 9% in the number of options granted. Column 2 presents the results of a regression that includes OC_{t-1} alongside the high and low investment indicator variables. The estimated coefficient on OC_{t-1} remains negative and statistically significant, and its magnitude falls only slightly (to 0.010). The results for high and low investment variables (for both *CAPEX* and *RD*) are similar to those reported in Table 3, Column 6. In untabulated specifications, we also add interaction terms between overconfidence and the investment variables. The coefficients of the interaction terms are small and not significantly different from zero.

Overall, the results in Table 4 suggest that there is no perfect overlap between CEO overconfidence and abnormal investment levels. The evidence suggests that boards respond to both overconfidence and abnormal investment in their contracting decisions, and that the investment variables contain information beyond that of the overconfidence measure. In other words, the overconfidence measure is not a sufficient statistic for CEO preferences.

These results are consistent with the idea that boards combine both indirect and direct evidence about CEO behavior and investment decisions when revising stock option grants. At the same time, this evidence lends further support to the CEO overconfidence hypothesis, i.e., boards adjust equity flows in response to evidence of CEO overconfidence.

4.3 Learning Effects

Our results show that abnormal levels of investment and measures of CEO overconfidence can predict changes in the number of options granted. This predictive ability is incremental relative to other contemporaneous firm-level variables. A possible explanation for these findings is that boards may glean information about CEOs' traits and preferences from their past decisions.

However, abnormal investment may also reflect other forces, such as investment opportunities not fully captured by models (2) and (3). Thus, even if boards do learn from past investment decisions, they may be learning about some unobservable variables not necessarily related to CEOs' traits and preferences.

In this subsection, we present a series of additional tests that are useful for evaluating the hypothesis that boards learn from past investment decisions.

4.3.1 Interactions between CEO tenure and abnormal investment

If boards learn about CEO preferences by observing low or high investment decisions, the incremental information they gather should be greater in the earlier years of a CEO's tenure rather than later in the CEO's career. Thus, the association between investment levels and changes in option grants may flatten with CEO tenure. However, a countervailing force may operate if equity-based pay is more effective for older CEOs (see Gibbons and Murphy 1992).

To consider the interactions between abnormal investment and CEO tenure, we rerun the regressions in Table 3, adding CEO tenure and its interaction terms with investment variables. We define *Tenure* as the number of years that the CEO has been in the CEO position, using data from Execucomp, supplemented by manual collection of missing observations. Table 5, Column 1, reports the results. Coefficients on $HCAPEX_{t-1}$, $LCAPEX_{t-1}$, and HRD_{t-1} remain negative, with similar levels of precision, and LRD_{t-1} is also negative, with marginal significance. Among the interaction terms, only $LRD_{t-1} \times Tenure$ is positive and marginally significant, providing some evidence that CEO tenure attenuates the effect of abnormal investment on changes in options grants. We conclude that, consistent with boards learning about CEOs from their investment decisions, there is some evidence, albeit weak, that CEO tenure moderates the impact of abnormal investment on changes in option grants.

4.3.2 Persistent overconfidence

If boards infer overconfidence from CEO option holding patterns in one period, observing the same option holding pattern over the next period should be less informative. Thus, the association between CEO overconfidence and changes in option grants should flatten with the continuous holding of deep-in-the-money options.

In Table 5, Column 2, we repeat the analysis in Table 4 after introducing a variable that counts the number of years in which CEO overconfidence has been observed ($OCYears_{t-1}$). This variable counts the number consecutive years in which OC=1 prior to and including $t-1$. The inclusion of this variable does not significantly change the previous results, as the coefficient to OC_{t-1} is still negative, but we find that $OCYears_{t-1}$ is positive and significant. This suggests that repeated and continuous observations of option holding behavior, in line with learning about CEO overconfidence, moderates the incremental information gathered from a single-year observation.

4.3.3 Learning from stock prices

If the stock price is a sufficient statistic for learning about CEO preferences and traits, boards do not need to use data on CEOs' investment decisions and option-holding behavior for changing compensation parameters. However, if the CEO has private information, both her actions and the stock price are jointly informative. In this subsection, we consider the possibility that boards combine information from stock prices, investment decisions, and option-holding behavior when learning about CEO preferences and traits.

The models in Tables 3 and 4 include controls for past stock returns. In Table 6, Column 1, we add to the model stock returns from $t-1$ to t and their interactions with our level variables. We find a marginally significant positive coefficient to $Return_t \times LCAPEX_{t-1}$, suggesting that the negative effect for $LCAPEX_{t-1}$ is counteracted by positive return performance. We find no other significant relationships for other interaction terms. Thus, we find that contemporaneous returns have some limited impact on the predictive power of abnormal investment and CEO overconfidence on changes in option grants, but also that current stock prices do not make the information contained in investment levels and measures of CEO overconfidence redundant. At the same time, there is evidence of some interaction between CEO behavior information and contemporaneous stock performance for predicting changes in option grants.

One issue with using stock returns in these regressions is that returns vary across firms for other fundamental reasons (in particular, due to systematic differences expected returns). While first-differences eliminate firm fixed-effects, such variation still affects the interaction terms. To address this issue partly, we consider alternative ways of combining information. We construct an indicator variable that equals one if the stock return is negative between $t-1$ and t; otherwise, it equals zero ($NegReturn_t$). We then interact this indicator with our key explanatory variables. An advantage of this approach is that we can be sure that negative returns are always unexpected, because all stocks must have positive expected returns. In contrast, a low positive return could still be expected (or even above expectations). Thus, we can be sure that a negative return is indeed bad news. A disadvantage of this approach is the possibility of multicollinearity issues, which are common when many indicator variables interact.

Table 6, Column 2, shows the results. In this specification, we find that the interaction of negative returns with abnormally low capital expenditures predicts decreases in option grants. This evidence is consistent with boards reducing the number of options granted to their CEOs if low capital expenditures are followed by a negative market reaction. This is also consistent with the finding from Column 1, in that a negative effect is primarily applicable to under-performing firms. No other interaction is statistically significant. Overall, we find some suggestive evidence that abnormal investment levels and CEO overconfidence contain information complementary to the information embedded in current prices.

4.4 Industry-based high and low investment measures

Our approach captures abnormal corporate investment by the extent to which investment levels deviate by amounts that would be justified by business fundamentals, as measured by models (2) and (3). There are potentially two issues with this approach. The first issue is related to interpretation. If the evidence is to be explained by boards reacting to past investment decisions, we need to assume that compensation committees can identify deviations of investment levels from "normal operational levels" as implied by the empirical model that we use. In other words, the model needs to be approximately right. This may be a crude assumption for many reasons, such as, for example, requiring a high level of board sophistication, which depends on the level of financial expertise (Ahmed and Duellman 2007; Güner, Malmendier, and Tate 2008; Krishnan and Visvanatha 2008). Second, our approach yields estimates of high and low investment levels based on regression residuals (estimated independent variables), which may lead to understated standard errors (Newey 1984).

To mitigate these two concerns, we repeat the analysis using simple measures of high and low investment, based on the deviation of capital expenditures and R&D from the industry median in each year. We construct dummy variables for cases where the deviation from the industry median is in the top or bottom quintile ($HCAPEX\_IND_{t-1}$, $LCAPEX\_IND_{t-1}$, $HRND\_IND_{t-1}$, and $LRND\_IND_{t-1}$). Table 7 reports the regression results. In Column 1, the coefficients to $LCAPEX\_IND_{t-1}$, $HCAPEX\_IND_{t-1}$ and HRD_IND_{t-1} are negative and statistically significant. As in Table 3, this evidence suggests that boards respond to evidence of both high and low investment in capital expenditure and high investment in R&D by reducing CEOs' stock option grants, even when high and low levels are relative to industry medians. In Column 2, we include OC_{t-1}. The results for the investment indicators remain, while the coefficient on OC_{t-1} is also negative and statistically significant, and of similar magnitude to the results in Table 4.

An alternative way of dealing with estimated independent variables (EIV) is to adjust standard errors for pre-estimation biases. A simple and robust method for achieving this is to use the EIV as *instruments* for the industry-based measures of high and low investment in instrumental variable regressions. In IV procedures, estimated instruments do not require standard errors to be adjusted. Our IV regression results (not tabulated) yield negative and significant coefficients for $LCAPEX\_IND_{t-1}$, $HCAPEX\_IND_{t-1}$, and HRD_IND_{t-1}, which are of higher magnitude to those reported in Table 7 (coefficients of −0.031, −0.032 and −0.024).[24]

4.5 Investment levels and other components of compensation

Our results show that high or low investment levels, especially in capital expenditures, predict reductions in option grants in subsequent periods. A natural question is whether this change in option-based compensation reflects a change in the equity/cash mix or a change in the overall level of compensation (or both). On one hand, evidence of abnormal investment could increase future cash-based compensation because boards rebalance CEO compensation towards cash after periods of high or low investment. That is, options and cash could be substitutes. On the other hand, evidence of abnormal investment could decrease future cash-based compensation because boards may also discipline CEOs who invest either too much or too little by reducing their total compensation. That is, boards may use a combination of implicit and explicit contracts with their CEOs. The net effect of abnormal investment on cash-based pay depends on which of these two forces dominate.

[24] Note that we do not use IV methods to claim causal effects; we use this method to obtain consistent standard errors with estimated independent variables. This procedure is similar to that of Newey (1984).

To address these possibilities, we estimate the following model:

$$\Delta Cash\_based\_pay \quad = \boldsymbol{z'}_{it-1}\boldsymbol{\alpha} + \Delta\boldsymbol{x'}_{it-1}\boldsymbol{\beta} + \boldsymbol{p'}_t\ \boldsymbol{\gamma} + e_{it,} \qquad (7)$$

where *ΔCash_based_pay* is either $\Delta Salary_{it+1}$ (the percentage change in salary from year *t* to year *t+1*) or $\Delta Bonus_{it}$ (the change in bonus, scaled by salary, from year $t-1$ to year *t*).[25] We specifically choose to model *ΔSalary* for period *t*+1, since salary is set in advance for the following period; i.e., changes in policy in time *t* are only effected from *t*+1. However, because bonuses are finalized at the year-end in respect of year *t*, we model *ΔBonus* for the period *t.* Our vector of control variables is the same as before, with some minor modifications. We replace cash compensation with change in equity compensation scaled by sales ($\Delta EquityCompensation_{t-1}$). Also, as we now model lead and contemporaneous cash compensation measures, which may be contingent on current period performance, we include Δ*Return* for years *t* and $t-1$, instead of years $t-1$ and $t-2$.

Table 8 presents the results of our cash-based analysis. Though our results on the key variables are mixed, we find some evidence of rebalancing, with positive and significant increases in both $\Delta Bonus_t$ and $\Delta Salary_{t+1}$ for LRD_{t-1}, and $\Delta Salary_{t+1}$ for $HCAPEX_{t-1}$. In Column 2, both high and low levels of R&D investment predict subsequent increases in CEO bonuses, but only LRD_{t-1} is statistically significant. In contrast, $LCAPEX_{t-1}$ predicts lower salaries in *t*+1, which is consistent with implicit incentives dominating the rebalancing effect.

The evidence is thus a bit mixed, but, overall, it suggests that abnormal R&D and high levels of CAPEX predict changes in cash-based compensation of an offsetting nature, i.e., decreases in stock option grants coincide with increases in cash-based pay. There is also some evidence of a countervailing effect, as $LCAPEX_{t-1}$ predicts lower salaries in *t*+1.

[25] Our inferences are similar when using the change in salary scaled by total compensation or change in log salary. For bonuses, salary is a commonly used scalar, as bonuses are frequently computed as a percentage of salary.

To assess changes in the entire equity portfolio, we also examine changes in restricted shares. On one hand, when designing compensation contracts, boards may consider restricted shares and options as complements. In that case, we would expect restricted share grants to fall following evidence of abnormal investment levels. On the other hand, the board may correct incentive structures that affect investment levels by replacing some of the stock options with restricted shares, which increase the downside risk to the CEO and therefore should reduce risk-taking compared to stock options. However, restricted shares are "*strictly less effective in motivating the CEO to uncover innovations because shares of stock also reward him for simply continuing business as usual*" (Laux, 2015, p. 276). To test these hypotheses, we repeat equation (6) replacing $\Delta \#Option\_Grants_{it}$ with changes in restricted share grants. We calculate $\Delta Restricted\ Shares_{it}$ as the change in restricted share grants divided by total compensation. The last column of Table 8 presents the results. Both high and low levels of R&D investment predict subsequent increases in restricted shares. This result adds further evidence on rebalancing effects, in the form of rises in restricted share grants, especially in response to evidence of high or low R&D.

4.6 Looking beyond the numbers

We focus primarily on examining changes in the number of option grants. We have argued that this "valuation-free" measure of option grants is useful because it is not contaminated by changes in stock prices that occur as a consequence of the option grants. However, as a proxy for equity-based incentives, this measure also has limitations. If boards grant options based on a target for their value, the number of options alone may not fully reflect the intended incentive consequences of the compensation contract.

On the other hand, we expect changes in the value of options to respond less to past abnormal investment than changes in the number of options. If boards optimally adjust the number of options after evidence of abnormal investment, the positive market reaction to this adjustment may increase the value of each option, partially offsetting the effect of reducing the number of options.

A simple measure of incentive intensity is the change in the proportion of incentive pay over total compensation. Following Otto (2014), this measure considers the dollar value of all incentive (non-salary) pay over total compensation. Given the evidence of rebalancing effects in both cash based pay and restricted shares grants we use an adjusted incentive pay measure that considers all non-cash and non-restricted shares pay. Table 9, Column 1 reports the results. The coefficients on HRD_{t-1} and LRD_{t-1} are negative and significant at conventional levels. In Column 2, the coefficient to OC_{t-1} is positive and significant.

We find similar results using the value of options scaled by total compensation (i.e., ignoring other equity components). While the coefficients of all indicators of abnormal investment levels exhibit the predicted direction, they are significant at conventional levels only for high and low R&D. Also, when adding OC_{t-1} in Column 4, the coefficient to *OC* is again positive and significant. The contrasting result for OC_{t-1} for these tests is to be expected. By construction, variable *OC* is typically high when current stock prices are high, because high underlying prices imply high option prices. Thus, even though the number of option grants falls, valuation-based measures of equity pay may increase.[26]

Overall, the results suggest that valuation-based measures of equity pay provide some, albeit weaker, evidence of revisions in equity pay in response to unusual investment levels and

[26] In unreported results, we also consider changes in the Black-Scholes implied delta (i.e., the derivative of the option value with respect to the underlying price) and vega (i.e., the derivative of the option value with respect to volatility). We use data shared by Lalitha Naveen, originally constructed for Coles et al. (2006) based on the methodology of Core and Guay (2002), and extended to 2014. Abnormal investment variables do not seem to be related to changes in delta and vega, with the exception of HCAPEXt−1 for vega.

CEO overconfidence. These results underscore the need to consider valuation-free measures of option grants. Incentive measures that are based on stock prices mix both board choices (the number of options) and consequences (stock price reactions to such choices). While such measures are useful for understanding incentives, they are noisy measures of board choices. Our approach of looking at numbers thus complements the analysis of valuation-based measures of incentives.

4.7 Change in stock option grants and subsequent investment

Our analysis suggests that drastic investment decisions temper firms' stock option grants, and one potential explanation for it is the firm learning about its CEO preferences and traits. Irrespective of the underlying reason, adjusting compensation arrangements in response to abnormal investment levels, if effective, should predict reversals to normal investment levels. Such reversals may take years and depend on several other factors, like co-movements with other governance mechanisms, potential CEO turnover, and firm-specific structural changes. To test whether firms' actions achieve their purported goal, we regress indicators of all non-high or low levels of abnormal investment on *CAPEX* (*NLH_CAPEX*) or R&D (*NLH_RD*) on lagged changes in option grants ($\Delta\#Option\_Grants_{t-1}$). In untabulated results, the coefficient on $\Delta\#Option\_Grants_{t-1}$ is negative and significant when we focus on option-granting firms in year $t-1$ (firms with non-zero $Option\_Grants_{t-1}$). The result remains when considering $\Delta\#Option\_Grants_{t-2}$. This additional analysis provides some evidence that negative changes in option grants predict reversals of abnormal investment for option-granting firms. s

5. Conclusion

We find that, despite some evidence of short-term rigidity, the number of options granted changes frequently, and such changes are predictable. CEOs who demonstrate unusual investment patterns, such as investing either too much or too little in physical assets or R&D, or CEOs that hold options that are deep in the money (which may be seen as a measure of overconfidence) appear to receive fewer options in subsequent years.

The evidence in this paper has several implications. Our findings suggest that boards actively incorporate both “hard” and “soft” information about their CEO (investment decisions and evidence of overconfidence) when they review their stock option-granting policies. That is, boards learn about the adequacy of current compensation arrangements by observing CEO investment decisions or option holding patterns. Other explanations are also possible. For example, our measure of high investment may be capturing some firm life-cycle effects, in which firms start investing more exactly at the time when a shift towards less equity-based compensation is needed. Even in that case, however, the conclusion that firms are actively changing option grants to fit their current situation remains valid. And the fact that levels of investment can predict such changes in compensation remains an interesting finding.

Malmendier and Tate (2005) argue that boards should take actions to counteract the possible inefficiencies introduced by biased CEOs. Consistent with Otto (2014), our paper presents evidence that boards *change* the compensation structure of CEOs who appear to be overconfident (as evidenced by their holding of in-the-money options) or who deviate from normal levels of investment. Moreover, the evidence suggests that, regardless of the underlying reasons for adjusting CEO option pay, boards seem to prefer less incentivized CEOs when CEOs display a tendency to deviate from the industry norm.

References

Ahmed, A. S., and S. Duellman. (2007). Accounting conservatism and board of director characteristics: An empirical analysis. *Journal of Accounting and Economics* 43 (2–3): 411–437.

American Institute of Certified Public Accountants Accounting Principles Board (1972). Opinions of the Accounting Principles Board 25: Accounting for stock issued to employees. New York: AICPA.

Amir, E., Y. Guan, and G. Livne. (2007). The association of R&D and capital expenditures with subsequent earnings variability. *Journal of Business Finance & Accounting* 34 (1–2): 222–246.

Athanasakou, V., N. C. Strong, and M. Walker. (2011). The market reward for achieving analyst earnings expectations: Does managing expectations or earnings matter? *Journal of Business Finance & Accounting* 38 (1–2): 58–94.

Baber, W. R., S.-H. Kang, and K. R. Kumar. (1998). Accounting earnings and executive compensation: The role of earnings persistence. *Journal of Accounting and Economics* 25 (2): 169–193.

Balachandran, S., B. Kogut, and H. Harnal. (2010). The probability of default, excessive risk, and executive compensation: A study of financial services firms from 1995 to 2008. Working paper, Columbia University.

Bartov, E. (1993). The timing of asset sales and earnings manipulation. *The Accounting Review* 68 (4): 840–855.

Bebchuk, L. A., Y. Grinstein, and U. Peyer. (2010). Lucky CEOs and lucky directors. *Journal of Finance* 65 (6): 2363–2401.

Bebchuk, L. A., and L. A. Stole. (1993). Do short-term objectives lead to under-or overinvestment in long-term projects? *Journal of Finance* 48 (2), 719–729.

Bebchuk, L. A., J. M. Fried, and D. I. Walker. (2002). *Managerial power and rent extraction in the design of executive compensation* (No. W9068). National Bureau of Economic Research.

Ben-David, I., J. R. Graham, and C. R. Harvey. (2013). Managerial miscalibration. *Quarterly Journal of Economics* 128 (4): 1547 - 1584.

Bens, D. A., V. Nagar, D. J. Skinner, and M. H. F. Wong. (2003). Employee stock options, EPS dilution, and stock repurchases. *Journal of Accounting and Economics* 36 (1–3): 51–90.

Bens, D. A., V. Nagar, and M. H. F. Wong. (2002). Real investment implications of employee stock option exercises. *Journal of Accounting Research* 40 (2): 359–393.

Bereskin, F.L., P.H. Hsu. (2014). Bringing in Changes: The Effect of New CEOs on Innovation. Working Paper, University of Delaware.

Berger, P. G. (1993). Explicit and implicit tax effects of the R&D tax credit. *Journal of Accounting Research* 31 (2): 131–171.

Bergstresser, D., and T. Philippon. (2006). CEO incentives and earnings management. *Journal of Financial Economics* 80 (3): 511–529.

Biddle, G. C., G. Hilary, and R. S. Verdi. (2009). How does financial reporting quality relate to investment efficiency? *Journal of Accounting and Economics* 48 (2–3): 112–131.

Brown, L. D., and Y. J. Lee. (2011). Changes in option-based compensation around the issuance of SFAS 123R. *Journal of Business Finance & Accounting* 38 (9–10): 1053–1095.

Bryan, S., L. Hwang, and S. Lilien. (2000). CEO stock-based compensation: An empirical analysis of incentive-intensity, relative mix, and economic determinants. *Journal of Business* 73 (4): 661–693.

Burns, N., and S. Kedia. (2006). The impact of performance-based compensation on misreporting. *Journal of Financial Economics* 79 (1): 35–67.

Bushee, B. J. (1998). The influence of institutional investors on myopic R&D investment behavior. *The Accounting Review* 73 (3): 305–333.

Call, A. C., S. Kedia, and S. Rajgopal. (2016). Rank and file employees and the discovery of misreporting: The role of stock options. *Journal of Accounting and Economics* 62 (2–3): 277–300.

Campbell, T. C., M. Gallmeyer, S. A. Johnson, J. Rutherford, and B. W. Stanley. (2011). CEO optimism and forced turnover. *Journal of Financial Economics* 101 (3): 695–712.

Carter, M. E., L. J. Lynch, and I. Tuna. (2007). The role of accounting in the design of CEO equity compensation. *The Accounting Review* 82 (2): 327–358.
Chang, W.-J., R. M. Hayes, and S. A. Hillegeist. (2016). Financial distress risk and new CEO compensation. *Management Science* 62 (2): 479–501.
Chatterjee, A., and D. C. Hambrick. (2007). It's all about me: Narcissistic chief executive officers and their effects on company strategy and performance. *Administrative Science Quarterly* 52 (3): 351–386.
Chauvin, K. W., and C. Shenoy. (2001). Stock price decreases prior to executive stock option grants. *Journal of Corporate Finance* 7 (1): 53–76.
Cheng, Q., and D. B. Farber. (2008). Earnings restatements, changes in CEO compensation, and firm performance. *The Accounting Review* 83 (5): 1217–1250.
Cheng, Q., and T. D. Warfield. (2005). Equity incentives and earnings management. *The Accounting Review* 80 (2): 441–476.
Choudhary, P., S. Rajgopal, and M. Venkatachalam. (2009). Accelerated vesting of employee stock options in anticipation of FAS 123-R. *Journal of Accounting Research* 47 (1): 105–146.
Cohen, D. A., A. Dey, and T. Z. Lys. (2008). Real and accrual-based earnings management in the pre- and post-Sarbanes-Oxley periods. *The Accounting Review* 83 (3): 757–787.
Cohen, R. B., B. J. Hall, and L. M. Viceira. (2000). Do executive stock options encourage risk-taking? Working paper, Harvard Business School.
Coles, J. L., N. D. Daniel, and L. Naveen. (2006). Managerial incentives and risk-taking. *Journal of Financial Economics* 79 (2): 431–468.
Core, J., and W. Guay. (1999). The use of equity grants to manage optimal equity incentive levels. *Journal of Accounting and Economics* 28 (2): 151–184.
Core, J., and W. Guay. (2002). Estimating the value of employee stock option portfolios and their sensitivities to price and volatility. *Journal of Accounting Research* 40 (3): 613–630.
Cornelli, F., Z. Kominek, and A. Ljungqvist. (2013). Monitoring managers: Does it matter? *Journal of Finance* 68 (2): 431−481.
Dechow, P. M., and R. G. Sloan. (1991). Executive incentives and the horizon problem. *Journal of Accounting and Economics* 14 (1): 51–89.
DeFusco, R. A., R. R. Johnson, and T.S. Zorn. (1990). The effect of executive stock option plans on stockholders and bondholders. *Journal of Finance 45* (2): 617–627.
Demsetz, H., and K. Lehn. (1985). The structure of corporate ownership: Causes and consequences. *Journal of Political Economy* 93 (6): 1155–1177.
Deshmukh, S., A. M. Goel, and K. M. Howe. (2013). CEO overconfidence and dividend policy. *Journal of Financial Intermediation* 22 (3):440–463.
Dutta, S., and Q. Fan. (2014). Equilibrium earnings management and managerial compensation in a multiperiod agency setting. *Review of Accounting Studies* 19 (3): 1047–1077.
Edmans, A., V. W. Fang, and K. A. Lewellen, (2017). Equity vesting and investment. *Review of Financial Studies* 30 (7): 2229–2271.
Edmans, A., X. Gabaix, T. Sadzik, and Y. Sannikov. (2012). Dynamic CEO compensation. *Journal of Finance* 67 (5): 1603–1647.
Efendi, J., A. Srivastava, and E. P. Swanson. (2007). Why do corporate managers misstate financial statements? The role of option compensation and other factors. *Journal of Financial Economics* 85(3): 667–708.
Espahbodi, H., P. Espahbodi, Z. Rezaee, and H. Tehranian. (2002). Stock price reaction and value relevance of recognition versus disclosure: the case of stock-based compensation. *Journal of Accounting and Economics* 33 (3): 343–373.
Fama, E. F., and K. R. French. (1997). Industry costs of equity. *Journal of Financial Economics* 43 (2): 153–193.
Feltham, G. A., and M. G. H. Wu. (2001). Incentive efficiency of stock versus options. *Review of Accounting Studies* 6 (1): 7–28.

Financial Accounting Standards Board. (1995). Statement of financial accounting standards No. 123: Accounting for stock-based compensation. Norwalk, CT: FASB.
Financial Accounting Standards Board. (2004). Statement of financial accounting standards No. 123 (revised 2004): Share-based payment. Norwalk, CT: FASB.
Gaver, J., and K. Gaver. (1993). Additional evidence on the association between the investment opportunity set and corporate financing, dividend, and compensation policies. *Journal of Accounting and Economics* 16 (1–3): 125–160.
Gervais, S., J. B. Heaton, and T. Odean. (2011). Overconfidence, compensation contracts, and capital budgeting. *Journal of Finance* 66 (5): 1735–1777.
Gibbons, R, and K. J. Murphy. (1992). Optimal incentive contracts in the presence of career concerns: Theory and evidence. *Journal of Political Economy* 100 (3): 468–505.
Goel, A. M., and A. V. Thakor. (2008). Overconfidence, CEO selection, and corporate governance. *Journal of Finance* 63 (6): 2737–2784.
Goldman, E., and S. L. Slezak. (2006). An equilibrium model of incentive contracts in the presence of information manipulation. *Journal of Financial Economics* 80(3): 603–626.
Gopalan, R., T. Milbourn, F. Song, and A. V. Thakor. (2014). Duration of executive compensation. *Journal of Finance* 69 (6): 2777–2817.
Grant, J., G. Markarian, and A. Parbonetti. (2009). CEO risk-related incentives and income smoothing. *Contemporary Accounting Research* 26 (4): 1029–1065.
Guay, W. R. (1999). The sensitivity of CEO wealth to equity risk: An analysis of the magnitude and determinants: managerial behavior, agency costs, and ownership structure. *Journal of Financial Economics* 53 (1): 43–71.
Güner, A. B., U. Malmendier, and G. Tate. (2008). Financial expertise of directors. *Journal of Financial Economics* 88 (2): 323–354.
Gunny, K. A. (2010). The relation between earnings management using real activities manipulation and future performance: Evidence from meeting earnings benchmarks. *Contemporary Accounting Research* 27 (3): 855–888.
Hall, B. J., and J. B. Liebman. (1998). Are CEOs really paid like bureaucrats? *Quarterly Journal of Economics* 113 (3): 653–692.
Hanlon, M., S. Rajgopal, and T. Shevlin. (2003). Are executive stock options associated with future earnings? *Journal of Accounting and Economics* 36 (1–3): 3–43.
Hayes, R. M., M. Lemmon, and M. Qiu. (2012). Stock options and managerial incentives for risk taking: Evidence from FAS 123R. *Journal of Financial Economics* 105 (1): 174–190.
Heron, R. A., and E. Lie. (2007). Does backdating explain the stock price pattern around executive stock option grants? *Journal of Financial Economics* 83 (2): 271–295.
Himmelberg, C. P., G. Hubbard, and D. Palia. (1999). Understanding the determinants of managerial ownership and the link between ownership and performance. *Journal of Financial Economics* 53 (3): 353–384.
Hirshleifer, D. A., A. Low, and S. H. Teoh. (2012). Are overconfident CEOs better innovators? *Journal of Finance* 67 (4): 1457–1498.
Hribar, P., and H. Yang. (2016). CEO overconfidence and management forecasting. *Contemporary Accounting Research* 33 (1): 204–227.
Hull, J., and A. White. (2004). How to value employee stock options. *Financial Analysts Journal 60* (1): 114–119.
Jensen, M. (1986). Agency costs of free cash flow, corporate finance, and takeovers. *American Economic Review* 76 (2): 323–329.
Kedia, S., and S. Rajgopal. (2009). Neighborhood matters: The impact of location on broad based stock option plans. *Journal of Financial Economics* 92 (1): 109–127.
Kim, E. H., and Y. Lu. (2011). CEO ownership, external governance, and risk-taking. *Journal of Financial Economics* 102 (2): 272–292.

Krishnan, G. V., and G. Visvanathan. (2008). Does the SOX definition of an accounting expert matter? The association between audit committee directors' accounting expertise and accounting conservatism. *Contemporary Accounting Research* 25 (3): 827–858.

Laux, V. (2015). Executive pay, innovation, and risk-taking. *Journal of Economics & Management Strategy* 24 (2): 275–305.

Malmendier, U., and G. Tate. (2005). CEO overconfidence and corporate investment. *Journal of Finance* 60 (6): 2661–2700.

Malmendier, U., and G. Tate. (2008). Who makes acquisitions? CEO overconfidence and the market's reaction. *Journal of Financial Economics* 89 (1): 20–43.

Malmendier, U., G. Tate, and J. Yan. (2011). Overconfidence and early-life experiences: The effect of managerial traits on corporate financial policies. *Journal of Finance* 66 (5): 1687–1733.

Martin, K. J. and R.S. Thomas. (2005). When is enough, enough? Market reaction to highly dilutive stock option plans and the subsequent impact on CEO compensation. *Journal of Corporate Finance* 11 (1–2): 61–83.

McNichols, M. F., and S. R. Stubben. (2008). Does earnings management affect firms' investment decisions? *The Accounting Review* 83 (6): 1571–1603.

Murphy, K. J. (2013). Executive Compensation: Where We Are, and How We Got There. In Constantinides, G., M. Harris, & R. Stulz (eds.), Handbook of the Economics of Finance. North Holland, Amsterdam, Netherlands: Elsevier Science.

Newey, W. K. (1984). A method of moments interpretation of sequential estimators. *Economics Letters* 14 (2): 201–206.

Otto, C. A. (2014). CEO optimism and incentive compensation. *Journal of Financial Economics* 114 (2): 366–404.

Pikulina, E., L. Renneboog, & P.N. Tobler. (2017). Overconfidence and investment: An experimental approach. *Journal of Corporate Finance* 43: 175−192.

Rajgopal, S., and T. Shevlin. (2002). Empirical evidence on the relation between stock option compensation and risk taking. *Journal of Accounting and Economics* 33 (2): 145–171.

Roychowdhury, S. (2006). Earnings management through real activities manipulation. *Journal of Accounting and Economics* 42 (3): 335–370.

Sanders, W., and D. Hambrick. (2007). Swinging for the fences: The effects of CEO stock options on company risk taking and performance. *Academy of Management Journal* 50 (5): 1055–1078.

Schrand, C. M., and S. L. C. Zechman. (2012). Executive overconfidence and the slippery slope to financial misreporting. *Journal of Accounting and Economics* 53 (1–2): 311–329.

Shue, K., and R. R. Townsend. (2017). Growth through rigidity: An explanation for the rise in CEO pay. *Journal of Financial Economics* 123 (1): 1–21.

Shue, K., and R. R. Townsend. (2017). How do quasi-random option grants affect CEO risk-taking? *Journal of Finance* 72 (6): 2551–2588.

Smith, C. W., and R. L. Watts. (1992). The investment opportunity set and corporate financing, dividend, and compensation policies. *Journal of Financial Economics* 32 (3): 263–292.

Stein, J. C. (1989). Efficient capital markets, inefficient firms: A model of myopic corporate behavior. *Quarterly Journal of Economics* 104 (4):655–69.

Yermack, D. (1995). Do corporations award CEO stock options effectively? *Journal of Financial Economics* 39 (2–3): 237–269.

Appendix

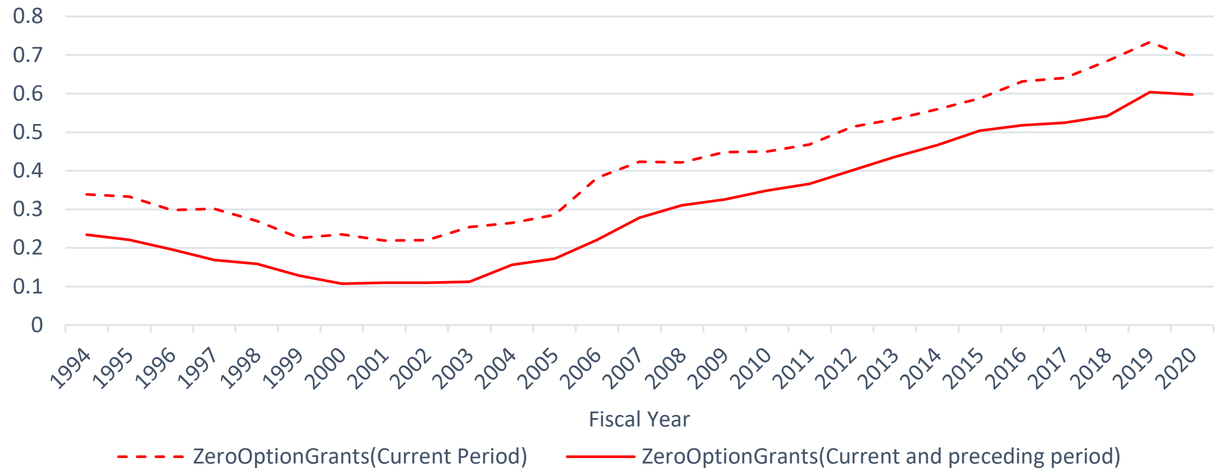
Definition of variables in alphabetical order

Variable	Description
#Option_Grants	Number of options granted during the year to the CEO, scaled by shares outstanding.
#OptionsZero	Equals 1 if the firm grants no options to the CEO during the year *t*, 0 otherwise.
#OptionsZerotoZero	Equals 1 if the firm grants no options to the CEO during both year $t-1$ and year *t*, 0 otherwise.
ACAPEX	Abnormal capital expenditures, calculated as the residual from annual regression models estimating normal capital expenditure based on the McNichols and Stubben (2008) model, for 48 Fama-French industry groups.
ARD	Abormal R&D, calculated as the residual from estimating a model of R&D based on Berger (1993) and Gunny (2010).
B/M	Ratio of book value of to market value of equity.
CAPEX	Capital expenditure (excluding R&D) divided by net property, plant and equipment.
CAPEXS	Capital expenditure (excluding R&D) divided by sales.
CashCompensation	Salary and Bonus, divided by sales.
CashShortfall	Cash flow shortfall calculated as common and preferred dividends plus cash flow used in investment activities minus cash flows from operations all divided by total assets.
CF	Cash flow from operations scaled by net property, plant and equipment.
EquityCompensation	Sum of restricted stock and stock option grants (measured at fair value), scaled by sales.
Exercisable_Options	Number of exercisable options owned by the CEO, scaled by shares outstanding.
FUNDS	Proxy for the firm's pre-R&D cash flow, defined as pre-tax income, plus interest expense, plus the R&D expense, plus depreciation divided by sales.
Growth	Growth in total assets.
HCAPEX	Dummy variable equal to 1 if the observation belongs to the top quintile of abnormal capital expenditure (*ACAPEX*), 0 otherwise. We derive abnormal capital expenditure based on the McNichols and Stubben (2008) model.
HCAPEX_IND	Dummy variable equal to 1 if the difference between the firm's *CAPEXS* (capital expenditure divided by sales) and the industry median *CAPEXS* is in the top quintile in year $t-1$, 0 otherwise.
HRD	Dummy variable equal to 1 if the observation belongs to the top quintile of abnormal R&D (*ARD*), 0 otherwise. We obtain *ARD* based on the models of Berger (1993) and Gunny (2010).
HRD_IND	Dummy variable equal to 1 if the difference between the firm's *RD* (R&D divided by sales) and the industry median *RD* is in the top quintile in year $t-1$, 0 otherwise.
LCAPEX	Dummy variable equal to 1 if the observation belongs to the bottom quintile of abnormal capital expenditure (*ACAPEX*), 0 otherwise. We

	derive abnormal capital expenditure based on the McNichols and Stubben (2008) model.
LCAPEX_IND	Dummy variable equal to 1 if the difference between the firm's *CAPEXS* (capital expenditure divided by sales) and the industry median *CAPEXS* is in the bottom quintile in year $t-1$, 0 otherwise.
Lev	Total debt divided by total assets.
LRD	Dummy variable equal to 1 if the observation belongs to the bottom quintile of abnormal R&D (*ARD*), 0 otherwise. We obtain *ARD* based on the models of Berger (1993) and Gunny (2010).
LRD_IND	Dummy variable equal to 1 if the difference between the firm's *RD* (R&D divided by sales) and the industry median *RD* is in the bottom quintile in year $t-1$, 0 otherwise.
Moneyness	Stock price divided by estimated exercise price of exercisable stock options, less 1.
NetOperatingLoss	Dummy variable equal to 1 if the firm reports operating losses, 0 otherwise.
NewCEO	Dummy variable equal to 1 if there is a change in CEO during the year, 0 otherwise.
OC	Dummy variable equal to 1 if the CEO holds exercisable options with a moneyness of at least 100%, and has done so at least twice in the sample period, 0 otherwise.
OCYears	The number consecutive years in which *OC*=1 prior to and including $t-1$.
QRT(2,3,4)	Dummy variable equal to 1 if *TobinQ* is in the second (third, fourth) quartile of its industry-year distribution.
RD	R&D expense divided by sales.
Return	Accumulated monthly stock return for the current year.
ROA	Profit before extraordinary items divided by average total assets.
Shares_Own	Shares owned by the CEO, excluding options, scaled by shares outstanding
Size	Natural log of sales revenue.
TobinQ	Total market capitalization plus book value of preferred stock, plus long-term debt, plus short-term debt all divided by total assets.
Tenure	Calculated as the number of days elapsed between the date of appointment and the last date of the fiscal year *t*, divided by 365.
Unexercisable_Options	Number of unexercisable options owned by the CEO, scaled by shares outstanding.
ΔSalary	Salary in year *t* less salary in year $t-1$, divided by salary in year $t-1$. The regression model uses *ΔSalary*, defined as salary in year *t+1* less salary in year *t*, divided by salary in year *t*.
ΔBonus	(Bonus in year *t* scaled by salary in year *t*), less (bonus in year $t-1$, scaled by salary in year $t-1$).
ΔRestrictedShares	Change in restricted shares granted during the year to the CEO (restricted shares grants/total compensation)$_t$ − (restricted shares grants/total compensation)$_{t-1}$.
ΔIncentivePay	(1−salary/total compensation−bonus/total compensation –restricted shares grants/total compensation)$_t$ − (1−salary/total compensation−bonus/total compensation –restricted shares grants/total compensation)$_{t-1}$.

Δ*$Option_Grants*	Change in dollar value of stock options from year t−1 to t, defined as the estimated fair value or Black-Scholes value of stock options granted to the CEO in year t scaled by total compensation in year t, less the value of options granted in t−1, scaled by total compensation in year t−1
Δ*#Option_GrantsNeg*	Equals *Δ#Option_Grants*, when *Δ#Option_Grants<0* for option-granting firms, i.e. firms with non-zero option grants in the either year *t−1* or year t (*#OptionsZerotoZero=0*), 0 otherwise.
Δ*#Option_GrantsPos*	Equals *Δ#Option_Grants*, when *Δ#Option_Grants>0* for option-granting firms, i.e. firms with non-zero option grants in either year *t−1* or year t (*#OptionsZerotoZero*=0), 0 otherwise.
Δ#OptionsZero/ Roundmultiples	Equals 1 if the firm grants the same number of stock options (*Δ#Option_Grants*) to the CEO in year t as in year *t−1*, or round multiples of the number granted in year *t−1*, 0 otherwise.
ΔSalaryPay	(Salary/total compensation)$_t$ – (salary/total compensation)$_{t-1}$.
σReturn	Standard deviation of monthly stock returns in the current year.

Figure 1 Zero option grants



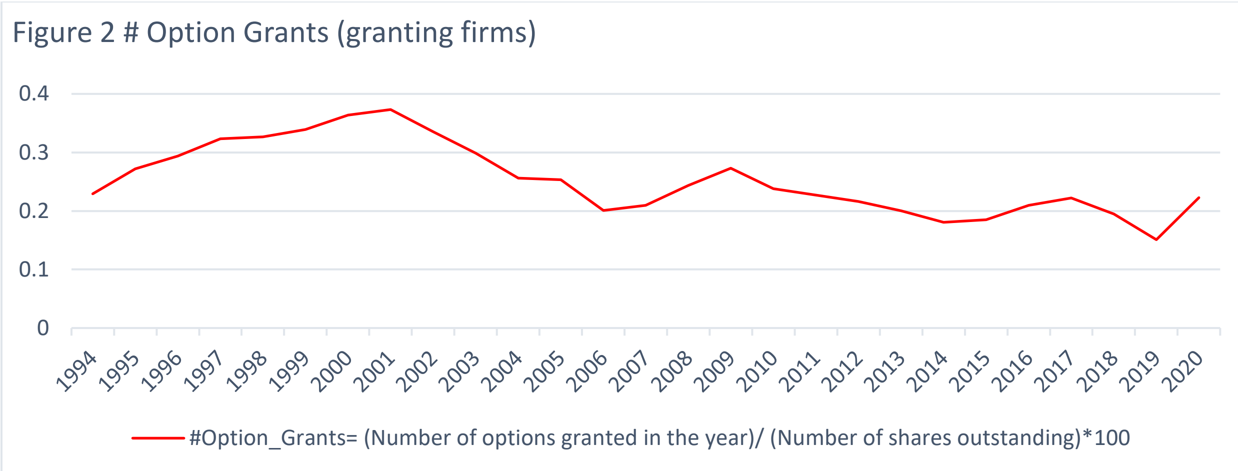


Figure 2 # Option Grants (granting firms)
0.4
0.3
0.2
0.1
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1994
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2019
2020
#Option_Grants= (Number of options granted in the year)/ (Number of shares outstanding)*100

Figure 3 Zero or round multiple changes in option grants (granting firms)

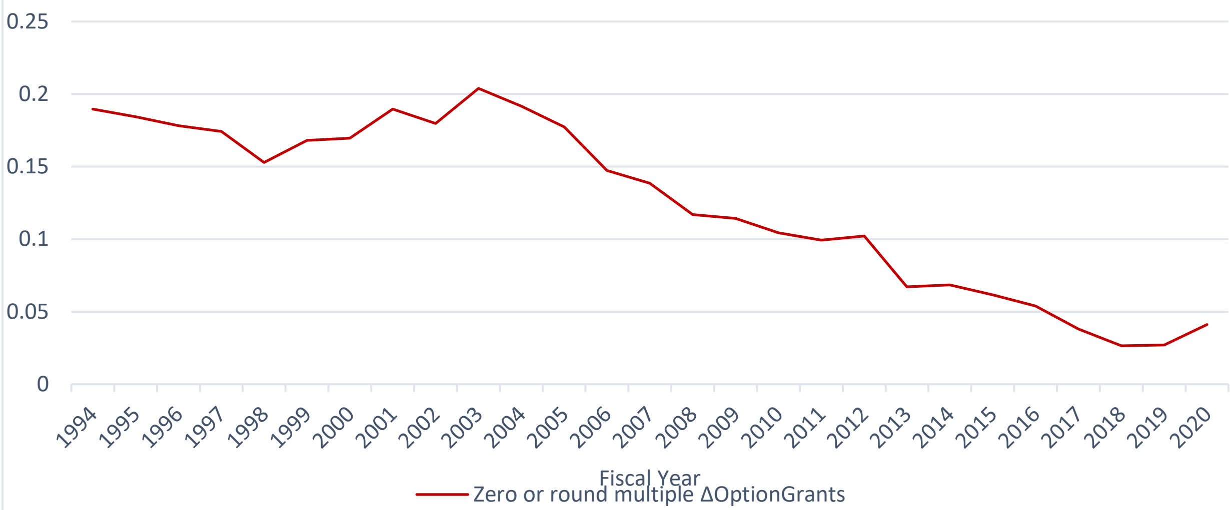

Figure 4 Positive versus negative changes in option grants (granting firms)

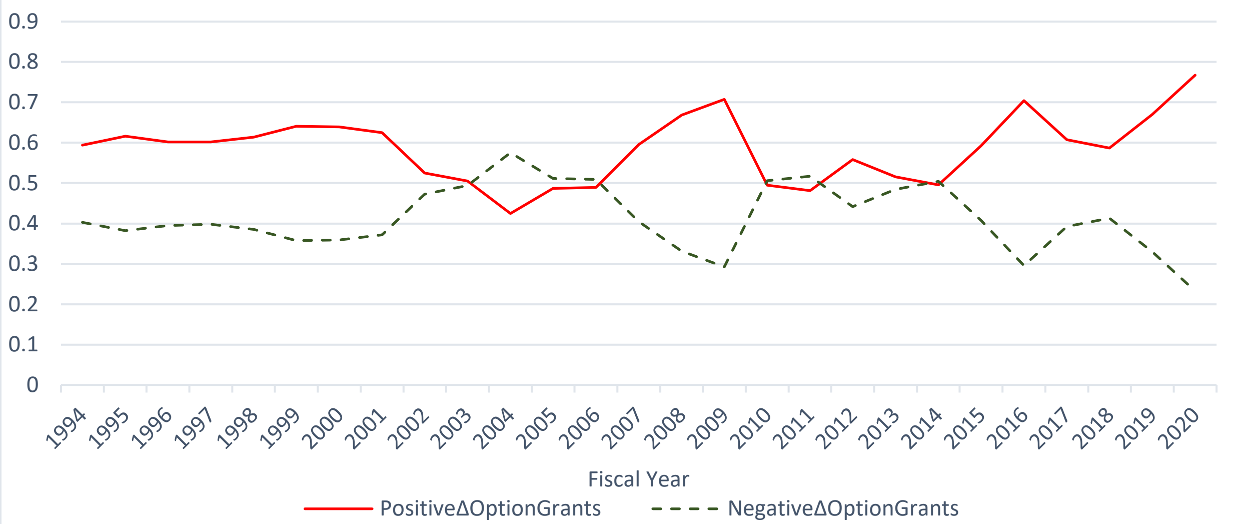

Table 1: Descriptive Statistics

This table reports descriptive statistics for our dependent variables, *Δ#Option_Grants*, *ΔSalary*, and *ΔBonus,* key variables of interest measuring abnormal corporate investment (R&D and capital expenditure), changes in director characteristics and holdings, and changes in firm characteristics (e.g. size, growth, leverage). Our sample consists of 29,085 observations from 2,548 U.S. firms from 1994–2020. Variables are as defined in the Appendix, and are presented in the form used in the regression model.

Variable	Mean	Q1	Median	Q3	S.D.
#Option_Grants (unscaled, '000)	122.065	0.000	35.000	147.430	223.635
#Option_Grants	0.153	0.000	0.047	0.190	0.268
Δ#Option_Grants	−0.009	−0.029	0.000	0.019	0.309
Δ#Option_Grants_Pos	0.331	0.000	0.000	1.000	0.470
Δ#Option_Grants_Neg	0.360	0.000	0.000	1.000	0.480
#OptionsZero	0.424	0.000	0.000	1.000	0.494
#OptionsZerotoZero	0.309	0.000	0.000	1.000	0.462
Δ#OptionsZero/Roundmultiples	0.079	0.000	0.000	0.000	0.269
$\Delta Salary_{t+1}$	0.057	0.000	0.036	0.083	0.131
ΔBonus	0.240	−0.370	0.011	0.383	1.317
Tenure	7.532	2.000	5.000	10.000	7.617
ARD_{t-1}	−0.003	−0.006	0.000	0.005	0.092
$ACAPEX_{t-1}$	−0.013	−0.114	−0.032	0.049	0.195
ΔRD_{t-1}	−0.001	0.000	0.000	0.000	0.029
$\Delta CAPEX_{t-1}$	−0.012	−0.058	0.000	0.050	0.214
$\Delta CashCompensation_{t-1}$	−0.055	−0.210	−0.011	0.131	0.933
$\Delta EquityCompensation_{t-1}$	−0.157	−0.317	0.000	0.335	4.933
$\Delta Exercisable\_Options_{t-1}$	0.002	−0.038	0.010	0.136	0.404
$\Delta Unexercisable\_Options_{t-1}$	−0.015	−0.080	0.000	0.035	0.312
$\Delta Size_{t-1}$	0.080	−0.003	0.070	0.157	0.196
$\Delta B/M_{t-1}$	0.009	−0.076	−0.001	0.083	0.252
$\Delta Return_{t-1}$	−0.022	−0.358	−0.035	0.301	0.708
$\Delta Return_{t-2}$	−0.020	−0.359	−0.028	0.313	0.746
$\Delta Shares\_Own_{t-1}$	−0.153	−0.069	0.003	0.058	1.163
$\Delta NewCEO_{t-1}$	−0.046	0.000	0.000	0.000	0.489
$\Delta NetOperatingLoss_{t-1}$	0.001	0.000	0.000	0.000	0.254
$\Delta CashShortfall_{t-1}$	0.005	−0.066	0.000	0.071	0.171
ΔLev_{t-1}	0.004	−0.025	0.000	0.022	0.072
$\Delta \sigma Return_{t-1}$	−0.001	−0.026	−0.001	0.023	0.052

Table 2: Correlation Matrix of Variables

This table reports correlations between key variables, with Spearman (Pearson) correlation coefficients and significance levels in the upper (lower) triangle of the matrix. All variables are as defined in the Appendix, and are presented in the form used in the regression model.

Variables	*Δ#Option_Grants*	$\Delta CAPEX_{t-1}$	ΔRD_{t-1}	$LCAPEX_{t-1}$	$HCAPEX_{t-1}$	LRD_{t-1}	HRD_{t-1}	OC_{t-1}	$\Delta Cash\ Compensation_{t-1}$	$\Delta Size_{t-1}$	$\Delta B/M_{t-1}$	$\Delta Return_{t-1}$
Δ#Option_Grants	1.000	−0.004	0.004	0.001	−0.009	−0.004	−0.018	−0.017	−0.026	−0.017	0.073	−0.071
		0.538	0.511	0.836	0.129	0.543	0.002	0.002	<.001	0.004	<.001	<.001
$\Delta CAPEX_{t-1}$	−0.004	1.000	−0.036	−0.285	0.381	0.012	−0.028	0.061	−0.046	0.183	−0.017	−0.105
	0.543		<.001	<.001	<.001	0.045	<.001	<.001	<.001	<.001	0.003	<.001
ΔRD_{t-1}	−0.002	−0.028	1.000	−0.005	0.002	−0.097	0.128	−0.019	0.019	−0.236	0.053	−0.042
	0.750	<.001		0.370	0.726	<.001	<.001	0.005	0.001	<.001	<.001	<.001
$LCAPEX_{t-1}$	−0.009	−0.302	−0.019	1.000	−0.238	0.084	0.158	0.041	0.000	−0.006	0.048	−0.026
	0.134	<.001	0.001		<.001	<.001	<.001	<.001	0.974	0.269	<.001	<.001
$HCAPEX_{t-1}$	−0.008	0.360	−0.003	−0.238	1.000	0.081	0.034	0.105	−0.097	0.183	0.019	−0.041
	0.185	<.001	0.558	<.001		<.001	<.001	<.001	<.001	<.001	0.001	<.001
LRD_{t-1}	0.005	0.006	−0.147	0.084	0.081	1.000	−0.238	0.045	−0.046	0.068	−0.026	0.016
	0.368	0.330	<.001	<.001	<.001		<.001	<.001	<.001	<.001	<.001	0.005
HRD_{t-1}	−0.017	−0.045	0.131	0.158	0.034	−0.238	1.000	0.048	−0.003	0.028	0.020	−0.009
	0.004	<.001	<.001	<.001	<.001	<.001		<.001	0.575	<.001	0.001	0.124
OC_{t-1}	−0.005	0.032	−0.021	0.041	0.105	0.045	0.048	1.000	−0.087	0.286	−0.112	0.010
	0.423	<.001	0.002	<.001	<.001	<.001	<.001		<.001	<.001	<.001	0.138
$\Delta Cash\ Compensation_{t-1}$	−0.021	−0.025	0.275	0.007	−0.073	−0.058	0.015	−0.063	1.000	−0.269	−0.193	0.241
	<.001	<.001	<.001	0.205	<.001	<.001	0.013	<.001		<.001	<.001	<.001
$\Delta Size_{t-1}$	−0.013	0.146	−0.329	−0.027	0.181	0.074	−0.006	0.243	−0.348	1.000	0.003	−0.081
	0.033	<.001	<.001	<.001	<.001	<.001	0.279	<.001	<.001		0.573	<.001
$\Delta B/M_{t-1}$	0.060	−0.011	0.042	0.027	0.026	−0.024	0.011	−0.076	−0.099	0.020	1.000	−0.606
	<.001	0.057	<.001	<.001	<.001	<.001	0.068	<.001	<.001	0.001		<.001
$\Delta Return_{t-1}$	−0.058	−0.081	−0.051	−0.026	−0.043	0.018	−0.009	0.001	0.166	−0.089	−0.499	1.000
	<.001	<.001	<.001	<.001	<.001	0.002	0.110	0.878	<.001	<.001	<.001	

Table 3: R&D, capital expenditures and changes in CEO option-based compensation

This table reports regression results of estimating changes in the number of option grants on R&D investment, capital expenditure, and two sets of control variables. $\Delta\#Option\_Grants_{it}$ is measured as the change in the number of options granted scaled by shares outstanding, from year $t-1$ to year t. $LCAPEX_{t-1}$ and $HCAPEX_{t-1}$ are indicator variables for firms with abnormal capital expenditure in the bottom and top quintiles in year $t-1$. LRD_{t-1} and HRD_{t-1} are indicator variables for firms with abnormal R&D expense in the bottom and top quintiles in year $t-1$. Our sample consists of 29,085 observations from 2,548 U.S. firms from 1994–2020. Detailed definitions of all variables are provided in the Appendix. *t*-statistics are shown in parentheses with significance indicated at ***p<0.01, **p<0.05, *p<0.10. The equations have been estimated using pooled OLS regressions with errors clustered by firm. Year dummies are omitted for brevity.

Variables	$\Delta\#Option\_Grants_{it}$					
	(1)	(2)	(3)	(4)	(5)	(6)
$LCAPEX_{t-1}$	−0.014***	−0.016***			−0.013***	−0.014***
	(−2.95)	(−3.55)			(−2.62)	(−2.97)
$HCAPEX_{t-1}$	−0.007	−0.013***			−0.007	−0.013***
	(−1.54)	(−2.86)			(−1.53)	(−2.66)
LRD_{t-1}			0.004	−0.001	0.007	0.002
			(1.09)	(−0.25)	(1.61)	(0.51)
HRD_{t-1}			−0.012***	−0.016***	−0.009**	−0.012***
			(−2.75)	(−3.81)	(−2.00)	(−2.90)
$\Delta CAPEX_{t-1}$	−0.006	−0.005	−0.004	−0.007	−0.006	−0.006
	(−0.45)	(−0.43)	(−0.33)	(−0.56)	(−0.47)	(−0.47)
ΔRD_{t-1}	−0.125	−0.233**	−0.094	−0.204**	−0.095	−0.203**
	(−1.30)	(−2.51)	(−0.96)	(−2.18)	(−0.97)	(−2.17)
$\Delta Size_{t-1}$	−0.036***	−0.069***	−0.037***	−0.072***	−0.036***	−0.069***
	(−3.10)	(−5.70)	(−3.24)	(−5.94)	(−3.07)	(−5.65)
$\Delta B/M_{t-1}$	0.075***	0.041***	0.075***	0.041***	0.075***	0.042***
	(6.15)	(3.50)	(6.12)	(3.49)	(6.17)	(3.51)
$\Delta Return_{t-1}$		−0.013***		−0.013***		−0.013***
		(−2.75)		(−2.61)		(−2.72)
$\Delta Return_{t-2}$		−0.008**		−0.008*		−0.008*
		(−1.97)		(−1.83)		(−1.93)
$\Delta CashCompensation_{t-1}$		0.003		0.003		0.003
		(0.91)		(0.88)		(0.88)
$\Delta Exercisable\_Options_{t-1}$		−0.030***		−0.030***		−0.030***
		(−3.63)		(−3.61)		(−3.61)
$\Delta Unexercisable\_Options_{t-1}$		−0.372***		−0.372***		−0.372***
		(−29.07)		(−29.05)		(−29.09)
$\Delta Shares\_Own_{t-1}$		−0.001		−0.000		−0.001
		(−0.25)		(−0.17)		(−0.24)
$\Delta NewCEO_{t-1}$		−0.019***		−0.018***		−0.019***
		(−3.90)		(−3.88)		(−3.91)
$\Delta NetOperatingLoss_{t-1}$		−0.003		−0.003		−0.003
		(−0.25)		(−0.25)		(−0.24)
$\Delta CashShortfall_{t-1}$		0.021		0.021		0.021
		(1.52)		(1.51)		(1.51)
ΔLev_{t-1}		0.093***		0.091***		0.093***
		(3.13)		(3.05)		(3.12)
$\Delta \sigma Return_{t-1}$		0.041		0.039		0.039
		(0.79)		(0.75)		(0.76)
Year fixed effects	YES	YES	YES	YES	YES	YES
Observations	29,085	29,085	29,085	29,085	29,085	29,085
Number of firms	2,548	2,548	2,548	2,548	2,548	2,548
Adjusted R^2	0.0064	0.1473	0.0064	0.1472	0.0066	0.1476

Table 4: R&D, Capital expenditures, overconfidence, and changes in CEO option-based compensation

This table reports regression results of changes in the number of option grants on overconfidence, R&D, capital expenditure, and a set of control variables. $\Delta\#Option\_Grants_{it}$ is measured as the change in the number of options granted scaled by shares outstanding from year $t-1$ to year t. OC_{t-1} is an indicator variable for firms with overconfident CEOs in year $t-1$. $LCAPEX_{t-1}$, $HCAPEX_{t-1}$, LRD_{t-1}, and HRD_{t-1} are indicator variables as defined in Table 3. Our sample consists of 22,902 observations from 2,378 U.S. firms from 1994–2020 with data available on CEOs' exercisable stock options. The vector of control variables includes the extended set used in Table 3. Detailed definitions of all variables are provided in the Appendix. *t*-statistics are shown in parentheses significance indicated at $^{***}p<0.01$, $^{**}p<0.05$, $^{*}p<0.10$. The equations have been estimated using pooled OLS regressions with errors clustered by firm. Remaining control variables and year dummies are omitted for brevity.

Variables	$\Delta\#Option\_Grants_{it}$	
	(1)	*(2)*
OC_{t-1}	−0.013***	−0.010***
	(−3.37)	(−2.66)
$LCAPEX_{t-1}$		−0.011**
		(−2.09)
$HCAPEX_{t-1}$		−0.014***
		(−2.66)
LRD_{t-1}		−0.002
		(−0.42)
HRD_{t-1}		−0.011**
		(−2.37)
$\Delta CAPEX_{t-1}$		0.005
		(0.39)
ΔRD_{t-1}		−0.157*
		(−1.67)
$\Delta Size_{t-1}$	−0.053***	−0.056***
	(−3.84)	(−3.99)
$\Delta B/M_{t-1}$	0.027**	0.028**
	(2.04)	(2.09)
Remaining controls	YES	YES
Year fixed effects	YES	YES
Observations	22,902	22,902
Number of firms	2,378	2,378
Adjusted R^2	0.1443	0.1450

Table 5: Learning effects from CEO Tenure and persistence in CEO overconfidence

This table reports regression results of changes in the number of option grants on R&D, capital expenditure, CEO tenure, CEO overconfidence, persistence in CEO overconfidence, and a set of control variables. $\Delta\#Option\_Grants_{it}$ is measured as the change in the number of options granted scaled by shares outstanding from year $t-1$ to year t. OC_{t-1}, $LCAPEX_{t-1}$, $HCAPEX_{t-1}$, LRD_{t-1}, and HRD_{t-1} are indicator variables as defined in Tables 3 and 4. *Tenure* is the number of years that the CEO has been in the CEO position. $OCYears_{t-1}$ is a count of the number consecutive years in which OC=1 prior to and including $t-1$. Our sample consists of 26,877 (22,902) observations from 2,519 (2,378) U.S. firms from 1994–2020 with necessary tenure and holding data, respectively. The vector of control variables includes those reported in Table 3. Detailed definitions of all variables are provided in the Appendix. *t*-statistics are shown in parentheses with significance indicated at $^{***}p<0.01$, $^{**}p<0.05$, $^{*}p<0.10$. The equations have been estimated using pooled OLS regressions with errors clustered by firm. Remaining control variables and year dummies are omitted for brevity.

Variables	$\Delta\#Option\_Grants_{it}$	
	(1)	*(2)*
$LCAPEX_{t-1}$	−0.018**	−0.011**
	(−2.47)	(−2.14)
$HCAPEX_{t-1}$	−0.019***	−0.014***
	(−2.66)	(−2.63)
$LCAPEX_{t-1} \times Tenure$	0.001	
	(1.01)	
$HCAPEX_{t-1} \times Tenure$	0.000	
	(0.77)	
LRD_{t-1}	−0.013*	−0.002
	(−1.92)	(−0.42)
HRD_{t-1}	−0.019***	−0.011**
	(−2.64)	(−2.40)
$LRD_{t-1} \times Tenure$	0.001*	
	(1.77)	
$HRD_{t-1} \times Tenure$	0.000	
	(0.73)	
Tenure	−0.000	
	(−0.92)	
OC_{t-1}		−0.020***
		(−3.34)
$OCYears_{t-1}$		0.003**
		(2.58)
$\Delta CAPEX_{t-1}$	0.003	0.005
	(0.26)	(0.39)
ΔRD_{t-1}	−0.165*	−0.157*
	(−1.78)	(−1.67)
Remaining controls	YES	YES
Year fixed effects	YES	YES
Observations	26,877	22,902
Number of firms	2,519	2,378
Adjusted R^2	0.1570	0.1451

Table 6: Learning from stock prices

The table reports regression results of changes in the number of option grants on overconfidence, R&D, capital expenditure, stock price performance and a set of control variables. Δ#*Option_Grants*$_{it}$ is measured as the change in the number of options granted scaled by shares outstanding from year $t-1$ to year t. OC_{t-1}, $LCAPEX_{t-1}$, $HCAPEX_{t-1}$, LRD_{t-1}, and HRD_{t-1} are indicator variables as defined in Tables 3 and 4. $Return_t$ is the stock return from $t-1$ to t. $NegReturn_t$ is an indicator variable that equals one if the stock return is negative between $t-1$ and t, and 0 otherwise. Our sample consists of 22,902 observations from 2,378 U.S. firms from 1994–2020 with data available on CEOs' exercisable stock options. The vector of control variables includes those reported in Table 3. Detailed definitions of all variables are provided in the Appendix. *t*-statistics are shown in parentheses with significance indicated at ***p<0.01, **p<0.05, *p<0.10. The equations have been estimated using pooled OLS regressions with errors clustered by firm. Remaining control variables and year dummies are omitted for brevity.

Variables	*Δ#Option_Grants*$_{it}$ *(1)*	Variables	*Δ#Option_Grants*$_{it}$ *(2)*
OC_{t-1}	−0.012***	OC_{t-1}	−0.009*
	(−2.82)		(−1.70)
$LCAPEX_{t-1}$	−0.015***	$LCAPEX_{t-1}$	−0.002
	(−2.68)		(−0.27)
$HCAPEX_{t-1}$	−0.016***	$HCAPEX_{t-1}$	−0.008
	(−2.91)		(−1.26)
LRD_{t-1}	−0.001	LRD_{t-1}	−0.001
	(−0.12)		(−0.24)
HRD_{t-1}	−0.011**	HRD_{t-1}	−0.013**
	(−2.25)		(−2.20)
$Return_t \times OC_{t-1}$	0.009	$NegReturn_t \times OC_{t-1}$	−0.004
	(0.72)		(−0.46)
$Return_t \times LCAPEX_{t-1}$	0.028*	$NegReturn_t \times LCAPEX_{t-1}$	−0.024**
	(1.81)		(−2.06)
$Return_t \times HCAPEX_{t-1}$	0.013	$NegReturn_t \times HCAPEX_{t-1}$	−0.014
	(0.96)		(−1.31)
$Return_t \times LRD_{t-1}$	−0.008	$NegReturn_t \times LRD_{t-1}$	−0.001
	(−0.53)		(−0.12)
$Return_t \times HRD_{t-1}$	0.001	$NegReturn_t \times HRD_{t-1}$	0.006
	(0.08)		(0.57)
$Return_t$	−0.011	$NegReturn_t$	0.005
	(−1.31)		(0.85)
Remaining controls	YES	*Remaining controls*	YES
Year fixed effects	YES	*Year fixed effects*	YES
Observations	22,902		22,902
Number of firms	2,378		2,378
Adjusted R^2	0.1452		0.1451

Table 7: R&D, Capital expenditures, overconfidence, and changes in CEO option-based compensation – industry-based measures

This table reports regression results of changes in the number of option grants on overconfidence, R&D, industry-adjusted capital expenditure, and a set of control variables. $\Delta\#Option\_Grants_{it}$ is measured as the change in the number of options granted scaled by shares outstanding from year $t-1$ to year t. OC_{t-1} is an indicator variable for firms with overconfident CEOs. LRD_IND_{t-1} and HRD_IND_{t-1} are indicator variables for firm years where the difference between the firm's *RD* (R&D divided by sales) and the industry median *RD* is in the bottom or top quintiles in year $t-1$, and $LCAPEX\_IND_{t-1}$ and $HCAPEX\_IND_{t-1}$ are indicator variables for firm years where the difference between the firm's *CAPEXS* (capital expenditure divided by sales) and the industry median *CAPEXS* is in the bottom or top quintile in year $t-1$. Our sample consists of 29,085 observations from 2,548 U.S. firms from 1994–2020 and 22,902 observations with data available on CEOs' exercisable stock options. The vector of control variables includes those reported in Table 3. Detailed definitions of all variables are provided in the Appendix. *t*-statistics are shown in parentheses with significance indicated at $^{***}p<0.01$, $^{**}p<0.05$, $^{*}p<0.10$. The equations have been estimated using pooled OLS regressions with errors clustered by firm. Remaining control variables and year dummies are omitted for brevity.

Variables	$\Delta\#Option\_Grants_{it}$	
	(1)	*(2)*
OC_{t-1}		−0.010**
		(−2.51)
$LCAPEX\_IND_{t-1}$	−0.011**	−0.012**
	(−2.27)	(−2.07)
$HCAPEX\_IND_{t-1}$	−0.020***	−0.025***
	(−3.68)	(−3.93)
LRD_IND_{t-1}	0.004	0.001
	(1.44)	(0.47)
HRD_IND_{t-1}	−0.011**	−0.012**
	(−2.48)	(−2.19)
$\Delta CAPEX_{t-1}$	0.001	0.011
	(0.04)	(0.80)
ΔRD_{t-1}	−0.217**	−0.159*
	(−2.34)	(−1.71)
$\Delta Size_{t-1}$	−0.067***	−0.053***
	(−5.37)	(−3.76)
$\Delta B/M_{t-1}$	0.041***	0.028**
	(3.47)	(2.08)
Remaining controls	YES	YES
Year fixed effects	YES	YES
Observations	29,085	22,902
Number of firms	2,548	2,378
Adjusted R^2	0.1476	0.1455

Table 8: Capital expenditures, R&D and changes in other elements of CEO compensation

This table reports regression results of changes in cash-based compensation and restricted shares grants on changes in R&D, capital expenditure, and a set of control variables. $\Delta Salary_{it+1}$ is measured as the percentage change in salary from year *t* to year *t+1* and $\Delta Bonus_{it}$ is measured as the change bonus, scaled by salary, from year *t−1* to year *t*. $\Delta RestrictedShares_{it}$ is the annual change in restricted share grants (restricted shares/total compensation). $LCAPEX_{t-1}$, $HCAPEX_{t-1}$, LRD_{t-1}, and HRD_{t-1}, are indicator variables as defined in Tables 3 and 4. The vector of control variables is similar to that used in Table 3, with the exception of cash-based compensation, which has been replaced with equity-based compensation. Our sample consists of 22,059 (28,889) observations from 2,358 (2,539) U.S. firms which have the necessary salary and bonus data from 1994–2020. Detailed definitions of all variables are provided in the Appendix. *t*-statistics are shown in parentheses with significance indicated at ***p<0.01, **p<0.05, *p<0.10. The equations have been estimated using pooled OLS regressions with errors clustered by firm. Remaining control variables and year dummies are omitted for brevity.

Variables	$\Delta Salary_{it+1}$	$\Delta Bonus_{it}$	$\Delta Restricted\ Shares_{it}$
	(1)	*(2)*	*(3)*
$LCAPEX_{t-1}$	−0.006***	−0.019	−0.160
	(−2.81)	(−1.53)	(−0.53)
$HCAPEX_{t-1}$	0.005**	−0.011	−0.299
	(2.06)	(−0.84)	(−0.98)
LRD_{t-1}	0.004*	0.032***	0.664***
	(1.78)	(2.89)	(2.79)
HRD_{t-1}	−0.002	0.011	0.415*
	(−0.83)	(0.98)	(1.67)
$\Delta CAPEX_{t-1}$	−0.013***	−0.043*	0.089
	(−2.91)	(−1.77)	(0.13)
ΔRD_{t-1}	0.080***	−0.492***	−6.057
	(2.63)	(−2.91)	(−1.36)
$\Delta EquityCompensation_{t-1}$	0.000	−0.000	
	(1.48)	(−0.03)	
$\Delta CashCompensation_{t-1}$			0.691***
			(3.76)
$\Delta \#Option\_Grants_{it-1}$			0.921**
			(2.14)
$\Delta Size_{t-1}$	0.042***	−0.312***	1.397**
	(7.75)	(−10.43)	(1.98)
$\Delta B/M_{t-1}$	−0.017***	−0.149***	−0.499
	(−3.58)	(−4.99)	(−0.78)
Remaining controls	YES	YES	YES
Year fixed effects	YES	YES	YES
Observations	22,059	28,889	29,030
Number of firms	2,358	2,539	2,539
Adjusted R^2	0.0338	0.0954	0.0027

Table 9: Alternative measures of option-based compensation

This table reports regression results of changes in equity-based compensation and the dollar value of stock options on changes in R&D, capital expenditure, and a set of control variables. $\Delta IncentivePay_{it}$ is the change in the proportion of compensation composed of equity from year $t-1$ to year t, and $\Delta\$Option\_Grants_{it}$, the change in the estimated fair value of stock options scaled by total compensation, from year $t-1$ to t. OC_{t-1}, $LCAPEX_{t-1}$, $HCAPEX_{t-1}$, LRD_{t-1}, and HRD_{t-1} are indicator variables as defined in Tables 3 and 4. The vector of control variables includes those reported in Table 3. Our sample consists of 26,339 (29,085) observations from 2,390 (2,548) U.S. firms which have the necessary $\Delta IncentivePay$ and stock option data from 1994–2020, with a reduced set of observations with data available on CEOs' exercisable stock options. Detailed definitions of all variables are provided in the Appendix. *t*-statistics are shown in parentheses with significance indicated at ***p<0.01, **p<0.05, *p<0.10. The equations have been estimated using pooled OLS regressions with errors clustered by firm. Year fixed effects are omitted for brevity.

Variables	$\Delta IncentivePay_{it}$		$\Delta\$Option\_Grants_{it}$	
	(1)	(2)	(3)	(4)
$LCAPEX_{t-1}$	0.002	0.006	−0.172	0.108
	(0.63)	(1.40)	(−0.46)	(0.25)
$HCAPEX_{t-1}$	−0.002	−0.006	−0.414	−0.752*
	(−0.67)	(−1.34)	(−1.13)	(−1.78)
LRD_{t-1}	−0.012***	−0.013***	−0.615**	−0.887**
	(−3.84)	(−3.33)	(−1.99)	(−2.40)
HRD_{t-1}	−0.011***	−0.012***	−0.849**	−0.997***
	(−3.28)	(−3.00)	(−2.57)	(−2.66)
OC_{t-1}		0.012***		1.269***
		(3.52)		(3.67)
$\Delta CAPEX_{t-1}$	0.015	0.022**	1.072	1.756*
	(1.49)	(2.07)	(1.14)	(1.70)
ΔRD_{t-1}	−0.114	−0.096	−14.156**	−13.138*
	(−1.57)	(−1.27)	(−2.01)	(−1.81)
$\Delta Size_{t-1}$	0.054***	0.038***	0.738	0.456
	(5.58)	(3.32)	(0.77)	(0.40)
$\Delta B/M_{t-1}$	−0.009	−0.015	−1.872**	−2.355***
	(−1.08)	(−1.64)	(−2.40)	(−2.63)
$\Delta Return_{t-1}$	0.009**	0.014***	0.938**	1.368***
	(2.51)	(3.49)	(2.53)	(3.21)
$\Delta Return_{t-2}$	0.003	0.004	0.539*	0.561
	(1.01)	(1.37)	(1.74)	(1.63)
$\Delta CashCompensation_{t-1}$	0.018***	0.015***	1.118***	1.057***
	(7.96)	(6.04)	(5.34)	(4.38)
$\Delta Exercisable\_Options_{t-1}$	−0.009*	−0.017***	−1.814***	−2.416***
	(−1.76)	(−2.96)	(−3.46)	(−4.20)
$\Delta Unexercisable\_Options_{t-1}$	−0.170***	−0.177***	−21.220***	−20.763***
	(−20.99)	(−20.07)	(−26.50)	(−23.32)
$\Delta Shares\_Own_{t-1}$	0.004**	0.003	0.185	0.174
	(2.14)	(1.63)	(1.22)	(0.84)
$\Delta NewCEO_{t-1}$	−0.009**	−0.005	−0.765**	−0.311
	(−2.29)	(−1.13)	(−2.04)	(−0.71)
$\Delta NetOperatingLoss_{t-1}$	−0.001	0.001	−0.557	−0.221
	(−0.06)	(0.08)	(−0.75)	(−0.27)
$\Delta CashShortfall_{t-1}$	0.001	−0.002	0.628	0.171
	(0.11)	(−0.17)	(0.56)	(0.14)

ΔLev_{t-1}	−0.026	−0.048*	−1.237	−3.148
	(−1.10)	(−1.84)	(−0.55)	(−1.23)
$\Delta \sigma Return_{t-1}$	0.052	0.098**	0.108	2.274
	(1.47)	(2.55)	(0.03)	(0.55)
Year fixed effects	YES	YES	YES	YES
Observations	26,339	20,785	29,085	22,902
Number of firms	2,390	2,230	2,548	2,378
Adjusted R^2	0.0455	0.0499	0.0837	0.0814