Are CEOs paid extra for riskier pay packages?

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Abstract

This paper quantifies the cost of CEO incentive compensation by estimating an elasticity of pay to the variance of pay. This metric is based on the benchmark moral hazard model widely used to study CEO pay. Using US CEO compensation data and a variety of empirical approaches, we find that CEOs with riskier pay packages are paid more. However, the estimated elasticity of pay to the variance of pay is small. This small elasticity implies a low risk aversion coefficient for CEOs and a risk premium that is at most 12% of total pay. This risk premium is about evenly split between compensation for risk in cash bonus, stock grants, and option grants. Overall, our findings suggest that incentive pay is not too costly for firms from a risk-diversification perspective, which may explain the heavy reliance on incentive pay by US firms, and cast doubt on the ability of the benchmark moral hazard model to explain CEO pay in the US.

Keywords: CEO pay, risk premium, incentives, contract theory, risk aversion, moral hazard, participation constraint, realized variance, ARCH, Incentive Lab.

JEL Classifications: D81, G30, J33, M52.

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1. Introduction

The last thirty years have seen an expansion of CEO pay in the US that has led to much debate. This expansion has come mostly via an increase in incentive pay components as opposed to fixed pay (e.g., Conyon, 2006, and Jensen and Murphy, 2018).[1] Assessing the level of incentive pay in CEO compensation as too high or too low requires understanding the optimality of the given level of pay-performance incentives (Core and Guay, 2010). Past studies have documented potential benefits and costs of incentive pay as they relate, for example, to manager-shareholder conflicts (e.g., Hadlock, 1998), risk-taking (Coles et al., 2006; Hayes et al. 2012), short-termism behavior (Bebchuk and Fried, 2006), earnings management (Bennett et al., 2017), and accounting fraud (Erickson et al., 2006). We contribute to this literature by quantifying the risk premium of incentive pay in the form of the increased direct compensation that boards have to pay their risk-averse CEOs for bearing extra incentive-pay risk.

We measure the risk premium by estimating how much more firms have to compensate their CEOs for offering riskier compensation packages. Our approach is anchored in the principal-agent moral hazard model (e.g., Holmstrom, 1979, Mirrlees, 1976, and Shavell, 1979), the work-horse model in empirical studies of CEO compensation. A fundamental hypothesis in this model is that incentive pay helps risk neutral shareholders reduce principal-agent conflicts with CEOs but comes with the cost of additional pay needed to compensate risk-averse CEOs for the undiversifiable risk that incentive pay imposes on them. [2]

In the standard moral hazard model, the elasticity of pay to variance of pay depends on the CEO's risk aversion. Thus, under the null of this model, we can assess the magnitude of the estimated elasticity by relating it to measures of risk aversion, and estimate the risk premium associated with incentive pay.

We use three empirical approaches to estimate the elasticity of pay to the variance of pay. The first approach uses Incentive Lab's actual CEO compensation contract provisions on the relation between performance metrics and performance-based compensation (i.e., cash bonus,

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[1] The Economist (2020) provides yet another article that questions the growth in executive pay in the US and the extent to which CEO pay is tied to performance.

[2] Conyon, Core and Guay (2011) call this hypothesis the "central tenet of agency theory and contracting" (p. 404). We discuss below how our paper relates to Conyon, Core and Guay (2011) and Fernandes, Ferreira, Matos, and Murphy (2013). We also discuss below why the trade-off between the level of pay and pay risk is different from the trade-off between firm risk and incentive pay.

stock grants, and option grants) collected from proxy statements (DEF 14A). The main advantage of these rich data is that we can evaluate, through a simulation exercise, the beginning-of-the-year conditional variance of the CEO's end-of-year pay. We are the first to directly estimate the cost to firms associated with incentive risk using detailed compensation contract information and to calculate the risk premium derived from cash bonus, stock grants, and options grants separately.

Consider, for example, the simplest contract that includes salary plus a cash bonus grant. The bonus grant may have a threshold payout of 100% of base salary, a target payout of 200% of base salary, and a maximum payout of 400% of base salary. The contract defines a metric, say net sales, and corresponding performance levels that determine the threshold, target, and maximum payouts. For such a contract, we would simulate the year-end value of net sales under the assumption that it is normally distributed. We would use the prior year value of net sales as the expected value and the prior volatility of net sales as the conditional volatility. For each simulated end-of-year value of net sales, we determine the expected bonus grant payout. The average and volatility of these values provide the mean and variance of bonus pay, respectively, which we would then combine with salary to determine the mean and variance of total pay.[3]

To peek into the full complexity of this simulation exercise, note that CEO contracts may grant bonus, stock, and options in any given year, and multiple grants of each kind are possible, where multiple performance metrics may be specified across grants and even in the same grant. We construct a variance-covariance matrix that accounts for the correlation across the different performance metrics. In addition, the performance metrics may (or may not) all have to be met to yield a payout, which we account for. Finally, these characteristics may change over time even for the same firm-CEO pair. Using these detailed compensation data, we regress total CEO pay on the simulated variance of pay. We find a positive and statistically significant elasticity of pay to the variance of pay.

The second approach models the conditional variance of total pay with realized variance of past CEO pay in the spirit of Schwert (1989) and Andersen and Bollerslev (1998). Using realized variance has the benefit that we can use the universe of ExecuComp firms, increasing the sample size considerably in both the cross section and time series. However, it comes at the cost

[3] Bizjak, Kalpathy, Li, and Young (2018) state that compensation consultants often use simulations when presenting the valuation of the awards to the board of directors. So, it is conceivable that compensation committees at the beginning of the year use a similar approach to evaluate whether enough pay is being offered on average to the CEO to compensate for the risk in her compensation package.

of having to assume that contract parameters are time invariant for each CEO, which is the standard assumption in empirical panel data studies estimating pay-for-performance parameters. The results of regressing total pay on realized variance of total CEO pay are consistent with the results using Incentive Lab data that explicitly deal with time variation in contract parameters.

The third approach uses a variant of Engle's (1982) autoregressive conditional heteroskedasticity (ARCH) model to jointly estimate the mean of total pay and the volatility of pay.[4] The ARCH model estimates an equation for the level of pay and another equation for the volatility of pay. This simultaneous determination of mean and variance of pay is consistent with the theory, where mean pay and the volatility of pay are jointly determined. By estimating the model in the full panel of ExecuComp firms, we minimize the limitation of this approach of requiring a large time series of data. We use an ARCH-in-mean model where the conditional volatility of pay enters the equation of mean pay. This approach, too, generates results that are consistent with the other two approaches.

Across the three approaches, the highest point estimate of the elasticity of pay to the variance of pay is 0.065. This estimate implies a coefficient of relative risk aversion around one, which is arguably a low value. For example, Becker (2006) and Conyon, Core, and Guay (2011) calibrate CEO relative risk aversion to 2 and 3. A value of relative risk aversion of 3 corresponds to an elasticity of pay to variance of pay of 1, about 15 times larger than our estimated value. Our low estimate of risk aversion suggests that incentive pay does not appear too costly for firms, and, as a result, may explain the phenomenal growth in CEO incentive pay over the last 30 years.[5]

Second, the estimated elasticity implies a risk premium associated with undiversifiable risk in incentive pay of about 12%. This risk premium appears small given that incentive pay represents, on average, over 70% of US CEO pay. The low risk premium is however consistent with compensation studies that estimate the additional pay caused by the risk in specific events. For example, Gipper (forthcoming) uses the SEC's implementation of the Compensation Discussion and Analysis requirement as a shock to pay risk and finds that compensation levels

[4] To the best of our knowledge this is the first paper that uses ARCH modeling to study CEO compensation data. We follow a long tradition in economics of using ARCH models to explain the time series behavior of economic variables, from inflation, in the path breaking study of Engle (1982), to GDP growth in Ramey and Ramey (1995), and to stock returns in Bollerslev, Engle, and Wooldridge (1988). The last two papers, like ours, model the conditional mean of the dependent variable as a function of its conditional variance.

[5] Dittmann and Maug (2007) assume that risk in pay comes only from stock and options. In calibrated versions of their model, they find that many firms would benefit from increasing incentive pay to their CEOs. We do not discuss the optimality of incentive pay since we are only measuring the costs of incentives.

increase by 11% after the mandatory disclosure. Carter et al. (2019) find that executives changing employers are paid an additional 14% to compensate for the risk of fit with the new firm. Our approach does not rely on specific events and thus represents an average risk premium.[6] In addition, our approach allows us to decompose the risk premium into the risk imbedded in cash bonus, stock grants, and options grants. We believe we are the first to show that each of these components contributes approximately equally to the total risk premium.

Third, the small economic magnitude of the link between total pay and the volatility of pay (that arises from incentive pay) suggests that incentives are not granted mainly based on considerations of risk sharing. Our evidence thus casts doubt on the ability of the benchmark moral hazard model to explain the cross-sectional variation in CEO pay in the US. We are not the first to make this point. Murphy and Jensen (2018) argue that the growth in incentive pay in the last two decades seems not to be driven by the provision of economic incentives.[7] Cadman, et al (2020) show that firms adjust their CEO equity grants to those of their peers to match outside job market opportunities and avoid CEO turnover, also consistent with levels of incentives being driven by factors other than risk diversification. In Becker (2006), his risk-sharing based model predicts significantly more incentives at risk aversion of 3 (close to Taylor's (2013) 2.8 estimate) than supported by the data for medium and high wealth CEOs. Our evidence is complementary to Fernandes et al. (2013), Murphy and Vance (2019), and Murphy and Sandino (2020), who all argue that risk sharing cannot fully explain the level of incentives observed in the US.

We study several reasons for the small estimated elasticity and risk premium. First, we consider the possibility that risk aversion varies in the cross section. Haubrich (1994) calibrates the agency model and shows that equity incentives increase sharply as CEO risk aversion decreases. This suggests that a low estimated elasticity could be due to the presence of a few CEOs with really low risk aversion. Using several proxies for risk aversion from the literature, we find no significant evidence that lower risk aversion is associated with a lower elasticity as predicted. We also show that CEO inside wealth does not qualitatively change the nature of our results.

[6] The risk premium that we estimate is not comparable to that in Conyon et al. (2011) (see their Table 5) because theirs is calculated as a fraction of total CEO wealth in the firm. We address total CEO wealth in the robustness section.

[7] Murphy and Jensen (2018) point to the deductibility rules of Section 162(m) of the IRS code. According to Rose and Wolfram (2002), Section 162(m) of the IRS Code appears to have kept CEO salaries capped at around $1 million over the last two decades causing the growth in pay to come from incentive pay, which was the component of pay not affected by the Section. As a result, the tax code may have created an inefficiency in pay by overexposing CEOs to risk for which they were not compensated.

Second, we consider a wide array of factors that may affect the relation between mean pay and the variance of pay: CEO's outside market opportunities (Oyer, 2004); CEO preference for positively skewed payouts (Hemmer, Kim and Verrecchia, 2000, Ross, 2004, and Chaigneau, 2015); CEO overconfidence (Malmendier and Tate, 2005 and 2008); CEO power (Bebchuk and Fried, 2003); and shocks to the CEO's marginal disutility of effort (Laffont and Martimort, 2002). We find that these characteristics do not significantly affect our finding of a low elasticity of mean pay to the volatility of pay across all our empirical specifications.

Third, while we focus on the risk premium associated with flow CEO incentive compensation, CEOs may bear more risk through previously awarded equity and option grants (e.g., Core et al., 2003). To assess the relevance of this concern, we include in our tests the volatility of CEO inside wealth, using the inside wealth variable in Coles et al. (2006). We show that the volatility of CEO inside wealth is not a statistically significant additional source of risk premium once we control for the volatility of current pay. We interpret this finding as suggesting that the cost of volatility associated with previous equity awards does not affect current pay arguably because the board has already compensated the CEO in the past for such volatility.

Following an early methodological contribution by Lambert, Larcker, and Verrecchia (1991), Conyon et al. (2011) and Fernandes et al. (2013) are the first to provide a direct test of the prediction that the provision of incentives is expensive. Our test differs from theirs in several respects. First, we simulate bonus, restricted stock and options grants, and, from these simulations, calculate the estimated variance of pay. In contrast, their estimate of a risk premium from incentives excludes volatility in pay from bonus, which according to our work is an important component of the risk premium. Second, because they do not use detailed data on CEO contracts, they are forced to make assumptions about the relation between pay and performance. We, on the other hand, do not require any such assumptions as we rely on a sample for which we have the actual contract parameters. To estimate the risk premium, they assume that the CEO's outside opportunity is fully diversified. However, such an assumption may lead to an overestimation of the risk premium; if, instead, a CEO's outside opportunity is to join another firm and be equally under-diversified, then the risk premium should be small.[8] Our simulation of variance does not require this additional assumption and avoids the potential bias. Third, because our sample focuses

[8] In fact, Cadman et al. (2020) show that a firm's CEO equity grants appear to be awarded to match its peer's CEO equity grants, particularly when the risk of losing the CEO to a competitor is high.

on the U.S., all CEOs are exposed to the same legal, taxation, and economic environment; these country-level characteristics impact the level and form of pay but may be hard to control for in cross-country studies such as theirs.

There is a large literature linking *stock return* volatility to equity incentives in CEO pay, referred to as a risk-return trade off. This literature has produced somewhat inconclusive results. While some studies find a positive association between firm stock return volatility and equity incentives, others find a negative association between the two (see for example Aggarwal and Samwick, 1999, Core and Guay, 2002, and Prendergast, 2002). The risk and reward trade-off we study is not equivalent to the hypothesis that equity incentives decrease with firm stock return volatility due to CEO's dislike of pay risk (proxied by firm stock return volatility). The trade-off we address is about total pay and the volatility of total pay, not the volatility of firm stock returns, nor the equity incentive component of pay alone.[9] A positive association between total pay and the variance of pay in agency models does not depend on the sign of the relation between firm's stock return volatility and equity incentives. In fact, the two relationships (i.e., the association between total pay and the variance of pay, and the association between equity incentives and the volatility of firm returns) are different empirical questions with different theoretical underpinnings. For example, Cheng, Hong, and Scheinkman (2015) argue that higher firm volatility not only indicates higher firm risk, but also indicates higher productivity. In their model, there is a trade-off between mean pay and volatility of pay implied by the agent's participation constraint as in our paper. However, in the same model, equity incentives could either increase or decrease in the firm's return volatility depending on how volatility affects firm productivity. We empirically test a trade-off, which to date, has only been considered theoretically.

The paper proceeds with a theoretical justification that the elasticity of pay to the variance of pay represents a way to capture the cost of incentive pay. Section 3 describes three approaches to estimate the variance of pay. Section 4 presents the data and Section 5 presents the results including tests that control for alternative hypotheses. Section 6 offers an array of robustness tests and Section 7 concludes with directions for future work. The Appendix contains details associated

[9] Our main tests rely on the participation constraint present in the benchmark moral hazard model. The participation constraint requires only information about the agent's expected utility. Other model predictions, including the much-studied sensitivity of incentive pay to stock return volatility, not only rely on the participation constraint but also on assumptions about the production function, the number of performance metrics used to incentivize the agent, and the principal's objective function.

with the simulation exercise using Incentive Lab data, and the definition of variables used in the empirical tests.

2. The variance of pay and the elasticity of pay

This section motivates using the variance of pay as a way to evaluate the level of uncertainty the CEO is exposed to in the various components of incentive pay. Using the standard principal-agent model, we then discuss how the elasticity of pay to the variance of pay is an appropriate metric to measure the cost of incentive pay.

2.1 Variance of pay as an aggregator of risk in performance grants

In the static, principal-agent model, the principal (i.e., shareholder) offers a compensation package, w, to the agent (i.e., CEO) which can vary with the agent's performance. The agent evaluates this compensation package with her expected utility $E\big(U(w,e)\big)$, where U is the agent's utility, e is the agent's effort, and E is the expectations operator. A risk averse agent prefers compensation packages with high average pay but dislikes compensation packages with high variance of pay. This can be illustrated using the static version of Holmstrom and Milgrom (1987) with normal shocks, exponential utility and separability between consumption and effort. In that model,

$$\log E\big(U(w,e)\big) = E(w) - \tfrac{\gamma}{2}V(w) - \text{cost of effort}, \qquad (1)$$

where $\gamma > 0$ is the constant absolute risk aversion coefficient, and $E(w)$ and $V(w)$ are, respectively, the mean and variance of pay.

The variance of pay summarizes the (utility) risk associated with not meeting different performance targets in performance-based components of pay or the fluctuation in market valuation of the newly awarded equity grants for the current year.

2.2 Elasticity of mean pay to variance of pay

In the static version of Holmstrom and Milgrom (1987), and in many other models, the principal chooses a pay package to maximize operating profits, net of the pay to the CEO. This maximization is subject to an incentive compatibility constraint and a participation constraint. Our paper focuses on the participation constraint

$$E\big(U(w,e)\big) \geq \overline{U}, \tag{2}$$

with $\overline{U}$ being the agent's utility under her best outside employment opportunity. Under general conditions, the optimal pay contract makes the participation constraint bind (Grossman and Hart, 1983). Under the Holmstrom and Milgrom assumptions, taking logarithms on both sides of constraint (2), and combining with (1), obtains

$$E_t(w_t) = \frac{\gamma}{2} V_t(w_t) + \text{cost of effort}_t + \bar{u}_t, \tag{1}$$

with $\bar{u} = \log(\overline{U})$.[10] Time subscripts are added so as to clarify that the information set used to compute the conditional moments refers to information available at the time when contracts are written, i.e., the beginning of period t, and w_t is the total pay realization through period t.

Equation (3) can be used to derive a metric for the cost of incentives. When incentives increase, the variance of pay, $V_t(w_t)$, also increases. If the firm wants to retain the CEO, then average pay must also increase. The elasticity of pay to the variance of pay describes the direct cost associated with incentive provision as it measures the additional mean pay the firm must give to the risk averse CEO so that she accepts the additional volatility associated with incentive pay. Any less mean pay implies that the participation constraint is violated and cannot be supported as an equilibrium outcome of the optimal contract. The origin of the elasticity of pay to variance of pay in Holmstrom and Milgrom (1987) is a risk and reward trade off that leaves the CEO indifferent between staying in the firm and leaving.

[10] The tradeoff between mean pay and volatility of pay is derived with the assumptions of exponential utility and of normality of shocks. Absent these assumptions, a Taylor series expansion of utility as a function of pay shows that a tradeoff exists provided the utility function displays concavity–that is, the CEO is risk averse–though the utility function may also put weight on higher moments of pay as we discuss in Section 5.3 below.

This cost to the firm described by the elasticity relies on the inability of the CEO to diversity her exposure to own-firm risk, a restriction that firms are keen on maintaining or else the incentives would be useless. Because the participation constraint is a fundamental component of the workhorse principal-agent model that guides almost all empirical investigations of CEO pay, we view the elasticity of pay to the variance of pay as a natural proxy for the cost of incentives to firms that arises from a risk diversification argument.

To estimate the elasticity of pay to variance of pay, we define the error term, ε_t, as the unpredictable residual in pay given information available at the beginning of period t

$$\varepsilon_t \equiv w_t - E_t(w_t). \tag{2}$$

By construction, $E_t(\varepsilon_t) = 0$, and the variance of ε_t conditional on beginning of period t information is $V_t(\varepsilon_t) = V_t(w_t) \equiv \sigma_t^2$ (see Taylor, 2013, for a similar specification of the residual). From (3) and (4), we obtain our regression specification

$$w_t = \lambda\sigma_t^2 + X_t'\beta + \varepsilon_t. \tag{3}$$

In this model, $\lambda = \frac{\gamma}{2}, V_t(\varepsilon_t) = \sigma_t^2$, and the vector X_t and the slopes β capture the drivers of the cost of effort and of outside opportunities. Once the elasticity λ is estimated, we can obtain the risk premium linked to incentive pay, $\lambda\sigma_t^2$. The risk premium is the portion of pay that arises because risk averse CEOs dislike variable pay.

The elasticity of pay to variance of pay is not identified from a causal relation because both variables are determined in equilibrium as is clear in equation (3). Rather, it defines a structural relation between the two variables: any shock to one of the variables must be met with a shock to the other to preserve their structural relation, otherwise the participation constraint in the model would be violated. The additional compensation in mean pay for a marginal increase in the variance of pay is dictated by the CEO's level of risk aversion. A parallel to our exercise exists in the asset pricing literature where expected returns are related to the variance of returns times risk aversion. There, too, the lack of portfolio diversification imposes risk on the investor that then requires further compensation. Just as in the asset pricing literature, the trade-off between mean pay and variance of pay is not a causal relation because both variables are determined in equilibrium in the agency model.

Our exercise is related to the literature that measures pay for performance sensitivities. That literature assumes that the most important performance metrics are contemporaneous stock returns and accounting returns. We show that CEO compensation contracts simultaneously use a variety of performance metrics including various accounting-based performance metrics. Past studies that estimate the pay-for-performance sensitivities using only just stock returns and accounting returns lack the ability to combine the risks that arise from all the different performance metrics, performance targets, and components pay. The variance of pay we rely on parsimoniously aggregates all such risk.

3. Estimating the variance of pay

We use three approaches to estimate the regression model in equation (5), each with a different estimate of σ_t^2 that we describe next.

3.1 Conditional variance using simulated variance from contract data

For every full-year CEO and every year, we use detailed contract information available at the beginning of each year to simulate the end-of-year distribution of CEO pay. From this simulation exercise, we obtain the expected mean and the variance of pay as of the beginning of the year.

Firms use two types of incentive pay to reward their CEOs: (i) time-vested incentive pay, and (ii) performance-vested incentive pay. Time-vested incentive pay includes time-vested restricted stock units (RSU) and time-vested stock options. Performance-vested incentive pay includes bonus, performance-vested RSU, and performance-vested stock options. Time-vested incentive grants are not linked to specific performance targets, but their value is linked to firm performance through the stock price. Performance-vested incentive grants and their value are linked to firm performance: CEOs need to first meet the performance targets prescribed in the compensation contracts to earn the grants, and then the grants' value is further linked to firm performance.

We simulate the value of time-vested and performance-vested incentive pay differently. For time-vested incentive pay, we simulate the stock price and multiply the simulated stock price by the number of RSU or options granted to get the dollar value of equity incentive pay. For performance-vested incentive pay, we take two inputs for the simulation: (i) compensation contract information collected by Incentive Lab from the plan-based awards table of the DEF 14 describing the relation between contracted performance metrics and the corresponding performance-based compensation (i.e., cash bonus, RSU grants, and option grants) and (ii) Compustat data on realizations of the different performance metrics over the past five years to estimate their mean and variance (covariance), which we use to estimate the simulated performance for the current year. We describe the procedure next leaving the details to the Appendix.[11]

The contract information is available at the firm-year-grant-metric level. For each performance metric used, Incentive Lab gives the threshold, target, and maximum level of the performance metric, and the threshold, target, and maximum level of the corresponding performance-based compensation. The CEO earns no performance-based compensation when actual firm performance is below the threshold and earns the maximum amount of performance-based compensation when actual firm performance is above its maximum. When the performance metric falls between its threshold and the maximum, the CEO earns performance-based compensation in an amount between its threshold and the maximum. We follow the firm policies disclosed in the proxy statements (DEF 14A) and fit a piece-wise linear function between the threshold, the target, and the maximum to determine the award amount.

To simulate pay for a CEO in a given year, we first simulate the performance metrics used by the firm in all the grants awarded in that year. It is possible for firms to use more than one performance metric for a given grant and to award several grants to the same CEO in a given year. We consider all metrics used for a given firm-year-CEO and simultaneously simulate all metrics for that year, while accounting for the joint distributional properties of the metrics. In particular, we assume a multivariate normal distribution for the vector of performance metrics used. For our main results, we set the mean of the multivariate normal distribution equal to last year's value of the respective performance metrics. We set the covariance matrix of the distribution equal to the

[11] Holden and Kim (2017) offer valuation formulas for performance equity grants. Because we consider bonus and equity plans simultaneously, and need to obtain measures of conditional volatility of pay, we have to use simulation methods.

sample covariance matrix of the performance metrics using five years of data prior to the grant year.[12] We then simulate performance outcomes 10,000 times for each firm-year-grant-metric observation. In a robustness exercise, we set the mean of the multivariate normal distribution equal to the end of the year actual value of the performance metrics.

We calculate simulated compensation by fitting the simulated performance metrics to the compensation contracts. Since performance is simulated at the firm-year-CEO-grant-metric level, we calculate the simulated compensation at the firm-year-CEO-grant-metric level. We then aggregate the metric-level compensation into the grant level based on information in Incentive Lab about the relation between the various performance metrics. Compensation contracts are either separable or non-separable contracts. Separable contracts allow CEOs to earn part of the bonus, RSU, or option grants even though some of the performance metrics do not meet their goal threshold, while non-separable contracts result in zero payout if any of the performance metric thresholds is not met. Further, following Incentive Lab, we add the equally-weighted pay from all metrics in separable contracts to get total simulated pay at the grant level. For a CEO with more than one grant in a given year, we add simulated pay from all her grants. We add salary, other compensation, and discretionary bonus to the simulated pay values at the firm-year-CEO level and calculate the mean, variance, and skewness across the simulated values.

3.2 Conditional variance using realized variance of pay

In the second empirical approach, we estimate σ_t^2 using past CEO-firm pay data. Specifically, we use the last 5 years of w_t to compute realized variance of pay,

$$RealizedVariance_t = \frac{1}{5}\sum_{s=1}^{5}(w_{t-s} - \overline{w}_t)^2, \tag{6}$$

where $\overline{w}_t$ is the 5-year sample mean. This estimator of the 5-year conditional volatility of pay is similar to Schwert's (1989) estimate of conditional monthly return volatility that uses daily data and to Andersen and Bollerslev's (1998) estimate of conditional daily return volatility that uses

[12] To simulate the value of option grants we estimate the volatility of stock returns using the last five years of monthly data and cap volatility by the average volatility across all simulation years. The ratio of price to sales is adjusted for stock splits using the lagged COMPUSTAT variable "ajex".

intraday data. The 5-year conditional volatility is a smooth function of the past 1-year conditional volatilities, which may introduce an upward bias on the estimated slope coefficient in equation (3). Preempting our results, the fact that we estimate a small slope coefficient, suggests that this bias is not severe.

If pay is a function of stock returns alone, then this estimator is a consistent estimator of the conditional volatility of pay. To see this point, evaluate the estimator in equation (6) applied to data generated by a model similar to Holmstrom and Milgrom (1987), where pay is a linear function of the firm's stock return, r_t, that is $w_t = m_0 + m_1 r_t$, and m_0 and m_1 are optimal contract parameters. Then

$$RealizedVariance_t = m_1^2 \frac{1}{5} \sum_{s=1}^{5} (r_{t-s} - \bar{r}_t)^2. \qquad (7)$$

Andersen and Bollerslev (1998) show that under general properties for stock returns, the estimator above converges to the conditional variance of pay in the model, i.e., $m_1^2 V_t(r_t)$, where $V_t(r_t)$ is the conditional volatility of stock returns, if we are allowed to sample returns at increasingly higher frequencies.

We expect realized variance to work well as an estimator under the null that pay evolves linearly with stock returns. Intuitively, if contract parameters are time invariant, any variation in pay is due to variation in the level of performance metrics, which can be captured by past realizations of the data. However, note that even in this simple example, there is more information in the realized volatility of pay than there is in the realized volatility of stock returns, because of the presence of the term m_1^2 that is firm specific (see, for example, Aggarwal and Samwick, 1999). More generally, realized volatility of pay and realized volatility of stock returns may not even be proportional to each other as realized variance of pay entails the variance of other performance metrics and their covariances.

The main advantage of using realized variance over the Incentive Lab simulated variance is the fact that we are able to use a sample using Execucomp data with twice as many observations. The main disadvantage over simulated variance is that the realized variance is potentially a less efficient way to estimate ex-ante volatility if contract parameters are time variant. The Incentive Lab simulation approach is particularly versatile along this dimension as we obtain estimates of the variance of pay that condition on firm-year-CEO actual contract parameters. While it is unclear how much of a constraint this is for the realized variance approach, we note that assuming time invariant contract parameters is the standard assumption in empirical models of CEO pay that use panel data regressions.[13] There is another disadvantage of using realized variance and actual total pay (measured by Execucomp variable TDC1) relative to using simulated variance and total pay; TDC1 uses the fair value of options and time-vested restricted shares. Two CEOs, one with $1 million salary and no other compensation, and another with $1 million of time-vested options and no other compensation, will display zero realized volatility over time when in fact the riskiness of their contracts is very different. This is likely to bias downwards any estimate of the elasticity of pay to variance of pay.

3.3 Conditional variance using ARCH model of variance of pay

The last empirical approach to estimating σ_t^2 uses the autoregressive conditional heteroskedasticity (ARCH) model. To the best of our knowledge, this is the first paper that estimates an ARCH model for CEO pay. Empirically, we assume that variance of pay can be modeled using

$$\sigma_t^2 = \alpha + \sum_{j=1,\ldots,p} \delta_j \varepsilon_{t-j}^2. \tag{8}$$

with the parameters $\alpha, \delta_j \geq 0$, and $j = 1, \ldots, p$ indexes the number of ARCH terms. We estimate equations (3) and (8) jointly as an ARCH-in-mean model. The estimation uses pooled data and so the parameters α and δ_j in the volatility equation and the parameters in the mean equation (3) are assumed identical across firms. The estimation of these models is done in an unrestricted fashion and we check ex-post the non-negativity constraints on the variance-equation parameters, $\alpha, \delta_j \geq 0$.

The empirical approaches using Incentive Lab data and the ARCH model have the advantage over the realized variance approach of not requiring the assumption of time invariant contract parameters. The ARCH approach does require that the variance of pay be stationary, that is $\delta_1 + \cdots + \delta_p < 1$.

[13] Some evidence in rigidity in contract parameters can be found in Shue and Townsend (2015).

In sum, we rely on various approaches to estimate the conditional variance of pay, each having its own advantages and disadvantages. While each approach faces its own unique challenge, we show that we obtain similar results regardless of the approach used.

4. Data

We use two main datasets, Incentive Lab by Institutional Shareholder Services and ExecuComp. Incentive Lab contains detailed compensation contract information for the 750 largest U.S. firms collected from proxy statements (DEF 14A) for CEOs and other executives starting from 1998. ExecuComp contains a combination of firms from S&P 500, S&P Midcap, and S&P Smallcap 600, plus backfilling of companies who were in one of the indices at some point, starting from 1992. For both datasets, we restrict our sample to CEOs serving a full year. This restriction ensures that we include only complete annual compensation and not partial year compensation, which would increase estimates of pay volatility unrelated to risk. In addition, we use financial data from Compustat, stock return data from CRSP, data on board of directors from Institutional Shareholder Services, and institutional holdings data from Thomson Reuters Institutional (13F) Holdings. The variables used are described in the Appendix.

When using the Incentive Lab data, we restrict the sample period to 2006-2016. The year 2006 marks the availability of the plan-based awards table. We restrict attention to contracts that use absolute performance metrics only (contract details for relative performance goals are generally insufficient in Incentive Lab and including them would greatly increase the complexity of the estimation model) and to contracts with quantitative performance metrics (data is not available on qualitative performance metrics such as customer satisfaction to conduct a simulation exercise). We include bonus, RSU grants and option grants (both performance-vesting and time-vesting grants).

We identify the specific performance metrics used in each contract. including whether a given performance metric is scaled (either by shares outstanding or by sales) or is expressed as a growth rate. It also collects textual information to more precisely describe the metric (e.g., when Incentive Lab variable "metric" has the value of "Cashflow", Incentive Lab variable "metricOther" clarifies whether it is operating cash flow, free cash flow or net cash flow). We use this detailed information for each compensation contract. Despite the large volume of metrics data in Incentive

Lab, not all grants in ExecuComp have accompanying metrics data in Incentive Lab. To define our 'clean sample', we drop firms that have actual bonus, RSU, or option payments in ExecuComp but for which there is no information in Incentive Lab. The clean sample collects only firm-years for which we can simulate all known performance components. We construct an 'alternative sample' that also includes observations for which we do not have complete contract information for the CEO for a given year (e.g., we may have bonus contract details but not restricted stock details despite observing that the CEO was paid some restricted stock, as well as bonus, in that year).[14]

From Incentive Lab, we obtain 55,076 compensation contracts at the firm-year-grant-metric level for bonus, RSU, and option grants. We are left with 20,524 compensation contracts at the metric level after excluding contracts with some missing values for the performance metrics or payouts, contracts with incomplete metric information (i.e., not all metric information is available for a given grant), and contracts where information on actual compensation is not available (i.e., salary data). The 20,524 compensation contracts at the firm-year-grant-metric level consist of 2,901 metrics for bonus contracts, 8,978 for time-vested RSU contracts, 1,746 for performance-vested RSU contracts, 6,868 for time-vested option contracts, and 31 for performance-vested option contracts. Considering only the firm-year observations for which there is data on past firm performance available in Compustat, the 'alternative sample' aggregates to 18,914 firm-year grants, or to 6,805 firm-year observations.

Our goal is to simulate total compensation for a given year, which requires contract information for all grants to be available for each year. In many instances, contract information is available in Incentive Lab on one form of compensation but not on another form of compensation due to incomplete compensation disclosures on firms' proxy statements. We are able to identify the existence of incomplete compensation contract data because information on actual compensation components paid out is available in a separate file in Incentive Lab as well as in ExecuComp. To obtain the 'clean sample', we exclude firm-years with incomplete compensation contract information from the alternative sample. After this exclusion, the sample has 939 firm-

[14] Bettis et al. (2018) also simulate pay from contract data in Incentive Lab. Their focus is on the valuation of equity grants only, while ours is on estimating annual outcomes of all performance grants, which makes our simulation procedure more complex. Therefore, our data requirements are more significant, resulting in a smaller sample size.

year observations with data available in Compustat on past performance required for the simulation. The Online Appendix presents detailed results of the sample selection procedure.

Table 1 presents the distribution of performance metrics used in the compensation contracts at the metric level (Panel A) and descriptive statistics for the number of performance metrics per grant/year and the number of grants per CEO/year (Panel B). For both Panels A and B, Columns 1 to 4 present results for the clean sample and Columns 5 to 8 present results for the alternative sample.

Across all awarded contracts, the use of accounting-based performance metrics dominates that of stock price-based performance metrics. Excluding time-vested contracts, for the clean (alternative) sample, 99% (97%) of the performance metrics are accounting-based. Among accounting-based performance metrics, EPS, sales, operating income, and cash flow are the four most commonly used performance metrics in both the clean and alternative samples. Based on the clean sample, on average, each bonus (restricted stock and option) contract uses 1.57 (1.07 and 1) performance metrics, and each CEO receives 1.11 (1.35 and 1.24) grants per year. The maximum number of performance metrics used in bonus (restricted stock and option) contracts is 4 (3 and 2). These numbers are similar to those in the alternative sample.

Table 2 provides descriptive statistics for our sample firms. The average (median) of the logarithm of CEO total annual compensation flow, TDC1, obtained from ExecuComp, is 7.91 (7.92) close to the average (median) logarithm of simulated CEO pay of 8.4 (8.37) in the clean sample. We use the logarithm of one plus total annual compensation in the empirical analysis to mitigate the effect of skewness in compensation. In robustness tests, we use the inside wealth variable in Coles et al. (2006) to capture the lack of diversification that comes from past equity grants.

The mean three-year lagged stock return (assuming dividends reinvested) is 11 percent with a standard deviation of 25 percent. The mean one-year stock return is 16 percent with a standard deviation of 46 percent. The mean ROA is somewhat smaller and also less volatile. The logarithm of market value for the average firm is 7.45, slightly higher than the median value, consistent with our sample being skewed towards larger firms. Sample firms have 56 percent of board members hired by the CEO (coopt) on average and have 68 percent of average institutional ownership. The CEOs in our ExecuComp sample are on average 56 years old and stay in that role for about 8.2 years. About 11 percent of our sample CEOs are founders of their firms. The mean (median) firm stock return volatility (i.e., variance of stock returns over the last 36 months) is 0.11 (0.10). The mean (median) log CEO pay volatility (i.e., measured with realized volatility) is 13.80 (13.89) in the ExecuComp sample, whereas the simulated log CEO pay volatility (i.e., measured by the log of the variance of simulated compensation) is 14.32 (14.40) in the clean sample of the Incentive Lab data.

Figure 1 plots the cross sectional means of actual (from ExecuComp) and simulated pay (using Incentive Lab data for the clean sample) over time. Total compensation is reflected in the top left panel, bonus in the top right, restricted stock grants in the bottom left, and option grants in the bottom right panel. Overall, the simulation procedure does well in capturing the value of bonus, restricted stock, options, and total pay. ExecuComp bonus is the realized value of compensation and simulated bonus is its expected value, and as such it is natural to expect yearly deviations that wash away with a large enough sample. Similar to ExecuComp, we use Black-Scholes to assess the value of option grants. We differ from ExecuComp because we simulate the stock price at the end of the year, whereas ExecuComp takes the realized end-of-year price. As with bonus, we expect yearly deviations to wash away in a large sample. However, we find that in the later part of the sample, the ExecuComp bonus and options' values are systematically above their simulated (expected) counterparts. One possible explanation for the gap in bonus is that firms appear to adjust performance metrics to boost executive bonus compensation (Kim and Yang, 2014). One possible explanation for the gap in options pay is that we have found that ExecuComp sometimes reports the combined value of restricted stock and options as restricted stock. Contrary to Bettis et al. (2018), we do not find that simulated fair values of restricted stock grants using Incentive Lab data differ significantly from the values reported in financial statements.

Panel A in Figure 2 plots the percentage of firms in the clean sample that offer any of the compensation grants. Options were more popular earlier in the sample, whereas bonus and restricted stock grants became more popular later in the sample. These trends in the clean sample are very similar to those displayed in the ExecuComp sample as depicted in panel B.

Figure 3 reproduces Figure 1, but now using the alternative sample. In this sample, we have firms with incomplete data in Incentive Lab on one or more compensation grants and this mostly explains the gap between simulated values and reported values. The figure indicates that this gap appears stable through the sample period.

Figure 4 plots simulated and reported values of total compensation across industries for the clean sample and the alternative sample. As in Figures 1 and 3, there is a gap between total reported pay and total simulated pay, but there are no apparent differences in this gap across industries. Overall, our simulated data appear to be largely consistent with realized pay, on average, suggesting the simulation did not entail any particular bias.

5. Results

5.1 Main results on elasticity of pay to variance of pay

Table 3, panel A reports the results of panel regressions of the logarithm of TDC1 on the logarithm of simulated variance of pay using ordinary least squares. Columns 1 through 4 report the results using the clean sample and Columns 5 through 8 report the results using the alternative sample. Standard errors are clustered by firm when no fixed effects are present and by firm and year when fixed effects are present.

The coefficient on the logarithm of simulated variance of pay describes the elasticity of pay to variance of pay or the average risk and reward trade off. This coefficient is positive and statistically significant at 1% level across all specifications. When fixed effects are included, the coefficient estimates drop significantly in both samples (in the clean sample, for example, the coefficient associated with simulated variance of pay is 0.179 without fixed effects (Column 1) and 0.072 when both firm and year fixed effects are included (Column 2)). When we add controls for other economic determinants of compensation, the coefficient on the logarithm of simulated variance of pay slightly decreases in both samples (to 0.065 in the clean sample (column 3)). In columns 4 and 8, we remove the contemporaneous performance controls since the model in equation (5) suggests a specification with only lagged variables and obtain similar results. Overall, we find that the estimated elasticity is statistically significant across all regressions and that the alternative sample produces somewhat lower estimates but with greater statistical significance due to the larger sample size.

With the exception of skewness in pay, most of the remaining controls have been previously documented in the literature. Focusing on columns 3 and 7 of panel A, we find that the coefficient on skewness in pay is positive and statistically significant only in the alternative sample. This positive coefficient on skewness is consistent with loss aversion utility (Agren, 2006) and with the view that firms use stock options to provide excess pay to CEOs (Bebchuk and Fried, 2004, made this argument when options were not expensed). We also find that firms with better contemporaneous ROA and stock return performance pay more to their CEOs. CEO outside opportunities measured by the average industry return have a positive, though statistically insignificant effect on mean pay. Entrenchment measured by the variable "coopt" has a positive, though statistically insignificant effect on pay. CEO pay is higher at larger firms and at firms where the CEO is not the founder.

The higher estimated coefficients in the regressions without firm fixed effects in panel A of Table 3 reveal that the trade-off between variance of pay and mean pay comes both from across firms and within firms. The cross sectional finding of a large effect across firms can also be seen in Panel B of Table 3, where we report cross-sectional regressions (using the same specification as in columns 3 and 7 of Panel A) and a Fama-MacBeth estimate of the average effect.[15] This panel shows overwhelming evidence of a positive relation between mean pay and variance of pay across firms for all cross sections for both the clean and alternative samples. The magnitude of the trade-off has some temporal dispersion, with a mean estimated coefficient close in magnitude to the pooled regression estimates without firm fixed effects. One concern in studies of CEO pay over time is that significant regulatory changes may lead to structural breaks in the model, invalidating the analysis. The evidence in Panel B of Table 3 significantly dispels this concern by showing a consistent positive estimate over time (except for 2013 in the clean sample) of the elasticity when using only cross-sectional variation in the data.

Table 3, Panel C replaces the logarithm of TDC1 as a dependent variable with the logarithm of the simulated mean pay from Incentive Lab. The regression results in significantly higher parameters estimates for the elasticity of pay to variance of pay. These estimates may be biased because of the possibility of correlated measurement error from the simulation in both the right-hand-side and left-hand-side variables. Of notice, too, is the fact that the increase in point estimates is close in magnitude to the increase in *t*-statistics, which means that the standard errors of the estimates also increase significantly.

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[15] The standard error on the estimate is computed with the bias correction proposed in Pontiff (1996) that accounts for time series correlation of the residuals.

Table 4 repeats the same exercise but uses the realized variance obtained from ExecuComp variable TDC1 as a measure of the conditional volatility of pay. The dependent variable is as before, the logarithm of TDC1. As in Table 3, standard errors are clustered by firm when no fixed effects are present and by firm and year when fixed effects are present. Across all specifications, the estimated coefficients using realized variance of pay are positive and significant at 1%. In the specification without fixed effects, the estimated elasticity describing the risk and reward trade off in pay is positive and higher than that in the alternative sample using Incentive Lab data (0.246 versus 0.090 from Panel A in Table 3). Introducing fixed effects and other controls, however, lowers the magnitude of the elasticity to levels that are slightly lower than those in panel A of Table 3 for the alternative sample (0.025 versus 0.034). Except for skewness in pay, the control variables discussed above retain similar signs but have higher statistical significance. In the Online Appendix, we report the cross-sectional regression results using the realized variance. The results are qualitatively similar to those in Table 3, Panel B.

Table 5 presents the results with the ARCH-in-mean model. Contrary to the specifications in Tables 3 and 4, the dependent variable in Table 5 is the level, not the logarithm, of TDC1, so that we capture the conditional variance of pay, not the conditional variance of the logarithm of pay. The main independent variable remains the logarithm of the variance of pay. To interpret the coefficient on variance of pay as an elasticity, we divide the estimated coefficient by the mean of pay. We use industry fixed effects as opposed to firm fixed effects, because the ARCH estimation in Stata cannot handle the large number of firm-specific indicator variables.

The elasticity of mean pay to variance of pay is positive and statistically significant at 1% across all specifications. In Column 3, that coefficient is 127.5, which dividing by the mean of TDC1 of $4,714 (the unit of TDC1 is thousands) gives an elasticity of 2.7%. This estimate is remarkably similar to the effect using the realized variance described above and presented in Table 4. The ARCH coefficients across the four specifications in Table 5 are all positive as expected so that variance is positive throughout.

The evidence of a low elasticity presented above is especially surprising given potential contractual features linked to option grants that push the estimates upward. First, increases in firm return volatility increase average pay through the higher value of options, and increase the variance of pay through the higher variance in the value of options. Thus, options are a natural mechanism for firms to use to induce a positive relation between conditional volatility of pay and conditional mean of pay in response to changing volatility of firm stock returns. Second, Black-Scholes option values (used in TDC1 and in our simulation of option grants) overstate the value of options for under-diversified CEOs and understate their risk.

5.2 Risk aversion and risk premia

In this subsection, we assess the economic magnitude of the elasticity of pay to variance of pay. The estimated elasticity of pay to variance of pay can be transformed into an estimate of the risk aversion coefficient. Estimating the model using the logarithms of pay and variance of pay is useful to reduce the skewness in these variables and to facilitate interpretation of the estimates as elasticities. However, to our knowledge, this empirical specification is not a direct representation of any preference specification, which constrains our ability to report on an implied estimate of risk aversion. The closest we can get to an estimate of risk aversion is to assume that CEOs have constant relative risk aversion preferences and that pay is log normally distributed. In that case, we can show that the expected log pay (our dependent variable) equals the volatility of log pay (our independent variable is the log of the volatility of pay) times $(\gamma-1)/2$, where $\gamma>0$ is risk aversion. Estimates of the elasticity of pay to variance of pay in the regressions above with fixed effects are about 0.065, yielding estimates of risk aversion of approximately 1.13. To put this value into perspective, asset pricing studies typically assume that the coefficient of relative risk aversion is around 10! It is possible though that CEOs have lower risk aversion than the marginal investor. In calibrated models of CEO pay, Becker (2006) and Conyon, Core, and Guay (2011) assume that CEO relative risk aversion is either 2 or 3. Taylor (2013) estimates CEO risk aversion to be 2.8. Still, Taylor's estimate is substantially higher than our estimate of risk aversion; it corresponds to an elasticity of pay to variance of pay of 0.9 (i.e., (2.8-1)/2=0.9), about 14 times larger than our estimated elasticity.

Equation (5) demonstrates that in the benchmark moral hazard model, the risk premium associated with incentive pay is given by $\lambda\sigma_t^2$. We can therefore estimate the fraction of total pay that is directly tied to compensating the CEO for pay volatility. Using the clean sample, as an example, the elasticity of pay in Column 4 of Panel A in Table 3 is 0.065. Given that the average volatility of pay in the clean sample is 14.32 (see Table 2), the risk premium represents 12% of the average logarithm of TDC1 (i.e., 0.065x14.32/7.91). Compared to the other estimated point elasticities in the various specifications (alternative sample with simulated variance, realized volatility of pay, and ARCH), this is an upper bound on the risk premium paid to US CEOs for bearing pay volatility. Arguably the risk premium is small given that on average over 70% of CEO pay is incentive based.

We further decompose the risk premium between the components attributable to cash bonus, stock grants, and option grants. In the clean sample, the mean logarithm of volatility of bonus pay is 11.8; the mean logarithm of volatility of stock grants is 12.5; and the mean logarithm of volatility of options grants is 13.2 (untabulated), implying an approximately equal contribution of each component of pay at risk to the total risk premium.[16] On the one hand this result is somewhat unexpected given the emphasis in the literature in studying risk in equity pay (e.g., Conyon et al., 2011, and Fernandes et al., 2013). On the other hand, it is arguably related to the fact that bonus pay represents a large fraction of total pay (on average bonus pay is 23% of total pay, whereas the average amount of stock grants is only 18% of total pay and the average amount of option grants is 23% of total pay, with the rest being salary).[17]

Overall, our findings of an implied low risk aversion coefficient and low risk premium can help explain the significant growth in incentive pay in the U.S. The results also cast doubt on using the moral hazard model, which relies on risk sharing arguments in the optimal design of incentives as a benchmark to explain the cross section of CEO pay in the US. Instead, our results are consistent with the claim in Murphy and Jensen (2018) that the growth in incentive pay in the US is unrelated to the provision of economic incentives and risk and reward arguments.

5.3 Alternative hypotheses

[16] The logarithm of the variance of pay is not equal to the sum of the logarithm of the variance of bonus, plus the logarithm of the variance of equity grants, plus the logarithm of the variance of options grants. However, it is the fact that the variances are of similar magnitude, not their specific levels, that indicates that the contribution of each to the total risk premium is the same.

[17] If we consider only the period after 2006, because of the shift away from options, these numbers are: bonus pay is 24% of total pay, stock grants is 29% of total pay, and the average amount of option grants is 15% of total pay, with the rest being salary.

This section considers several extensions of the basic Grossman and Hart model that could explain the finding of a low elasticity of mean pay to variance of pay.

Following Oyer (2004), Laffont and Martimort (2002) and Nickerson (2017), CEO's outside opportunities may be type dependent, correlating positively with CEO pay. If the CEO's outside opportunities happen to covary negatively with the variance in pay, then mean and variance of pay may be negatively related causing a downward bias in the elasticity due to an omitted variable problem. Following Himmelberg and Hubbard (2000), and Oyer (2004), the regressions above use lagged values of stock performance of the firm's industry, and lagged own stock performance, respectively, to describe outside opportunities.[18]

An entrenched CEO may be able to guarantee an expected utility under the optimal contract that is above her reservation utility, generating slack in the participation constraint that depends on the level of CEO entrenchment. If greater slack comes with high volatility of pay, and this effect is strong enough, then mean and variance of pay would be positively related in ways that do not reflect the risk and reward trade off that we investigate. The regressions above use Coles et al. (2014) co-opted board measure as well as the percentage ownership by institutional investors to capture the possibility of rent seeking by the CEO.

If the utility function is nonseparable in consumption and effort, then incentives may be provided by reducing the marginal cost of effort. For example, higher CEO pay creates status enjoyed by the CEO that reduces the cost of effort for the CEO. In such cases, the participation constraint is not binding and the risk and reward trade-off in pay may not be directly implied by the participation constraint (see Laffont and Martimort, 2002). For cost of effort proxies, in the regressions above we use CEO age and log of CEO tenure, the volatility of stock returns, an indicator variable for when the CEO is the founder, and the lagged value of the firm's market capitalization.

We include in the regressions simulated skewness. Hemmer, Kim and Verrecchia (2000), Ross (2004), and Chaigneau (2015) using a more general utility specification than mean-variance utility predict a preference for positive skewness, besides a disutility to volatility associated with risk aversion. A prudent CEO would prefer positive skewness in pay if she dislikes downside risk, i.e., the third partial derivative of utility with respect to pay is positive (Chaigneau, 2015). A

[18] In untabulated results, we control outside opportunities using industry times year fixed effects and find similar results to those shown above.

prudent CEO requires less mean pay if awarded a contract with positively skewed payouts, say through option grants. In addition, if skewness in pay is positively related to the variance of pay, then a strong enough effect of volatility of pay on skewness can introduce a downward bias in the relation between mean and volatility of pay due to an omitted variable. The effect of skewness of pay on mean pay is not unambiguous. Agren (2006) shows that loss averse investors prefer negative skewness, which predicts that skewness should instead have a positive association with mean pay.[19]

We control for CEO overconfidence. There is evidence that CEOs overestimate the performance of their investments while underestimating the risks (e.g., Dittrich et al., 2005, Huang and Kisgen, 2013, Kolasinski and Li, 2013, and Malmendier and Tate, 2005 and 2008). This overconfidence can be used by the shareholders to save on the costs of incentive provision by offering contracts that are incentive-intensive (Gervais, Heaton and Odean, 2011). We use the Humphery et al. (2016) overconfidence indicator that is based on whether the CEO holds deep-in-the money options that have vested.

Laffont and Martimort (2002) show that in moral hazard models if the agent is risk neutral and there is a limited liability constraint that sets a lower bound to pay, then this new constraint together with the incentive compatibility constraint imply the participation constraint. That is, if the limited liability constraint is binding, then the principal is constrained in her ability to induce effort and the participation constraint may be slack. In this case, the risk-return trade-off breaks down. This explanation is less realistic unless one wants to dismiss the long-standing assumption of risk averse CEOs. Accordingly, we do not explore it further.[20]

6. Robustness analysis

Because the theoretical motivation for the elasticity of pay to variance of pay ties its value to risk aversion, we consider several proxies of risk aversion and modify our estimation by allowing the

[19] Interestingly, Dittmann et al (2010) show that options are still optimal with loss averse agents.
[20] In addition to the control variables shown in the paper, we have also used IPO activity, average industry ROA, and median of peer pay as proxies for outside opportunities. We also have included a concentration index of institutional holdings to proxy for governance, and a concentration index for business segments and book-to-market value to proxy for job complexity. For brevity and because these variables are insignificant, we drop them from the main results.

sensitivity of pay to variance of pay to depend on these proxies. Haubrich (1994) shows that in the agency models of Grossman and Hart (1983) and Holmstrom and Milgrom (1987), equity incentives increase sharply as CEO risk aversion decreases. This suggests that the low elasticity may be driven by the presence of a few low risk averse CEOs. To proxy for risk aversion, we consider CEOs' early-life exposure to fatal disasters (Bernile et al., 2017), whether the CEO possesses a private pilot license (Cain and McKeon, 2016), whether the CEO is a depression baby (Malmendier and Nagel, 2011), CEO gender (Borghans et al., 2009), and CEO marital status (Roussanov and Savor, 2014). We do not find any significance of these proxies using any of our variance of pay proxies. The results are available upon request.

There is a literature going back to Jensen and Murphy (1990) and Hall and Liebman (1998) that suggests that incentive risk stems also from CEOs' holdings of stock and options from prior grants. As a result, a criticism of our exercise is that variation in annual pay may constitute a relatively small proportion of the incentive risk imposed on the typical CEO (e.g., Core et al., 2003). In Table 6, we present two tests of alternative ways in which CEO firm equity wealth may affect the estimates of the elasticity of pay to volatility in pay. In the first test, we add the volatility of CEO inside wealth (calculated as in equation (6)) as a control variable using the inside wealth variable in Coles et al. (2006). Table 6 shows that the volatility of CEO inside wealth is not a statistically significant additional source of risk premium once we control for the volatility of current pay (compare the results in columns 1 and 2 with that in column 3). One interpretation is that our estimate speaks to the cost born out of volatility in current pay only; the cost of volatility associated with previous equity awards does not affect current pay arguably because the CEO has already been compensated in the past for such volatility. In the second test, we interact a dummy that equals one for values of the level of CEO wealth in the top quintile with the variance of pay. We test the hypothesis that a CEO with high levels of firm equity is less diversified and commands a higher risk premium for current incentive payouts. The point estimate on the interaction term is positive, consistent with the hypothesis, but the effect is small and statistically insignificant (see columns 4 and 5). Overall, we do not observe that CEO inside wealth, its level or volatility, significantly changes our main results.

The Online Appendix includes a proxy for risk of turnover to the regressions. We find that the prospect of forced turnover is associated with less pay to the CEO, contrasting with evidence in Peters and Wagner (2014). We also find that the estimated elasticity of pay to variance of pay is virtually unchanged. The reason for the similarity in results with regards to the elasticity is the small unconditional probability of CEO forced turnover in the US (Peters and Wagner, 2014, show that it is just under 3%).

We also report in the Online Appendix the results from simulating mean pay and the variance of pay using concurrent (i.e. measured in time *t*) variables as the mean in the conditional distribution of the performance metrics. This specification presumes that the board has perfect foresight when designing the contracts, which is unrealistic but constitutes an upper bound on the board's information set. The analyses reported in Section 5 constitute a lower bound on the board's information as it assumes the board relies solely on past information. Overall, the results on the elasticity of pay to variance of pay are largely unchanged.

In summary, although we cannot fully rule out the possibility that the low compensation for risk in the cross section of U.S. CEOs is not subject to an omitted variable bias, we are comforted by the result that our conclusion does not change after inclusion of a long list of controls in the regressions and of several robustness tests.

7. Conclusion

We examine the cost of incentive provision due to CEO risk sharing, a theoretically motivated measure. The benchmark moral hazard model of Grossman and Hart (1983) has a fundamental prediction imbedded in the model's participation constraint that mean pay and the volatility of pay are positively related; incentive pay is costly due to CEO's lack of diversification. Using a variety of methods to test this prediction and a variety of datasets for US CEOs, including simulations using detailed data collected by Incentive Lab on CEO contracts, we find a positive association between mean pay and variance of pay. However, the compensation for risk in pay appears too small to be fully consistent with standard risk diversification arguments.

Our results cast doubt on the ability of the benchmark moral hazard model to explain the cross-section of US CEO pay. We have considered several extensions to this model in an attempt to explain its limited success. None of the extensions considered changes the qualitative nature of our conclusion. Within the context of optimal contracting models, there are departures from the Grossman and Hart (1983) model that are worth studying in future research. One is to introduce dynamic considerations. For example, models of career concerns (Axelson and Baliga, 2009, Gibbons and Murphy, 1992, or Noe and Rebello, 2012) will have an implicit trade-off between mean and volatility of consumption streams as opposed to mean and volatility of current pay. Another is agent heterogeneity. Models with adverse selection in agent type or models of assortative matching (e.g., Tervio, 2008, and Edmans, Gabaix and Landier, 2009) generally predict that the participation constraint holds for only one agent type. If CEO compensation data come from a cross section where the participation constraint holds only for a few of the CEOs, then there is a downward bias in the risk and reward trade off.

While this paper tries to assess the cost of incentive provision due to CEO's lack of diversification, the larger question of what is the optimal level of incentives still remains. Future research should concentrate on developing more tools directed at identifying and quantifying the benefits of incentive provision.

Appendix

This appendix further details on the simulation exercise using Incentive Lab data. It also contains a table with the definitions of variables used in the paper.

Simulation using the Incentive Lab data

We use information available at the beginning of the year to simulate expected pay and variance of pay for the current year.

Firms use two types of incentive pay to reward their CEOs: (i) time-vested incentive pay, and (ii) performance-vested incentive pay. Time-vested incentive pay includes time-vested restricted stock units (RSU) and time-vested options: a certain number of RSU or options is granted with the passage of time, regardless of actual firm performance. Performance-vested incentive pay includes bonus, performance-vested RSU, and performance-vested options: the amount of cash or the number of RSU or options granted depends on actual firm performance as prescribed in the compensation contracts. For time-vested incentive pay, the grant itself is not linked to specific performance targets; only the valuation of the equity grants is linked to firm performance reflected in stock price. For performance-vested incentive pay, both the grant itself and the valuation (of equity grants) are linked to firm performance: CEOs need to first meet the performance targets prescribed in the compensation contracts to earn the grants, and then the valuation of the equity grants is further linked to firm performance reflected in stock price.

For time-vested incentive pay, we conduct a one-step simulation exercise: we simulate expected stock price (by simulating price to lagged sales ratio), and then multiply simulated stock price by the number of RSU or options granted to get the dollar value of expected equity incentive pay. For performance-vested incentive pay, we conduct a two-step simulation exercise: first we simulate expected firm performance; then we fit expected firm performance to the pre-determined compensation contracts to estimate the amount of bonus or the number of RSU/options granted; for RSU and options, we also simulate expected stock price to convert expected number of RSU/options into dollar values. We provide details of the two-step simulation exercise for performance-vested incentive pay below.

For performance-vested incentive pay, we take two inputs for the simulation: (i) compensation contract information from Incentive Lab, which describes the relationship between the chosen performance metric (metrics) and the corresponding performance-based compensation (i.e., cash bonus or equity grants), and (ii) actual performance in the past five years from Compustat, the mean and variance (covariance) of which are used to estimate simulated performance for the current year. We then fit the simulated performance from (ii) to the compensation contracts estimated in (i) to generate simulated pay. Since we simulate 10,000 times for each firm-year-CEO-grant, we can calculate the expected pay and variance of pay from the 10,000 simulations for each firm-year-CEO. We describe details of the procedures below.

Compensation contract fitting. We estimate the compensation contracts using the Incentive Lab data. Incentive Lab data provides information on: (i) the performance metrics used in the compensation contracts (variable name: "metric"), (ii) the threshold, target, and maximum level of each performance metric (variable names: "goalThreshold", "goalTarget", and "goalMax"), and (iii) the threshold, target, and maximum level of the compensation (variable names: "nonEquityThreshold", "nonEquityTarget", and "nonEquityMax" for bonus, and "equityThreshold", "equityTarget", and "equityMax" for equity grants).

When actual firm performance is below the threshold of the performance metric indicated in the contract, the CEO does not earn any performance-based compensation; when actual firm performance equals the target performance metric indicated in the contract, the CEO earns the target amount of performance-based compensation; when actual firm performance is above the maximum of the performance metric indicated in the contract, the CEO earns the maximum amount of performance-based compensation; when actual performance falls between the threshold and the maximum of the performance metric indicated in the contract, the CEO earns performance-based compensation in the amount between the target and the maximum of the performance-based compensation indicated in the contract.

For firms with no missing values of the contract details (i.e., threshold, target, and maximum for the performance metric and the performance-based compensation), we can fit the compensation contracts using either (i) piece-wise linear estimation (i.e., two linear slopes: one between the threshold and the target, the other between the target and the maximum), or (ii) quadratic estimation. For firms with missing values of the target performance metric or target compensation, we have to fit the compensation contracts using the linear estimation (i.e., one linear slope between the threshold and the maximum). We drop firms with missing values of the threshold or the maximum, because the missing values make it impossible to estimate the contracts.

We implement the contract estimations in four steps. In the first step, we construct a sample of compensation contracts that meets the following three criteria: (i) using absolute performance metrics only, (ii) including cash and equity compensation contracts only, and (iii) including contracts for CEOs only. In particular, we start with the Absolute Performance Goals Data (referred to as "GpbaAbs" by Incentive Lab) to get all compensation contracts using absolute performance metrics. We drop firms that use relative performance metrics in addition to absolute performance metrics, (i.e., the variable "numRelative" has a positive value). We then limit the sample to cash and equity compensation contracts by merging the Grants of Plan-Based Awards Table (referred to as "GpbaGrant"): we keep contracts where the "AwardType" variable in GpbaGrant has the value of "cashShort", "cashLong", "Option", or "rsu". Next, we limit the sample to include contracts for CEOs only by merging the Participant Data by Fiscal Year (referred to as "ParticipantFY"): we keep contracts where the "currentCEO" variable in ParticipantFY has the value of one.

In the second step, we classify each firm-year-CEO into one of seven groups: (i) firm-years with bonus contracts only, (ii) firm-years with RSU contracts only, (iii) firm-years with option contracts only, (iv) firm-years with bonus and RSU contracts only; (v) firm-years with bonus and option contracts only; (vi) firm-years with RSU and option contracts only, and (vii) firm-years with bonus, RSU, and option contracts. We separately examine the seven groups because we need to ensure contract details are available for simultaneously simulating all performance metrics for a given firm-year-CEO. Some firms may have an actual compensation component without disclosing the contract details. For example, a firm may have reported values of RSU grants in ExecuComp, but lack contract details on Incentive Lab (either not listed in GpbaAbs or showing missing values of the contract details in GpbaAbs); these firms are dropped in our clean sample, but kept in our alternative sample. In constructing our sample, we first use Incentive Lab contract information to classify the seven groups of firms described above; the seven groups combined is our alternative sample. We then merge the alternative sample with actual compensation from

ExecuComp to construct the clean sample.[21] The online appendix tabulates the sample selection process.

In the third step, we pinpoint the specific performance metrics used in each contract. In particular, "GpbaAbs" has five relevant variables for this task: (i) the variable "metric" lists the name of the performance metric, (ii) the indicator variable "metricIsPerShare" describes whether the performance metric is scaled by the number of common stocks; (iii) the indicator variable "metricIsMargin" describes whether the performance metric is scaled by sales; (iv) the indicator variable "metricIsGrowth" describes whether the performance metric is measured as the growth rate; and (v) the variable "metricOther" provides additional textual information about the performance metric. For example, when "metric" has the value of "Cashflow", several possibilities exist: if all three indicator variables equal zero, it means the performance metric used in the contract is the dollar amount of cash flow; if "metricIsPerShare" equals one, "metricIsMargin" equals zero, and "metricIsGrowth" equals one, it means the performance metric used in the contract is the growth rate of cash flow per share. In addition, the textual description in "metricOther" may indicate it is operating cash flow or free cash flow rather than net cash flow. We consider all possible combinations of the indicator variables as well as the additional

[21] We use the following procedures to construct our sample consisting of seven groups of firms described before. (i) The "bonus only" group in the *alternative* sample consists of firms that only have bonus contract information in Incentive Lab (i.e., no RSU or option contract information available). To get from the "bonus only" group in the *alternative* sample to the "bonus only" group in the *clean* sample, we exclude firms having actual RSU payment or actual option payment or both as indicated in ExecuComp. (ii) The "RSU only" group in the *alternative* sample consists of firms that only have RSU contract information in Incentive Lab (i.e., no bonus or option contract information available). To get from the "RSU only" group in the *alternative* sample to the "RSU only" group in the *clean* sample, we exclude firms having actual bonus payment or actual option payment or both as indicated in ExecuComp. (iii) The "options only" group in the *alternative* sample consists of firms that only have option contract information in Incentive Lab (i.e., no bonus or RSU contract information available). To get from the "options only" group in the *alternative* sample to the "options only" group in the *clean* sample, we exclude firms having actual bonus payment or actual RSU payment or both as indicated in ExecuComp. (iv) The "bonus and RSU only" group in the *alternative* sample consists of firms that only have bonus and RSU contract information in Incentive Lab (i.e., no option contract information available). To get from the "bonus and RSU only" group in the *alternative* sample to the "bonus and RSU only" group in the *clean* sample, we exclude firms having actual option payment as indicated in ExecuComp. (v) The "bonus and options only" group in the *alternative* sample consists of firms that only have bonus and option contract information in Incentive Lab (i.e., no RSU contract information available). To get from the "bonus and options only" group in the *alternative* sample to the "bonus and options only" group in the *clean* sample, we exclude firms having actual RSU payment as indicated in ExecuComp. (vi) The "RSU and options only" group in the *alternative* sample consists of firms that only have RSU and option contract information in Incentive Lab (i.e., no bonus contract information available). To get from the "RSU and option only" group in the *alternative* sample to the "RSU and option only" group in the *clean* sample, we exclude firms having actual bonus payment as indicated in ExecuComp. (vii) The "bonus, RSU, and options" group in the *alternative* sample consists of firms that have bonus, RSU, and option contract information in Incentive Lab. The sample composition for this group is the same for both the *alternative* sample and the *clean* sample.

information in the textual description from “metricOther” to pinpoint the performance metric used in each compensation contract.

In the fourth step, we fit the contract using linear or quadratic estimation. Specifically, for firms with no missing values for the contract details, i.e., firms with all three pairs of data points available: the threshold x1 and y1, the target x2 and y2, and the maximum x3 and y3 (x refers to performance and y refers to compensation), we use both methods to fit the same contract: piece-wise linear and quadratic. For firms with missing values for the contract target, i.e., firms with only two pairs of data points available: the threshold x1 and y1, and the maximum x2 and y2, we use the linear method to fit the contract. Once the contracts are estimated, we can then apply the simulated performance to get simulated compensation. We present results from the linear estimation in the paper; results from the quadratic estimation are available upon request.

Performance Simulation. We simulate current year performance using actual performance in the past five years from Compustat. The Incentive Lab contract information is presented at the firm-year-grant-metric level. It is possible for firms to use more than one performance metric for a given grant (contract). It is also possible for firms to set up several grants (contracts) for the same CEO in a given year. We consider all metrics used for a given firm-year-CEO and simultaneously simulate all metrics for that year. In particular, for each CEO and year, we assume a multivariate normal distribution for all performance metrics used for a given CEO across all contracts; we set the mean of the joint normal distribution equal to the actual values in the previous year (i.e., year $t-1$),[22] and set the covariance matrix for the joint normal distribution equal to the covariance matrix calculated from the actual values of the performance metrics in the past five years (i.e., years $t-5$ to $t-1$). Using these assumptions, we run 10,000 simulations for each firm-year-grant-metric, which provides simulated performance for estimating simulated compensation.

In our main test, we convert the performance metrics stated in dollar amount into scaled variables to make the covariance matrix comparable with other scaled metrics (i.e., metrics expressed as a rate or ratio such as growth rate, margin, per share value, ROA, etc.). In particular, when the performance metric is the dollar amount of sales, we simulate the firm's sales growth rate, and then get the dollar amount of simulated sales as $simulated\, sales_t = sales_{t-1} \times (1 + simulated\, sales\, growth\, rate_t)$; when the performance metric is operating income, profits

[22] In a robustness check, we set the mean of the joint normal distribution equal to the actual values in the current year (i.e., year t), and get qualitatively similar results.

before tax, net income, cash flow, etc., which can have negative values in the past five years, we simulate the corresponding performance scaled by lagged total assets, and get the dollar amount of the simulated performance as $simulated\ performance_t = total\ assets_{t-1} \times simulated\ scaled\ performance_t$.[23]

While bonus contracts are written on the dollar value of cash payment, equity grants are written on the number of shares granted. Thus we need a price estimate to convert the simulated number of shares granted to the dollar value. Because price is related to accounting performance, we avoid simulating price directly; instead, we simulate the price to lagged sales ratio to get simulated price. In particular, $simulated\ price_t = sales_{t-1} \times simulated\ price\ to\ lagged\ sales\ ratio_t$. Because of the price estimates, for all CEOs with restricted stock grants or option grants, the covariance matrix for the joint normal distribution includes the price to lagged sales ratio as an additional input variable in addition to the actual performance metrics used in the compensation contracts.

Compensation Simulation. We calculate simulated compensation by fitting the simulated performance to the estimated compensation contracts. Since the simulated performance is conducted at the firm-year-CEO-grant-metric level, we first calculate the simulated compensation at the firm-year-CEO-grant-metric level. We then collapse the metric level compensation into the grant level compensation based on information in the variable "performanceGrouping", which describes the relationship between the various performance metrics.

The compensation contracts can be described in two overall patterns: (i) separable contracts, and (ii) non-separable contracts. While separable contracts allow CEOs to earn part of the bonus (or equity grant) when some of the performance metrics are not met, non-separable contracts result in zero bonus (or equity grant) if any of the performance metric is not met.

Incentive Lab assumes that the performance metrics in the separable or non-separable contracts are equal weighted (data on metric weights are not collected by Incentive lab). Take the example of a separable contract with three performance metrics, each metric is worth one third of the total compensation indicated in that contract. As a result, we assign the weight of one third to each simulated pay at the metric level, and add the weighted pay from all three metrics to get total simulated pay at the grant level. For CEOs with more than one grant in a given year, we add

[23] In a robustness check, we simulate the dollar amount of performance metrics directly without the scaled conversion. We obtain similar results whether the simulated performance is scaled or not.

simulated pay from all grants for a given CEO. As explained before, if a contract is separable, it is possible for a CEO to miss some performance metrics and still earn some performance-based compensation.

For non-separable contracts, we impose an additional requirement for consolidating the metric level simulated pay to the grant level simulated pay: if any of the simulated performance metric does not meet the goal threshold set in the contract, then the total grant level simulated pay is zero.

Once we have 10,000 simulated pay at the firm-year-CEO level, we can calculate the mean, variance, and skewness of the simulated pay from the 10,000 simulated results for each firm-year-CEO. To make simulated total pay comparable to TDC1 in ExecuComp, we set expected total pay for the current year using information available at the beginning of the year to be the sum of: (i) salary, (ii) mean simulated pay from the procedures described above, (iii) other compensation (Compustat variable "othcomp"), and (iv) non-performance-based bonus (Compustat variable "bonus" after 2006). Since salary is constant for a given year, assuming zero variance and skewness of other compensation, expected variance of total pay equals variance of simulated pay, and skewness of total pay equals skewness of simulated pay.

Variable definitions

Total Compensation (TDC1)	=	Total annual compensation flow is calculated as the sum of salary, bonus, other annual compensation (e.g., gross-ups for tax liabilities, perquisites, preferential discounts on stock purchases), long-term incentive payouts, restricted stocks granted during the year (determined as market value of the date of the grant), the value of stock options granted (estimated using the Black-Scholes formula or total grant-date present value of options awarded when Black-Scholes is not available), and all other compensation (e.g., payouts for cancellation of stock options, 401K contributions, signing bonuses, tax reimbursements) before 2006. After 2006, annual compensation flow is calculated as the sum of salary, bonus, non-equity incentive plan compensation, the grant-date fair value of option awards, the grant-date fair value of stock awards, and other compensation.
Log of TDC1	=	The natural logarithm of total compensation (TDC1).
CEO Inside Wealth	=	Value of the CEO's stock and option portfolio (in $000s) from Coles, et al. (2006) plus salary, bonus, and other annual compensation (othcomp) before 2006; or value of the CEO's stock and option portfolio plus salary, bonus, non-equity incentive plan compensation, and other compensation after 2006.
Simulated Mean Pay	=	Simulated total annual compensation, calculated as the sum of (i) salary, (ii) the mean value of the sum of simulated bonus, simulated restricted stock, and simulated stock options from 10,000 simulations for each firm-year-CEO; (iii) other annual compensation (Compustat variable "othcomp"), and (iv) non-performance-based bonus (Compustat variable "bonus" after 2006).
Log of Simulated Mean Pay	=	The natural logarithm of simulated total annual compensation.
3-Year Stock Return	=	The 3-year total return to shareholders, including the monthly reinvestment of dividends.
Firm Volatility	=	The standard deviation of monthly stock returns calculated over months $t-37$ to $t-1$.
Average Industry Return	=	Average of all the firms' annual stock return that are in the same industry, defined as firms in the same 4-digit Global Industry Classification System (GICS).
Log of Market Capitalization	=	The natural logarithm of the market capitalization, calculated as number of shares outstanding multiplied by the firm's stock price at the end of fiscal year.

Overconfidence	=	Indicator variable equal to one if the CEO has held options for at least two years in a row that are deep in the money, where deep in the money is defined as when the average value per option is at least 67% of the option strike price, zero otherwise.
Co-Opted Board (Coopt)	=	Indicator variable equal to one if the number of directors hired after the CEO took office is above the sample mean, zero otherwise.
CEO Age (Age)	=	The age of the CEO while in office.
Log of CEO Tenure	=	The natural logarithm of the number of years the CEO has been in office at the firm.
CEO is Founder (Founder)	=	Indicator variable equal to one if the CEO is also the founder of the firm, zero otherwise.
Institutional Holdings Percent	=	Percentage of the firm's shares outstanding that are owned by all institutional investors. This is obtained by Thomson Reuters Institutional (13f) Holdings – Stock Ownership (variable "instown_perc").
Realized Variance of CEO Pay	=	The natural logarithm of the variance of CEO total pay flow (TDC1) calculated over the last 5 years ($t-5$ to $t-1$).
Realized Variance of CEO Wealth		The natural logarithm of the variance of CEO inside wealth calculated over the last 5 years ($t-5$ to $t-1$).
Simulated Variance of CEO Pay	=	The natural logarithm of the variance of the sum of simulated bonus, simulated restricted stock, and simulated stock options from the 10,000 simulations for each firm-year-CEO.
Realized Skewness of CEO Pay	=	Skewness of CEO total pay flow (TDC1) calculated over the last 5 years ($t-5$ to $t-1$).
Realized Skewness of CEO Wealth	=	Skewness of CEO inside wealth calculated over the last 5 years ($t-5$ to $t-1$).
Simulated Skewness of CEO Pay	=	Skewness of the sum of simulated bonus, simulated restricted stock, and simulated stock option from the 10,000 simulations for each firm-year-CEO.

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Table 1. Frequency Distribution of Performance Metrics

Panel A reports the frequency distribution of the performance metrics used in compensation contracts at the metric level. Panel B reports descriptive statistics for the number of performance metrics per grant/year, and the number of grants per CEO/year. For both Panel A and Panel B, Columns 1 to 4 (5 to 8) present results for the clean (alternative) sample.

Panel A. Metric Level Information

	Clean Sample				Alternative Sample			
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	Bonus	Restricted Stock	Options	Combined	Bonus	Restricted Stock	Options	Combined
Book Value	0	2	0	2	0	2	0	2
Cashflow	87	23	0	110	189	78	3	270
EBIT	31	7	0	38	53	12	0	65
EBITDA	62	13	0	75	141	75	5	221
EBT	37	13	0	50	82	27	0	109
EPS	194	56	4	254	372	269	6	647
Earnings	60	19	0	79	127	44	0	171
FFO	8	1	0	9	17	5	0	22
Operating Income	76	20	0	96	210	86	3	299
Profit Margin	14	3	0	17	38	22	0	60
ROA	18	4	0	22	29	22	0	51
ROE	41	22	1	64	76	83	1	160
ROI	4	1	0	5	6	3	0	9
ROIC	47	38	0	85	86	125	0	211
Sales	130	26	1	157	274	173	7	454
Stock Price	2	3	1	6	10	72	2	84
Time	0	880	821	1,701	0	5,318	5,022	10,340
Total (metric level)	**811**	**1,131**	**828**	**2,770**	**1,710**	**6,416**	**5,049**	**13,175**

Table 1. Panel B. Grant Level and CEO Level Information

	Clean Sample				Alternative Sample			
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	Bonus	Restricted Stock	Options	Combined	Bonus	Restricted Stock	Options	Combined
Number of performance metrics per grant/year								
Min	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Mean	1.57	1.07	1.00	1.15	1.53	1.05	1.00	1.07
Std. Dev.	0.71	0.27	0.03	0.43	0.70	0.24	0.06	0.31
Skewness	1.18	3.98	28.71	3.24	1.27	6.00	31.01	5.05
Max	4.00	3.00	2.00	4.00	5.00	4.00	3.00	5.00
Number of grants per CEO/year								
Min	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Mean	1.11	1.35	1.24	2.57	1.08	1.29	1.15	1.81
Std. Dev.	0.38	1.00	1.23	1.61	0.33	0.80	0.74	1.15
Skewness	4.52	6.81	7.67	3.00	5.04	6.67	9.90	3.75
Max	4.00	13.00	12.00	13.00	4.00	15.00	12.00	15.00

Table 2. Descriptive Statistics

This table presents descriptive statistics for the variables used in the tests. The appendix gives detailed definitions of each variable, data source and time availability. *N* is the number of observations, and *Px* is the percentile *x* value of the sample distribution, with *x*=1, 25, 50 (median), 75, and 99.

VARIABLES	N	Mean	Std. Dev.	P1	P25	P50	P75	P99
ln of simulated CEO total pay (clean sample)	939	8.4	0.88	5.75	7.84	8.37	8.94	11.12
ln of total compensation (TDC1)	37,322	7.91	1.07	5.30	7.16	7.92	8.68	10.34
ln of CEO wealth	29,567	9.90	1.44	6.73	8.93	9.83	10.79	13.97
3-year shareholder return	34,963	0.11	0.25	-0.53	-0.03	0.10	0.23	1.02
Firm return volatility	35,936	0.11	0.06	0.04	0.07	0.10	0.14	0.34
Average industry return	37,319	0.16	0.24	-0.41	0.01	0.15	0.30	0.85
ln of market value	32,836	7.45	1.64	3.63	6.35	7.35	8.47	11.67
Overconfidence indicator	37,320	0.34	0.47	0.00	0.00	0.00	1.00	1.00
Co-opted board (coopt)	20,905	0.56	0.32	0.00	0.29	0.55	0.88	1.00
CEO age (age)	36,495	55.82	7.38	39.00	51.00	56.00	60.00	76.00
CEO tenure	34,731	8.23	7.39	0.92	2.92	5.92	10.92	35.92
Founder indicator (founder)	37,322	0.11	0.32	0.00	0.00	0.00	0.00	1.00
Percent of institutional ownership	29,852	0.68	0.22	0.07	0.54	0.70	0.83	1.13
Simulated variance of CEO pay (ln of variance(simulated pay)) (clean sample)	939	14.32	2.6	6.33	12.83	14.4	15.98	21.47
Realized variance of CEO pay (ln of variance(TDC1))	24,813	13.80	2.53	6.75	12.34	13.89	15.45	18.66
Realized variance of CEO wealth (ln of variance(wealth))	17,147	18.04	3.20	10.69	16.15	18.02	19.90	25.52
Simulated skewness of CEO pay (skewness(simulated pay)) (clean sample)	939	0.77	0.85	-1.01	0.1	0.64	1.19	4.00
Realized skewness of CEO pay (skewness(TDC1))	24,794	0.29	0.70	-1.33	-0.21	0.31	0.84	1.49

ROA	32,339	0.04	0.09	-0.43	0.01	0.04	0.08	0.25
Earnings volatility	32,344	0.05	0.10	0.00	0.01	0.03	0.06	0.42
MTB	32,341	1.91	1.23	0.76	1.14	1.49	2.16	7.76
Leverage	32,341	0.40	0.25	0.02	0.20	0.36	0.58	0.94
RET	32,344	0.16	0.46	-0.75	-0.11	0.11	0.35	2.12

Table 3. Panel A. The Risk and Reward trade off in TDC1 Using Simulated Conditional Volatility

This table presents results from regressions of the natural log of TDC1 on the natural log of simulated conditional variance of pay using Incentive Lab data and compensation contract information available at the beginning of each year. Columns 1—4 (5—8) report results using the clean sample (alternative sample). Columns 1 and 5 (2—4 and 6—8) report results without (with) firm and year fixed effects included. Robust *t*-statistics are reported in parentheses, clustered by firm (firm and year) in Columns 1 and 5 (2—4 and 6—8). Significance at 1%, 5%, and 10% is indicated by ***, **, and *, respectively.

	log of TDC1							
	Clean Sample				Alternative Sample			
VARIABLES	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
log simulated	0.179***	0.072***	0.065***	0.060***	0.090***	0.033***	0.034***	0.032***
variance of Pay	(10.65)	(4.60)	(3.86)	(3.63)	(14.71)	(8.37)	(6.93)	(5.80)
Simulated			-0.020	-0.010			0.011**	0.011**
skewness			(-0.79)	(-0.37)			(2.85)	(2.79)
Lag 3-year stock			0.240	0.232			0.120*	0.132*
return			(1.76)	(1.68)			(2.09)	(2.19)
Lag avg industry			0.141	0.135			0.067	0.083
return			(1.47)	(1.33)			(1.17)	(1.40)
Coopt			0.091	0.169			0.033	0.025
			(0.44)	(0.80)			(0.55)	(0.43)
Institutional			0.082	0.034			-0.125*	-0.139*
holding %			(0.27)	(0.10)			(-1.87)	(-1.97)
Firm return			-1.204*	-1.046			-0.651	-0.713**
volatility			(-2.08)	(-1.56)			(-1.71)	(-2.37)
Founder			-0.241	-0.252*			-0.128**	-0.133**
			(-1.79)	(-1.97)			(-3.07)	(-3.03)
Age			0.011	0.013			0.003	0.004
			(0.95)	(1.30)			(0.98)	(1.36)
Log CEO			0.038	0.034			0.069**	0.067**

tenure			(0.37)	(0.31)			(2.46)	(2.54)
Log lag market			0.314**	0.143			0.258***	0.144***
value			(2.86)	(1.73)			(8.24)	(5.62)
Overconfidence			-0.025	-0.046			-0.028	-0.018
			(-0.42)	(-0.82)			(-1.04)	(-0.62)
ROA			0.787**				0.344**	
			(2.25)				(2.73)	
Earnings			0.238				-0.152	
volatility			(0.32)				(-0.56)	
MTB			-0.069				-0.016	
			(-1.31)				(-0.88)	
Leverage			0.324				0.133	
			(0.88)				(0.96)	
RET			0.381**				0.260***	
			(3.06)				(7.00)	
Constant	5.954***				7.561***			
	(23.35)				(86.66)			
Observations	939	769	565	573	6,805	6,718	4,881	4,948
Adj. R-squared	0.322	0.805	0.809	0.795	0.135	0.772	0.813	0.802
Firm + Year FE	NO	YES	YES	YES	NO	YES	YES	YES
Cluster s.e.	Firm	Firm/Year	Firm/Year	Firm/Year	Firm	Firm/Year	Firm/Year	Firm/Year

Table 3. Panel B. Fama-MacBeth Regressions

This table presents results from Fama-Macbeth regressions of the natural log of TDC1 on the natural log of simulated conditional variance of pay using Incentive Lab data and compensation contract information available at the beginning of each year. Standard errors on the average slope are corrected according to Pontiff (1996). All control variables are included.

VARIABLES (RHS variance)	(1) Log of TDC1 Clean Sample	(2) Log of TDC1 Alternative Sample
CROSS SECTION		
2006	0.198	0.091
2007	0.151	0.093
2008	0.129	0.062
2009	0.181	0.085
2010	0.139	0.066
2011	0.176	0.073
2012	0.147	0.046
2013	-0.025	0.049
2014	0.024	0.050
2015	0.293	0.050
2016	0.108	0.035
Average slope	0.14***	0.06***
T-stat (corrected)	7.44	3.56
Observations	677	4,971
Number of groups	11	11

Table 3. Panel C. The Risk and Reward trade off in Simulated Pay Using Simulated Conditional Volatility

This table presents results from regressions of the natural log of simulated mean pay on the natural log of simulated conditional variance of pay using Incentive Lab data and compensation contract information available at the beginning of each year. Columns 1—4 (5—8) report results using the clean sample (alternative sample). Columns 1 and 5 (2—4 and 6—8) report results without (with) firm and year fixed effects included. Robust *t*-statistics are reported in parentheses, clustered by firm (firm and year) in Columns 1 and 5 (2—4 and 6—8). Significance at 1%, 5%, and 10% is indicated by ***, **, and *, respectively.

	log of Simulated Mean Pay							
	Clean Sample				Alternative Sample			
VARIABLES	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
log simulated	0.275***	0.217***	0.211***	0.214***	0.204***	0.175***	0.163***	0.163***
variance of pay	(22.80)	(17.81)	(17.84)	(17.94)	(33.10)	(21.60)	(17.39)	(18.19)
Simulated			-0.179***	-0.176***			-0.023*	-0.024*
skewness			(-4.65)	(-4.83)			(-1.89)	(-2.04)
Lag 3-year stock			0.072	0.085			0.161**	0.116*
return			(0.64)	(0.65)			(2.99)	(1.82)
Lag avg industry			-0.002	0.055			0.056	0.065
return			(-0.02)	(0.53)			(0.74)	(0.77)
Coopt			0.105	0.119			0.083	0.077
			(0.65)	(0.74)			(1.39)	(1.28)
Institutional			-0.473*	-0.509**			-0.072	-0.061
holding %			(-2.01)	(-2.30)			(-1.06)	(-0.93)
Firm return			-0.114	-0.271			0.125	0.108
volatility			(-0.18)	(-0.38)			(0.32)	(0.27)
Founder			-0.129	-0.132			-0.044	-0.043
			(-1.10)	(-1.21)			(-1.08)	(-1.09)
Age			-0.005	-0.009			0.002	0.003
			(-0.48)	(-0.67)			(0.95)	(1.04)
Log CEO			0.115	0.121			0.049	0.047

tenure			(1.37)	(1.24)			(1.49)	(1.39)
Log lag market value			0.188**	0.127*			0.198***	0.169***
			(2.26)	(1.94)			(7.22)	(7.11)
Overconfidence			-0.070	-0.083			-0.043	-0.055*
			(-0.89)	(-1.19)			(-1.66)	(-2.15)
ROA			0.345				0.185	
			(0.85)				(0.96)	
Earnings volatility			-0.730				-0.006	
			(-1.04)				(-0.02)	
MTB			-0.056				-0.040*	
			(-1.15)				(-1.99)	
Leverage			-0.141				0.278	
			(-0.53)				(1.73)	
RET			0.080				0.028	
			(0.88)				(0.71)	
Constant	4.463***				5.431***			
	(24.69)				(63.82)			
Observations	939	769	565	573	6,805	6,718	4,881	4,948
Adj. R-squared	0.658	0.841	0.847	0.847	0.545	0.740	0.757	0.753
Firm + Year FE	NO	YES	YES	YES	NO	YES	YES	YES
Cluster s.e.	Firm	Firm/Year	Firm/Year	Firm/Year	Firm	Firm/Year	Firm/Year	Firm/Year

Table 4. The Risk and Reward trade off in Pay Using Realized Conditional Volatility

This table presents results from regressions of the natural log of TDC1 on realized conditional volatility of pay. The measures of conditional variance of pay are lagged to reflect the information known at the beginning of the period and are based on TDC1. Robust *t*-statistics are reported in parentheses. Significance at 1%, 5%, and 10% is indicated by ***, **, and *, respectively.

	log of TDC1			
VARIABLES	(1)	(2)	(3)	(4)
Lag log realized var(TDC1)	0.246***	0.046***	0.025***	0.024***
	(38.92)	(6.29)	(3.39)	(3.24)
Realized skewness			-0.041***	-0.042***
			(-3.14)	(-3.15)
Lag 3-year stock return			0.224***	0.213***
			(3.69)	(3.39)
Lag avg industry return			0.092**	0.123***
			(2.70)	(3.79)
Coopt			0.161**	0.153**
			(2.76)	(2.54)
Institutional holding %			0.086	0.147
			(1.00)	(1.39)
Firm return volatility			-0.192	-0.260
			(-0.70)	(-0.93)
Founder			-0.102**	-0.092**
			(-2.62)	(-2.43)
Age			-0.006*	-0.007**
			(-1.83)	(-2.17)
Log CEO tenure			-0.004	0.004
			(-0.13)	(0.13)
Log lag market value			0.287***	0.166***
			(8.47)	(6.38)
Overconfidence			0.057**	0.072**
			(2.28)	(2.78)
ROA			0.599***	
			(3.23)	
Earnings volatility			0.050	
			(0.31)	
MTB			-0.017	
			(-0.95)	

Leverage			0.210	
			(1.59)	
RET			0.303***	
			(8.32)	
Constant	4.789***			
	(54.75)			
Observations	16,769	16,522	10,189	10,346
Adj. R-squared	0.4048	0.7600	0.7917	0.7825
Firm + Year FE	NO	YES	YES	YES
Cluster s.e.	Firm	Firm/Year	Firm/Year	Firm/Year

Table 5. The Risk and Reward trade off in Pay Using ARCH Conditional Volatility

The table presents estimates of ARCH-in-mean models on TDC1. The estimations assume an ARCH(p) model for the conditional heteroskedasticity; industry fixed effects are from one-digit SIC; the ARCH-in-mean term is the natural logarithm of the estimated variance of the left-hand side variable; t-statistics are computed using White robust standard errors; the residuals follow a student-t distribution and the priming values are obtained from the estimated variance of the residuals from OLS. Significance at 1%, 5%, and 10% is indicated by ***, **, and *, respectively.

	(1)	(2)	(3)	(4)
VARIABLES	TDC1	TDC1	TDC1	TDC1
Lag log var(TDC1)	128.0***	150.0***	127.5***	143.4***
	(12.02)	(12.41)	(6.97)	(7.33)
Constant	-87.0	-2242.4***	-14530***	-12734***
	(-0.52)	(-3.39)	(-16.31)	(-16.41)
Industry and Year FE	NO	YES	YES	YES
Controls - ALL	NO	NO	YES	NO
Controls - ALL but contemporaneous performance	NO	NO	NO	YES
ARCH(1) coefficient	2.16***	2.42***	1.58***	1.67***
	(22.33)	(20.10)	(13.80)	(13.72)
ARCH constant (in millions)	2.57***	2.37***	2.62***	2.28***
	(18.67)	(16.26)	(13.07)	(12.50)
Observations	37,322	37,322	10,530	10,369

Table 6. The Effect of CEO Wealth on the Elasticity of Pay

The table evaluates the effect of CEO wealth on the elasticity of pay. The dependent variable is the natural log of TDC1. Columns 1, 3, and 4 (Columns 2 and 5) use simulated conditional variance of pay and simulated skewness of pay (realized variance of pay and realized skewness of pay) from the alternative Incentive Lab sample (ExecuComp sample). Highwealth is defined as CEO wealth in the top quintile of the distribution. All regressions include firm and year fixed effects. Robust *t*-statistics are reported in parentheses, clustered by firm and year. Significance at 1%, 5%, and 10% is indicated by ***, **, and *, respectively.

	log of TDC1				
VARIABLES	(1)	(2)	(3)	(4)	(5)
Log variance of pay	0.030***	0.018*		0.034***	0.018*
	(3.99)	(1.88)		(6.65)	(1.97)
Log variance of CEO wealth	-0.001	-0.003	0.003		
	(-0.14)	(-0.55)	(0.56)		
Highwealth				-0.047	0.001
				(-0.55)	(0.00)
Log variance of pay*Highwealth				0.001	0.002
				(0.19)	(0.16)
Controls - ALL	YES	YES	YES	YES	YES
Observations	2,562	8,197	2,562	3,739	8,016
Adj. R-squared	0.830	0.781	0.824	0.816	0.780
Firm + Year FE	NO	YES	YES	YES	YES
Cluster s.e.	Firm	Firm/Year	Firm/Year	Firm/Year	Firm/Year

Figure 1. Clean Sample Simulated Pay Versus Actual Pay

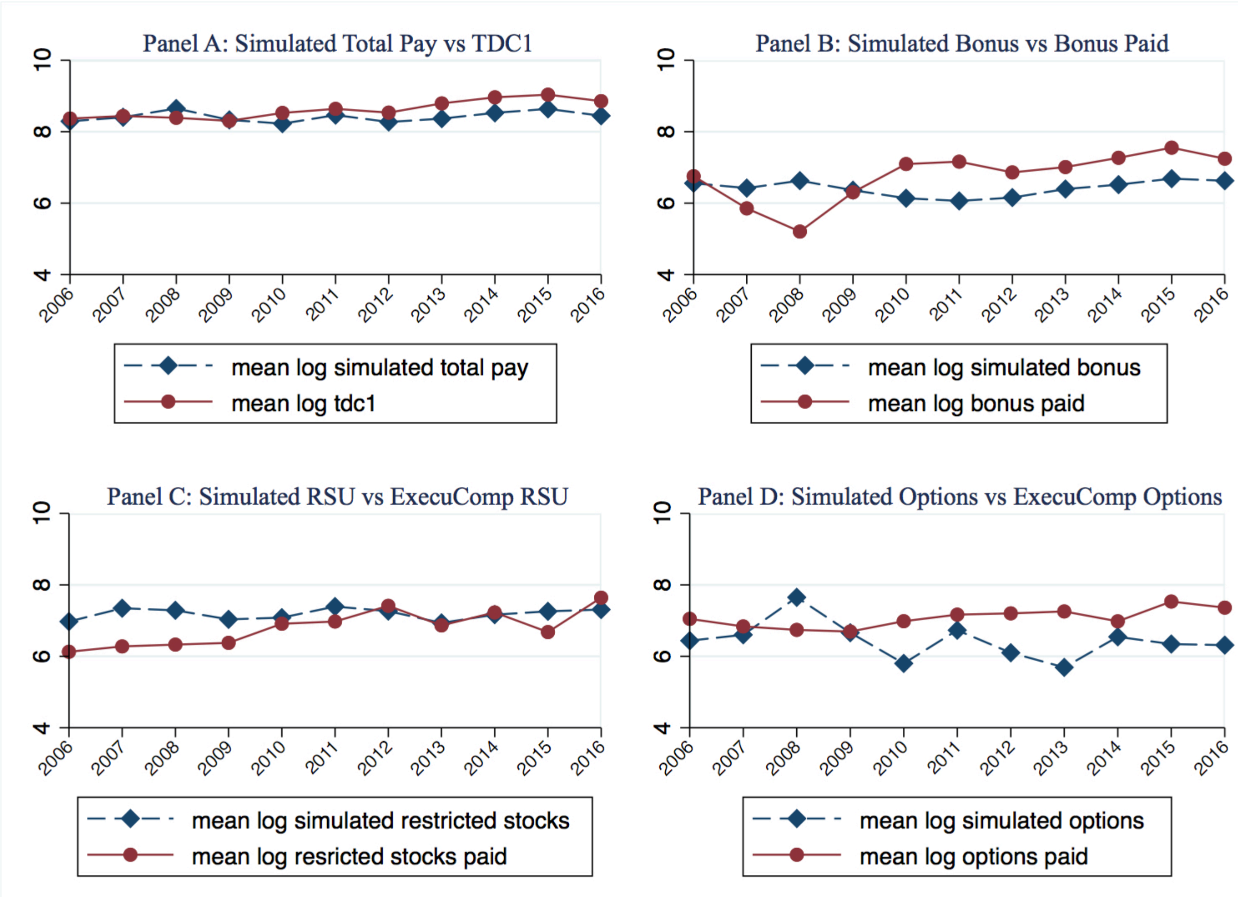


Figure 2. Clean Sample Grant Frequency Incentive Lab Versus ExecuComp

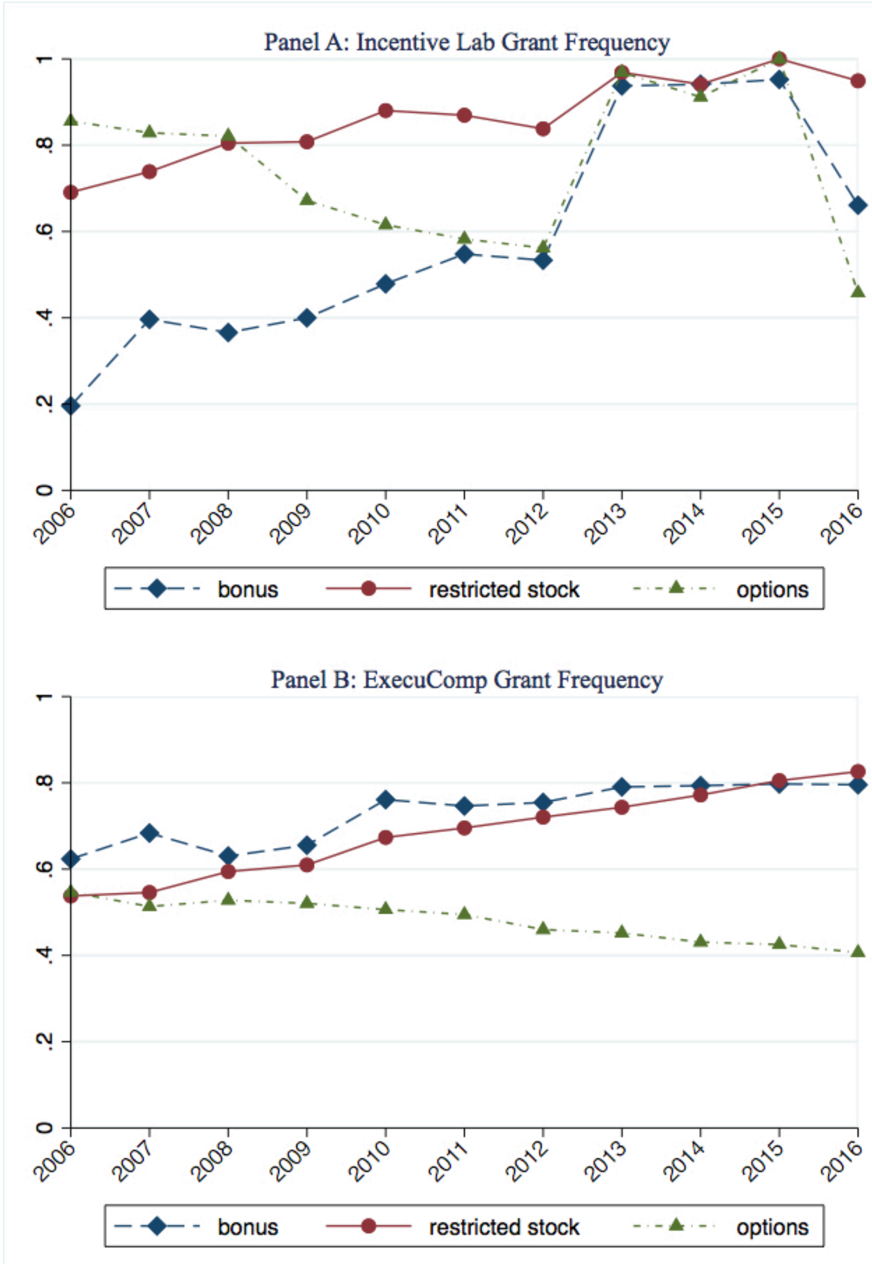


Figure 3. Alternative Sample Simulated Pay Versus Actual Pay

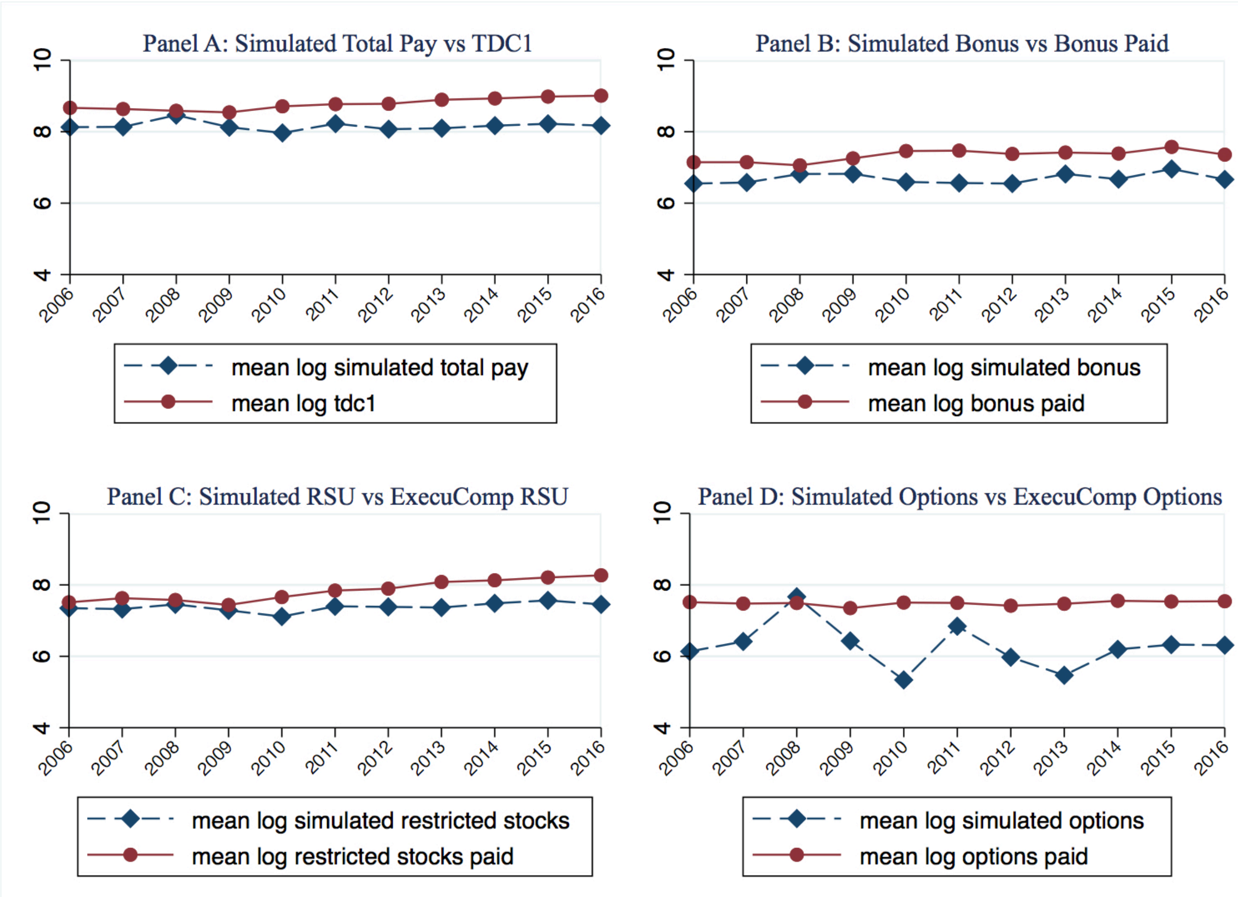
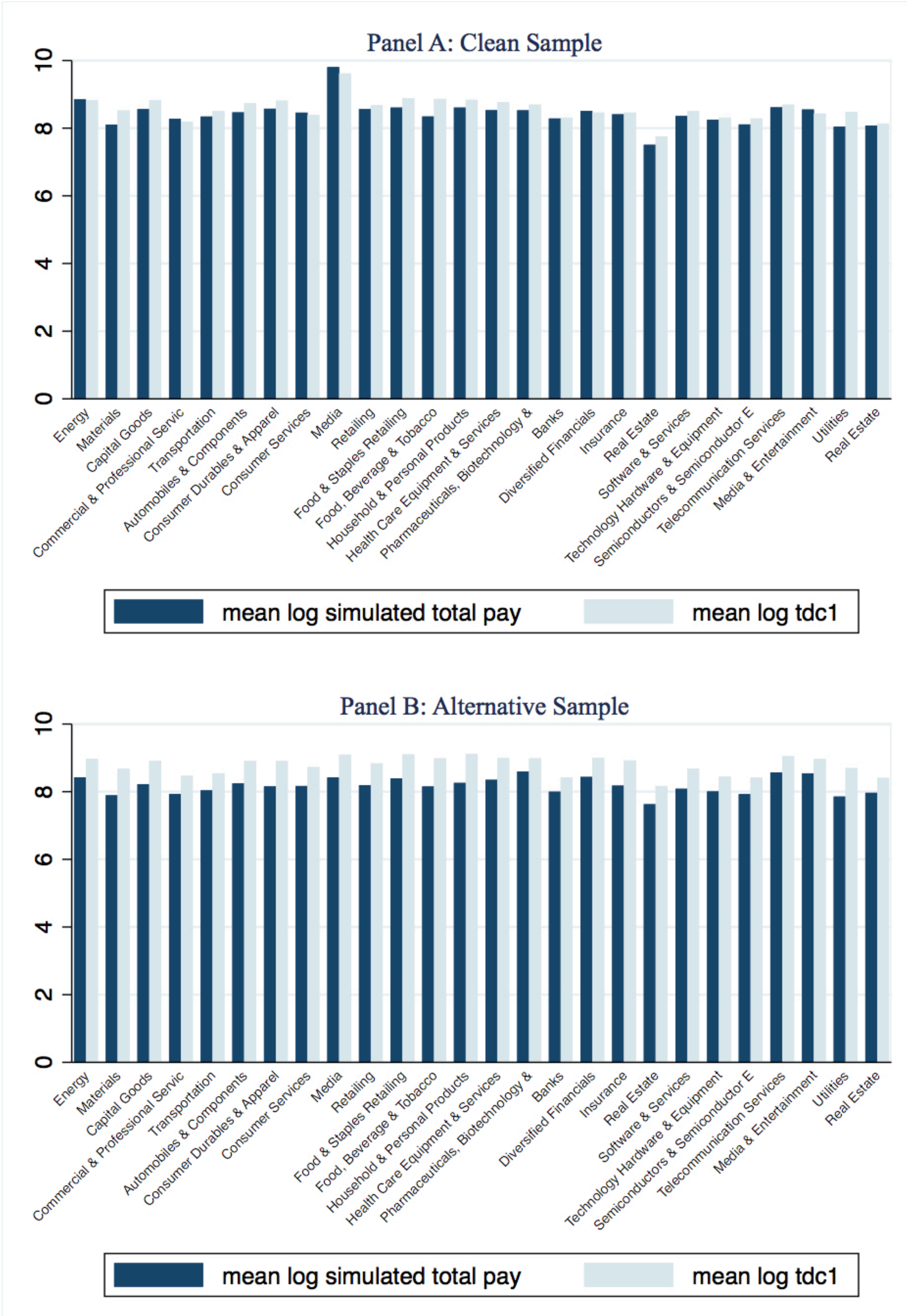


Figure 4. Simulated Pay Versus Actual Pay by GICS 4-digit Industry



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