Lower Salaries and No Options?
On the Optimal Structure of Executive Pay

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Abstract

We estimate a standard principal agent model with constant relative risk aversion and lognormal prices for a sample of 598 US CEOs. The model is widely used in the compensation literature, but it predicts that almost all of the CEOs in our sample should hold no stock options. Instead, CEOs should have lower base salaries and receive additional shares in their companies. For a typical value of relative risk aversion, almost half of the CEOs in our sample would be required to purchase additional stock in their companies from their private savings, investing on average one tenth of their wealth. The model predicts contracts that would reduce average compensation costs by 20% while providing the same incentives and the same utility to CEOs. We investigate a number of extensions and modifications of the standard model (taxes, liquidity constraints, incentives for risk taking, dynamic investment in the stock market), but find none of them to be fully satisfactory. We conclude that the standard principal agent model typically used in the literature cannot rationalize observed contracts. One reason may be that executive pay contracts are suboptimal.

JEL Classification: G30, M52

Keywords: Executive Compensation, Stock Options
“We don't give options because it would be a lottery ticket.” (Warren Buffet)

“There will be no new stock option grants from Microsoft. Instead, we will award actual stock to our employees.” (Steve Ballmer, Microsoft)

1 Introduction

This paper analyzes the optimal structure of CEO pay, or, more specifically, the optimal balance between stock, options and base salary in executive compensation contracts. We develop a new methodology to estimate and test efficient contracting models and apply it to a model of efficient contracting that is widely used in the literature on executive compensation. This model assumes constant relative risk aversion and lognormally distributed stock prices. On this basis we determine optimal contracts for a sample of CEOs and conclude that the model cannot generate observed contracts. In particular, it rarely predicts options. We explore a number of alternative modeling approaches but find none of them to be convincing. We conclude that we need a different contracting model to understand salient features of executive compensation contracts. Our results would also be consistent with the view that observed compensation practice suffers from significant defects and cannot be explained by an efficient contracting model.

The literature on the structure of executive compensation contracts has developed two complementary perspectives on executive stock options.1 One perspective highlights the fact that stock options are “expensive” because they are risky (e. g. Oyer and Schaefer, 2002). For typical parameter values, an option that is worth $100 to diversified investors may only be worth $20-$40 to an undiversified, risk-averse CEO. From another perspective, stock options are “cheap” because they provide more incentives for the same dollar outlay than an equivalent investment in stock, so companies save on compensation costs for providing incentives (e. g. Hall and Murphy, 2000). We bring these perspectives together in the context of a complete contracting model and argue that the relative importance of both perspectives depends on whether the model also features downward

1Despite the long list of references at the end of this paper, we make no attempt here to survey the large literature on executive stock options, let alone the still larger literature on executive compensation. Excellent surveys on various aspects of the subject include Abowd and Kaplan (1999), Murphy (1999), Prendergast (1999), Core, Guay, and Larcker (2002), and Hall and Murphy (2003).
constraints on fixed salaries. To illustrate this point, consider a simple numerical example. Suppose a company can provide the same incentives (and therefore induce the same action by the CEO) with either one share with a market value of $100 and a subjective value (certainty equivalent) of $40, or with options with a market value of $95 and a subjective value of $25.

<table>
<thead>
<tr>
<th>Stock</th>
<th>Options</th>
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<tbody>
<tr>
<td>Market Value</td>
<td>$100</td>
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<tr>
<td>Subjective Value</td>
<td>$40</td>
</tr>
<tr>
<td>Risk Premium</td>
<td>$60</td>
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If the CEO’s base salary is variable, then stock dominates options. In this case, the company incurs additional compensation costs of $70 if incentives are provided through options (award options worth $95, reduce base salary by $25). The same incentives cost the company only $60 if incentives are provided with stock. However, if base salaries are rigid, then only market values are relevant and options are indeed a cheaper way to provide the same incentives and the company saves $5 (=$100-$95) by using options.

In order to substantiate this argument, we calibrate a principal agent model of efficient contracting that has become standard in the literature on executive compensation contracts, especially in quantitative analyses of the design features of these contracts. The model combines preferences with constant relative risk aversion (CRRA) and lognormally distributed prices. Applications of this model to executive compensation date back at least to Lambert, Larcker, and Verrecchia (1991).² Other models, like those using preferences with constant absolute risk aversion or normally distributed prices, are seldom used, and mostly in order to generate qualitative results and closed form solutions, rarely in order to estimate, calibrate, or simulate models in order to obtain quantifiable results.³ Hence, we feel entitled to argue that our modeling approach implements a variant of the

²CRRA preferences and lognormal prices have been used by Lambert, Larcker, and Verrecchia (1991), Hall and Murphy (2000), (2002), Himmelberg and Hubbard (2000), Hall and Knox (2002), Jenter (2002) and Oyer and Schaefer (2003). Closely related are models that combine CRRA-preferences with geometric binomial trees or geometric Brownian motion models of stock price development that generate identical or similar distributions of stock prices. Binomial models were used by Huddart (1994) and Carpenter (1998), Brownian motion models by Tian (2001), Johnson and Tian (2000a), (2000b), and Ingersoll (2002).

We develop a new methodology to applying and testing this model: We estimate the relevant model parameters for a sample of 598 CEOs. In particular, we aggregate option holdings into a representative option and estimate non-firm wealth from previous years’ income of the CEO. For risk aversion we use a grid of values that cover the range which other researchers have suggested as plausible. Then we numerically determine the optimal contract for each CEO (and each level of risk aversion) in our dataset. Finally, we compare the optimal contracts implied by the model with the actual contracts we observe and evaluate whether they are statistically and economically different.

Our main result is that the model cannot account for a prominent feature of 96% of the CEOs in our sample: we almost never obtain stock options as part of an optimal contract. While the CEOs in our sample hold on average options on 1.3% of their companies, the model cannot account for more than 0.1% even for very low levels of risk aversion. According to the model, the large majority of CEOs should not have any stock options at all. An immediate implication is that CEOs should also receive lower base salaries and more restricted stock. Indeed, for a typical level of risk aversion (CRRA=3), 49% of the CEOs in our sample (mostly the more wealthy ones) should receive no base salary at all and use some of their private savings to purchase additional stock in their companies.

We then investigate the savings a company could obtain by rebalancing the CEO’s compensation package from its present structure to that predicted by the model. We find that contracts that provide the same level of expected utility and the same incentives to the CEO would be cheaper by 20% or $12.7 million on average for those CEOs in our sample who currently hold options (assuming CRRA=3) so the difference to actual contracts is also economically meaningful.

We investigate a number of ways to modify the model to yield predictions closer to observed contracts. In line with the intuition of the numerical example above, assuming that base salaries cannot be adjusted downward would immediately reconcile the model with observed contracts. However, if we stipulate that observed base salaries are optimal, then the solution of our model is

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fully determined by the constraints of the problem, so we would effectively assume the result we set out to show. We are therefore not persuaded by this way to fix the model.

A more promising model would abandon the effort-aversion approach altogether and employ the argument that options are awarded to provide risk-taking incentives. We investigate this hypothesis in the context of our model. While options do make CEOs more risk-tolerant, we find this effect to be too weak to actually explain observed contracts even though it may be a small part of a complete explanation. Next we recompute all our results for a model that incorporates personal and corporate taxes. We document the tax advantage of options, but without changing our main results. We also check for possibly incorrect measurements of wealth and find that our analysis is robust to errors in this dimension. Similarly, we argue that hedging by the CEO through trading in the stock market is unlikely to change our results. We conclude that the standard version of the principal agent model and several variants cannot accommodate stock options, so that this model is also ill-suited to analyze design features of stock option contracts.

Taking an altogether different perspective, our results could be cited as supporting evidence for the view that CEO compensation does not conform to the efficient contracting paradigm, and that stock options are a vehicle for rent extraction. We discuss this by analyzing if the inefficiency predicted by our model is related to the strength of CEO incentives. While our results are consistent with inefficient contracting, we do not regard them as conclusive evidence. Also, it is difficult to reconcile the inefficient contracting view with other evidence in the literature. Summarizing, our

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4This argument goes back to Smith and Stulz (1985). We discuss the literature on this topic in greater detail below.


7Bebchuk, Fried, and Walker (2002) and Bebchuk and Fried (2003) regard the observed structure of executive compensation as evidence for rent extraction. Bertrand and Mullainathan (2000) adopt this view only for companies that have weak governance systems.

8In addition to our evidence, see also Core, Holthaussen, and Larcker (1999), Himmelberg, Hubbard, and Palia (1999), and Bertrand and Mullainathan (2000) for evidence on systematic variations between economic variables and CEO compensation that corroborates efficient contracting models. Kedia and Mozumdar (2002) and Hanlon, Shevlin and Rajgopal (2003) find evidence for the performance impact of stock options. The latter study concludes that there is little evidence for rent extraction.
analysis suggests that there is no simple explanation of the discrepancy between observed contracts and the contracts predicted by our model.

Our empirical approach is new and compares with two other methodologies that are widely applied in the literature. Several authors have calibrated a model like ours in order to analyze various aspects of executive compensation contracts by making parametric assumptions about a "typical" CEO. However, then conclusions are sensitive to parametric assumptions that differ across CEOs, so calibrating the model to observed parameter values of individual CEOs puts our conclusions on a firmer empirical foundation. An alternative approach is to explore the implications of efficient contracting models using regression analysis. Cross-sectional regressions test the qualitative, directional implications of theoretical models, whereas our approach also tests the quantitative implications, which is a more stringent test. However, we have to make additional assumptions about functional forms that are absent from reduced-form regressions. To the best of our knowledge, the only structural test of a principal agent model of compensation is Margiotta and Miller (2000), who do not look at options and cannot reject the implications of their model.

The following Section 2 develops the theoretical model in detail. Section 3 explains our empirical methodology and how to implement the model. Section 4 presents and discusses our empirical results and provides some robustness checks. In Section 5 we investigate modifications of the base model that may help to reconcile it with the empirical evidence. In Section 6 we present some further thoughts about the limitations of our approach and directions for future research. The more technical aspects of our analysis can be found in the appendix.

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9 See also Garen (1994), Haubrich (1994), Haubrich and Popova (1998), and Margiotta and Miller (2000) for different econometric approaches. None of these studies allows for stock options. Hall and Murphy (2002) conclude that stock options “are a particularly expensive way to convey compensation,” but they do not investigate the relative costs to provide incentives.

10 The closest paper to ours based on this paradigm is Lambert and Larcker (2004), who solve a complete principal agent model and seem to come to different conclusions from ours. We discuss their work below. An incomplete list of calibration exercises includes Lambert, Larcker, and Verrechia (1991), Hall and Murphy (2000), (2002), Hall and Knox (2002), and Jenter (2002).

11 See the literature cited in footnote 8 above and the discussion in the survey of Core, Guay, and Larcker (2002), section 3.2. Some papers find results that support the principal agent model, e. g. Aggarwal and Samwick (1999) Kedia and Mozumdar (2002). Others come to different conclusions, e. g. Core and Guay (2002b) who contradict Aggarwal and Samwick’s findings on methodological grounds, and Yermack (1995), who reports that variables associated with agency models explain almost none of the cross-sectional variation in the use of options.
2 Theoretical Model

**General.** We develop a single-period principal agent framework, following Holmström (1979). The risk-neutral principal (shareholders) offers a contract to the risk-averse and effort-averse agent (CEO). The CEO consumes only at date \( T \), which marks the end of the period. At this point in time the market value of the firm equals \( P_T \). We ignore leverage and do not distinguish between the market value of equity and the market value of the firm. The principal cannot observe the agent’s effort directly. As a consequence, the contract cannot be a function of effort, but it can be a function of \( P_T \).

**Technology and Uncertainty.** The end of period value of the firm \( P_T \) depends on the effort \( e \) of the CEO, \( e \in [0; \infty) \), and a standard normal random variable \( u \). We use risk-neutral pricing throughout and denote the risk-free rate of interest by \( r_f \). We will discuss our valuation approach in greater detail below (see p. 7). We specify:

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

Hence, the distribution of \( P_T(u, e) \) is log-normal with expected present value under the risk-neutral density equal to \( P_0 = E [P_T \exp \{-r_f T\}] \). \(^{13}\) \( P_0(e) \) satisfies standard monotonicity and concavity assumptions typically made for production functions, so \( \frac{\partial P_0}{\partial e} > 0 \) and \( \frac{\partial^2 P_0}{\partial e^2} < 0 \). In any rational expectations equilibrium, \( P_0 \) is equal to the market value of equity at the effort level \( e^* \) chosen by the manager under the given contract, so \( P_0(e^*) \) is equal to the observed market capitalization.

**Permissible Contracts.** We assume that the contract can be described by three parameters: a base salary \( \phi \), the number of shares in the company \( n_S \) (expressed as a fraction of all shares outstanding), and the number of options on the company’s stock \( n_O \) (also expressed in terms of the

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\(^{12}\) This expression assumes a company that does not pay dividends. For a company that pays dividends, \( P_0(e) \) needs to be replaced with \( P_0(e) \exp \{-dT\} \) for the purpose of valuing options, where \( d \) is the dividend yield expressed the same way as \( r_f \). We adjust for dividends in our empirical work but abstract from them here. The density of the lognormal distribution is given in equation (17) in the appendix.

\(^{13}\) Here and in the following all expectations are taken with respect to the probability distribution of \( u \sim N(0,1) \). We should really write \( P_0 = E [P_T(u, e) e^{-r_f T}] \) and also write \( W_T, \pi_T, \) etc. below as functions of \( u \). However, we submerge reference to \( u \) for ease of exposition.
number of shares outstanding). So, for a company with 10m shares outstanding, where the CEO has 100,000 shares and 50,000 options, we have \( n_S = 0.01 \) and \( n_O = 0.005 \). We further assume that all options granted to the CEO have identical maturity \( T \) and strike price \( K \). The strike price \( K \) is expressed as the strike price for \( n_O = 1 \), i.e., for the whole company. We denote by \( W_0 \) the wealth of the CEO that is not invested in the firm’s securities as of time \( t = 0 \) and refer to it as “non-firm wealth.” We assume that she invests all her non-firm wealth at the risk-free rate \( r_f \), so her end of period wealth (at date \( T \)) is:

\[
W_T = (\phi + W_0) \exp \{r_f T\} + n_S P_T (u, e) + n_O \max \{P_T (u, e) - K, 0\} .
\] (2)

Note that this specification implicitly assumes that base pay (including bonus payments) is paid out today and invested, while all other components of pay lead to cash flows to the CEO at date \( T \).

Preferences. The CEO’s utility is separable in wealth and effort and has constant relative risk aversion with risk-aversion parameter \( \gamma \):

\[
U(W_T, e) = V(W_T) - C(e) = \frac{W_T^{1-\gamma}}{1-\gamma} - C(e) .
\] (3)

The costs of effort are assumed to be given by some convex cost function \( C(e) \) with \( \frac{\partial C}{\partial e} > 0 \) and \( \frac{\partial^2 C}{\partial e^2} > 0 \). We assume that the CEO has outside employment opportunities that give her expected utility \( \overline{U} \). Expected utility is \( E[U(W_T, e)] \), where expectations are taken with respect to the distribution of \( W_T \) from (2).

Risk-Neutral Pricing. We assume risk-neutral pricing in order to ensure consistency of our approach. We could allow for a return \( \mu > r_f \) only in a model where the CEO could also invest in the stock market and receive the risk-premium without exposure to firm-specific risk. Suppose we would only introduce a risk-premium on the company’s stock in the present model, without also

\(^{14}\)If \( \gamma = 1 \), we define \( V(W_T) = \ln(W_T) \). We do not use \( \frac{W_T^{1-\gamma}-1}{\gamma} \) (which would make \( U(W_T, e) \) continuous in \( \gamma \) at \( \gamma = 1 \)) for numerical reasons.
allowing the CEO to trade in the market. Then any CEO with sufficiently low risk aversion (low $\gamma$) would value the company’s stock and stock options higher than the market. The reason is that investing in her own company’s securities would be the only way the CEO could then obtain an expected return above the risk-free rate. In order to avoid the paradoxical outcome that the CEO is willing to pay a premium above the market price on her company’s securities, we work with risk-neutral pricing in (1). Effectively, this amounts to the assumption that all risk in the model is firm-specific. We show below that the implied approximation error is small, whereas the opposite assumption - treating all risk as systematic - would seriously bias our results.15

**Theoretical Solution.** We apply the two-stage approach of Grossman and Hart (1983) and ask which contract is optimal for implementing a given level of effort. Denote the pay of the manager in currency units of time $T$ by

$$\pi_T = \phi \exp (r_f T) + n_S P_T + n_O \max \{P_T - K, 0\} \quad .$$

(4)

Note that $W_T = W_0 \exp \{r_f T\} + \pi_T$. We denote the present value of expected pay by $\pi_0 = E[\exp \{-r_f T\} \pi_T]$. Then:

$$\pi_0 = \phi + n_S P_0 + n_O BS \quad ,$$

(5)

where $BS$ is the Black-Scholes value of the option. The principal’s problem then is to find the contract that implements the chosen effort level $\pi$ with the lowest costs:

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15 See Section 4.3 below and Hall and Murphy (2000) and Tian (2001) for other approaches. The latter also concludes that CEOs sometimes value options higher than the market. Cai and Vijh (2004) argue along the same lines and show that introducing the market index reduces the value of options to the CEO.
\[
\min_{(\phi,n_S,n_O)} \pi_0 = \phi + n_S P_0 + n_O BS \tag{6}
\]

s.t. \[E [U (W_T, \bar{\tau})] \geq \bar{U}, \tag{7}\]

\[\bar{\tau} = \arg \max_{e \in [0, \infty)} E [U (W_T, e)] , \tag{8}\]

\[0 \leq n_S \leq 1, \quad n_O \geq 0 , \tag{9}\]

\[\phi + W_0 \geq 0 . \tag{10}\]

Here (7) represents the participation constraint, (8) represents the incentive compatibility constraint, and (9) define admissible contracts. Condition (10) explicitly allows for negative base salaries. In the context of our model this can best be interpreted as a payment by the CEO in exchange for stock and option grants. However, the CEO cannot pay more than her total initial non-firm wealth.

In a second step, the principal will search over all pairs of effort \(\bar{\tau}\) and minimized costs \(\pi_0^*(\bar{\tau})\) in order to find the optimal contract \(e^*\). We do not consider this second step in this paper. No matter what the optimal effort level \(e^*\) is, it must solve the first step of the optimization problem (6) - (10): a given contract is not optimal if the same effort level can be implemented with a less costly contract. It is this implication that we are going to check for observed CEO contracts in the empirical part of this paper.

In Appendix A.1 we discuss the analytic solution to the optimal contracting problem for a general function \(\pi (P_T)\) that is not constrained to be implemented with stock and options. There we show that the optimal contract is neither convex nor concave for all values of \(P_T\). In particular, we find that the optimal contract is concave for all prices \(P_T\) above a certain threshold. It is therefore not possible to implement the optimal contract with stock and a portfolio of options except if we allowed for contracts where the CEO writes options.\(^{16}\) We exclude such contracts here as they seem to be of theoretical interest only. Also, we can determine the parameters of the

\(^{16}\)However, the slope of \(\pi (P_T)\) always remains positive, so the number of options the CEO writes would never exceed the number of shares plus positive option holdings.
function \( \pi(P_T) \) only if we specify functional forms for the impact of the CEO’s effort and for the utility costs of effort. Assumptions on these functions seem arbitrary and would not allow us to test and apply the standard model in its general form. We therefore take a different route and develop an empirical methodology that relies on program (6) - (10), but which does not make assumptions about functional forms other than (1) and (3).

3 Empirical Methodology and Data

3.1 Empirical Implementation

Our first step towards developing an implementable version of the model is to apply the first-order approach and to replace (8) with the respective first order condition for utility maximization by the CEO. We discuss how we validate the applicability of the first-order approach below. Hence, we replace the incentive compatibility constraint (8) with the first order condition for (8):

\[
\frac{\partial}{\partial e} E[U(W_T, e^*)] = E \left[ \frac{\partial V(P_0)}{\partial P_0} \frac{\partial P_0(e^*)}{\partial e} \right] - \frac{\partial C(e^*)}{\partial e} = 0 .
\]  

(11)

In order to rewrite (11), we define the notion of a utility-adjusted pay for performance-sensitivity, \( UPPS \), as follows:

\[
UPPS = \frac{\partial}{\partial P_0} \exp \{-r_fT\} E[U(W_T, e^*)] .
\]  

(12)

In the case of risk-neutrality (\( \gamma = 0 \)), we have \( \frac{\partial U}{\partial W_T} = 1 \) for all \( W_T \) and it is easy to show that \( UPPS \) equals \( n_S + n_O N(d_1) \), where \( N(d_1) \) is the option delta from the Black-Scholes formula. This is just the standard definition of pay for performance-sensitivity under risk-neutrality that has been widely used in the analysis of executive stock options. This justifies the definition of (12) as a utility-adjusted pay for performance-sensitivity. Substitution of (12) into the first order condition (11) yields:

\[
UPPS = \frac{\partial C}{\partial e} \exp \{-r_fT\} \equiv k(e^*) ,
\]  

(13)

where \( k \) is a function that is unknown to the observer and that depends only on the parameters of the manager’s cost function and the technology of the company, but is independent of the
parameters of the contract. Conversely, UPPS depends only on the observable contract parameters, the CEO’s wealth, and her risk-aversion $\gamma$, but not on the unknown functions $P_0(e)$ and $C(e)$. The last aspect makes this formulation of the problem attractive for numerical work. We can calculate the unknown values $U$ and $k(e^*)$ from the data assuming that the incentive compatibility constraint and the participation constraint are satisfied and binding. Then we must have $k(e^*) = UPPS(\phi^d, n^d_S, n^d_O; \gamma)$ and $E[V(W_T(\phi^d, n^d_S, n^d_O; \gamma), P_0)] = U - C(e^*)$. We obtain our final program:

$$\min_{(\phi, n_S, n_O)} \pi_0 = \phi + n_SP_0 + n_OBS$$

s.t. $E[V(W_T(\phi, n_S, n_O; \gamma), P_0)] = E[V(W_T(\phi^d, n^d_S, n^d_O; \gamma), P_0)]$, \hspace{1cm} (14)

$UPPS(\phi, n_S, n_O; \gamma, P_0) = UPPS(\phi^d, n^d_S, n^d_O; \gamma, P_0)$,

$0 \leq n_S \leq 1, \hspace{1cm} n_O \geq 0, \hspace{1cm} \phi \geq -W_0$.

The only unknown variable that remains in our model is $\gamma$, so we use a grid for various values of $\gamma$ between 0.5 and 10. This interval encompasses the range of values for risk aversion that researchers in the field of executive compensation regard as reasonable.\textsuperscript{17} We also calibrated a simple model where the CEO can invest in a diversified portfolio and the risk-free asset and found that values of $\gamma$ much below 2 lead to unrealistic predictions about CEO’s investment policies.\textsuperscript{18}

Conditional on using the right value of $\gamma$ and assuming that the optimal contract indeed solves (14), the optimal contract must be equal to the observed contract, i.e. $(\phi^*, n^*_S, n^*_O) = (\phi^d, n^d_S, n^d_O)$. If the optimal contract significantly differs from the observed contract then either the assumed level of risk aversion $\gamma$ is wrong or the observed contract is not optimal. Program (14) has a very intuitive interpretation. We want to find a contract that provides the CEO with the same utility and the

\textsuperscript{17}There is no consensus on the correct value for the Arrow-Pratt measure of relative risk aversion. Campbell, Lo, and McKinlay (1997), ch. 8, discuss the extensive literature in macroeconomics that has suggested values for $\gamma$ up to 10 or 20 in order to reconcile asset pricing models with the equity premium puzzle. Chetty (2003) uses a model of labor supply and finds estimates around 1. Extracting estimates of risk aversion from asset prices has also not converged to a consensus, e. g. Ait-Sahalia and Lo (2000) summarize research on the subject (see their Table 7) that finds values between 0 and 55. The compensation literature typically uses lower values (e. g. Murphy, 1999, uses 1, 2, and 3).

\textsuperscript{18}Consider a CEO with CRRA-utility who can invest in a market portfolio with $\sigma = 0.17$ and a risk premium over the risk-free rate of 4%. Then a CEO with $\gamma = 0.5$ would leverage her portfolio and invest 277% of her wealth in the market portfolio. With $\gamma = 1$ she would still invest 138%, with $\gamma = 2$ the portfolio would be 69% in the market and 31% in the risk-free asset.
same incentives as the observed contract, but that is less costly to shareholders compared to the observed contract.

The first-order approach allows us to solve program (6) - (10) without making any further assumptions on the cost function $C(e)$ except convexity and on the production function $P_0(e)$ except concavity. However, the agent’s objective $E[U(W_T,e)]$ may still not be concave in effort and have multiple local optima, as $W_T$ is a convex function of $P_T$. Then the first-order condition is satisfied at each of these local optima. The modified program (14) suggests an optimal contract $(\phi^*,n^*_S,n^*_O)$, that satisfies the first-order condition at the same effort level $e^*$ as the observed contract $(\phi^d,n^d_S,n^d_O)$. This shows only that the global optimum under the existing contract remains a local optimum under the contract that solves (14). This does not rule out the possibility that the global optimum for the agent under the new contract implies an entirely different effort level $e \neq e^*$. If the effort level chosen by the agent under the new contract is higher ($e > e^*$), then no problem arises for our approach as this would also imply a higher value for the firm $P > P_0$. However, we need to verify that the agent does not choose a lower level of effort under the contract that solves program (14).

In our case, we cannot establish the validity of the first-order approach analytically because we restrict the shape of the optimal contract. Instead, we formulate a sufficient condition for the applicability of the first-order approach and validate it empirically. We prove the following result in Appendix A.

**Proposition 1 (First-order approach):** Let $(\phi^*,n^*_S,n^*_O)$ be the optimal contract that solves (14). Also, let $e^*$ be the effort level chosen under the existing contract. If

$$UPPS(\phi^*,n^*_S,n^*_O;\gamma,P) \geq UPPS(\phi^d,n^d_S,n^d_O;\gamma,P_0)$$

(15)

for all $P \leq P_0$, then the agent will never choose an effort level $e < e^*$ under the new contract $(\phi^*,n^*_S,n^*_O)$. Condition (15) is always satisfied for all contracts where $n^*_O = 0$.

Hence, we check (15) for a grid of 100 equally spaced values of $P$ in the interval $(0,P_0]$ whenever $n^*_O > 0$. 12
3.2 Dataset

For implementing (14), we need data on the contract parameters $\phi^d$, $n_S^d$, and $n_O^d$, the CEO’s wealth $W_0$, the firm value $P_0$, the dividend yield $d$, the option maturity $T$, the strike price $K$, the stock volatility $\sigma$, and the risk free rate $r_f$. Our data are constructed from the Compustat ExecuComp Database, which contains compensation data on 21,086 executives from 2,448 firms over the period 1992 to 2000.\(^{19}\) We first identify all executives in the database who were CEO in 2000 and have a continuous history (as chief or non-chief executive) of at least five years (1995-1999) in the database. We focus on CEOs in order to prevent correlations due to multiple observations from the same firm.

We match $P_0$ to the market capitalization at the 1999 fiscal year end and take the 1999 values of the dividend yield $d$ and the volatility $\sigma$ directly from the database. The fixed salary $\phi^d$ is determined as the sum of salary and bonus in 2000 and includes all types of compensation other than stock and options.\(^{20}\) Hence we implicitly assume that bonus payments have no relevance for the CEO’s incentives.\(^{21}\) We use only current-period data to estimate $\phi^d$. This ignores the fact that the CEO receives base salary payments every year between now and $T$. Incorporating this feature would have the same numerical impact as an increase in non-firm wealth $W_0$, which we study below. We therefore abstract from this feature.

$n_S^d$ and $n_O^d$ are the numbers of shares and options held by the CEO at the end of the 1999 fiscal year. ExecuComp does not provide details of all option parameters, and we approximate the option portfolios held at the end of 1999 using the algorithm described by Core and Guay (2002a). According to this algorithm, we approximate options granted before 1999 by two hypothetical option grants that are calculated from information on, respectively, exercisable and unexercisable options. We add the options granted in 1999 to these two hypothetical options grants in order to arrive at an estimate of the option portfolio held at the end of the 1999 fiscal year. Then we calculate the exercise price $K$ and the maturity $T$ of a representative option that aggregates the

\(^{19}\)We did not have access to a more recent version of ExecuComp. We discuss the potential bias arising from this in the conclusion.

\(^{20}\)More precisely, $\phi^d$ is the sum of the following four ExecuComp data types: Salary, Bonus, Other Annual, and All Other Total. We do not include LTIP (long term incentive pay), as these are typically not awarded annually.

\(^{21}\)This seems defensible. Hall and Liebman (1998) argue that the impact of stock options and stocks on CEO wealth dwarfs the impact of bonus payments.
salient features (value and sensitivity to price) of the CEO's option portfolio. We refer the reader to Appendix B for further details. Appendix B also describes the procedure which we used to estimate non-firm wealth from the CEO's past income. We restrict our sample to those CEOs where we have at least five years of continuous and complete history on ExecuComp in order to obtain reasonable estimates of the CEO's non-firm wealth. Later we perform robustness checks in order to establish that our results do not depend on potential estimation errors.

From the initial 1,696 CEOs in 2000, we lose 103 CEOs for which necessary data items (stock volatility in 1999 or adjustment factor) are missing, and 886 CEOs due to the required history of at least five years. The five-year cut-off provides a reasonable balance between the accuracy of our estimates and sample size. Another 27 CEOs are lost because they were executives in more than one company in at least one year of their history. For the remaining 680 CEOs we estimate their options portfolio and their wealth from the ExecuComp database as described in Appendix B. At this stage, we lose 17 CEOs because of inconsistent or missing data on their option holdings, and 65 CEOs, because our wealth estimate is negative, which can happen if the amounts deducted for the purchase of stock are large. We retain 598 CEOs in our sample that satisfy all our data requirements. 21 CEOs (3.5%) have no options in their compensation package while 254 CEOs (42%) have options on more than 1% of their company.

Table 1, Panel A provides descriptive statistics for the main parameters and Panel B displays similar statistics for the larger group of executives in the ExecuComp database who were CEO in 2000. While the CEOs in our sample are similar with respect to the value of their stock holdings, our data requirements have a tendency to exclude CEOs with more options (mean of 1.3% in the sample, 1.5% in ExecuComp) and lower salaries (mean of $2m in the sample, $1.7m in ExecuComp). Also,

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22 The only study we know of that uses an estimate of wealth is Becker (2003), who uses a Swedish dataset based on tax filings. No such information is available for the U.S.

23 We do not require that the CEOs have been CEO during the entire 5 years. We only require that they were CEO in 2000.

24 If we required eight years of continuous history, we would retain only 360 CEOs compared to our current sample of 598. Shortening the length of continuous history in the database required biases our wealth estimates downward. Requiring an eight-year history would increase our median estimate of $W_0$ by 27% (mean: 21%). We compensate for this bias with appropriate robustness checks (see Section 4.3).

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CEOs in our sample are somewhat more experienced (age 57 in our sample, 55 in the database). Finally, note that the stock volatility is lower in our sample (38%) than in the full ExecuComp database (44%). In view of our results, the sample is biased in favor of the model: the savings from recontracting predicted by our model are higher for higher volatility, higher option holdings, and for younger, less wealthy CEOs. We would therefore expect even stronger results if we could establish reliable parameter estimates for the larger sample.

4 Empirical Results

4.1 Description of optimal contracts

Result 1: The model cannot replicate observed option holdings. We first compare the option holdings from optimal contracts with those actually observed.

[Insert Table 2 about here]

The first - and probably most surprising - result of our analysis is that stock options are almost never optimal for plausible levels of risk aversion. The model predicts positive option holdings only for 1.3% of all CEOs at $\gamma = 3$, and even for extremely low levels of risk aversion this fraction does not rise above 14% ($\gamma = 0.5$). Moreover, whenever the model does predict options as part of the optimal contract, the fraction of options predicted is miniscule: for $\gamma = 3$ optimal option holdings are 0.003%, or 0.27% of actual option holdings. The t-statistic for equal option holdings is 17.3, indicating the complete failure of the model with respect to predicting option holdings. The magnitude of the failure of the model depends on risk aversion, but even for levels of risk aversion as low as 0.5 the model predicts only 5.5% of actual option holdings. Moreover, we only obtain positive option holdings if the constraint $\phi \geq -W_0$ is binding, in all other cases optimal option holdings are always zero. (We discuss this aspect further in Section 5 below.)

This result is striking and suggests that the constraint $n_O \geq 0$ is almost always binding to produce a corner solution at $n_O = 0$. This also suggests that the concave part of the optimal unconstrained $\pi(P_T)$ –function discussed above always dominates the shape of the optimal contract constrained to consist of stock and a long position in call options. Only for very low levels of risk
aversion and for a small number of CEOs is the optimal contract in the convex region of the optimal contract.

Note that we cannot always compute the optimal contract for low option holdings, especially at very low levels of risk aversion, in which case we drop the observation. To some extent this reflects an economic problem rather than a purely numerical problem. For risk-neutral managers \((\gamma = 0)\), there is a continuum of optimal solutions, as the optimal contract can either contain 100% options, 100% stock, or anything in between. At this point, any incentives provided by options can be replicated with stock and vice versa, and the valuation of options and stock is the same for the CEO and diversified shareholders. Then the costs of providing incentives with stock and with options are the same, assuming - as we do here - that base salaries can be adjusted appropriately (see the discussion of Result 3 below for additional details on this point).

For low levels of risk aversion we can sometimes not validate the applicability of the first-order approach. There are 3 CEOs with positive option holdings under the contract that solves (14) where condition (15) is violated for \(\gamma = 0.5\). We can always ensure the validity of the first-order approach for all CEOs and for all values of \(\gamma\) equal to 1 or higher. Table 2 reports separate results for the sample including and excluding observations where the first-order approach might be violated.

**Result 2: CEOs should hold more stock.** It follows directly from the mechanics of the model that lower option holdings are balanced by higher stock holdings in order to maintain incentives. Hence, stock holdings in optimal contracts are uniformly higher, and for any given level of risk aversion the algorithm provides a unique optimal level of stock holdings commensurate with maintaining incentives.

Table 3 shows the increase in stock holdings for different levels of risk aversion. If we measure the increase in stock holdings required by optimal contracts by looking at the difference \(n^*_S - n^d_S\), then we find for \(\gamma = 3\) an increase by 0.27% (median), respectively, 0.47% (mean). Hence, on

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25 Table 2 reports the number of CEOs where we can compute the optimal contract in the second column. See Appendix C for a discussion of our numerical approach and the numerical problems we encountered in computing contracts for some parameter values.
average, CEOs in our sample would be required to hold half a percentage point more of their company’s stock. This would correspond to a median increase of about 95% in CEO stock holdings or an additional investment of $4.7m in their company’s stock. Hence, while the reduction in option holdings required by optimal contracts may look dramatic, the corresponding increase in stock holdings required to maintain incentives at their existing level is relatively moderate.

Table 3 also demonstrates that the number of additional shares required to be held by the CEO decreases markedly as the CEO’s risk aversion $\gamma$ increases. This is reflected in the exchange ratio that is displayed in the rightmost column of Table 3. The exchange ratio is the number of shares given to the CEO for each option taken away from him. As the CEO’s risk-aversion rises, stock becomes progressively better at providing incentives, so fewer shares need to be granted to replace one option.

Result 3: CEOs should receive lower base salaries. If we substitute stock for less valuable options, then the base salary needs to decrease so that the CEO’s expected utility stays constant and the participation constraint (7) is binding. More importantly, in a large number of cases the CEOs in our sample should have negative base salaries $\phi$ according to the model. If base salaries are negative, then CEOs are required to invest some of their private savings in their company’s stock in addition to the stock grants they receive.

Table 4 reports statistics on the change between optimal base pay $\phi^*$ suggested by the model and actual base pay $\phi^d$ as observed in the data. The distribution is highly skewed, so we report means and medians. In Table 4 we also show the proportion of CEOs whose optimal base pay is negative and who would be required to invest into their company’s stock from their private savings. We see that cuts in base salaries are often dramatic. For $\gamma = 3$ the median pay cut is $1.3$m, or 96 percent. In addition, nearly half of the CEOs in our sample should not earn a positive base salary at all at this level of risk aversion and invest in their company’s stock instead. Finally note that, as the CEOs risk aversion $\gamma$ increases, the pay cuts suggested by our model decrease substantially. This is an immediate consequence of the fact that the exchange ratio reported in Table 4 decreases.
in $\gamma$. If the number of additional shares the CEO is required to hold falls, then the cut in base pay necessary to hold her expected utility constant falls as well. Finally, we observe that base salary is negatively correlated with wealth. This is intuitive as higher wealth leads to lower absolute risk aversion and therefore a higher exchange ratio of stock for options. Note that we calculate wealth on the basis of past income. So, according to the model, some CEOs received too high fixed salaries in the past, leading to a larger accumulation of non-firm wealth. These contracts need a stronger rebalancing away from options and fixed salary to more stock.

Table 5 demonstrates the effect of these pay cuts on the CEOs’ savings. The table displays the absolute and relative amount of their wealth (excluding stock and options already held) that they should invest in additional shares. For $\gamma = 3$, each CEO needs to invest $2.3$m or 10.9% of her wealth on average.

**Result 4. Implied savings from optimal contracts are significant.** In the previous parts of this section we have analyzed how optimal contracts would differ from the contracts actually observed. Now we turn to the question of economic significance. After all, we would not expect companies to invest resources into finding optimal contracts for their CEOs if deviations from optimality are not costly. We assess the economic significance by comparing expected costs of total compensation of optimal contracts, $\pi_0^*$, to the costs of observed compensation contracts, $\pi_d^0$. Hence $\pi_0^d - \pi_0^*$ is our measure for evaluating economic significance. Results are summarized in Table 6.

Based on our model and assuming $\gamma = 3$, on average about 20% of total costs of CEO compensation could be saved by moving from observed contracts to the contracts suggested by the model (median 16.4%). While this number is significant as a proportion of compensation costs as well as in absolute dollar terms (about $12.7$m (mean), respectively, $2.6$m (median) per CEO), the number is not large in relation to the size of most companies. The average savings as a percentage of firm value is merely 0.35%. Note, however, that we only consider CEOs in our analysis. Since typically
the structure of compensation packages is similar for all executives within a single company, such a company could save considerably more than suggested by Table 6 if they adjusted the pay structure for all their executives. Altogether we conclude that the difference between observed contracts and contracts generated by the conventional model are statistically and economically significant.

4.2 Incorporating Taxes

So far our analysis ignores taxes. The optimal contracts calculated from our model suggest that CEOs should receive no options, lower base salaries, and more restricted stock. In this subsection we investigate the impact of taxes on our analysis. We differentiate between personal and corporate taxes. We carefully distinguish between restricted stock awarded by the company to the CEO and unrestricted stock that the CEO either held previously or that she bought from her own funds at the beginning of the contract period \(t = 0\). More specifically, we make the following assumptions:26

**Base salary.** The fixed component \(\phi\) of compensation is paid at time \(t = 0\) and is fully taxed at the personal level. For tax purposes it is regarded as a bonus and is therefore tax deductible at the corporate level. However, if \(\phi < 0\), then neither the company nor the CEO receives a tax credit as we treat this as a purchase of unrestricted stock by the CEO.

**Stock option grants.** Stock options are exercised at time \(t = T\). At this point in time, the gain from exercising the options, \(P_T - K\), is taxed at the personal level and creates a deductible expense for the company.

**Restricted stock grants and unrestricted stock.** Restricted stock may or may not be tax deductible at the corporate level. Tax law allows expensing of restricted stock and base salary up to a total of $1 million. Also, restricted stock can be expensed if it is awarded as part of a shareholder approved incentive plan. We assume that this is generally the case and treat restricted stock as a tax deductible expense for the company at the end of the vesting period. At the personal level,

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26The analysis is based on Hall and Liebman (2000). The precise analysis of taxes is somewhat tedious. We have prepared a short technical document that reparameterizes our model in order to allow for taxes along the lines described in the text. This document is available from the authors upon request.
the CEO defers taxes on the grant until the time when vesting lapses and we assume that this is the end of the contract period, \( t = T \) on the value \( P_T \) per share. Unrestricted stock is a purchase by the CEO from after-tax income and has no tax consequences other than taxes on dividends and capital gains.

**Dividends and capital gains.** Dividends are taxed at the personal level at the time of payment. We assume that the after tax dividend is reinvested in the company’s stock. Capital gains can be deferred indefinitely and are never taxed.

We use a tax rate of 42% for personal taxes and a rate of 35% for corporate taxes. Based on this analysis, we obtain our last result.

**Result 5.** Tax effects explain small positive option holdings for a small number of CEOs. Table 7 displays key results for the optimal contracts implied by the model for those CEOs who have positive option holdings.

We now obtain larger option holdings compared to the case without tax effects (cf. \( n_O^* = 0.003\% \) in Table 2 to 0.005\% in Table 7, Panel A for \( \gamma = 3 \)). However, while the relative increase is substantial, the absolute increase is marginal. The number of contracts with positive option holdings increases from 1.3\% to 1.9\% of CEOs. The size and number of positive option holdings decreases in risk aversion, as we would expect given that the costs of options compared to stock derive mainly from their riskiness. Moreover, the number of shares that need to be granted in order to displace one option increases slightly: the change in stockholdings is now 0.51\% instead of 0.47\% without tax considerations (\( \gamma = 3 \)). Hence, the resulting cut in base salary (about $3.3 million instead of $3.8 million for \( \gamma = 3 \)) is somewhat lower. The favorable tax treatment of options also reduces the benefits to the company from 20.3\% of total pay (cf. Table 6) to 15.0\% of total pay. Clearly, the order of magnitude of these savings does not change greatly.

The number of CEOs for whom we cannot verify the validity of the first-order approach increases somewhat relative to the case without taxes (cf. the notes to Table 2). Note that this only
implies that we cannot assure that sufficient conditions for the validity of the first-order approach hold, given that we impose no restrictions other than concavity on the production function \( P_0 (e) \). However, this problem is small for levels of risk aversion higher than 1. We conclude that tax effects explain a small part of the use of stock options for a small number of CEOs, but the effects are not strong enough compared to the effects that disfavor options discussed above.

### 4.3 Robustness Checks

In this subsection we discuss some of the assumptions made above in order to assess the robustness of our conclusions presented so far.

**Measurement of Wealth.** The variable measured with the least accuracy in our data is certainly initial non-firm wealth \( W_0 \). In order to establish how sensitive our results are to errors in initial wealth, we multiply our wealth estimates by a multiplier \( M_W \) and compute optimal contracts assuming \( \gamma = 3 \). Results for other levels of risk aversion would be qualitatively similar. We consider multipliers \( M_W \) in the range from 0.1 to 5. The main results are summarized in Figure 1. The main observations from the figure are:

- Optimal base salaries will decrease as a function of \( M_W \).
- The CEO’s investment required in stock increases as \( M_W \) is raised.
- The savings from recontracting are a declining function of wealth. For example, if we double each CEO’s wealth \( (M_W = 2) \), then savings drop by 27% (the median drops by 35%).

On the whole we observe what we would expect as a result of constant relative risk aversion where absolute risk aversion drops as wealth increases. The effect of an increase in wealth is therefore the same as the effect of a drop in risk aversion. However, none of our qualitative conclusions is affected.

**Market Risk and Firm-Specific Risk.** In the discussion of our valuation approach above we briefly hinted at the fact that our approach may overstate the riskiness of options to the CEO as
Figure 1: **Comparative statics for wealth.** We vary our measure of wealth by multiplying $W_0$ for each CEO by a constant factor $M_W$ between 0.1 and 5. We assume $\gamma = 3$. The solid lines represent the raw data, so different points reflect slightly different subsamples as optimal contracts could not be computed for some values of $M_W$ for some CEOs. The dashed lines interpolate the missing values from adjacent points. Cut in base pay is defined as in Table 4, relative savings as in Table 6, options explained as in Table 2. All values refer to means.

she could eliminate the market component of this risk by trading in the market index, an aspect not included in our model. We check for the importance of the distinction between firm-specific risk and market risk as follows. We estimate firm-specific risk $\sigma^2_\varepsilon$ by using the relationship $\sigma^2_\varepsilon = \sigma^2 - \beta^2 \sigma^2_M$, where $\sigma^2_M$ represents the volatility of the market and $\beta$ the CAPM-beta. We assume $\beta = 1$ for all companies in our sample and estimate $\sigma_M = 0.17$ for the year 2000. Then we numerically recalculate all contracts with $\sigma^2_\varepsilon$ instead of $\sigma^2$. However, we still use total risk $\sigma^2$ in order to calculate the costs of options to the company. We summarize our results in Table 8.

[Insert Table 8 about here]

None of the qualitative results of our analysis changes, so CEOs are still required to give up base salary for more stock. The comparative static properties of the model remain intact, so holdings of restricted stock decrease and base salaries increase with risk aversion. Ultimately, a completely satisfactory answer must rest on a more complete model that explicitly models investments in the
stock market. Existing research based on numerical examples is consistent with our findings.27

5 Interpretations and Extensions

The results from Section 4 leave us with the robust conclusion that observed practice does not conform to the predictions of our model. In this section we investigate if appropriate modifications of our model would generate observed contracts as results of efficient contracting. Ultimately, we want to understand how we should interpret our results: either as a rejection of the model or as a rejection of the efficient contracting view of CEO compensation.

Sticky base salaries. A simple way to fix our model would be to introduce a sticky base salary constraint. Assume that CEOs’ base salaries cannot be cut below a certain threshold value, and that this value coincides with the observed base salary, so we would add the constraint $\phi \geq \phi^d$ to program (14). Then we would find immediately that all contracts are rationalized as optimal contracts of this modified program. To see this, recall that our model trades off a combination of options and base salary against stock. Rebalancing the portfolio towards fewer options and more stock is feasible only if we can reduce base salaries at the same time, we cannot just shift between stock and options.28

One plausible economic reason for sticky CEO base salaries are liquidity constraints: if the CEO demands some compensation to finance consumption today because she cannot borrow against future compensation, then she will not accept a contract that offers more deferred compensation in exchange for a lower base salary. Such a constraint is always implicit in the argument that options are a “cheaper” form of incentive compensation, which we discussed in the introduction. If we add one stock option to the CEO’s compensation package, then this increases compensation costs by $BS$ and the pay for performance sensitivity increases by $N(d_1) < 1$. Hence, the price per unit of incentives (”delta”) is $BS/N(d_1)$. The delta of a share is 1 and it costs $P_0$. Hence, stock options are cheaper in providing incentives if $BS/N(d_1) < P_0$. Delta may be adjusted to allow for risk.

28 Mathematically, adding the minimum salary constraint leads to a program where the solution is already determined by the constraints, so no further optimization is possible.
aversion and exposure to firm-specific risk. This argument is correct if we ask: what is the best form to provide incentives, *holding base salary constant*? In an unconstrained model where base salaries can vary the comparison of dollar costs of pay for performance sensitivity is irrelevant: then we must compare the CEO’s *risk premiums* for options and for stock.\(^{29}\)

If this liquidity hypothesis were true, then we should observe more options in the compensation packages of those CEOs who have lower wealth, other things being equal. Also, CEOs of larger firms should find it more difficult to purchase additional stock to provide significant incentives. Table 9 investigates if these predictions are borne out by the data. The dependent variable is the proportion of options in risk-neutral pay for performance sensitivity, defined as:

\[
\text{Proportion of options} = \frac{n_{ON}(d_1)}{n_{ON}(d_1) + n_S}.
\]

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\]

[Insert Table 9 about here]

Initial wealth and firm size (measured by the log of market capitalization) both have a highly significant effect on the proportion of options. As expected, the effect of initial wealth is negative and the effect of firm size positive. Even though the slope estimates are highly significant, the economic effects are rather small, even after controlling for volatility (cf. regression (3)): doubling a CEO’s wealth decreases the proportion of options in her incentive pay by only about 5.9 percentage points. Similarly, doubling the market capitalization of her company increases her proportion of options by about 4.2 percentage points. Also, the adjusted R-squared is only 14% and a large part of the variation in the proportion of options remains unexplained. Our dataset contains some very wealthy CEOs who hold options (e.g. Michael Dell), and it seems implausible that they could be liquidity-constrained. Also companies might underwrite a loan and thereby help to overcome liquidity constraints. Hence, the liquidity hypothesis remains somewhat unconvincing and cannot explain most of the variation in the data.

We also suspect that liquidity constraints are stronger for younger CEOs and those who have

\(^{29}\)It seems that the imposition of a more stringent limited liability constraint also explains most of the apparent difference between Lambert and Larcker’s (2004) results and ours. They also make somewhat different parametric assumptions and allow the level of incentives to vary in their example. We suspect that loosening the limited liability constraint in their analysis would dramatically reduce the optimal option holdings they find.
joined the company more recently. With increasing age and tenure, CEOs would then successively exercise options and hold more stock of the company. This hypothesis is borne out by the data (see regressions (5) - (7) in Table 9), but again, the quantitative impact is small: an increase in tenure of 1 year reduces the proportion of options by 0.57%, so a CEO who has been with the firm for 10 years has on average 5.7% less of her incentive pay in options compared to a CEO who has just joined. Table 9 is also useful to compare our methodology with regression analysis: all variables in Table 9 are significant and have the predicted signs. This indicates that the model’s qualitative implications are correct, even though the quantitative implications do not get close to matching the data.

**Dynamic Trading.** Another potential shortcoming of our analysis is that a static model may overstate the CEO’s aversion to risky options by not allowing her to hedge the systematic risk of the firm. Ingersoll (2002) presents a model with dynamic trading and computes the dollar costs for the incentives provided by options and stock. However, his method implicitly assumes a liquidity constraint, as he compares dollar costs of securities and not the net costs of awarding stock and options (risk premia, see above). If we calibrate his model to our sample assuming that base salaries are flexible, then no CEO would have options as part of the optimal contract.

**Optimism and Overconfidence.** Our valuation methodology assumes that CEOs use the same assumptions for valuing stock options as the stock market. Oyer and Schaefer (2002) suggest that CEOs may be overconfident or overly optimistic about the future development of the stock of their companies. We tested this in the context of our model (results not reported) by adding an annual premium to the risk-free rate (only from the CEO’s perspective, not for market values). This increases the CEO’s valuation of options more than her valuation of shares. We find only very moderate increases in option holdings for plausible assumptions about optimism (a premium up to 10% per year). Qualitatively, we replicate the results of Oyer and Schaefer in this respect.

**Incentives to invest in risky projects.** Another explanation for the use of stock options that was first formulated by Smith and Stulz (1985) holds that options provide incentives for managers
to invest in risky projects. Indirect evidence in support of this notion was found by a number of studies.\textsuperscript{30} We can approach this question from the perspective of our model as follows. A CEO would be deterred from investing in a positive NPV project if the project increases the risk of the company and her utility decreases in the volatility of the company, so that $\frac{\partial EU}{\partial \sigma} < 0$. Hence, we compute this derivative and determine by how much the CEO’s utility would fall from an increase in volatility by 1 percentage point (e.g., from 0.30 to 0.31) and compare this change in utility between the observed contract and the optimal contract prescribed by the model.\textsuperscript{31} Table 10 summarizes our results.

[Insert Table 10 about here]

In the left part of the table we compute the percentage reduction in utility from a 1 percentage point increase in volatility. For example, for $\gamma = 3$, utility decreases on average by 2.50% from a 1 percentage point increase in volatility under the actual contract, and by 2.99% under the optimal contract that does not contain any options. Hence, the option holdings in observed contracts remove about one sixth of the utility-decline. In the right hand part of the table we provide another approach to the same data. Here, we define a CEO as risk-averse if her utility declines by more than 1% from a 1 percentage point increase in volatility, as risk-loving if her utility increases by more than 1%, and as risk-neutral otherwise. With this definition and $\gamma = 3$, 26.6% of all CEOs are classified as risk-neutral under the observed contract, but only 18.9% under the optimal contract. Other definitions of risk-neutrality do not generate qualitatively different results.\textsuperscript{32}

We interpret these results as saying that observed contracts normally do not change the CEO’s attitude towards risk appreciably in one way or another. The proportion of CEO’s whose risk-aversion is practically neutralized by their option holdings (so that $\frac{\partial EU}{\partial \sigma} \approx 0$) is small, no matter

\begin{itemize}
  \item Williams and Rao (2000) show that CEOs with more stock options tend to undertake risk-increasing acquisitions.
  \item Tufano (1996) shows that companies in the gold mining industry hedge more if their executives own more stocks and less if they hold more options.
  \item Guay (1999) provides evidence that companies with more growth opportunities provide their executives with more incentives to take risks.
  \item Rajgopal and Shevlin (2001) find that stock options increase the inclination to take risks in a study of oil and gas producers.
  \item Similarly, Li (2002) presents evidence consistent with the view that companies continuously adjust the contracts of their CEOs if they deviate from contracts that provide optimal risk-taking incentives.
\end{itemize}

\textsuperscript{31} Guay (1999) analyzes sensitivities of wealth to risk by looking at 0.01-changes in $\sigma$.

\textsuperscript{32} We also constructed the same table requiring that CEO’s utility remain within a +/-0.1% band for them to be called risk-neutral. This reduces the proportion of CEO’s labelled risk-neutral to 3.3% (observed contract) and 0.7% (optimal contract) respectively.
which definition of “practically neutralized” we apply. We therefore conclude that the use of stock options to create risk-taking incentives cannot explain the pervasive use of stock options in its own right, even though it may be part of a more complex explanation.\textsuperscript{33}

\textbf{Alternative Technologies.} The choice of the lognormal distribution which has become standard for many applications may bias the results against options. As the theoretical discussion in Appendix A shows, the unrestricted optimal contract is convex only because of the limited wealth constraint (10) for all $\gamma \geq 1$. Hemmer, Kim, and Verrecchia (2000) suggest the Gamma distribution as an alternative model for the technology in a principal agent model and show that it can generate convex contracts for $\gamma = 0.5$. We therefore repeat our analysis and replace the lognormal distribution with the Gamma distribution and calibrate the distribution again to match the first two moments (market capitalization and standard deviation of returns). Table 11 summarizes the main results.

[Insert Table 11 about here]

The structure of Table 11 resembles that of Table 7. We corroborate the result of Hemmer, Kim, and Verrecchia (2000): for $\gamma = 0.5$, we obtain significant option holdings for a significant number of CEO’s.\textsuperscript{34} However, for larger values of risk aversion the differences between the lognormal distribution and the Gamma distribution become small, and for $\gamma \geq 4$ implied savings are on average larger with the Gamma model than with the lognormal model. For reasons discussed above (see p. 11), we do not believe the region below $\gamma = 1$ to be particularly relevant and conclude that this approach does not lead to a substantially more realistic model.

\textbf{Inefficient contracting.} Instead of attempting to improve our model, we may alternatively put more trust in the model as it stands and conclude that the CEO-compensation contracts we observe are the outcome of inefficient contracting. If this is indeed the case, then less efficient

\textsuperscript{33} Other authors have also expressed scepticism on the view that options uniformly increase risk-taking incentives, see e. g. Carpenter (2000) and Ross (2003).

\textsuperscript{34} This leads also to a violation of the sufficient conditions for the validity of the first-order approach in a large number of cases. Hence, for low value of $\gamma$ this analysis is valid only if we are also prepared to assume conditions stronger than just concavity of the production function, respectively, convexity of the cost function.
contracts should be the outcome of inefficient governance and we should observe that variables measuring the effectiveness of corporate governance are positively correlated with measures of contracting efficiency.\textsuperscript{35} Note that, according to our model, the use of options is the primary source of contracting inefficiency. This result coincides with the popular argument that options are a form of hidden compensation that is not fully perceived by the market, as evidenced by managers’ resistance to the expensing of employee stock options.\textsuperscript{36}

A complete exploration of the relationship between corporate governance and contractual efficiency is clearly beyond the scope of this paper. Here we just provide some evidence that tests the inefficient contracting view. We measure the efficiency of contracting by the savings available from more efficient contracting according to the model, defined as $\left( \pi_d^\ast - \pi_0^\ast \right) / \pi_0^d$. As a proxy for the efficiency of governance we use the level of incentives of the CEO from owning stock and options, measured by the pay for performance-sensitivity under risk neutrality, $n_S^d + n_O^d N(d_1)$.\textsuperscript{37} We find that those firms in which CEOs have weaker incentives (i.e., lower $PPS$) can realize higher savings from recontracting: the correlation between $PPS$ and savings is $-21.6\%$ and statistically significant at the 1%-level. When we control for wealth and the size of the company (regression results not reported) however, the effect of $PPS$ on savings is only marginally significant. Hence, if firms with a low pay for performance-sensitivity are those with weaker corporate governance, then the quality of corporate governance is negatively correlated with the use of options, and therefore larger potential savings from the optimal contracts implied by our model.\textsuperscript{38}

\section{Discussion and Conclusion}

We analyze executive compensation contracts using a standard, one-period principal agent model of efficient contracting with CRRA-utility and lognormal distribution of prices and estimate it for a

\textsuperscript{35}Benz, Kucher, and Stutzer (2000) argue along these lines and show that executives from firms with less effective governance receive more options.

\textsuperscript{36}See Dechow, Hutton, and Sloan (1996) for an analysis of arguments accounting for this resistance and Guay, Kothari and Sloan (2003) for a partial refutation of this argument based on the observation that the costs of stock option schemes are much larger than can be justified by revealed preferences to report higher earnings.

\textsuperscript{37}Note that this approach does not put similar variables on the right hand side and the left hand side of the regression. The dependent variable (savings) is related to the composition of the contract between stock and options, whereas the independent variable ($PPS$) is a measure of the level of incentives.

\textsuperscript{38}A similar conclusion follows also from Habib and Ljungqvist (2003).
sample of 598 US CEOs. Our assumptions are widely used in the compensation literature, but the model yields predictions that markedly differ from observed compensation schemes. Generally, the model predicts that optimal compensation schemes should have no or at best miniscule holdings of stock options, and that incentives should essentially be provided through restricted stock. In addition, base salaries should be lower, and many CEOs would be required to invest some of their savings into their company’s stock. By switching from observed contracts to optimal contracts, companies could realize economically significant savings.

We discuss four different modifications of our model that may help to reconcile it with observed compensation practice.

- We observe that we can fix the model by assuming that CEO base salaries cannot decrease if CEOs are liquidity constrained, but our regression evidence provides only limited support for this view.\(^{39}\)

- Taxes may favor options, but incorporating taxes into our analysis does not yield qualitatively different results.

- Options may be awarded to provide incentives to invest in risky projects rather than effort incentives, but our results indicate that only a small number of observed compensation packages seem to be designed to accomplish this.

- Alternative technologies may yield better results. We check this for the Gamma distribution which has been suggested before and find that results are similar for realistic levels of risk aversion. Similarly, Feltham and Wu (2001) use a CARA-normal model and present analytic results showing that stock is more efficient than stock options.

Our results may be exaggerated quantitatively by using data from the year 2000, which saw a peak in option compensation. We would therefore expect that using more recent data would change our numbers, however, without influencing our general, qualitative conclusions.\(^{40}\) We feel

\(^{39}\) See Kedia and Mozumdar (2002) for the argument that options help to overcome liquidity constraints at the firm level.

\(^{40}\) Towers Perrin (2004) reported in 2004 that "(...) run rates have decreased over the past three years as companies have begun to shift their equity compensation from primarily stock options to more full-value shares."
compelled to conclude that neither the conventional model nor any of its obvious extensions or modifications explain the pervasive practice of awarding stock options to CEOs. More may be gained from models including other features like career concerns (Holmström and Ricarti Costa, 1986, Nohel and Todd, 2004), preferences not based on expected utility (see Jost and Wolff, 2003), employee retention (Oyer, 2003), or incentives to make optimal liquidation decisions (Inderst and Müller, 2003). Behavioral biases like valuation errors in capital markets (undervaluation of dilution through stock options) may also account for the widespread use of options.41 We also consider the hypothesis that stock option awards are an expression of weak corporate governance, and find moderate support for this hypothesis. This discussion extends beyond the scope of our paper and we mainly contribute a new dependent variable to this discussion by computing the savings from recontracting predicted by an efficient contracting model.

Another avenue for further research may be the explicit consideration of the dynamic aspects of contract negotiation. The standard model and its variants discussed in this paper are static and as a result any empirical implementation ignores the fact that contracts are adjusted every year and that the structure of contracts today determines the positions of each party in future negotiations.

We regard the search for a parsimonious model that explains existing compensation practice as an important task for future research. This model should provide a more satisfactory answer to questions of optimal option design (such as reloading, repricing, indexing, or strike prices) that have so far been analyzed in the context of a model that cannot generate optimal contracts with options.

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41 See Garvey and Milbourn (2002) for evidence on valuation errors in the stock market.
7 Appendix

A Theoretical Analysis

A.1 Solving for the General Contract

In this appendix we discuss a more general contract that can be written as a general pay-function $\pi(P_T)$, which denotes the compensation the manager receives at time $T$. From (1), $P_T$ is distributed lognormal with parameters $\mu(e)$ and $\sigma^2 T$, where

$$\mu(e) = \ln(P_0(e)) + \left(r_f - \frac{\sigma^2}{2}\right)T.$$  \hfill (16)

Then $\log(P_T) = \mu(e) + u\sigma \sqrt{T}$ is normal with mean $\mu(e)$ and standard deviation $\sigma \sqrt{T}$. We denote the density of $P_T$ for a given level of effort $e$ by $f(P_T|e)$:

$$f(P_T|e) = \frac{1}{P_T\sqrt{2\pi}T} \exp\left\{ -\frac{[\ln P_T - \mu(e)]^2}{2\sigma^2 T} \right\}.$$  \hfill (17)

Then the likelihood ratio is

$$\frac{df(P_T|e)/de}{f(P_T|e)} = \mu'(e) \frac{\ln P_T - \mu(e)}{\sigma^2 T}$$

with $\mu'(e) = P_0'(e)/P_0(e)$. This maps our model into Holmström’s (1979) framework. Denote the Lagrange multipliers on the participation constraint (PC) and the incentive compatibility constraint (IC) by $\lambda_{PC}$ and $\lambda_{IC}$ respectively. Both Lagrange multipliers need to be positive. Then the optimal contract $\pi^*(P_T)$ for a given level of effort $e$ is fully described by Holmström’s equation (7), adapted to our model:

$$(W_0 \exp(r_f T) + \pi^*(P_T))^\gamma = \lambda_{PC} + \lambda_{IC} \mu'(e) \frac{\ln P_T - \mu(e)}{\sigma^2 T} \equiv \alpha_0 + \alpha_1 \ln P_T,$$  \hfill (18)

where $\alpha_1 = \frac{\lambda_{IC} P_0'(e)}{\sigma^2 T P_0(e)} > 0$, $\alpha_0 = \lambda_{PC} - \alpha_1 \mu(e)$.  

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Observe that the limited wealth constraint (10) implies that $W_T \geq 0$ for all $P_T$, so the argument of the utility function cannot be negative. Similarly, the principal enjoys limited liability and cannot pay a compensation larger than the value of the firm itself. Therefore, the constraints on $\pi (P_T)$ are:

$$-W_0 \exp (r_f T) \leq \pi (P_T) \leq P_T .$$

However, the right hand side of (18) will be negative for $P_T < \exp (-\alpha_0 / \alpha_1)$. We therefore obtain the following solution for $\pi (P_T)$:

$$\pi^* (P_T) = \begin{cases} 
(\alpha_0 + \alpha_1 \ln P_T)^{1/\gamma} - W_0 \exp (r_f T) & \text{if } P_T \geq \exp (-\alpha_0 / \alpha_1) \\
-W_0 \exp (r_f T) & \text{if } P_T < \exp (-\alpha_0 / \alpha_1)
\end{cases} .$$

(19)

Standard analysis of (19) yields the following results. The solution $\pi^*$ to the optimal contracting problem is constant at $-W_0 \exp (r_f T)$ for all prices below $\exp (-\alpha_0 / \alpha_1)$. At $P_T = \exp (-\alpha_0 / \alpha_1)$ the function is not differentiable and to the right of $P_T = \exp (-\alpha_0 / \alpha_1)$ its slope is positive. The function is convex at $P_T = \exp \{-\alpha_0 / \alpha_1\}$: for any $P_1, P_2$ such that $P_1 < \exp (-\alpha_0 / \alpha_1) < P_2$ and for any $a \in [0; 1]$ we have that $a \pi^* (P_1) + (1 - a) \pi^* (P_2) > \pi^* (\exp (-\alpha_0 / \alpha_1))$. The function is concave over the whole interval $[\exp (-\alpha_0 / \alpha_1), \infty]$ if $\gamma \geq 1$. For $\gamma < 1$, the $\pi^*$-function is convex if

$$P_T \in \left[ \exp \left\{-\frac{\alpha_0}{\alpha_1}\right\}, \exp \left\{\frac{1 - \gamma}{\gamma} - \frac{\alpha_0}{\alpha_1}\right\} \right] ,$$

and concave to the right of this interval, with an inflection point that is decreasing in $\gamma$. The optimal contract $\pi^* (P_T)$ is therefore neither convex nor concave.

A.2 Proof of Proposition 1:

We prove the claim by contradiction. Suppose there would be an optimal effort level $\hat{e} < e^*$. This effort level would have to satisfy (13), so that $UPPS (\phi^*, n_S^*, n_O^*, \gamma; P (\hat{e})) = k (\hat{e})$. Note that $k (e)$

\[42\] For a discussion on limits on the sharing function $\pi$ see also Holmström (1979), p. 77.
is strictly increasing in $e$:

$$\frac{dk(e)}{de} = \exp(-r_f T) \frac{C''(e) P'(e) - C'(e) P''(e)}{P'(e)^2} > 0,$$

as $C$ and $P$ are both increasing and $C$ is convex and $P$ is concave. However, then (13) can only be satisfied if

$$UPPS(\phi^*, n^*_S, n^*_O; \gamma, P(e^*)) < UPPS(\phi^*, n^*_S, n^*_O; \gamma, P(\hat{e})) = UPPS(\phi^d, n^d_S, n^d_O; \gamma, P_0)$$

which is ruled out by (15). For $n^*_O = 0$, $E[U(W_T, e)]$ is a concave function of $P$, as $U$ is concave and $W_T$ is then linear in $P_T$. Then (15) is always satisfied.

**B Construction of the Dataset**

This appendix provides a more detailed discussion of the construction of our non-firm wealth variable $W_0$ and the representative option.

**Wealth.** The ExecuComp database has no variable for wealth, so we need to approximate wealth from other variables. We proceed as follows. Every CEO is assumed to have zero wealth on the date when she enters the database. Denote the end of the fiscal year when the CEO enters the database by $t_E$, so we assume that $W_{t_E-1} = 0$. Similarly, denote the end of the fiscal year where we observe and evaluate the contract by $t_0$ (“today”). Then for each year we calculate the CEO’s net cash inflow as follows:

- Fixed salary $\phi$ (after tax)
- Dividend income from shares held in own company (after tax)
- Value of restricted stock granted
- Personal taxes on restricted stock that vest during the year
- Net value realized from exercising options (after tax)
- Cash paid for purchasing additional stock
= Cash Income.
Here, fixed salary $\phi$ is defined as the sum of the following four ExecuComp data types: Salary, Bonus, Other Annual, and All Other Total. Following Hall and Liebman (2000), we use the following personal tax rates: 31% for 1992, 39.6% for 1993, and 42% from 1994 onwards.

As ExecuComp records only the value but not the number of restricted shares granted, we add the value to cash income and deduct the cash needed for purchasing the change in stockholdings. Likewise, we add the value realized from exercising options. So if the CEO exercises $n$ options but does not sell any shares and does not receive any restricted stock grants in this period, we add the net value realized from exercising the options (i.e. the value of the $n$ shares at the time the options were exercised minus the strike price) to cash income and deduct $n$ times the market price of the shares at fiscal year end. Due to fluctuations in stock prices, this method will lead to some errors. However, there is no alternative to this approach, because we do not know the strike price of the options exercised. If the CEO sells more shares than she receives from restricted grants or exercising options, her stock holdings decrease and the item “cash paid for purchasing additional stock” above becomes negative. If a CEO changed her employer during her history in the database, we assume that she sold all unrestricted stock in the old company and exercised all exercisable options for which we know the strike price before she has been hired by the new company. Restricted stock and unexercisable options are assumed to be lost. In addition, we assume that she bought the shares held in the new company that were not granted to her in the first year.

Denote the cash inflow during fiscal year $t$ by $y_t$. We assume that the CEO invests all her surplus cash at the risk-free rate of interest and does not consume. We assume that all cash inflows are realized at the end of the fiscal year and invested at the risk-free rate $r_{f}^{t+1}$ during the next fiscal year. Data on the annual one-year risk-free rate $r_f$ has been obtained from the Federal Reserve Board’s website (http://www.federalreserve.gov). Then we obtain our estimate for the CEO’s (non-stock) wealth:

\[
W_0 = y_{t_0} + \sum_{t=t_0}^{t_0-1} y_t \prod_{s=t+1}^{t_0} (1 + r_f^s) .
\]

(20)

Our approximation biases wealth downward by assuming that wealth is zero at the date the CEO enters the database. Also, wealth is biased upward from our assumption of zero consumption. Finally, there may be an additional error from assuming that all savings are invested at the risk-free
rate. Most of our sample period coincides with the stock market boom in the late 1990’s, so this aspect will also bias wealth downward. We cannot determine how these effects net out.

**Stock Options.** We approximate the options portfolios held by the CEOs at the end of the 1999 fiscal year using the algorithm proposed by Core and Guay (2002). Then we construct a representative option that summarizes the salient features of this option portfolio. We do this by creating a composite option that matches the value and the option delta of the option portfolio. Denote the number of options of type $\tau$ (with strike price $K^\tau$ and maturity $T^\tau$) by $n^\tau_O$. We set the number of composite options held by the CEO to $n_O = \sum \tau n^\tau_O$ and denote by $BS$ the Black-Scholes value of this option and by $N(d_1)$ the option delta. Then we determine the maturity $T$ and the strike price $K$ of the composite option by solving the following system of equations for each CEO:

\[
\sum \tau n^\tau_O BS(P_0, K^\tau, \sigma, r_f, 0.7T^\tau) = n_O BS(P_0, K, \sigma, r_f, T) \quad ,
\]

\[
\sum \tau n^\tau_O N(d_1^\tau) = n_O N(d_1) \quad .
\]

Conditions (21) and (22) form a system of two equations in the two unknowns $K, T$, which represent the free parameters of the composite option. We take into account the fact that most CEOs exercise their stock options before maturity by multiplying $T^\tau$ by 0.7 before calculating the representative option (see Huddart and Lang, 1996, and Carpenter, 1998). For $r_f$ we use the U.S. government bond yield with 6-year maturity from January 2000, because the average maturity of the representative options is 5.9 years in our sample as shown in Table 1. The two remaining parameters ($P_0, \sigma$) are given by the data. Hence, our procedure establishes parameters for the options that do not change the value of these options to shareholders and how this valuation changes as a function of the stock price. For CEOs who do not have any options, we set $K = P_0$ and $T = 10$ as these are the typical values for newly granted options.
C Numerical Considerations

For our numerical calculations, we reparameterize (14) by \( n = n_S + n_O \) and \( a = n_O/n \), so that the contract parameters are \((\phi, a, n)\) instead of \((\phi, n_S, n_O)\). We consider 9 different values for the CEO’s risk aversion parameter \( \gamma \): 0.5, 1, 2, 3, 4, 5, 6, 8, and 10. For each CEO and each value of \( \gamma \), we solve problem (14) by performing a grid search on \( a \) over the unit interval in steps of 0.02. Note that, for a given \( a \), the incentive compatibility constraint and the participation constraint form a system of two non-linear equations in the two unknowns \( \phi \) and \( n \). We solve this system numerically in order to obtain \( \phi \) and \( n \) for each \( a \). Then we can evaluate the objective just as a function of \( a \) alone. Finally, we determine the minimum of \( \pi_0(\phi(a), a, n(a)) \) over all \( a \). We apply this procedure for each value of \( \gamma \). In this way we obtain optimal contracts for 5,382 \( \gamma \)-CEO-combinations.

We encounter some numerical problems in the first step of our optimization procedure when we try to find \( \phi \) and \( n \) for a given CEO-\( \gamma \)-\( a \)-combination. Our algorithm does not converge for 4.4% of the 274,482 CEO-\( \gamma \)-\( a \)-combinations. Most problems occur for extreme values of \( \gamma \) and \( a \). For \( \gamma = 0.5 \), the algorithm does not converge in 13.8% of all cases. For \( \gamma = 8 \) and \( \gamma = 10 \), we have 5.9% and 13.4% such convergence problems. For the remaining values of \( \gamma \), the algorithm does not converge in only 1.1% of all cases. In a visual inspection of the functions \( \pi_0(a) \) we find a few non-monotonicities that are clearly due to numerical problems: In two cases (for \( \gamma = 0.5 \)) we observe \( n_O(a) = 0 \) for all \( a \), which clearly is an error, because by construction \( n_O(a) \) must be larger than zero if \( a > 0 \). We therefore exclude these two CEO-\( \gamma \)-combinations. For two CEOs and \( \gamma = 1 \), we find that \( n_O(a) = 0 \) for some large \( a \), so we exclude these values (21 CEO-\( \gamma \)-\( a \)-combinations). Finally, we exclude 3 CEO-\( \gamma \)-\( a \)-combinations that are obvious single outliers.
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Table 1: Description of the dataset

This table displays mean, median, standard deviation, minimum and maximum of eleven variables. Panel A describes our sample of 598 US CEOs. Panel B describes all 1,417 executives who were CEO in 2000 according to the ExecuComp database. Panel B also contains the statistic of the two-sample t-test for equal mean (allowing for different variances). Before calculating this statistic, we removed all observations from the sample in Panel B that are also contained in the sample in Panel A.

### Panel A: Dataset with 598 U.S. CEOs

<table>
<thead>
<tr>
<th>Variable</th>
<th>Symbol</th>
<th>Mean</th>
<th>Median</th>
<th>Std. Dev.</th>
<th>Minimum</th>
<th>Maximum</th>
</tr>
</thead>
<tbody>
<tr>
<td>Base Salary ($'000)</td>
<td>φ</td>
<td>2,037</td>
<td>1,261</td>
<td>2,570</td>
<td>97</td>
<td>22,109</td>
</tr>
<tr>
<td>Stock (%)</td>
<td>n_s</td>
<td>2.29%</td>
<td>0.29%</td>
<td>6.00%</td>
<td>0.00%</td>
<td>46.34%</td>
</tr>
<tr>
<td>Options (%)</td>
<td>n_O</td>
<td>1.29%</td>
<td>0.84%</td>
<td>1.82%</td>
<td>0.00%</td>
<td>24.32%</td>
</tr>
<tr>
<td>Value of stock ($ mil)</td>
<td>n_S P_0</td>
<td>91.98</td>
<td>6.62</td>
<td>571.95</td>
<td>0.00</td>
<td>11,814.08</td>
</tr>
<tr>
<td>Value of options ($ mil)</td>
<td>n_O BS</td>
<td>29.47</td>
<td>6.11</td>
<td>104.42</td>
<td>0.00</td>
<td>1,334.43</td>
</tr>
<tr>
<td>Market Value ($ mil.)</td>
<td>P_0</td>
<td>9,857</td>
<td>1,668</td>
<td>27,845</td>
<td>7</td>
<td>280,114</td>
</tr>
<tr>
<td>Wealth ($'000)</td>
<td>W_0</td>
<td>34.60</td>
<td>6.86</td>
<td>234.79</td>
<td>0.03</td>
<td>5,431.72</td>
</tr>
<tr>
<td>Option Delta</td>
<td>N(d_1)</td>
<td>0.834</td>
<td>0.856</td>
<td>0.126</td>
<td>0.001</td>
<td>1.00</td>
</tr>
<tr>
<td>Maturity (years)</td>
<td>T</td>
<td>5.89</td>
<td>5.54</td>
<td>1.96</td>
<td>1.20</td>
<td>22.18</td>
</tr>
<tr>
<td>Stock Price Volatility</td>
<td>σ</td>
<td>0.377</td>
<td>0.335</td>
<td>0.196</td>
<td>0.136</td>
<td>3.487</td>
</tr>
<tr>
<td>Age of CEO</td>
<td></td>
<td>57</td>
<td>57</td>
<td>7</td>
<td>36</td>
<td>84</td>
</tr>
</tbody>
</table>

### Panel B: All 1,417 ExecuComp CEOs in 2000

<table>
<thead>
<tr>
<th>Variable</th>
<th>Symbol</th>
<th>Mean</th>
<th>Median</th>
<th>Std. Dev.</th>
<th>Minimum</th>
<th>Maximum</th>
<th>T-test statistic</th>
</tr>
</thead>
<tbody>
<tr>
<td>Base Salary ($'000)</td>
<td>φ</td>
<td>1,718</td>
<td>1,059</td>
<td>3,150</td>
<td>0</td>
<td>90,000</td>
<td>3.43</td>
</tr>
<tr>
<td>Stock (%)</td>
<td>n_S</td>
<td>2.97%</td>
<td>0.35%</td>
<td>6.78%</td>
<td>0.00%</td>
<td>56.42%</td>
<td>-3.32</td>
</tr>
<tr>
<td>Options (%)</td>
<td>n_O</td>
<td>1.45%</td>
<td>0.96%</td>
<td>1.88%</td>
<td>0.00%</td>
<td>27.93%</td>
<td>-2.74</td>
</tr>
<tr>
<td>Value of stock ($ mil)</td>
<td>n_S P_0</td>
<td>132.44</td>
<td>6.45</td>
<td>1,385.87</td>
<td>0.00</td>
<td>47,838.75</td>
<td>-1.07</td>
</tr>
<tr>
<td>Market Value ($ mil.)</td>
<td>P_0</td>
<td>8,012</td>
<td>1,256</td>
<td>27,551</td>
<td>7</td>
<td>508,329</td>
<td>2.15</td>
</tr>
<tr>
<td>Stock Price Volatility</td>
<td>σ</td>
<td>0.435</td>
<td>0.384</td>
<td>0.205</td>
<td>0.136</td>
<td>3.487</td>
<td>-9.36</td>
</tr>
<tr>
<td>Age of CEO</td>
<td></td>
<td>55</td>
<td>55</td>
<td>8</td>
<td>29</td>
<td>86</td>
<td>7.41</td>
</tr>
</tbody>
</table>

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Table 2: Option holdings implied by the model

This table displays the mean option holdings (the mean of \( n_{O^*} \)), the fraction of CEOs with positive option holdings (\( n_{O^*} > 0 \)) and the paired two-sample t-test statistic for equal mean in observed and predicted option holdings. In addition, the table shows the average proportion of observed options that can be explained by predicted options for those CEOs who have positive observed option holdings. Results are shown for nine different values of the parameter of risk aversion \( \gamma \). The number of CEOs varies between the different levels of risk aversion as we exclude those CEO–\( \gamma \)-combinations, for which we could neither find an interior solution nor calculate the costs of the contract for \( n_{O} = 0 \). We also exclude those CEOs for whom we could not verify the validity of the first-order approach.

<table>
<thead>
<tr>
<th>Risk aversion</th>
<th>Number of CEOs</th>
<th>Fraction with options &gt; 0</th>
<th>Mean option holdings as % of actual holdings</th>
<th>t-statistic for equal mean option holdings</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.5</td>
<td>503</td>
<td>13.12%</td>
<td>0.054%</td>
<td>5.054%</td>
</tr>
<tr>
<td>0.5</td>
<td>506</td>
<td>13.64%</td>
<td>0.059%</td>
<td>5.523%</td>
</tr>
<tr>
<td>1.0</td>
<td>594</td>
<td>10.77%</td>
<td>0.041%</td>
<td>4.009%</td>
</tr>
<tr>
<td>2.0</td>
<td>591</td>
<td>5.25%</td>
<td>0.014%</td>
<td>1.597%</td>
</tr>
<tr>
<td>3.0</td>
<td>598</td>
<td>1.34%</td>
<td>0.003%</td>
<td>0.272%</td>
</tr>
<tr>
<td>4.0</td>
<td>597</td>
<td>0.34%</td>
<td>0.001%</td>
<td>0.023%</td>
</tr>
<tr>
<td>5.0</td>
<td>598</td>
<td>0.00%</td>
<td>0.000%</td>
<td>0.000%</td>
</tr>
<tr>
<td>6.0</td>
<td>591</td>
<td>0.00%</td>
<td>0.000%</td>
<td>0.000%</td>
</tr>
<tr>
<td>8.0</td>
<td>520</td>
<td>0.00%</td>
<td>0.000%</td>
<td>0.000%</td>
</tr>
<tr>
<td>10.0</td>
<td>458</td>
<td>0.00%</td>
<td>0.000%</td>
<td>0.000%</td>
</tr>
</tbody>
</table>

Table 3: Change in stock holdings implied by the model

This table displays means and medians of four variables that describe the change in the CEOs’ stock holdings between observed contracts and optimal contracts for 577 CEOs who have positive observed option holdings. The change in stock holdings is expressed as a percentage of all outstanding equity, \( n_{S^d} - n_{S^*} \). The change in value is the change in stock holdings multiplied by the firm’s market value, \( (n_{S^d} - n_{S^*})P_0 \). The relative change is the change in stockholdings scaled by the observed stock holdings, \( (n_{S^d} - n_{S^*})/n_{S^d} \). The exchange ratio is minus the change in stock holdings divided by the change in option holdings, \(- (n_{S^d} - n_{S^*})(n_{O^d} - n_{O^*})\). Results are shown for nine different values of the parameter of risk aversion \( \gamma \). The number of CEOs varies between the different levels of risk aversion as we exclude those CEO–\( \gamma \)-combinations, for which we could neither find an interior solution nor calculate the costs of the contract for \( n_{O} = 0 \). For \( \gamma = 0.5 \), we also exclude 3 CEOs for whom we could not verify the validity of the first-order approach.

<table>
<thead>
<tr>
<th>Change in stock holding Mean</th>
<th>Median</th>
<th>Change in value ($ '000) Mean</th>
<th>Median</th>
<th>Median relative change</th>
<th>Exchange ratio Mean</th>
<th>Median</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.5</td>
<td>484</td>
<td>0.973%</td>
<td>0.553%</td>
<td>33,887</td>
<td>8,430</td>
<td>157.35%</td>
</tr>
<tr>
<td>1</td>
<td>573</td>
<td>0.829%</td>
<td>0.486%</td>
<td>32,023</td>
<td>8,705</td>
<td>158.64%</td>
</tr>
<tr>
<td>2</td>
<td>570</td>
<td>0.635%</td>
<td>0.380%</td>
<td>26,760</td>
<td>6,356</td>
<td>122.79%</td>
</tr>
<tr>
<td>3</td>
<td>577</td>
<td>0.472%</td>
<td>0.272%</td>
<td>21,476</td>
<td>4,667</td>
<td>95.04%</td>
</tr>
<tr>
<td>4</td>
<td>576</td>
<td>0.361%</td>
<td>0.197%</td>
<td>16,596</td>
<td>3,428</td>
<td>67.31%</td>
</tr>
<tr>
<td>5</td>
<td>577</td>
<td>0.282%</td>
<td>0.144%</td>
<td>12,908</td>
<td>2,590</td>
<td>53.13%</td>
</tr>
<tr>
<td>6</td>
<td>570</td>
<td>0.226%</td>
<td>0.109%</td>
<td>10,081</td>
<td>1,880</td>
<td>39.08%</td>
</tr>
<tr>
<td>8</td>
<td>500</td>
<td>0.173%</td>
<td>0.080%</td>
<td>6,811</td>
<td>1,062</td>
<td>23.67%</td>
</tr>
<tr>
<td>10</td>
<td>440</td>
<td>0.133%</td>
<td>0.051%</td>
<td>4,806</td>
<td>567</td>
<td>13.48%</td>
</tr>
</tbody>
</table>

\( ^b \) This includes 3 CEOs for whom we could not verify the validity of the first-order approach.
Table 4: Change in base salaries implied by the model

This table displays means and medians of two variables that describe the change in the CEOs’ base salary between observed contracts and optimal contracts for 577 CEOs who have positive observed option holdings. The change in base salary is the nominal difference between the observed base salary and the optimal base salary according to our model, $\phi^d - \phi^*$. The relative change in base salary is the change in base salary scaled by the observed base salary, $(\phi^d - \phi^*)/\phi^d$. In addition, the table displays the proportion of CEOs with negative base salary under the optimal contract ($\phi^* < 0$). Negative base salaries mean that the CEO must invest this amount of money from her own savings into her company’s stock. Results are shown for nine different values of the parameter of risk aversion $\gamma$. The number of CEOs varies between the different levels of risk aversion as we exclude those CEO–$\gamma$–combinations, for which we could neither find an interior solution nor calculate the costs of the contract for $n_0 = 0$. For $\gamma = 0.5$, we also exclude 3 CEOs for whom we could not verify the validity of the first-order approach.

<table>
<thead>
<tr>
<th>Risk aversion</th>
<th>Number of CEOs</th>
<th>Change in base salary ($'000)</th>
<th>Relative change in base salary</th>
<th>Fraction with base salary &lt; 0</th>
<th>Correlation between salary change and wealth</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Mean</td>
<td>Median</td>
<td>Mean</td>
<td>Median</td>
</tr>
<tr>
<td>0.5</td>
<td>484</td>
<td>-7,652</td>
<td>-3,046</td>
<td>-415.32%</td>
<td>-239.66%</td>
</tr>
<tr>
<td>1</td>
<td>573</td>
<td>-6,888</td>
<td>-2,924</td>
<td>-356.83%</td>
<td>-216.41%</td>
</tr>
<tr>
<td>2</td>
<td>570</td>
<td>-5,122</td>
<td>-1,961</td>
<td>-253.68%</td>
<td>-137.91%</td>
</tr>
<tr>
<td>3</td>
<td>577</td>
<td>-3,821</td>
<td>-1,319</td>
<td>-182.17%</td>
<td>-95.83%</td>
</tr>
<tr>
<td>4</td>
<td>576</td>
<td>-2,786</td>
<td>-888</td>
<td>-131.58%</td>
<td>-64.75%</td>
</tr>
<tr>
<td>5</td>
<td>577</td>
<td>-2,066</td>
<td>-637</td>
<td>-97.71%</td>
<td>-47.37%</td>
</tr>
<tr>
<td>6</td>
<td>570</td>
<td>-1,501</td>
<td>-478</td>
<td>-73.49%</td>
<td>-31.61%</td>
</tr>
<tr>
<td>8</td>
<td>500</td>
<td>-874</td>
<td>-228</td>
<td>-45.91%</td>
<td>-16.68%</td>
</tr>
<tr>
<td>10</td>
<td>440</td>
<td>-496</td>
<td>-110</td>
<td>-26.57%</td>
<td>-8.56%</td>
</tr>
</tbody>
</table>

Table 5: Investment of wealth under optimal contracting

This table displays means and medians of two variables that describe the additional investment the CEO should make into his own company according to the optimal contract. Results are presented for the sample of 577 CEOs who have positive observed option holdings. Wealth that must be invested is equal to $-\min(\phi^d, 0)$. Investment relative to wealth is this investment scaled by the CEO’s wealth, $-\min(\phi^d, 0)/W_0$. Results are shown for nine different values of the parameter of risk aversion $\gamma$. The number of CEOs varies between the different levels of risk aversion as we exclude those CEO–$\gamma$–combinations, for which we could neither find an interior solution nor calculate the costs of the contract for $n_0 = 0$. For $\gamma = 0.5$, we also exclude 3 CEOs for whom we could not verify the validity of the first-order approach.

<table>
<thead>
<tr>
<th>Risk aversion</th>
<th>Number of CEOs</th>
<th>Wealth that must be invested ($'000)</th>
<th>Investment relative to wealth</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Mean</td>
<td>Median</td>
</tr>
<tr>
<td>0.5</td>
<td>484</td>
<td>5,844</td>
<td>1,746</td>
</tr>
<tr>
<td>1</td>
<td>573</td>
<td>5,094</td>
<td>1,505</td>
</tr>
<tr>
<td>2</td>
<td>570</td>
<td>3,481</td>
<td>450</td>
</tr>
<tr>
<td>3</td>
<td>577</td>
<td>2,338</td>
<td>0</td>
</tr>
<tr>
<td>4</td>
<td>576</td>
<td>1,485</td>
<td>0</td>
</tr>
<tr>
<td>5</td>
<td>577</td>
<td>960</td>
<td>0</td>
</tr>
<tr>
<td>6</td>
<td>570</td>
<td>594</td>
<td>0</td>
</tr>
<tr>
<td>8</td>
<td>500</td>
<td>269</td>
<td>0</td>
</tr>
<tr>
<td>10</td>
<td>440</td>
<td>113</td>
<td>0</td>
</tr>
</tbody>
</table>

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Table 6: Savings from switching to optimal contracts

This table displays means and medians of three variables that describe the savings the firm could realize by switching from observed contracts to optimal contracts for 577 CEOs who have positive observed option holdings. Savings are the difference in compensation costs between observed contracts and optimal contracts, \(\pi_0^d - \pi_0^*\). Savings as percentage of total pay are \((\pi_0^d - \pi_0^*)/\pi_0^d\), and savings as percentage of firm value are \((\pi_0^d - \pi_0^*)/P_0\). Results are shown for nine different values of the parameter of risk aversion \(\gamma\). The number of CEOs varies between the different levels of risk aversion as we exclude those CEO–\(\gamma\)–combinations, for which we could neither find an interior solution nor calculate the costs of the contract for \(n_o = 0\). For \(\gamma = 0.5\), we also exclude 3 CEOs for whom we could not verify the validity of the first-order approach.

<table>
<thead>
<tr>
<th>Risk aversion</th>
<th>Number of CEOs</th>
<th>Savings ($'000)</th>
<th>Savings as percentage of total pay</th>
<th>Savings as percentage of firm value</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Mean</td>
<td>Median</td>
<td>Mean</td>
</tr>
<tr>
<td>0.5</td>
<td>536</td>
<td>690</td>
<td>179</td>
<td>1.71%</td>
</tr>
<tr>
<td>1</td>
<td>573</td>
<td>2,292</td>
<td>606</td>
<td>5.09%</td>
</tr>
<tr>
<td>2</td>
<td>570</td>
<td>7,387</td>
<td>1,583</td>
<td>13.20%</td>
</tr>
<tr>
<td>3</td>
<td>577</td>
<td>12,722</td>
<td>2,648</td>
<td>20.29%</td>
</tr>
<tr>
<td>4</td>
<td>576</td>
<td>16,764</td>
<td>3,585</td>
<td>25.40%</td>
</tr>
<tr>
<td>5</td>
<td>577</td>
<td>19,704</td>
<td>4,154</td>
<td>29.14%</td>
</tr>
<tr>
<td>6</td>
<td>570</td>
<td>21,842</td>
<td>4,595</td>
<td>31.92%</td>
</tr>
<tr>
<td>8</td>
<td>500</td>
<td>24,998</td>
<td>5,373</td>
<td>35.54%</td>
</tr>
<tr>
<td>10</td>
<td>440</td>
<td>27,721</td>
<td>5,799</td>
<td>37.49%</td>
</tr>
</tbody>
</table>

Table 7: Optimal contracts with personal and corporate taxes

This table displays the means of six variables that describe the optimal contract for the extended model which takes into account personal and corporate taxes. Results are presented for the sample of 577 CEOs who have positive observed option holdings. Average option holdings is the mean of \(n_o\). The change in stock holdings is expressed as a percentage of all outstanding equity, \(n_s^d - n_s^*\). The change in base salary is the nominal difference between the observed base salary and the optimal base salary according to our model, \(\phi^d - \phi^*\). Savings are the difference in compensation costs between observed contracts and optimal contracts, \(\pi_0^d - \pi_0^*\). Savings as percentage of firm value are \((\pi_0^d - \pi_0^*)/P_0\). Results are shown for nine different values of the parameter of risk aversion \(\gamma\). The number of CEOs varies between the different levels of risk aversion as we exclude those CEO–\(\gamma\)–combinations, for which we could neither find an interior solution nor calculate the costs of the contract for \(n_o = 0\). The number of CEOs for whom we could not verify the sufficient condition (15) is shown in the column 'Violations of cond. (15)'.

<table>
<thead>
<tr>
<th>Risk aversion</th>
<th>No. of CEOs</th>
<th>Violations of cond. (15)</th>
<th>Average option holdings</th>
<th>Fraction with options &gt; 0</th>
<th>Change in stock holdings</th>
<th>Change in base salary ($'000)</th>
<th>Savings ($'000)</th>
<th>Savings as % of total pay</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.5</td>
<td>536</td>
<td>137</td>
<td>0.322%</td>
<td>44.59%</td>
<td>0.768%</td>
<td>-3,583</td>
<td>327</td>
<td>1.116%</td>
</tr>
<tr>
<td>1.0</td>
<td>576</td>
<td>40</td>
<td>0.140%</td>
<td>23.78%</td>
<td>0.777%</td>
<td>-4,754</td>
<td>1,223</td>
<td>3.393%</td>
</tr>
<tr>
<td>2.0</td>
<td>565</td>
<td>3</td>
<td>0.016%</td>
<td>5.84%</td>
<td>0.650%</td>
<td>-4,114</td>
<td>4,137</td>
<td>9.387%</td>
</tr>
<tr>
<td>3.0</td>
<td>570</td>
<td>2</td>
<td>0.005%</td>
<td>1.93%</td>
<td>0.510%</td>
<td>-3,259</td>
<td>7,157</td>
<td>15.005%</td>
</tr>
<tr>
<td>4.0</td>
<td>576</td>
<td>0</td>
<td>0.000%</td>
<td>0.35%</td>
<td>0.403%</td>
<td>-2,527</td>
<td>9,605</td>
<td>19.533%</td>
</tr>
<tr>
<td>5.0</td>
<td>576</td>
<td>0</td>
<td>0.000%</td>
<td>0.17%</td>
<td>0.325%</td>
<td>-1,993</td>
<td>11,565</td>
<td>22.907%</td>
</tr>
<tr>
<td>6.0</td>
<td>573</td>
<td>0</td>
<td>0.000%</td>
<td>0.00%</td>
<td>0.268%</td>
<td>-1,542</td>
<td>12,969</td>
<td>25.399%</td>
</tr>
<tr>
<td>8.0</td>
<td>531</td>
<td>0</td>
<td>0.000%</td>
<td>0.00%</td>
<td>0.201%</td>
<td>-1,008</td>
<td>15,455</td>
<td>29.221%</td>
</tr>
<tr>
<td>10.0</td>
<td>471</td>
<td>0</td>
<td>0.000%</td>
<td>0.00%</td>
<td>0.162%</td>
<td>-633</td>
<td>17,031</td>
<td>31.645%</td>
</tr>
</tbody>
</table>
Table 8: Optimal contracts when CEOs hedge systematic risk

This table displays the means of four key parameters of the optimal contract (base salary $\phi^*$, stock holdings $n_S^*$, option holdings $n_O^*$, and relative savings $(\pi^d - \pi_o^d)/\pi_o^d$) for the base model and for an adjusted model. The base model assumes that the total volatility of the stock, $\sigma^*$, must be borne by the CEO. The adjusted model assumes that the systematic part of the risk is hedged by the CEO. We adjust volatility by deducting market risk, which we estimate to be 17.0% from monthly returns of the S&P500 in the year 2000. The results for the base model are shown in the central part of the table, those for the adjusted model in the right part of the table. Results are presented for the sample of 564 CEOs who have positive observed option holdings and whose firm’s volatility is higher than 17%. The number of CEOs varies between the different levels of risk aversion as we exclude those CEO-γ-combinations, for which we could neither find an interior solution nor calculate the costs of the contract for $n_O = 0$ for either contract. We also exclude 14 CEO-γ-combinations for which we could not verify the validity of the first-order approach. The increase in stock holdings with increasing risk aversion γ for high levels of γ is an artifact of the changing composition of the sample. It disappears if we only consider those 249 CEOs for which we can calculate both optimal contracts for all values of γ.

<table>
<thead>
<tr>
<th>Risk aversion</th>
<th>Number of CEOs</th>
<th>Base salary ($'000)</th>
<th>Stock holdings</th>
<th>Option holdings</th>
<th>Relative savings</th>
<th>Base salary ($'000)</th>
<th>Stock holdings</th>
<th>Option holdings</th>
<th>Relative savings</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.5</td>
<td>411</td>
<td>-5,166</td>
<td>3.28%</td>
<td>0.05%</td>
<td>1.75%</td>
<td>-5,855</td>
<td>3.29%</td>
<td>0.07%</td>
<td>7.14%</td>
</tr>
<tr>
<td>1</td>
<td>558</td>
<td>-4,842</td>
<td>2.74%</td>
<td>0.04%</td>
<td>5.19%</td>
<td>-5,728</td>
<td>2.76%</td>
<td>0.06%</td>
<td>10.05%</td>
</tr>
<tr>
<td>2</td>
<td>547</td>
<td>-3,050</td>
<td>2.58%</td>
<td>0.01%</td>
<td>13.29%</td>
<td>-4,188</td>
<td>2.63%</td>
<td>0.03%</td>
<td>14.70%</td>
</tr>
<tr>
<td>3</td>
<td>562</td>
<td>-1,688</td>
<td>2.36%</td>
<td>0.00%</td>
<td>20.63%</td>
<td>-3,036</td>
<td>2.42%</td>
<td>0.02%</td>
<td>19.82%</td>
</tr>
<tr>
<td>4</td>
<td>561</td>
<td>-651</td>
<td>2.25%</td>
<td>0.00%</td>
<td>25.78%</td>
<td>-2,103</td>
<td>2.31%</td>
<td>0.01%</td>
<td>23.82%</td>
</tr>
<tr>
<td>5</td>
<td>561</td>
<td>66</td>
<td>2.17%</td>
<td>0.00%</td>
<td>29.39%</td>
<td>-1,282</td>
<td>2.23%</td>
<td>0.01%</td>
<td>27.02%</td>
</tr>
<tr>
<td>6</td>
<td>550</td>
<td>560</td>
<td>2.11%</td>
<td>0.00%</td>
<td>32.23%</td>
<td>-536</td>
<td>2.17%</td>
<td>0.00%</td>
<td>29.85%</td>
</tr>
<tr>
<td>8</td>
<td>444</td>
<td>1,162</td>
<td>2.49%</td>
<td>0.00%</td>
<td>35.07%</td>
<td>650</td>
<td>2.53%</td>
<td>0.00%</td>
<td>33.54%</td>
</tr>
<tr>
<td>10</td>
<td>383</td>
<td>1,421</td>
<td>2.83%</td>
<td>0.00%</td>
<td>36.53%</td>
<td>1,185</td>
<td>2.86%</td>
<td>0.00%</td>
<td>35.61%</td>
</tr>
</tbody>
</table>

Table 9: Explaining options by wealth and firm size

This table displays the results of three OLS regressions of the proportion of options in risk-neutral pay for performance sensitivity $n_O^d \cdot N(d_1)/(n_O^d \cdot N(d_1) + n_S^d)$ on the log of wealth $W_0$, the log of the firm value $P_0$, the firm’s stock volatility, and the CEO’s age and job tenure. All regressions include an intercept (results not shown) and are performed for all 598 CEOs in our sample. The table displays the slope estimates and their standard errors in parentheses. * indicates significance at the 5% level. ** indicates significance at the 1% level.

<table>
<thead>
<tr>
<th>Independent Variable</th>
<th>(1)</th>
<th>(2)</th>
<th>(3)</th>
<th>(4)</th>
<th>(5)</th>
<th>(6)</th>
<th>(7)</th>
</tr>
</thead>
<tbody>
<tr>
<td>log(W0)</td>
<td>-0.0510** (0.0084)</td>
<td>-0.0855** (0.0092)</td>
<td>-0.0924** (0.0136)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>log(P0)</td>
<td>0.0215** (0.0069)</td>
<td>0.0608** (0.0078)</td>
<td>0.0634** (0.0114)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Volatility</td>
<td>0.0314 (0.0617)</td>
<td>0.2206** (0.0617)</td>
<td>0.2759* (0.1310)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Age</td>
<td>-0.0071** (0.0017)</td>
<td>0.0018 (0.0026)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Tenure</td>
<td>-0.0070** (0.0015)</td>
<td>-0.0057** (0.0017)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Adjusted R2</td>
<td>0.0568</td>
<td>0.0143</td>
<td>-0.0012</td>
<td>0.1417</td>
<td>0.0275</td>
<td>0.0697</td>
<td>0.2102</td>
</tr>
<tr>
<td>Observations</td>
<td>598</td>
<td>598</td>
<td>598</td>
<td>598</td>
<td>560</td>
<td>289</td>
<td>268</td>
</tr>
</tbody>
</table>
Table 10: The CEO’s attitude towards investments in risky projects

This table displays results on the change of the CEO’s utility to an increase in the firm’s volatility by 0.01, i.e.

\[ E[V(\phi, n_5, n_{10}, \sigma + 0.01)] - E[V(\phi, n_5, n_{10}, \sigma)]/E[V(\phi, n_5, n_{10}, \sigma)] . \]

Results are shown for the complete sample of 598 CEOs. Columns (3) to (6) show the mean and the median of this change, once for the observed contract and once for the optimal contract. Columns (7) to (12) contain the proportion of CEOs we classify as risk-averse, risk-neutral, or risk-loving under the given contract. We call a CEO ‘risk-neutral’ if her sensitivity to a 0.01 increase in volatility (as defined above) falls in the interval [-0.01; 0.01]. If the CEO’s sensitivity is smaller than -0.01, we call her risk-averse. If the CEO’s sensitivity exceeds 0.01, we call her ‘risk-loving’. Results are shown for nine different values of the parameter of risk aversion \( \gamma \). The number of CEOs varies between the different levels of risk aversion as we exclude those CEO–\( \gamma \)-combinations, for which we could neither find an interior solution nor calculate the costs of the contract for \( n_0 = 0 \). For \( \gamma = 0.5 \), we also exclude 3 CEOs for whom we could not verify the validity of the first-order approach. Results for \( \gamma = 1 \) are not comparable to the results for other values of \( \gamma \), because the utility function is not continuous in \( \gamma \) at \( \gamma = 1 \) (see Footnote 14).

<table>
<thead>
<tr>
<th>Risk aversion</th>
<th>Number of CEOs</th>
<th>Sensitivity under observed contract</th>
<th>Sensitivity under optimal contract</th>
<th>Attitude under observed contract</th>
<th>Attitude under optimal contract</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Mean</td>
<td>Median</td>
<td>Mean</td>
<td>Median</td>
</tr>
<tr>
<td>0.5</td>
<td>503</td>
<td>-0.15%</td>
<td>-0.12%</td>
<td>-0.29%</td>
<td>-0.26%</td>
</tr>
<tr>
<td>1</td>
<td>594</td>
<td>-0.07%</td>
<td>-0.06%</td>
<td>-0.10%</td>
<td>-0.09%</td>
</tr>
<tr>
<td>2</td>
<td>591</td>
<td>-1.15%</td>
<td>-0.88%</td>
<td>-1.46%</td>
<td>-1.22%</td>
</tr>
<tr>
<td>3</td>
<td>598</td>
<td>-2.50%</td>
<td>-1.90%</td>
<td>-2.99%</td>
<td>-2.35%</td>
</tr>
<tr>
<td>4</td>
<td>597</td>
<td>-3.80%</td>
<td>-2.76%</td>
<td>-4.35%</td>
<td>-3.39%</td>
</tr>
<tr>
<td>5</td>
<td>598</td>
<td>-5.01%</td>
<td>-3.60%</td>
<td>-5.55%</td>
<td>-4.23%</td>
</tr>
<tr>
<td>6</td>
<td>591</td>
<td>-6.13%</td>
<td>-4.37%</td>
<td>-6.64%</td>
<td>-4.91%</td>
</tr>
<tr>
<td>8</td>
<td>520</td>
<td>-8.01%</td>
<td>-5.51%</td>
<td>-8.38%</td>
<td>-5.90%</td>
</tr>
<tr>
<td>10</td>
<td>458</td>
<td>-10.06%</td>
<td>-6.22%</td>
<td>-10.31%</td>
<td>-6.67%</td>
</tr>
</tbody>
</table>
Table 11: Optimal contracts with Gamma-distributed stock price

This table displays the means of six variables that describe the optimal contract for the alternative model in which the stock price $P_0$ follows a Gamma distribution. Results are presented for the sample of 577 CEOs who have positive observed option holdings. Average option holdings is the mean of $n_o$. The change in stock holdings is expressed as a percentage of all outstanding equity, $n_s^d - n_s^*$. The change in base salary is the nominal difference between the observed base salary and the optimal base salary according to our model, $\phi^d - \phi^*$. Savings are the difference in compensation costs between observed contracts and optimal contracts, $\pi_0^d - \pi_0^*$. Savings as percentage of firm value are $(\pi_0^d - \pi_0^*)/P_0$. Results are shown for nine different values of the parameter of risk aversion $\gamma$. The number of CEOs varies between the different levels of risk aversion as we exclude those CEO–$\gamma$-combinations, for which we could neither find an interior solution nor calculate the costs of the contract for $n_o = 0$. The number of CEOs for whom we could not verify the sufficient condition (15) is shown in the column ‘Violations of cond. (15)’.

<table>
<thead>
<tr>
<th>Risk aversion</th>
<th>No. of CEOs</th>
<th>Violations of cond. (15)</th>
<th>Average option holdings</th>
<th>Fraction with options &gt; 0</th>
<th>Change in stock holdings</th>
<th>Change in base salary ($'000)</th>
<th>Savings ($'000)</th>
<th>Savings as % of total pay</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.5</td>
<td>571</td>
<td>513</td>
<td>2.462%</td>
<td>99.82%</td>
<td>78.81%</td>
<td>-1.001%</td>
<td>7,740</td>
<td>381</td>
</tr>
<tr>
<td>1.0</td>
<td>557</td>
<td>0</td>
<td>0.023%</td>
<td>5.75%</td>
<td>0.00%</td>
<td>0.995%</td>
<td>-5,635</td>
<td>334</td>
</tr>
<tr>
<td>2.0</td>
<td>569</td>
<td>0</td>
<td>0.006%</td>
<td>1.41%</td>
<td>0.00%</td>
<td>0.790%</td>
<td>-3,740</td>
<td>5,251</td>
</tr>
<tr>
<td>3.0</td>
<td>571</td>
<td>0</td>
<td>0.002%</td>
<td>0.18%</td>
<td>0.00%</td>
<td>0.574%</td>
<td>-2,661</td>
<td>12,398</td>
</tr>
<tr>
<td>4.0</td>
<td>570</td>
<td>0</td>
<td>0.000%</td>
<td>0.00%</td>
<td>0.00%</td>
<td>0.420%</td>
<td>-1,800</td>
<td>18,016</td>
</tr>
<tr>
<td>5.0</td>
<td>564</td>
<td>0</td>
<td>0.000%</td>
<td>0.00%</td>
<td>0.00%</td>
<td>0.321%</td>
<td>-1,279</td>
<td>21,977</td>
</tr>
<tr>
<td>6.0</td>
<td>565</td>
<td>0</td>
<td>0.000%</td>
<td>0.00%</td>
<td>0.00%</td>
<td>0.253%</td>
<td>-946</td>
<td>24,679</td>
</tr>
<tr>
<td>8.0</td>
<td>539</td>
<td>0</td>
<td>0.000%</td>
<td>0.00%</td>
<td>0.00%</td>
<td>0.168%</td>
<td>-525</td>
<td>27,973</td>
</tr>
<tr>
<td>10.0</td>
<td>515</td>
<td>0</td>
<td>0.000%</td>
<td>0.00%</td>
<td>0.00%</td>
<td>0.120%</td>
<td>-337</td>
<td>30,197</td>
</tr>
</tbody>
</table>