Indexing Executive Compensation Contracts*

Ingolf Dittmann† Ernst Maug‡ Oliver Spalt§

April 26, 2013

Abstract

We analyze the efficiency of indexing executive pay by calibrating the standard model of executive compensation to a large sample of US CEOs. The benefits from linking the strike price of stock options to an index are small and fully indexing all options would increase compensation costs by about 50% for most firms. Indexing has several effects with overall ambiguous impact; the quantitatively most important effect is to reduce incentives, because indexed options pay off when CEOs' marginal utility is low. The results also hold if CEOs can extract rents and extend to the case of indexing shares.

JEL Classifications: G30, M52
Keywords: Executive compensation, indexed options, relative performance evaluation, pay for luck

*We thank Pierre Chaigneau, Jeff Coles (discussant at the CEAR workshop), Alex Edmans, Yaniv Grinstein (WFA discussant), Wayne Guay, Zacharias Sautner, an anonymous referee, and seminar participants at the Asian Finance Association meetings, the CEAR/Finance workshop on Incentives and Risk-Taking at Georgia State University, the Conference on Executive Compensation and Corporate Governance in Rotterdam, at Copenhagen Business School, Goethe University Frankfurt, HEC Montréal, HEC Paris, London Business School, London School of Economics, Maastricht University, the University of Michigan Business School, Tilburg University, University College Dublin, Vienna University of Economics and Business, and the 2010 Western Finance Association Meetings. Ingolf Dittmann acknowledges financial support from NWO through a VIDI grant.

†Erasmus University Rotterdam, P.O. Box 1738, 3000 DR, Rotterdam, The Netherlands. Email: dittmann@ese.eur.nl. Tel: +31 10 408 1283.

‡University of Mannheim, D-68131 Mannheim, Germany. Email: maug@bwl.uni-mannheim.de, Tel: +49 621 181 1952.

§Tilburg University, P.O. Box 90163, 5000 LE, Tilburg, The Netherlands. Email: o.g.spalt@uvt.nl. Tel: +31 13 466 3545.

"*Investors should encourage equity-based plans that filter out at least some of the gains in the stock price that are due to general market or industry movements. With such filtering, the same amount of incentives can be provided at a lower cost.*" (Bebchuk and Fried (2004), p. 190).

"Options can easily be designed to make executives' incentives more rational – so that exceptional performers can earn greater returns than they would with standard options, while poor performers are appropriately penalized. How? Tie the price an executive pays for stock when he exercises his options (...) to a broader market index." (Rappaport, Wall Street Journal, March 30, 1999, p. 1).

1 Introduction

Standard principal-agent theory prescribes that managers should not be compensated on exogenous risks, such as general market movements. Rather, firms should index pay and use contracts that filter exogenous risks (e.g., Holmstrom (1979, 1982); Diamond and Verrecchia (1982)). This prescription is intuitive and agrees with common sense: CEOs should only receive exceptional pay for exceptional performance and "rational" compensation practice should not permit CEOs to obtain windfall profits in rising stock markets. However, observed compensation contracts are typically not indexed. Specifically, stock options almost never tie the strike price of the option to an index that reflects market performance or the performance of peers.[1] Commentators often cite this glaring difference between theory and practice as evidence for the inefficiency of executive compensation practice and, more generally, as evidence for major deficiencies of corporate governance in US firms (e.g., Rappaport and Nodine (1999); Bertrand and Mullainathan (2001), and Bebchuk and Fried (2004)). This paper therefore contributes to the discussion about which compensation practices reveal deficiencies in the pay-setting process.[2]

[1]Murphy (1999) reports that only one out of 1,000 firms in his sample had an indexed option plan. See Meulbroek (2002) for the case of one company that used indexed options. Other forms to use indexation for limiting windfalls from strong stock market performance are also rare. For example, Bettis, Bizjak, Coles, and Kalpathy (2010) find that only 35 of the 983 firm-years in their sample use the stock market index or the stock performance of industry peers for performance-vesting conditions (see their Table 2, Panel D). Jenter and Kanaan (2008) show that CEO turnover becomes more likely after poor market or industry performance, which is inconsistent with the notion that firms shield CEOs' human capital from market risk. We comment in Section 2 on the difference between indexing and relative performance evaluation; there is some evidence that the latter does occur in practice.

[2]Bebchuk and Fried (2004) sparked a controversy on the efficiency properties of a range of compensation arrangements, which has yielded numerous surveys and policy proposals. See, e.g., Core and Guay (2010); Edmans and Gabaix (2009) and Weisbach (2007) for surveys.

This paper addresses the indexation of compensation contracts with a particular focus on indexed options, which link the strike price to an index and are a central theme in the debate about executive pay.[3] We highlight two main contributions. First, we show analytically that indexed options differ from conventional options in three important ways: (1) the underlying asset of indexed options has a lower volatility; (2) the underlying asset does not earn a risk premium and therefore has a lower drift rate; (3) indexing increases the strike price of the option. We show that the first effect not only generates the familiar benefits from risk sharing, but also improves incentives; a simple intuition for this effect is that reducing volatility reduces the probability that in-the-money options expire out of the money and therefore increases the option's utility-adjusted delta. The latter two effects reduce incentives because they implicitly raise the performance benchmark, reduce the probability that the option ends up in the money, and therefore reduce the utility-adjusted deltas of options.[4]

Proponents of indexation often rely on the risk-sharing component of the first effect, whereas more critical voices emphasize the third effect.[5] The drift-rate effect is usually neglected. By contrast, our analysis shows that a proper assessment of indexation needs to look at the impact of all three effects jointly and weigh the advantages from (1) against the disadvantages from effects (2) and (3). The efficiency of indexing stock options is theoretically ambiguous and ultimately an empirical question.

Our second contribution is to calibrate the standard model used in the compensation literature individually to each CEO in a large sample of US CEOs. Calibration allows us to quantify the costs and benefits from indexing for each individual CEO, determine how the different effects play out, and identify the cases in which indexing is beneficial. Our calibration approach also reveals to what extent the trade-offs between the different effects are the same for all CEOs. The central finding from our calibration analysis is that across

[3]See Rappaport and Nodine (1999); Johnson and Tian (2000); Hall and Murphy (2000, 2002), and Bebchuk and Fried (2004)

[4]There is a fourth effect, which is empirically of minor importance and therefore not emphasized here. It implies that indexed options retain some exposure to market risk.

[5]See the belief in "lower costs" in the opening quotes as an example for a focus on the first effect and Murphy (2002) as a statement of the third effect.

the many different scenarios we consider, indexing creates either small savings or large costs. In many empirically relevant cases indexed options provide incentives at a higher cost than conventional options, which is in line with the skepticism expressed by Murphy (2002), but contrary to widely held beliefs that the absence of indexation indicates poor governance. We suggest that the absence of indexation can be explained based on the fundamental trade-off between risk and incentives.

In our baseline case we analyze the full indexation of stock options under the assumption that contracting is efficient and managers do not extract rents; in terms of our model, the last condition implies that shareholders have to adjust base salaries to ensure that managers' participation constraint remains satisfied. We find that full indexation of stock options increases compensation costs by more than 50% on average in our baseline parameterization. In dollar terms, average CEO pay would increase by $32.5 million ($1.5 million at the median). Only about 15% of firms would benefit from indexing all options of the CEO. The few firms that benefit from indexation are high-beta, high-risk firms that have CEOs with a relatively high level of absolute risk aversion. For these firms the benefits from the reduction in volatility (the first effect of indexed options discussed above), which improves incentives as well as risk-sharing, outweigh the costs of reduced incentives from a stricter performance hurdle (the second and third effect). In particular, a higher beta creates a larger scope to reduce risk through indexation.

We extend our baseline setting in several dimensions. We first analyze partial indexation and allow firms to optimally choose the proportion of stock options they wish to index. Then the efficiency gains from indexation are non-negative by construction. For our baseline parameterization firms would save 2.3% of compensation costs on average, which is less than $1 million for the average CEO. Still, the adverse effects of indexation on incentives imply that three quarters of the firms in our sample would optimally choose not to index their CEOs' options at all.

Our analysis shows that the indexation of stock options as proposed in the literature is unwarranted in most cases, but leaves open whether alternative forms of indexation may still be beneficial. We therefore examine two alternative forms of indexation in additional tests. First, we analyze options on indexed stock. Indexed stock is a security that carries only the firm-specific risk of the stock and has an expected return equal to the risk-free rate. At-the-money options on indexed stock improve on indexed options, because options on indexed stock avoid the implicit increase in the strike price (effect (3) above), and therefore provide incentives more efficiently compared to indexed options, which are out of the money and have a lower delta. We confirm that options on indexed stock are more effective. However, the gains from using them are still limited, because of the adverse effect of the reduction in the drift-rate of the underlying asset (effect (2) above); more than 40% of firms would optimally use only conventional, non-indexed options rather than options on non-indexed stock.

Second, we analyze indexed stock itself. Indexing stock does not involve any of the complications associated with the strike price we encountered with indexed options or with options on indexed stock. Hence, we expect indexed stock to perform better than any of the options we study. Interestingly, this conjecture is confirmed, but the gains are not large: Fully indexing all restricted shares leads to efficiency gains near zero, whereas optimal partial indexation of stock leads to gains that are about 25% to 30% larger than those observed for the partial indexation of options. In absolute terms, savings are always small, because the volatility effect and the drift-rate effect carry over from the case of stock options to shares. The analysis of indexed stock and options on indexed stock allows us to isolate the different effects we highlight above and to compare securities with different exposures to these effects. This comparison is one of the contributions of this paper.

Finally, we adopt the perspective of the rent-extraction view (e.g., Bebchuk and Fried (2004)). This step of the analysis is important because proponents of the rent-extraction view may not agree with the presumption that shareholders have to compensate CEOs for the loss associated with exchanging valuable conventional options for much less valuable indexed options. We model rent extraction in our context by dropping the assumption that CEOs' outside options are binding. Effectively, we ask which contracts would be optimal if firms only want to provide a given level of incentives, but do not need to be concerned about retaining the CEO. In this framework we ask whether indexation is an appropriate strategy for shareholders to recapture rents. The analysis shows that for about half of all CEOs, indexation does not help with recovering rents. Indexation would still increase CEO pay levels by more than 20% on average if firms were required to fully index stock options. Optimal partial indexation leads to cost savings of just under 8% of compensation costs. The intuition for these results is that indexing leads to inefficient incentive provisions for the same reasons as in the efficient contracting case.

We conduct all our analyses for a range of different parameterizations and subject the results to several robustness checks. Specifically, our findings are not driven by our treatment of the CEO's investment in the stock market as exogenous and are also not attributable to the fact that stock market risk is associated with a risk premium.

The model we use is a standard principal-agent model with CRRA utility and lognormal stock prices. This modeling strategy has become standard in much of the compensation literature and our results can therefore be compared directly with previous work.[6] The impact of the three main effects of indexing options is theoretically ambiguous and depends on parameter values, which makes calibrations at the individual CEO level the research strategy of choice. Our approach is also fairly general and does not require additional assumptions about functional forms other than concavity of the production function and convexity of the effort cost function of the CEO.[7] However, two assumptions are necessary to ensure tractability. First, we do not endogenize the balance between stock and options and only discuss to what extent it is optimal to index the shares and options in observed contracts. The focus on observed contracts is necessary as the CRRA-lognormal setup would

[6]See e.g., Lambert, Larcker, and Verrecchia (1991); Hall and Murphy (2000, 2002); Himmelberg and Hubbard (2000); Hall and Knox (2004), and Oyer and Schaefer (2005).

[7]We still require additivity in the utility function. See, e.g., Edmans, Gabaix, and Landier (2009) for a model that uses a multiplicative modeling approach.

hardly feature options as part of the optimal contract (Dittmann and Maug (2007)). Second, we do not allow for changes in the level of effort and hold it fixed at the level implied by the observed contract. In Section 7 we argue why we believe the effects we identify to be robust and why we believe the benefits from indexation to be always limited, if not outright negative, in non-standard setups that overcome these limitations of our approach.

The intuitive appeal of indexation is closely related to Holmstrom's (1979) seminal work on the informativeness principle. The informativeness principle implies that there exists an optimal contract that filters all exogenous risks. However, this optimal contract will generally be a highly non-linear function, and Holmstrom himself observes that filtering risks does not take the simple form of subtracting an index from the output measure except for some special cases (Holmstrom (1982), p. 377). Nothing in our work contradicts the informativeness principle. Instead, we follow the compensation literature and analyze observed contracts that can be constructed from shares and stock options, which are empirically more relevant, but not necessarily optimal. Whether indexing these contracts improves efficiency is an open question that cannot be resolved by appealing to the informativeness principle. Our calibrations show that indexing options moves piecewise linear contracts further away from efficiency. Furthermore, other simple forms of indexation are more beneficial, even though they also fall short of filtering all exogenous risks. The informativeness principle can therefore provide only limited guidance for the optimal design of observed, piecewise-linear contracts.

2 Discussion of the literature

Several contributions in the literature address the glaring gap between the prescriptions of standard economic models and observed compensation practice within the efficient contracting paradigm. First, relative performance evaluation might induce unwanted incentives to intensify industry competition (e.g., Aggarwal and Samwick (1999)); indexed options might provide incorrect incentives for entering or exiting industries (e.g., Dye (1992); Gopalan, Milbourn, and Song (2010)); indexed options might be tax inefficient (e.g., Göx (2008));

indexed options could be replicated by managers through appropriate rebalancing of their own portfolio between the benchmark portfolio and the riskfree asset if such rebalancing would be costless (e.g., Garvey and Milbourn (2003); Jin (2002); Maug (2000)). Our analysis complements this previous literature on the lack of indexation, but we abstract from the additional channels identified in that literature, which biases our analysis towards finding larger improvements from indexation. Most importantly, we show that adding specific assumptions about the strategic context of the firm, the tax code, or the CEO's trading opportunities is not necessary to explain the absence of indexing.

Our work is also related to a number of papers that discuss the indexation of options, or design features of stock option more broadly. Rappaport and Nodine (1999) and Bebchuk and Fried (2004) both propose indexed options, but rely on intuitive arguments and numerical examples. None of them discusses the consequence of indexation on incentives for risk-averse CEOs. Hall and Murphy (2000, 2002) and Ross (2004) provide important insights on changes in the strike price, but do not explicitly analyze indexing and do not consider the countervailing volatility effect. Murphy (2002) argues that indexed options have a low probability of being in the money and argues that these options are inferior to in-the-money options, but links his argument to the subjective value of options to CEOs, i.e., to their participation constraint, and not to their incentives, which we show is the critical ingredient. The paper that is perhaps closest to our is Chaigneau (2012) who endogenizes the structure of pay but works in a framework without risk-aversion and with normally distributed stock prices. Chaigneau (2012) does not calibrate his model to observed CEO compensation contracts.

Our paper also contributes to the broader literature on relative performance evaluation (e.g., Antle and Smith (1986); Bertrand and Mullainathan (2001); Garvey and Milbourn (2003)). It is important to note that the empirical design used in the literature on relative performance evaluation addresses a somewhat different question than we do, because it analyzes ex post payouts, which include changes over time in fixed salaries as well as in the value of new stock and option grants. These dynamic considerations are absent from static theoretical models, which predict that benchmarks are built into ex ante contracts. While all forms of ex ante indexation would be reflected in the regressions used in the empirical literature on relative performance evaluation, the converse is not true: In fact, the evidence on relative performance evaluation may not reflect indexation of ex ante contracts at all (see footnote 1). For example, if boards regard CEOs' performance relative to their peers as information about CEOs' talent, superior performance relative to a benchmark reveals the CEO's superior abilities and boards will increase pay as they update their assessment of the CEO's talent – a dynamic consideration that is unrelated to the design of ex ante contracts, which are supposed to provide efficient incentives. Alternatively, CEOs and compensation committees may use benchmarking opportunistically to support claims for higher compensation (Faulkender and Yang (2010)). In our discussion we therefore distinguish two definitions. We use the term indexation narrowly to refer to the benchmarking of ex ante contracts against an index with the intent to remove pay for luck. By contrast, we use the term relative performance evaluation more broadly, so that it also includes the ex post adjustment of fixed compensation and bonus payments.

3 Research design

We consider a standard principal-agent model in the spirit of Holmstrom (1979). In this section, we develop the model, present our calibration approach, and explain the construction of our data set.

3.1 The model

The CEO (agent) provides costly and unobservable effort on behalf of shareholders (principal). At the beginning of the period (time 0) shareholders propose a contract to the CEO. When the CEO accepts the contract, she exerts effort e during the contracting period, and this effort positively affects the end-of-period stock price P_T, where T denotes the length of the contracting period. As effort is not observable, the contract depends only on the stock price P_T and on the stock market index M_T, and generates a payoff π_T to the agent at the end of the period. We denote the beginning of period stock price by P_0 and normalize the value of the index at time zero so that $M_0 = 1$; M_T therefore denotes the return on the stock market index.

The CEO's utility. The CEO's wealth that is not invested in her own firm is denoted by W_0. For brevity we refer to W_0 as non-firm wealth. A fraction $\omega \in [0, 1]$ of this wealth is invested in the market portfolio and yields a return per dollar invested of M_T at the end of the period, while the remaining wealth is invested at the risk-free rate r_f. We treat ω as an exogenous parameter in most of our analysis. The CEO also owns n_{SU} unrestricted shares. We treat unrestricted shares as part of the CEO's portfolio and not as a part of the contract with the firm, whereas restricted shares are a part of the contract. We assume that these are not part of the contract negotiations, but that they contribute to her incentives and her wealth. The CEO's end-of-period wealth therefore is

$$W_T = W_0 \left((1-\omega)e^{r_f T} + \omega M_T\right) + n_{SU} P_T + \widetilde{\pi}_T, \tag{1}$$

where $\widetilde{\pi}_T$ is the CEO's income from the employment with the firm. The CEO's utility is additively separable in end-of-period wealth and effort, i.e., $u(W_T, e) = U(W_T) - C(e)$, where $C(e)$ is increasing and convex. The CEO is risk-averse in wealth with constant relative risk aversion (CRRA):

$$U(W_T) = \frac{1}{1-\gamma} W_T^{1-\gamma}, \tag{2}$$

where γ is the coefficient of relative risk aversion (if $\gamma = 1$, we define $U(W_T) = ln(W_T)$). We use constant relative risk aversion because this assumption has become the benchmark model in the compensation literature. The CEO's outside option when she declines the contract is $\underline{U}$.

Contracts and shareholders' optimization. We consider piecewise linear contracts that consist of a fixed salary ϕ, the number of restricted shares n_{SR}, and the number of options n_O, where we express n_{SR} and n_O as a proportion of all outstanding shares. Moreover, a proportion $\psi \in [0,1]$ of the options is indexed, so that the CEO's compensation is

$$\widetilde{\pi}_T = \phi e^{r_f T} + n_{SR} P_T + n_O \left(\psi O_T^{idx} + (1-\psi) max \left\{ P_T - K, 0 \right\} \right).$$

Here, K is the strike price of the option and O_T^{idx} is the payoff of an indexed option. The base salary is paid at the beginning of the contracting period and invested at the risk-free rate r_f. The firm has access to capital markets, so the cost to the firm from granting the contract is the time zero market value of the securities granted to the CEO, which we denote by π_0. Shareholders' objective is therefore to minimize π_0:

$$\min \quad \pi_0 = \phi + n_{SR} P_0 + n_O \left(\psi JT + (1-\psi) BS \right) \tag{3}$$

In (3), BS stands for the Black-Scholes value of options and JT denotes the value of indexed options according to the valuation formula of Johnson and Tian (2000), which we provide below. Shareholders' problem is to minimize the market value of compensation costs π_0 subject to the two constraints that (1) the CEO accepts the contract and that (2) she will exert the desired effort level e^*. Shareholders therefore minimize π_0 subject to:[8]

$$E\left[u\left(W_T, e^*\right)\right] \geq \underline{U}, \tag{4}$$

$$\frac{d}{de} E\left[u\left(W_T, e^*\right)\right] = 0. \tag{5}$$

[8] For the incentive compatibility constraint, we assume that the first-order approach is satisfied. A sufficient condition is that the optimization problem is globally concave, and this is the case if the cost function $C(e)$ is sufficiently convex and the production function $P_0(e)$ is sufficiently concave. Dittmann and Maug (2007) numerically check whether the optimal contract induces the CEO to choose less effort than the observed contract. We do not follow their approach here, because our main result is that the improvement of the optimal contract over the observed contract is only marginal, so that we do not suggest that firms should switch to the optimal contract.

Stock price and market index. We assume that the end-of-period stock price P_T is lognormally distributed,

$$P_T = P_0\left(e\right)\exp\left\{\left(\mu_P - \frac{\sigma_P^2}{2}\right)T + u_P\sigma_P\sqrt{T}\right\}, \tag{6}$$

where $P_0\left(e\right)$ is an increasing and concave function in effort e, μ_P is the expected annual total return (dividends plus capital gains), σ_P is the annual standard deviation of stock returns, u_P is a standard normal random variable, and T denotes the length of the contracting period. Similarly, the end-of-period value of the stock market index M_T is lognormally distributed (recall that $M_0 = 1$):

$$M_T = \exp\left\{\left(\mu_M - \frac{\sigma_M^2}{2}\right)T + u_M\sigma_M\sqrt{T}\right\}. \tag{7}$$

The definitions of μ_M, and σ_M are analogous to those for P_T. The actions of the CEO do not affect the value of the index. Furthermore, u_P and u_M are correlated with a coefficient of correlation ρ. The CAPM holds, so $\beta = \rho\frac{\sigma_P}{\sigma_M}$ and[9]

$$\mu_P = r_f + \beta\left(\mu_M - r_f\right). \tag{8}$$

Indexed stock. For ease of exposition, we discuss indexed stock first and then introduce indexed options. Conventional stock earns a return P_T/P_0 and an expected return equal to μ_P. By contrast, indexed stock filters the systematic component and earns an expected return equal to the risk-free rate. We construct indexed stock from the residual between the actual stock price P_T and the expected stock price conditional on the market index. Johnson and Tian (2000) show that the expected value of P_T given the value of the index M_T is:

$$E\left[P_T|M_T\right] = H_T \equiv P_0 M_T^{\beta} e^{\eta T}, \tag{9}$$

[9] Compared to the setup of Johnson and Tian (2000), we ignore the possibility of deviations from the security market line here. In their notation, we set $\alpha = 0$.

where

$$\eta \equiv (1-\beta)\left(r_f + \frac{1}{2}\rho\sigma_M\sigma_P\right). \tag{10}$$

Here, H_T represents the systematic component of stock returns. Consider the simple case with $\beta = 1$. Then we have $\eta = 0$ and $H_T = P_0 M_T$, i.e., the expected stock price at time T conditional on the market index equals the current stock price, multiplied by the return on the market. If $\beta = 0$, then $\rho = 0$ and $H_T = P_0 exp\,(r_f T)$; the market index provides no information for predicting the stock price in this case. With the help of this definition we define the return on indexed stock as $(P_T/H_T)\,exp\,(r_f T)$ and normalize the price of an indexed share by setting it equal to the price of one conventional share at $t = 0$, i.e., $P_0^{idx} = P_0$. Then the price of an indexed share at time T equals

$$P_T^{idx} = P_0 \frac{P_T}{H_T} exp\,(r_f T). \tag{11}$$

In the appendix we show that the terminal value of indexed stock P_T^{idx}can be written analogously to (6) as:

$$P_T^{idx} = P_0 exp\left\{\left(r_f - \frac{\sigma_I^2}{2}\right)T + u_I\sigma_I\sqrt{T}\right\}. \tag{12}$$

$$\text{where: } \sigma_I = \sigma_P\sqrt{1-\rho^2}, \tag{13}$$

$$u_I = \left(u_P\sigma_P - u_M\rho\sigma_P\right)/\sigma_I. \tag{14}$$

The standard normal random variable u_I reflects the firm-specific variation in stock returns and is uncorrelated with u_M. Firm-specific risk is measured by σ_I. It is useful to rewrite the stock price P_T as

$$\begin{gathered} P_T = b\,P_T^{idx} M_T^{\beta}, \\ where\ b = exp\,((\eta - r_f)\,T). \end{gathered} \tag{15}$$

Hence, the price of a conventional share can be expressed as the product of the price of an indexed share and the market-related component $b\,M_T^{\beta}$.

Payoffs and valuation of indexed options. We follow Johnson and Tian (2000) and define the payoff of indexed options as

$$O_T^{idx} = max\left\{P_T - H_T, 0\right\}. \tag{16}$$

Hence, the strike price of an indexed option is equal to the expected value of the stock price conditional on the market index. Indexed options are in the money only if the return on the firm's stock beats the market index. For example, if the market moves up by 5%, then a CEO in a firm with $\beta = 1$ will only receive a payoff from indexed options if the firm's stock appreciates by more than 5%. We use the formula of Johnson and Tian (2000) to value indexed options at time $t = 0$ and denote the corresponding "Johnson-Tian" value of these options by JT. This value is given by:

$$JT = e^{-dT}\left[P_0 N(d_1^{idx}) - P_0 N(d_2^{idx})\right], \tag{17}$$

$$\text{where: } d_1^{idx} = \frac{\sigma_I\sqrt{T}}{2},\ d_2^{idx} = -\frac{\sigma_I\sqrt{T}}{2}. \tag{18}$$

3.2 Calibration

We use the calibration method introduced by Dittmann and Maug (2007).[10] We denote the observed contract by $(\phi^d, n_S^d, n_O^d, \psi = 0)$ ("d" stands for "data") and assume that the observed contract implements the desired effort level e^* and does not leave the CEO with a rent. We define the utility-adjusted pay-for-performance sensitivity $UPPS$ as:[11]

$$UPPS(\phi, n_S, n_O, \psi) \equiv \frac{d}{dP_0} E\left[U(W_T(\phi, n_S, n_O, \psi))\right]. \tag{19}$$

[10] See also the technical document by Dittmann, Zhang, Maug, and Spalt (2011), which explains the technical aspects of their calibration algorithm in more detail.

[11] Note that for the case of risk neutrality where $V(W_T) = W_T$, $UPPS$ reduces to the more familiar pay-for-performance sensitivity, which in our case is equal to $n_S + n_O(1-\psi)N(d_1) + n_O\psi N(d_1^{indx})$; $N(d_1)$ and $N(d_1^{indx})$ denote the delta of conventional options and indexed options, respectively.

We focus mostly on the indexation of options and discuss the indexation of restricted shares later. We do not endogenize the balance between restricted stock and options of the contract. Dittmann and Maug (2007) show that a CRRA-lognormal model as we analyze here suggests significant efficiency gains from replacing options with stock and we do not wish to confound the efficiency gains from indexation with the efficiency gains from changing the balance between stock and options. Hence, whenever we analyze the indexation of options we satisfy the incentive compatibility constraint (5) by replacing conventional options with an appropriate number of indexed options, while fixing the number of restricted and unrestricted shares at their observed levels. The CEO and shareholders therefore bargain over fixed salary ϕ, the number of options n_O, and the proportion ψ of options that are indexed. (We sometimes use the subscripts 'S' and 'O' on ψ to refer to the degree of indexation of shares and options, respectively, but omit the subscript if the meaning is unambiguous.) Then the optimization problem (3) to (5) can be rearranged as follows:[12]

$$\min_{\{\phi,n_O,\psi\}} E\left[\pi_0(\phi,n_O,\psi)\right] \tag{20}$$

subject to:

$$E\left[U\left(W_T\left(\phi,n_O,\psi\right)\right)\right] \geq E\left[U\left(W_T\left(\phi^d,n_O^d,0\right)\right)\right], \tag{21}$$

$$UPPS(\phi,n_O,\psi) \geq UPPS(\phi^d,n_O^d,0), \tag{22}$$

$$\psi \in [0,1]\,. \tag{23}$$

Hence, we search for the cheapest contract that provides the CEO with at least the same utility as the observed contract and that induces at least the same level of effort as the observed contract. If indexing is important, a contract with $\psi > 0$ should be optimal and

[12]We use similar steps to Dittmann and Maug (2007) and Dittmann, Maug, and Spalt (2010) here. Note that this step effectively substitutes out the production function $P(e)$ and the cost function $C(e)$ and permits us to proceed without specifying their functional forms. As a consequence, we can only analyze the structure of the contract and not the overall level of pay, which is given from the observed contract.

significantly cheaper than the observed contract.

We can completely parameterize the expressions in (21) and (22) by determining appropriate values for the contract parameters ϕ^d, n_S^d, and n_O^d, the parameters of the stock price processes (6) to (8), and the CEO's risk aversion parameter γ.

In our baseline setting, we take the CEO's exposure to the stock-market ω as exogenous and fixed. There are two reasons for this step, one practical and one conceptual. On the practical side, fully endogenizing ω would render the problem intractable.[13] We will *partially* endogenize ω later, however, and show that we can come close to endogenizing ω; our conclusions are not affected. On the conceptual side, fixing ω is a conservative assumption that biases us towards finding larger savings from indexation and therefore against our conclusions. In fact, the literature on the homemade-indexing argument points out that the benefits from indexing may in some instances be completely annihilated if the CEO could choose her investment in the stock market ω optimally. Then the CEO would remove any excess exposure to stock market risk herself and indexation would yield no further improvements (Garvey and Milbourn (2003); Jin (2002), and Maug (2000)).

3.3 Data

We use the ExecuComp database to construct CEO contracts at the beginning of fiscal year 2006. We first identify all persons in the database who were CEO during the full year 2006 and executive of the same company in 2005. We calculate the base salary ϕ as the sum of salary, bonus, and "other compensation" from 2006 ExecuComp data and take information on stock and option holdings from the end of fiscal year 2005 . We regard the data for 2006 as more representative for our purposes as subsequent years were affected by the financial crisis.

[13] There is no closed-form solution of the CEO's portfolio problem and we would therefore have to work with a nested optimization problem where the firm first chooses the optimal contract and the CEO then adjusts her private portfolio accordingly. Also, the firm would have to anticipate the CEO's actions, so that the inner optimization problem would have to be solved at every point where the outer optimization problem is evaluated. It is unlikely that such a model can be solved in a reasonable amount of time with today's computing power.

We estimate each CEO's option portfolio with the method proposed by Core and Guay (2002) and then aggregate this portfolio into one representative option. We set the representative option to be at the money and calculate the number of representative options n_O^d and the maturity T of the representative option so that they have the same Black-Scholes value and the same option delta as the estimated option portfolio.[14] In this step, we lose five CEOs for whom we cannot numerically solve this system of two equations in two unknowns.

We take the firm's market capitalization P_0 from the end of 2005. While our formulas above abstract from dividend payments for the sake of simplicity, we adjust option values for dividends in our empirical work and use the dividend yield d from 2005. We estimate the firm's stock return volatility σ and CAPM$-\beta$ from monthly CRSP stock returns over the five fiscal years 2001 to 2005 and drop all firms with fewer than 45 monthly stock returns. The risk-free rate is set to the U.S. government bond yield with five-year maturity from January 2006.

We estimate non-firm wealth W_0 of each CEO from the ExecuComp database by assuming that all historic cash inflows from salary and the sale of shares minus the costs of exercising options have been accumulated and invested year after year at the one-year risk-free rate. We assume that the CEO had zero wealth when she entered the database, which biases our estimate downward, and that she did not consume since then, which biases our estimate upward. To arrive at meaningful wealth estimates, we discard all CEOs who do not have a history of at least five years for 2001 to 2005 on ExecuComp. During this period, they need not be CEO. This procedure results in a data set with 755 CEOs.

Table 1 provides an overview of our data set. The median CEO in the sample owns 0.25% of the stock of his company, of which 0.02% is restricted and 0.23% is unrestricted. Median option holdings are on 1.02% of the company's stock. Median base salary is \$1.04m, and the

[14] We take into account the fact that most CEOs exercise their stock options before maturity by multiplying the maturities of the individual option grants by 0.7 before calculating the representative option (see Huddart and Lang (1996) and Carpenter (1998)). In these calculations, we use the stock return volatility from ExecuComp and, for the risk-free rate, the U.S. government bond yield with 5-year maturity from January 2006. Data on risk-free rates were obtained from the Federal Reserve Board's website. For CEOs who do not have any options, we set $T = 7$ (10-year maturity multiplied by 0.7) as this is the typical maturity for newly granted options.

median non-firm wealth is \$13.49m.

The only parameter in our model that we cannot estimate from the data is the manager's coefficient of relative risk aversion γ. We use $\gamma = 2$ as a baseline case for most of our analysis and also report results for $\gamma = 1$ and $\gamma = 3$.[15]

Murphy (1999) reports that in a sample of 627 firms that granted stock options to their executives in 1992, only one firm used indexed options. Since ExecuComp does not report indexing, we therefore assume that all stock and options in the observed contract are not indexed. This assumption implies that we might overstate the potential efficiency gains from indexing.

Indexing should not be confused with performance vesting. In recent years, more and more option grants do not vest automatically after a certain time period but only when some performance criterion (e.g., a minimum return on assets) has been achieved (see, e.g., Bettis, Bizjak, Coles, and Kalpathy (2010)). Note also that some bonus schemes like phantom stocks or bonuses that depend on the performance of a peer group constitute relative performance pay (see Murphy (1999)). By treating bonuses as fixed salary, we do not include these features in our stylized observed contract.

4 Full indexation of options

In this section we present the core of our analysis and investigate the costs and benefits on fully indexing CEOs' stock options. We first analyze the optimization problem (20) to (23) with the provision that options are fully indexed ($\psi = 1$).

[15] Different strands of the literature use different values of relative risk aversion and there is no consensus on this subject. Ait-Sahalia and Lo (2000) survey the research on this topic, which supports values between 0 and 55. The macroeconomic literature typically uses higher values (see Campbell, Lo, and MacKinlay (1997), chapter 8, for a survey and discussion). The compensation literature often uses lower values. For example, Murphy (1999) uses 1, 2, and 3, and Hall and Murphy (2002) use 2 and 3. Dittmann, Maug, and Spalt (2010) calibrate a loss-aversion model and show that it fits compensation data well. The degree of relative risk-aversion implied by their analysis varies between 0.2 and 1.

4.1 Result 1: Full indexation is costly

Table 2 shows the results for three values of the coefficient of relative risk aversion γ (1, 2, and 3) that have been considered in the literature (e.g., Hall and Murphy (2002)). For each value of γ, the table provides the results for five levels of the proportion ω of CEO non-firm wealth that is invested in the stock market. The table reports the means of the base salary ϕ and of option holdings n_O in the optimal contract. Finally, we report the efficiency gains S from recontracting. We first calculate the costs of the observed contract π^d and the cost of the optimal contract predicted by the model, π^*. These estimates are obtained from evaluating the costs of the contract π_0 from (3) for the parameters of the observed contract and for the optimal contract, respectively. Efficiency gains are defined as the difference between these costs scaled by π^d, so $S = (\pi^d - \pi^*)/\pi^d$ ("S" for "savings"). Our numerical routines do not converge for all observations and all parameterizations. The number of observations in Table 2 therefore varies slightly.

Our first important result is that compensation costs increase dramatically for plausible parameterizations of our model. We use $\gamma = 2$ and $\omega = 0.5$ as our baseline case, i.e., we assume that CEOs invest 50% of their wealth in the stock market. Negative savings S indicate an increase in compensation costs. Hence, for our baseline case, compensation costs increase by 55.65% on average. For many parameterizations the average increase in compensation costs exceeds 50%. There is significant cross-sectional variation and the distribution is skewed and becomes more skewed for higher levels of risk aversion: for higher levels of risk aversion, the median cost increase is lower, whereas the average cost increase from indexation is larger. The proportion of firms that benefit from full indexation also increases with risk aversion from 5.90% for $\gamma = 1$ to 27.27% for $\gamma = 3$ (always for $\omega = 0.5$).

The remaining part of this section analyzes these puzzling findings in more detail. Table 2 offers important clues from comparing fixed compensation ϕ and the number of options n_O for indexed contracts with those for observed contracts. For our baseline case, the number of options increases from an average of 1.49% in terms of the number of outstanding shares for the observed contract (see Table 1) to 3.40% for the indexed contract. Hence, one conventional option is replaced on average by 2.29 (=3.40/1.49) indexed options to maintain incentives (UPPS from equation (19)) at the same level as in the original contract, which indicates that one indexed option provides substantially lower incentives compared to one conventional option. Similarly, base salaries increase from an average of \$1.616 million to an average of \$3.051 million, an increase of 89%. This observation shows that managers value the higher number of indexed options much less than the conventional options from the original contract they give up. Both findings are important for the following discussion.

We observe that the number of CEOs for whom our algorithm converges decreases with risk aversion. The numerical problems hide an underlying problem from incentivizing and compensating CEOs with indexed options, because the algorithm does not converge for those CEOs who do not obtain sufficient incentives from indexed options so that the incentive compatibility constraint cannot be satisfied for any value $n_O \leq 1$. Hence, if we would permit the number of indexed options to exceed 100% of the outstanding shares, then the distributions reported in Table 2 would become even more skewed and indexation would become even less desirable.

4.2 Result 2: Indexation destroys incentives

The main result from the previous section is that full indexation makes compensation more costly for the large majority of firms. We analyze the reasons for this finding by decomposing the savings from indexation in two steps. In the first step, we fix option holdings at their observed level ($n_O = n_O^d$). The algorithm then minimizes objective (20) only subject to the participation constraint (21) and omits the incentive compatibility constraint (22). This step allows us to isolate the benefits from improved risk-sharing, i.e., the benefits we could obtain if indexation would have no impact on incentives. We refer to these gains as "gross efficiency gains." The resulting contract has costs π_G and generates efficiency gains $S_G \equiv \left(\pi^d - \pi_G\right)/\pi^d$. In the second step we compute the efficiency gains from restoring incentives,

$S_I = S - S_G$, which is a measure of the effectiveness of indexed options as instruments to provide incentives. These additional savings result from a change in the number of options and a related adjustment in base salary. After the second step the contract simultaneously satisfies the participation constraint (21) as well as the incentive compatibility constraint (22).

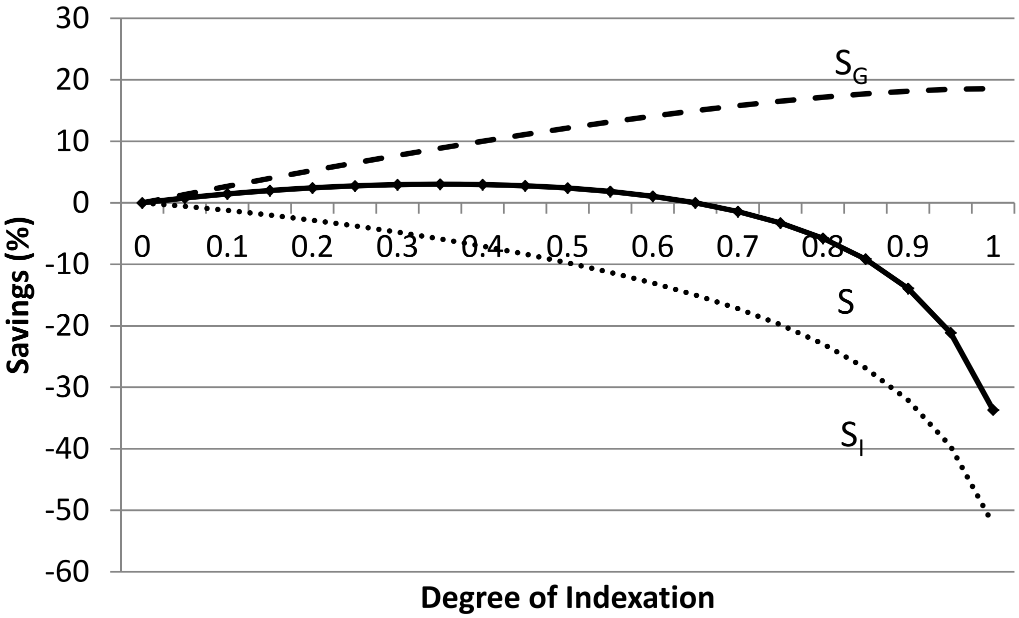
The first column of Table 3 shows the gross efficiency gains S_G, the gains from restoring incentives S_I, and the total efficiency gains S as percentages of the costs of the original contract π^d from fully indexing all options. We perform the calculations for three different parameterizations. The table reports a further breakdown on which we comment below.

Gross gains from indexing S_G equal 13.2% of compensation costs for the baseline parameterization with $\gamma = 2$ and $\omega = 0.5$. Hence, if firms could simply enjoy the benefits from improved risk-sharing by replacing each conventional option with an otherwise identical indexed option without paying any attention to incentive effects, then compensation costs would decline by 13.2%. In unreported results we find that these gains increase with risk aversion, which is intuitive because improved risk sharing matters more if the risk premium paid to the CEO is larger. In the second step, the model increases the number of options so that the indexed options generate the same incentives as the conventional options in the original contract. The resulting increase in compensation costs is economically significant, with 70.8% for the baseline scenario. Hence, the gains from risk-sharing are more than outweighed by the losses from less efficient incentive provision. Costs from restoring incentives are higher for lower values of ω. Table 3 reports the changes in incentives as $\Delta UPPS$ in the last line of each panel. For the baseline parameterization, incentives decline by 9.8% compared to the original contract if options are fully indexed. This is in direct contrast to the view that "the same amount of incentives can be provided at a lower cost", expressed in the opening quote. In fact, the results in Table 3 show that indexed options are inferior to standard options for most firms precisely because indexation destroys incentives.

Figure 1 illustrates the effects from the previous discussion by showing the net efficiency

Figure 1: Efficiency gains for an example CEO

This figure shows total savings, S, gross savings S_G, and the savings from restoring incentives S_I as a function of the degree of indexation ψ for an example CEO from our sample. This CEO has the following parameters: $\beta = 1.5$, $\phi_d = \$1.5$m, $n_O = 1.6\%$, and $W_0 = \$43$m. The optimal degree of indexation for which savings are maximized is $\psi^* = 35\%$ and savings at this degree of indexation would be $S = 3.03\%$.



gains S and their two components, S_G and S_I, as a function of the degree of indexation ψ. The figure repeats our procedure for a grid of exogenously fixed values $\psi \in [0, 1]$ for a typical CEO in our sample. Several findings emerge. First, full indexation would be optimal if risk-sharing would be the only objective, since S_G is maximized for $\psi = 1$. The resulting savings would be substantial, which explains the intuitive appeal of indexed options. Second, and most importantly, indexation destroys incentives for all values of ψ. This effect is especially pronounced for high degrees of indexation. Third, for full indexation, the savings from improved risk-sharing are outweighed by the increased costs from restoring incentives, so that the net effect S is negative. Finally, the figure suggests that net benefits S can be slightly positive with partial indexation for sufficiently low ψ's. This is exactly what we find if we endogenize ψ (see Section 5.1 below).

4.3 Result 3: The performance benchmark of indexed options is too strict

The difference between indexed options and conventional options. In the next step of our analysis we study which aspect of indexation makes indexed options less efficient for providing incentives to CEOs. Recall from (15) that we can rewrite the stock price as $P_T = P_T^{idx} b M_T^{\beta}$, where P_T^{idx} is the price of an indexed share and $b\,M_T^{\beta}$ is a function of the systematic component of the stock price defined in (15). Similarly, the strike price H_T of an indexed option can be rewritten using (15) as

$$E\left[P_T|M_T\right] = H_T = P_0 exp(r_f T) b M_T^{\beta}. \tag{24}$$

We can now rewrite the payoff of one indexed option given in (16) by using (24) and (15) as:

$$O_T^{idx} = \; max(P_T - H_T, 0) = b M_T^{\beta} max\left(P_T^{idx} - P_0 exp\left\{r_f T\right\}, 0\right). \tag{25}$$

A number of observations emerge from (25). First, the payoff of an indexed option can be written as the payoff of options on indexed stock P_T^{idx}; indexed stock has a drift rate equal to the risk-free rate r_f and is only subject to firm-specific risk σ_I. Recall that we normalize indexed shares so that their price at time $t = 0$ equals that of conventional shares. Second, indexed options are out of the money; because their strike price equals $P_0 exp(r_f T) > P_0$. Third, and finally, the payoff O_T^{idx} of one indexed options equals $b\,M_T^{\beta}$ options on indexed stock, where $b\,M_T^{\beta}$ reflects the component of the stock price P_T that is related to the stock-market index M_T. The last step shows that indexing options does not fully insure CEOs against fluctuations in the market index. Full insurance would require that the option payoff is independent of the stock market index, and therefore of $b\,M_T^{\beta}$. Intuitively, doubling the market index doubles the strike price of the option and the stock price, but thereby it also doubles the difference between the stock price and the strike price; it should hold it constant to achieve full insurance.[16]

We apply these insights by providing a further decomposition of the incentive and risk-sharing effects in Table 3. The point of departure are the conventional options. We then go through the following sequence of steps:

1. Reduce the volatility of the underlying asset from σ_P to σ_I. We refer to the impact of this change as the *volatility effect*.

2. Reduce the drift rate of the underlying asset from μ_P to r_f. We refer to the impact of this change as the *drift-rate effect*. This step together with the previous step replaces an at-the-money option on conventional stock with terminal value P_T with an at-the-money option on indexed stock. These options have a terminal payoff equal $max\left\{P_T^{idx} - P_0, 0\right\}$. For brevity, we refer to these options as options on indexed stock.

3. Increase the strike price from P_0 to $P_0 exp(r_f T)$. We refer to the impact of this change as the *strike-price effect*.

4. Replace each option on indexed stock by $b\, M_T^{\beta}$ such options. This effect reintroduces market exposure into the contract and we therefore label it the *market-exposure effect*.

These four steps together transform one conventional option into one indexed option. Each step is associated with one effect, which allows us to calculate the impact of this effect separately, holding all else equal. We perform these calculations separately for the gross savings from risk-sharing S_G, the savings from restoring incentives to their original level, S_I, the total savings from indexation, S, and for the change of incentives, $\Delta UPPS$. For the calculations of S_G and $\Delta UPPS$ we only adjust fixed compensation so that the CEO's participation constraint remains satisfied. For the calculations of S_I and S we adjust the number of options as well as fixed compensation to satisfy the incentive compatibility constraint.

[16] Consider an indexed option with a strike price of 8 on stock with a current price of 10 when the index value equals 100. Doubling the index value to 200 implies that the strike price and the stock price both double to 20 and 16, respectively. (Assume beta is 1.) Then the payoff of the indexed option doubles from 2 to 4.

The volatility effect (VOLE). The results in Table 3 show that the volatility effect has a positive impact on both components of savings as well as incentives. This result obtains for all parameterizations we consider. The positive impact on gross savings is intuitive and reflects the familiar benefits from improved risk-sharing. More surprisingly, reducing the volatility of the underlying asset by itself also improves incentives. In our baseline case, reducing volatility increases incentives for 94% of the CEOs, hence, the effect is not unambiguous.

To investigate this effect further we observe that $UPPS$ can be rewritten from (19) as $E\left[U'W'P_T/P_0\right]$, where $U' = \frac{\partial U}{\partial W_T}$ is the derivative of the utility function and $W' = \frac{\partial W_T}{\partial P_T}$ is the derivative of the wage function.[17] To simplify notation and the discussion, we denote by V the indirect utility function $V(P_T) = U(W(P_T))$, which gives the CEO's utility as a function of the end-of-period stock price P_T, so that $V' = U'W'$. We shall refer to $V' = \frac{\partial V}{\partial P_T}$ as the marginal indirect utility function. Then we can write $UPPS$ as the expectation of the marginal indirect utility function:

$$\begin{aligned} UPPS &= \frac{1}{P_0} E\left[V'(P_T)P_T\right] \\ &= \frac{1}{P_0} E\left[V'\right] E\left[P_T\right] + \frac{1}{P_0} Cov\left[V', P_T\right], \end{aligned} \tag{26}$$

where $Cov\left[V', P_T\right]$ denotes the covariance of the stock price and marginal indirect utility.

Ross (2004) points out that the indirect utility function may have surprising properties that violate simple intuitions built on the properties of the direct utility function $U(W_T)$. In the appendix we derive the following properties of V':

$$\frac{V''}{V'} = -\gamma \frac{W'}{W} + \frac{W''}{W'}, \tag{27}$$

$$\frac{V'''}{V'} = \gamma\left(1+\gamma\right)\left(\frac{W'}{W}\right)^2 + \frac{W'''}{W'} - \frac{\gamma}{W}\frac{W''}{W'}\left(2+W'\right). \tag{28}$$

Observe from (27) and (28) that marginal indirect utility can be increasing in P_T ($V'' > 0$)

[17] The CEO's wealth function $W(P_T)$ is not everywhere differentiable, but we could approximate it with a differentiable function that is arbitrarily close to $W(P_T)$ and everywhere differentiable. See Ross (2004) for a similar exposition strategy.

even though direct marginal utility is decreasing ($U'' < 0$), and marginal indirect utility can be concave ($V''' < 0$), even though direct marginal utility is convex ($U''' > 0$). Both of these features are related to the convexity of the wage function, expressed as W''/W', and to the pay-for-performance sensitivity (PPS) of the wage function, which is here measured as W'/W.[18] From (26), we can identify two effects of volatility on incentives from both components of the equation.

1. **Convexity of the marginal indirect utility function.** The only part of the first term in (26) that is affected by volatility is the expected marginal indirect utility $E[V']$, which increases with the volatility of the stock price if and only if V' is convex. This effect is best understood by considering a wage function with a significant portion of compensation in options, so that the wage function is sufficiently convex. More specifically, if W'' is large and W''' comparatively small, then $V''' < 0$ from (28), V' is concave, and a reduction in volatility increases incentives. To see the economic intuition consider two scenarios. If the stock price is high, the wage function is steep, but incentive provision is ineffective because marginal utility is low. Conversely, if the stock price is low, marginal utility is high, but there is no incentive provision because the options are out of the money and have a low delta, so the wage function is very flat. Hence, incentive provision is most effective for intermediate stock prices. A reduction of volatility leads to intermediate stock prices more often and thereby improves incentives.[19]

2. **Covariance of firm value and marginal indirect utility.** The second term in (26) represents the covariance between the stock price and marginal utility, $Cov(V', P_T)$, scaled by P_0. This term is best understood if we abstract from options and focus

[18] More precisely, W'/W represents the percentage change in pay relative to a dollar change in firm value. Conventional measures of pay-for-performance sensitivity refer to the dollar (percentage) change in compensation compared to the dollar (percentage) change in firm value. See Edmans et al. (2009) for a detailed discussion of different measures of incentives.

[19] An effect related to this one has been noted before by Gjesdal (1982) and Arnott and Stiglitz (1988), who show that increasing the noise of the performance measure may improve incentives if the first-order condition is convex in the performance measure.

on contracts for which the wage function is approximately linear ($W'' \approx W''' \approx 0$). Then this term is non-zero if and only if the CEO is risk averse, otherwise, $V'' = 0$ from (27) and V' would be constant. For risk-averse CEOs, performance-related pay provides lower payoffs in states where firm value is low and marginal utility is high, so that incentive provision is potentially effective, and higher payoffs in those states where firm value is high, marginal utility is low, and incentive provision is therefore less effective. This negative correlation between firm value and the efficacy of incentive provision is reflected in $Cov\,(V', P_T)$. A reduction in the volatility of the stock price increases this covariance by reducing it in absolute value, and therefore increases $UPPS$ and improves incentives.

Observe that for both terms in (26), the impact of a reduction in volatility is theoretically ambiguous. Reducing volatility can have a positive impact on the first term only if the wage function is sufficiently convex and $V''' < 0$ from (28), whereas the impact on the second term can be positive only if V' is downward sloping, i.e., if the wage function is *not* too convex (see (27)). It is therefore unsurprising that we obtain different effects for different CEOs in our empirical results.

A simple intuition that explains our observations on the indexation of options for almost all CEOs can be built on the case when the CEO is risk neutral. Then marginal indirect utility directly reflects the properties of the wage function so that $\frac{V''}{V'} = \frac{W''}{W'}$ and $\frac{V'''}{V'} = \frac{W'''}{W'}$.[20] We show in the appendix that we can rewrite $UPPS$ from (26) more simply as $UPPS = U'exp\,(\mu_P T)\,(n_S + n_O \Delta)$ in this case, where Δ refers to the delta of the option calculated under the statistical measure and marginal utility U' is a constant independent of P_T. The option-delta Δ decreases with volatility for in-the-money options, because a higher volatility reduces the likelihood that the option matures in the money; the opposite holds for out-of-the-money options. This effect is described in more detail in Chaigneau (2012). The representative options we analyze are in-the-money options, hence a reduction of the

[20]In this special case when γ can be neglected, the marginal indirect utility function is convex (concave) only if the convexity of the wage function is increasing (decreasing).

volatility of the underlying asset increases the option delta and thereby incentives ($UPPS$).

The intuition based on the delta-effect is somewhat limited, because we discover in untabulated results that the volatility effect on incentives is also positive for contracts that consist entirely of restricted stock.[21] The argument based on deltas does not apply if we index restricted stock for linear wage functions, showing that the effect of indexation on the covariance term in (26) is important.

The drift-rate effect (DE). The reduction of the drift-rate reduces gross savings, incentives, and net savings, for all parameterizations we consider and annihilates most of the gains from the volatility effect. In parallel to the volatility effect, the change in the drift rate affects several components of $UPPS$, which can be seen from (26). First, a reduction in the drift rate reduces stock prices and therefore $E[P_T]$, which in turn reduces $UPPS$. Second, reducing the drift-rate of the underlying asset of the option from μ_P to r_f reduces the slope of the wage function W'. Intuitively, a reduction in the drift rate moves the probability mass of the distributions of the stock price and CEOs' wealth to the left. As a result, the options are moved further out of the money and the probability that the stock price at maturity exceeds the strike price declines, which reduces the option's delta and its utility-adjusted delta.[22] Hence, incentive provision becomes more expensive. and the impact of the drift-rate effect on S_I and on $\Delta UPPS$ is therefore negative.

The decline in the drift-rate implies that the subjective value of the option to the CEO declines, so that the difference between the value of the option to shareholders and the subjective value of the option to the CEO increases. The reason is that the market value of the option is unaffected by a decline in the drift rate, because the drift rate of the underlying

[21] For these calculations, we convert all options into restricted shares so that the incentive compatibility constraint remains satisfied.

[22] The utility-adjusted delta takes into account the valuation of states by the CEO as opposed to the valuation by the market. The concept has also been used by Hall and Murphy (2002) and Dittmann and Maug (2007). Note that the utility-adjusted delta is related to but different from UPPS, which applies to the whole contract and not just to the options. For a CEO who has no shares ($n_{RS} = n_{NR} = 0$) the two concepts coincide. An increase in the strike price has a stronger impact on the utility-adjusted delta compared to the risk-neutral delta because marginal utility is declining.

asset does not enter the valuation of the option. A reduction in the drift rate is best interpreted as a change in the entire economy such that other investors become less risk averse and therefore demand a lower compensation for risk, whereas the risk aversion of the CEO is held constant. Hence, the market's *expected* return and the *required* return for the payoffs of the option both decline in lockstep, leaving the market value of the option unchanged. By contrast, the CEO just receives a lower payoff without a corresponding decline in risk aversion, which implies a lower subjective value. Consequently, options become less attractive as instruments of compensation. This difference is a deadweight cost of awarding options and the option becomes therefore less efficient for compensating the CEO, so gross savings S_G also decline.

Options on indexed stock. The previous two effects (VOLE and DE) together amount to replacing conventional options with at-the-money options on indexed stock. We therefore calculate the joint impact of the volatility effect and the drift-rate effect in the column headed "Options on indexed stock" in Table 3. Using options on indexed stock instead of indexed options creates incentives and value for the baseline scenario, for which compensation costs decline by 4.3%. The benefits from using options on indexed stock increases in the CEO's private investment in the stock market ω and are negative only for $\gamma = 2$ and $\omega = 0$. Hence, options on indexed stock can in some cases provide sizeable benefits, whereas indexed options always create large costs. We further analyze options on indexed stock in Section 5.2.

The strike-price effect (SPE). The most important difference between indexed options and options on indexed stock is that indexed options have a higher strike price. The strike-price effect has a moderately positive impact on gross savings, but a much larger and negative influence on incentives with a decline in $\Delta UPPS$ of 11.6% and a total increase in compensation costs of 62.9% for the baseline case. The additional costs from restoring incentives S_I are quantitatively much larger for the strike-price effect than for any of the other three effects. Proponents of indexation cite the stricter performance benchmark as the main advantage of indexing options, because "poor performers are appropriately penalized" (see the opening quote by Rappaport). It turns out that it is precisely this aspect of indexation which is particularly problematic. The reason is that the stricter performance benchmark reduces the probability that the option ends up in the money, and therefore reduces the option's delta and incentives. Under the stricter performance hurdle, options pay off only if the stock price is high, which is the case whenever wealth is high and marginal utility is correspondingly low. Hence, increasing the strike price moves payoffs to a region in which incentive provision is less efficient. This shift is similar to the observation Ross (2004) labels the "translation effect," only that our observation is on marginal utility, whereas Ross analyzes the utility function itself. Equation (26) suggests that the shift of payoffs to a region where stock prices are higher and marginal utility is lower reduces the covariance $Cov\left(V', P_T\right)$ and therefore reduces $UPPS$.

Comparing the strike-price effect with the drift-rate effect. The SPE and the DE have in common that they both affect the likelihood that the option matures in the money. Accordingly, both effects have a negative impact on the option's delta and therefore on incentives. However, the impact of the strike-price effect on S_I is larger than the drift-rate effect. Moreover, the impact of the DE and the SPE on the gross benefits S_G have opposite signs, hence, the two effects are not entirely symmetric. Note that a reduction in the drift-rate changes the expected value and also the variance of the lognormal stock price. However, it has no impact on the market valuation of options, because the drift rate affects payoffs and the discount rate for these payoffs in the same way. By contrast, an increase in the strike price reduces the value of the option. The reduction in the variance of the stock price for a reduction in the drift rate is particularly important, because it works in the same direction as the volatility effect and therefore provides a countervailing effect to the reduction in the likelihood of maturing in the money. As a result, increasing the strike price has a bigger impact on savings than reducing the drift rate.

The opposite impact of both effects on S_G is noteworthy. Our algorithm requires that the participation constraint is satisfied. CEOs and the market value out-of-the-money options much less than at-the-money options and the model compensates for CEOs' loss by increasing their fixed compensation. Hence, the strike-price effect induces a replacement of at-the-money options with a combination of out-of-the-money options and fixed compensation, and this shift makes compensation altogether less risky and therefore more efficient. By contrast, the drift-rate effect does not change the strike price and the valuation of the option by the market, but it does reduce CEOs' valuation of the options, thereby increasing the deadweight costs.

The market-exposure effect (MEE). Finally, we observe that the market exposure effect, which results from multiplying the number of options with $b\,M_T^{\beta}$ is a second-order effect.[23] (We therefore do not list this effect among the three important effects in the Introduction.) It is positive for low values of ω and negative for large values of ω, which suggests that additional exposure to the market is desirable if CEOs have little exposure from their outside investments ($\omega = 0$) and vice versa.

4.4 Result 4: Indexed options only benefit high-beta, high-risk firms with risk-averse CEOs

Table 2 shows that indexation saves compensation costs for a minority of firms. In Panel A of Table 4 we split the sample into the group of 78 firms for which full indexation reduces compensation costs, and the 538 firms for which full indexation increases compensation costs to better understand which firms would benefit from indexation. We refer to the first group as indexing beneficiaries and to the second group as non-beneficiaries. The table shows that gross savings S_G do not differ much across the two groups (15.3% vs. 12.9%). By contrast, while indexation destroys incentives for almost all firms, the additional costs from

[23] Meulbroek (2001) also observes that indexed options do not do what they promise, because they do not remove all market exposure and she suggests an alternative security that is similar to options on indexed stock. However, she does not observe that this effect is relatively minor compared to the other disadvantages of indexed options.

restoring incentives, $-S_I$, are much larger for non-beneficiaries (4.8% vs. 80.4%). Hence, the difference between the two groups is mostly determined by the impact of indexation on incentives. The highly significant difference for $\Delta UPPS$ supports this conclusion: For beneficiaries the decline in incentives is only 6.9%, compared to 23.8% for non-beneficiaries.

We augment the two-sample split in Panel A of Table 4 with a table of correlations between the main parameters and the components of savings from indexation in Panel B. (Correlations that are statistically different from zero at the 5%-level are in bold face.) We find that the CAPM-β and firm-specific risk σ_I are both significantly higher for indexing beneficiaries. The effect for the CAPM-β is intuitive because a higher β implies that indexation removes more of the variance of compensation, and a reduction in the variance improves incentives through the volatility effect; observe from Panel B that β is highly and positively correlated with the incentive measure $\Delta UPPS$, with S_I, and with S_{VOLE}, the total savings from the volatility effect. We return to the influence of firm-specific risk below.

We compare the probability of the option finishing in the money for both conventional options, $Prob(P_T > K)$, and indexed options, $Prob(P_T > H_T)$.[24] In addition, we report the change in the probability of receiving a payoff from options, which is the difference between the two probabilities and denoted by $\Delta Prob \equiv Prob(P_T > H_T) - Prob(P_T > K)$. The increase in costs is most pronounced when indexation makes it less likely for the executive to receive a payout from her options. Panel B shows that $\Delta Prob$ is highly correlated with $\Delta UPPS$ and the savings from the drift and strike-price effects, both of which are related to incentive destruction. A main reason why indexation destroys incentives is therefore that payoffs become less likely and are moved to a region in which marginal utility is lower, so that providing incentives becomes more costly.

The probability of being in the money does not differ significantly between beneficiaries and non-beneficiaries for indexed options, but the same probability is much higher for the conventional options of non-beneficiaries than for those of beneficiaries. Hence, firms are

[24] Hall and Murphy (2000, 2002) also focus on the probability of options finishing in the money to analyze variations in the strike price.

more likely to benefit from indexation if the negative effect, which indexing has on the likelihood that the options finish in the money, is lower in absolute value. Panel B of Table 4 shows that the correlation between $\Delta Prob$ and σ_I is 0.70. Hence, conventional options on higher-volatility stocks have a lower probability of finishing in the money than conventional options on lower-volatility stocks, so that indexing these options has a smaller adverse impact on incentives from the strike-price effect. High-volatility firms benefit from indexation because they have less to lose from the strike-price effect. Interestingly, Bettis, Bizjak, Coles, and Kalpathy (2010) find that higher-volatility firms apply higher stock-price hurdle rates when they implement stock-price vesting provisions. Their finding may reflect a similar logic because higher hurdles are easier to achieve, and therefore less costly, for high-volatility firms.

We calculate the certainty equivalent wealth $CE(W_T)$ as the fixed wealth at time T that would give the same utility to the CEO as her compensation contract together with her unrestricted stock holdings and outside wealth. The table reports the ratio of the certainty equivalent to expected end-of-period wealth $E(W_T)$, which is a measure for the CEO's risk tolerance or the negative of absolute risk aversion; for a risk-neutral CEO this ratio would be one and for a very risk-averse CEO this ratio would be small. On average, indexing beneficiaries have more risk-averse CEOs and Panel B of Table 4 shows that the negative correlation between the savings from indexation and risk tolerance can be attributed entirely to the gross savings S_G from improved risk sharing. It is intuitive that more risk-averse CEOs benefit more from improved risk-sharing.

There is a qualitatively significant effect for the maturity T of the representative option; T equals 4.6 for beneficiaries, but 7.7 for non-beneficiaries. Increasing maturity makes the distribution of the terminal stock price more risky and also more skewed. From Panel B this has a positive impact on S_G, but a larger and negative impact on the costs of restoring incentives. Quantitatively the effect of T is small, however.

5 The optimal indexation of options

The previous section analyzes the case in which firms fully indexed stock options ($\psi = 1$). In this section we allow for any value of ψ on the unit interval and also consider a different form of indexing by introducing options on indexed stock.

5.1 Endogenizing the degree of indexation

We expand the initial setting and allow firms to choose the degree of indexation ψ optimally within the unit interval. Figure 1 shows that partial indexation may be beneficial even if full indexation is not. The algorithm for this case solves the full program (20) to (23). Again, we hold the number of unrestricted and restricted shares constant and change the number of options so as to maintain incentives. Consequently, CEOs receive $\psi^* n_O$ indexed options and $(1 - \psi^*)\, n_O$ conventional options. We report the results in Table 5. The efficiency gains from indexation are now non-negative for all firms by construction, because firms can choose $\psi = 0$ if there is no level of indexation at which the firm benefits from indexation. Table 5 reports the fraction of firms that choose no indexation ($\psi = 0$) and full indexation ($\psi = 1$) as well as the means and medians for the optimal degree of indexation ψ^*.

The efficiency gains firms can realize with an optimal mixture between indexed options and conventional options are small across many specifications considered in Table 5. For the baseline case with $\gamma = 2$ and $\omega = 0.5$ firms index on average 12.74% of their options and 76.46% of firms do not use indexed options at all. For 2.93% of firms, full indexation ($\psi = 1$) is optimal. The efficiency gains firms can realize by indexing options are 2.28% of total compensation costs on average and zero for the median firm. Indexation becomes more valuable if the CEO is more risk-averse and if the CEO's investment in the stock market is high. Both findings are intuitive because CEOs have an optimal exposure to the stock market. If the assumed level of exposure ω is higher than their optimal exposure, they prefer indexed options. Also, their preferred stock market exposure declines with risk aversion, resulting in larger benefits from risk sharing and therefore from indexation if risk aversion is higher. The same observation also obtains for the full indexation case in Table 2, but there it takes the form of smaller cost increases for higher values of ω and γ. We observe larger efficiency gains in Table 5 if we simultaneously assume large stock market investments ω and high levels of risk-aversion γ. However, such a combination of high γ and high ω may not be very plausible, because CEOs choose their investment in the stock market, and their optimal exposure to the stock market is inversely related to their risk aversion. The parameters ω and γ can therefore not both be high.

5.2 Options on indexed stock

The analysis in Table 3 suggests that options on indexed stock may be better instruments for indexing CEO compensation contracts than indexed options. In Table 6 we repeat the analysis of the previous table, but we use options on indexed stock instead of indexed options. Hence, the optimal degree of indexation ψ^* now reflects that the CEO receives $\psi^* n_O$ at-the-money options on indexed stock. For brevity we only report report results for $\gamma = 2$.

We find that options on indexed stock are more frequently used in optimal CEO compensation contracts than indexed options. For the baseline case, the optimal degree of indexation is 27.37%, compared to only 12.74% for indexed options. There are far fewer CEOs without any indexation (47.61% instead of 76.46%) and the number of CEOs whose contracts are fully indexed increases from 2.93% to 8.36%. Efficiency gains increase by a factor of more than three from 2.28% to 7.61%, which is economically sizeable, although still far from spectacular. This difference corresponds to dollar savings that are about $2.5 million higher for the average CEO. Median savings are also zero for options on indexed stock. The number of options is smaller for contracts with options on indexed stock ($n_O = 1.349\%$) compared to contracts with indexed options (1.479%), whereas fixed compensation is higher for the former ($\phi =$\$1.911m) compared to the latter ($1.793m), which shows that options on indexed stock are more efficient. We conclude that options on indexed stock are better instruments for indexing CEO compensation contracts. The reason is that options on indexed stock are at the money, whereas indexed options are not. The strike-price effect, which accounts for most of the additional incentive costs associated with indexed options, does therefore not apply to options on indexed stock.

6 Extensions and robustness checks

In this section we expand on the analysis of the previous two sections by (1) allowing for the possibility that managers extract rents, (2) considering the indexation of restricted stock, (3) partially endogenizing the private investment of CEOs in the market portfolio, and (4), by incorporating the possibility that contracts are benchmarked against a source of risk that is not priced.

6.1 Indexation when managers extract rents

Proponents of indexed options see the lack of relative performance evaluation and the apparent prevalence of pay for luck as evidence for the rent-extraction view of executive compensation. From this point of view the previous analysis is not convincing because it assumes a binding participation constraint. By contrast, the rent-extraction view suggests that CEOs do not have any outside opportunities that allow them to accept alternative employments if indexation reduces their utility.

It is not clear how the perspective of the rent-extraction view should be modeled. The main tenet of this view is that CEOs extract rents in the form of hidden compensation, which could be recovered through better structured contracts. We therefore proceed by performing the same analysis as above under the assumption that CEOs' participation constraints do not bind. Hence, a reduction in utility from indexation will not be compensated through an increased base salary. Instead, we assume that base salaries are given and fixed at their observed levels. However, we need to adjust the number of options in order to be able to satisfy the incentive compatibility constraint.

Another modeling alternative we considered would model negotiations between shareholders and the CEO as a Nash bargaining game in which the CEO has all the bargaining power. The results from such a game would not be much different from efficient contracting because Nash bargaining leads to efficient contracts. These contracts would be similar to the ones we obtain in the previous section, only that CEOs extract higher payoffs, mostly through higher fixed salaries. Indexation and the structure of contracts would be affected only through the associated wealth effects. The insights from such an exercise would be limited. Our approach leads us to overstate the benefits from indexation because the participation constraint is probably binding for some CEOs but not for others.[25]

Table 7 shows the results for the rent-extraction case for full indexation (Panel A) and for optimal indexation (Panel B), in both cases for $\gamma = 2$. Panel A reveals that firms would still incur substantially higher costs with indexed contracts in the full indexation case. Firms would have to pay 23.24% more in our baseline case (\$11.9 million for the average CEO). Savings would again be zero for the median firm. The reason is that indexation destroys incentives, which shareholders wish to maintain even if they wish to recover rents. We therefore obtain results similar to those in the efficient contracting case.

In the optimal indexing case (Panel B), indexation leads to a decline of compensation costs of 7.82% for the baseline case compared to 2.28% under efficient contracting. Savings are positive for 61.19% of firms. The main reason for these higher savings is that fixed compensation ϕ stays at the level of the observed contract, whereas in the efficient contracting case the CEO would need to be compensated for accepting indexed options in exchange for conventional options. We conclude that savings from indexation are modest even under the favorable assumptions of the rent-extraction view because the adverse effects of indexation on incentives remain a first-order issue.

[25]Bertrand and Mullainathan (2001) argue that the use of relative performance evaluation is correlated with the quality of corporate governance. We still drop the participation constraint for all CEOs in our sample and not just for the CEOs in firms with poor corporate governance.

6.2 Indexation of restricted stock

In this section we consider the indexation of restricted stock and compare it with the indexation of stock options. We introduce indexed stock above, which has a payoff P_T^{idx} given by (11) and (12), carries only firm-specific risk but no market risk, and has an expected return equal to the risk-free rate. We analyze the indexation of restricted stock but do not consider the simultaneous indexation of options.[26] We index only restricted stock and not unrestricted stock because unrestricted stock is CEOs' property and therefore not part of their compensation package. The CEO's compensation is then given by

$$\widetilde{\pi}_T = \phi e^{r_f T} + n_{SR}\left(\psi_S P_T^{idx} + (1-\psi_S)P_T\right) + n_O max\left\{P_T - K, 0\right\}. \quad (29)$$

We solve program (20) to (23) for the efficient contracting case as in the previous section above, with two modifications. First, we optimize over ψ_S rather than ψ_O, and second, we adjust the number of restricted share units n_{SR}, rather than the number of stock options n_O.[27]

The results are shown in Table 8. Panel A reports the results for full indexation and Panel B the results for optimal indexation. Panel C reports the savings from indexing restricted stock again, but this time expressed as a percentage of the value of all restricted shares in the observed contract. For better comparison, we also report the savings from indexing options from Tables 2 and 5 rescaled and expressed as a percentage of the market value of stock options in the observed contract.

Several salient features emerge. With full indexation, the number of CEOs for whom full indexation leads to positive efficiency gains is 25.43% for the baseline parameterization and

[26] Our analytic tools cannot determine optimal levels of indexation for stock and options independently, because indexing stock and indexing options are very close substitutes. There are many combinations of the degrees of indexation for stock and options that are approximately equivalent with respect to the objective function we maximize.

[27] In unreported results we also examine indexation of restricted stock in an all-share contract that does not contain any options. Dittmann and Maug (2007) show that this contract is optimal for almost all CEOs in the CRRA-lognormal model if options are restricted to be non-negative. We find results that are qualitatively very similar. In fact, savings from indexation are even lower (i.e., more negative) for the all-share contract.

therefore larger than the corresponding number for options (15.24%, see Table 5, Panel B). Optimal indexation is higher by a factor of about two to three for stock compared to options with $\psi_S = 35.67\%$ compared to $\psi_O = 13.44\%$ for the baseline parameterization.

Savings appear to be sometimes lower for restricted stock than for stock options, particularly with optimal indexation, but this inference is misleading, because we express efficiency gains as a percentage of compensation costs and restricted stock forms a smaller proportion of compensation compared to stock options. In Panel C we therefore rescale the efficiency gains from indexing restricted stock by the market value of each CEO's restricted stock, and the efficiency gains from indexing options by the Black-Scholes value of each CEO's stock options. When we do that we find that the indexation of restricted stock is comparatively more efficient than the indexation of options. The difference is large with full indexation, where a cost reduction of 3.73% for restricted stock compares with a cost increase of 70.66% for options. The differences are marginal with optimal indexation.

These results can be understood from our decomposition of effects in Section 4.3. Only the volatility effect and the drift-rate effect are relevant for restricted stock, whereas the strike-price effect is absent by construction. Since it is mainly the strike-price effect that is responsible for large efficiency losses, indexing stock is not nearly as problematic as indexing options. Restricted stock is therefore more similar to the options on indexed stock we discuss above, and similar conclusions therefore obtain.

6.3 Homemade indexing and endogenizing ω

The analysis so far assumes that CEOs' choice of their investment in the stock market, ω, is given exogenously. We cannot fully endogenize ω for computational reasons, but we can move one step towards calculating optimal values for ω. We proceed as follows. We maximize the CEO's utility with respect to ω given the observed contract. We refer to the resulting values ω^* as pseudo-optimal. We then calculate the optimal contract as before given the pseudo-optimal ω^*. In the last step, we use the optimal contract and again maximize CEO utility with respect to ω, and the denote this second-step pseudo-optimal value as ω^{**}. The second-stage values ω^{**} are very close to the first stage values ω^{*}, which suggests that the results are not far from those we would obtain if we could fully endogenize ω.

Table 9 shows the results for the pseudo-optimal values ω^{*} and ω^{**} for $\gamma = 1$, 2, and 3. We find that results with pseudo-optimal ω's are very similar to those found in Table 5 above. Not surprisingly, ω's decrease in risk-aversion. For the benchmark case $\gamma = 2$, ω^{*} is on average 0.72 and the resulting endogenous contract parameters ϕ and ψ are in between the values reported in Table 5 for $\omega = 0.5$ and $\omega = 0.75$; the value for optimal option holdings n_O is also very close to those found before. The savings from indexation are 1.90% and therefore a little lower than those found before (2.28%). Hence, if we let the CEO adjust her exposure to market-wide risk, then savings from indexation decline because the CEO's portfolio choice now partially does what the firm would have done otherwise, which is the homemade indexing effect.

The quantitative implications of the homemade indexing effect are remarkably small. Even though the CEO can choose her exposure optimally, the capacity of the firm to create additional value by adjusting this exposure is reduced only by about one sixth from 2.28% to 1.90% of compensation costs.

The impact of the homemade indexing effect is low for two reasons. First, we restrict ω to be positive and less than one. Observe from Table 5 that for $\gamma = 2$, these restrictions are binding for about two thirds of all CEOs: 61.22% of CEOs would prefer to have no indexation even if their market exposure is maximal at $\omega = 1$, and 1.86% of CEOs would prefer full indexation even if their exposure is already minimized at $\omega = 0$. Second, and most importantly, the CEO's choice of ω cannot perfectly undo her exposure to market-wide risk from conventional options. The theoretical models for the homemade indexing argument (Garvey and Milbourn (2003); Jin (2002), and Maug (2000)) all work within a framework in which the CEO receives a linear contract, she has some variant of mean-variance preferences, and all risks are normally distributed. In such a linear-normal framework the CEO can undo her exposure to market risk from the contract perfectly. In more general frameworks, such as ours, fully eliminating risk would require a more complex dynamic hedging strategy, which we do not permit in the model and which may be hard to implement in practice (see also our discussion of this point in Section 2). Since the CEO cannot fully eliminate market risk by a one-off choice of ω, the firm can create value by indexing contracts.

6.4 The market risk premium

As a final check, we investigate how our results depend on the equity risk premium. We know from the literature on the equity premium puzzle that investors with constant relative risk aversion seek exposure to market risk if we assume levels of risk aversion between one and three, as we do in our analysis above. We therefore set the market risk premium to zero to show that our results do not follow from the fact that CEOs simply want a high exposure to market risk. Assuming a market risk premium of zero is certainly too extreme, but may serve as a useful benchmark for our analysis.

In Table 10 we repeat our previous analysis with a market risk premium of zero. In these tests we adjust fixed compensation ϕ so that the expected utility of the CEO with a zero market risk premium equals that of the CEO in the previous analysis with a 4%-market risk premium. We do this in order to neutralize a mechanical wealth effect, because a lower market risk premium reduces CEOs' expected end-of-period wealth, which increases their absolute risk aversion and their marginal utility and would therefore distort our results. Panel A reports the results for the case with full indexation and Panel B reports the results for optimal indexation for $\gamma = 2$.

Our findings show that even with a zero market risk premium, indexation would substantially increase costs in the full indexation case. For optimal indexation, savings are higher than in the benchmark case and indexation would be profitable for more firms. But even under the somewhat unrealistic assumption of a zero market risk premium, optimal indexation would be only 63.49% for the baseline case and savings are sizeable but not large. In untabulated results we conduct the same analysis for levels of the market risk premium of 2% and 6% and find that the use of indexation and the gains from indexation both decline monotonically as the market risk premium increases.

The intuition can be best grasped from the decomposition into four effects we introduced in Section 4.3. Eliminating the market risk premium neutralizes the negative impact of the drift-rate effect, which makes indexation more beneficial. By contrast, the strike-price effect still destroys incentives, independently of the market risk premium. Note also that the market-exposure effect is quantitatively small in Table (3), which suggests that the exposure to and reward for market risk have quantitatively only a small impact. We conclude that our results do not just reflect effects from the market risk premium known from the literature on the equity premium puzzle.

7 Discussion of the modeling approach

Our analysis relies on a conventional framework with constant relative risk aversion and log-normally distributed stock prices, which has become standard in the compensation literature (see footnote 6 in the Introduction). In this section we discuss three potential limitations of our approach and how they might affect our results. First, the optimal contract in the model we use generally does not feature options. Second, we do not fully endogenize the balance between shares and options. Third, we hold effort constant at the level implied by the observed contract.

Dittmann and Maug (2007) show that optimal contracts in a CRRA-lognormal model are mostly concave and generally do not feature options. If contracts are restricted to be piecewise linear and negative option holdings are not permitted, the optimal contracts are almost always linear, all-share contracts. The contracting models of Hemmer, Kim, and Verrecchia (1999); Dittmann, Maug, and Spalt (2010) and Dittmann and Yu (2011) endogenize options in a framework that is in many respects similar to ours, which naturally poses the question why we do not use one of these models to analyze indexation. However, a common feature of these models is that they create a scope for options in a framework in which firms are better off by giving CEOs convex compensation functions. It is therefore unsurprising that they all imply that CEOs are not very risk averse, with levels of relative risk aversion between 0.5 and 1.[28] With such a low level of risk aversion, CEOs obtain only small risk premiums to compensate them for the risk of variable pay. Since the benefits from indexation are related to improved risk-sharing, any model in which the CEO receives a small risk premium automatically implies that the benefits from indexation must be small. Our results in Table 5 confirm this intuition: With $\gamma = 1$, savings from indexing are around 0.3% of compensation costs. By construction, models that endogenize options are most likely inconsistent with a significant impact from indexation, positive or negative. In addition, the findings of such a model would likely depend on the specific way in which options are endogenized and any inferences on indexation would be contingent on the particular details of these models. Given these methodological caveats, we therefore opt for the standard model, but believe that if may be valuable if future research complements our work by looking at other modeling assumptions.

An altogether different modeling framework, which can accommodate convex compensation functions with suitable assumptions on the CEO's marginal cost of effort, is the dynamic model of Edmans and Gabaix (2011). Calibrating their dynamic model with indexation would require parameterizing the cost-of-effort function as well as their "felicity" function, which is beyond the scope of our paper.

The previous discussion implies that we cannot discuss how indexation affects the optimal balance between stock and options. If we would endogenize the composition of the contract between stock and options, we would only obtain the familiar result that CRRA-lognormal models favor shares over options. Holding the composition of the contract constant at the

[28]Dittmann and Maug (2007) show that the results of Hemmer, Kim, and Verrecchia (1999) obtain with a value of relative risk aversion of 0.5, as Hemmer, Kim, and Verrecchia (1999) propose, but that their claim is not robust to choosing higher levels of risk aversion. The loss-aversion model of Dittmann, Maug, and Spalt (2010) implies that the risk premium paid to the CEO is consistent with levels of relative risk aversion that are generally lower than one. The model of Dittmann and Yu (2011) can potentially accommodate higher risk premiums by assuming that the benefits from risk-taking are very large, but also obtains its best fit if relative risk aversion is only 0.5.

observed level is therefore a natural choice in our modeling framework. We do not believe that this assumption affects our qualitative conclusions, because our analysis shows that indexation moves options even further away from the optimal contract and makes them less efficient rather than more efficient. It is therefore unlikely that endogenizing the mix between shares and options would lead to larger option holdings and larger benefits from indexation. In addition, recall from Section 6.2 that the qualitative conclusions we obtain for options carry over if we analyze the indexation of shares. Hence, the composition of the contract cannot drive our results.

Finally, we hold the effort level constant at the value implied by the observed contract and believe that this aspect is innocuous. Dittmann and Maug (2007) show that it is possible to show significant gains from changing the contract even when effort is held constant. Not endogenizing effort does therefore not bias savings to be low. More fundamentally, we consider the analysis here as the second stage of a two-stage Grossman and Hart (1983) problem in which the optimal contract for a given effort level is chosen at the first stage and the optimal effort level is chosen at the second stage, depending on the costs of implementing effort from the first stage. Imposing full indexation would increase the costs of implementing any given effort level if full indexation is costly, which would therefore most likely yield lower optimal levels of effort in a model with endogenous effort. Accordingly, our analysis would understate the true costs of indexation. Conversely, if indexation has small (large) benefits, the influence on the optimal first-stage effort level is likely to be positive and small (large). In either case, we expect that a fully-developed two-stage analysis with endogenously chosen optimal effort levels would lead to larger effects without affecting the signs of the effects we find.[29]

[29] It might also be possible to justify our effort assumption by assuming that the marginal benefit of the CEO's effort for the firm is sufficiently high, relying on a similar argument as Edmans and Gabaix (2011).

8 Conclusion

We calibrate a standard contracting model and introduce indexed contracts. The analysis shows that indexing stock options by varying the strike price with a broad market index or industry index can be expressed analytically as a combination of four different transformations, of which three are important: (1) a reduction of volatility of the underlying assets, which improves risk sharing as well as incentives ("volatility effect"), (2) a reduction in the drift rate of the underlying asset ("drift-rate effect"), and (3) an increase in the strike price ("strike-price effect"). The last two effects have a negative impact on incentive provision, whereas the impact of the volatility effect is positive.

Our calibration shows that full indexation significantly *increases* compensation costs for almost all CEOs. Partial indexation creates benefits for a small number of firms, in particular, high-risk, high-beta firms. Interestingly, the positive effect for high-risk firms is mainly driven by a smaller adverse impact on incentives and not by improved benefits from risk-sharing. Our analysis implies that intuitive reasoning based on the notion that executives should not obtain windfall profits may lead one astray, because indexing requires CEOs to outperform the market and creates contracts with very poor incentive properties.

A central implication from our analysis is that it is hard to build a credible case of seriously deficient pay setting on the absence of indexation in observed CEO pay contracts. Even under assumptions that are biased toward producing large savings, indexing options generates small benefits at best. We highlight that corporate policies that require firms to fully index stock options can back-fire and substantially increase, rather than decrease, CEO pay levels. Firms may therefore correctly avoid indexation, so that observing "pay for luck" does not show that observed compensation practice is inefficient.

References

Aggarwal, R. K., and A. A. Samwick, 1999, "Executive Compensation, Strategic Competition, and Relative Performance Evaluation: Theory and Evidence," *Journal of Finance*, 54(6), 1999–2043.

Ait-Sahalia, Y., and A. W. Lo, 2000, "Non-Parametric Risk Management and Implied Risk Aversion," *Journal of Econometrics*, 94, 9–51.

Antle, R., and A. Smith, 1986, "An Empirical Investigation of the Relative Performance Evaluation of Corporate Executives," *Journal of Accounting Research*, 24(1), 1–39.

Arnott, R., and J. E. Stiglitz, 1988, "Randomization with Asymmetric Information," *RAND Journal of Economics*, 19(3), 344–362.

Bebchuk, L. A., and J. M. Fried, 2004, *Pay Without Performance - The Unfulfilled Promise of Executive Compensation*. Harvard University Press.

Bertrand, M., and S. Mullainathan, 2001, "Are CEOS Rewarded for Luck? The Ones without Principals Are," *Quarterly Journal of Economics*, 116(3), 901–932.

Bettis, J. C., J. Bizjak, J. L. Coles, and S. L. Kalpathy, 2010, "Stock and Option Grants with Performance-Based Vesting Provisions," *Review of Financial Studies*, 23(10), 3849–3888.

Campbell, J. Y., A. W. Lo, and A. C. MacKinlay, 1997, *The Econometrics of Financial Markets*. Princeton University Press.

Carpenter, J. N., 1998, "The Exercise and Valuation of Executive Stock Options," *Journal of Financial Economics*, 48(2), 127–158.

Chaigneau, P., 2012, "On the Value of Improved Informativeness," *Working Paper, HEC Montreal*.

Core, J. E., and W. R. Guay, 2002, "Estimating the Value of Stock Option Portfolios and Their Sensitivities to Price and Volatility," *Journal of Accounting Research*, 40(3), 613–640.

——— , 2010, "Is CEO Pay Too High and Are Incentives Too Low? A Wealth-Based Contracting Framework," *The Academy of Management Perspectives*, 24(1), 5–19.

Diamond, D. W., and R. E. Verrecchia, 1982, "Optimal Managerial Contracts and Equilibrium Security Prices," *The Journal of Finance*, 37(2), 275–287.

Dittmann, I., and E. Maug, 2007, "Lower Salaries and No Options? On the Optimal Structure of Executive Pay," *Journal of Finance*, 62(1), 303–343.

Dittmann, I., E. Maug, and O. Spalt, 2010, "Sticks or Carrots? Optimal CEO Compensation when Managers are Loss Averse," *Journal of Finance*, 65(6), 2015–2050.

Dittmann, I., and K.-C. Yu, 2011, "Providing Effort and Risk-Taking Incentives: The Optimal Compensation Structure for CEOs," *Working Paper, Erasmus University Rotterdam*.

Dittmann, I., D. Zhang, E. G. Maug, and O. G. Spalt, 2011, "Note on the Calibration of Executive Compensation Models," *Working Paper, Erasmus University Rotterdam*.

Dye, R. A., 1992, "Relative Performance Evaluation and Project Selection," *Journal of Accounting Research*, 30(1), 27–52.

Edmans, A., and X. Gabaix, 2009, "Is CEO Pay Really Inefficient? A Survey of New Optimal Contracting Theories," *European Financial Management*, 15(3), 486–496.

——— , 2011, "Tractability in Incentive Contracting," *Review of Financial Studies*, 24(9), 2865–2894.

Edmans, A., X. Gabaix, and A. Landier, 2009, "A Multiplicative Model of Optimal CEO Incentives in Market Equilibrium," *Review of Financial Studies*, 22(12), 4881–4917.

Faulkender, M. W., and J. Yang, 2010, "Inside the Black Box: The Role and Composition of Compensation Peer Groups," *Journal of Financial Economics*, 96(2), 257–270.

Garvey, G., and T. Milbourn, 2003, "Incentive Compensation When Executives Can Hedge the Market: Evidence of Relative Performance Evaluation in the Cross Section.," *Journal of Finance*, 58(4), 1557–1581.

Gjesdal, F., 1982, "Information and Incentives: The Agency Information Problem," *The Review of Economic Studies*, 49(3), 373–390.

Gopalan, R., T. T. Milbourn, and F. Song, 2010, "Strategic Flexibility and the Optimality of Pay for Luck," *Review of Financial Studies*, 23(5), 2060–2098.

Grossman, S. J., and O. D. Hart, 1983, "An Analysis of the Principal-Agent Problem," *Econometrica*, 51(1), 7–45.

Göx, R., 2008, "Tax incentives for inefficient executive pay and reward for luck," *Review of Accounting Studies*, 13(4), 452–478.

Hall, B. J., and T. A. Knox, 2004, "Underwater Options and the Dynamics of Executive Pay-to-Performance Sensitivities," *Journal of Accounting Research*, 42(2), 365–412.

Hall, B. J., and K. J. Murphy, 2000, "Optimal Exercise Prices for Executive Stock Options," *American Economic Review*, 90(2), 209–214.

——— , 2002, "Stock Options for Undiversified Executives," *Journal of Accounting and Economics*, 33(2), 3–42.

Hemmer, T., O. Kim, and R. E. Verrecchia, 1999, "Introducing Convexity into Optimal Compensation Contracts," *Journal of Accounting and Economics*, 28(3), 307–327.

Himmelberg, C. P., and R. G. Hubbard, 2000, "Incentive Pay and the Market for CEOs: An Analysis of Pay-for-Performance Sensitivity," *Working Paper, Columbia University*.

Holmstrom, B., 1979, "Moral Hazard and Observability," *Bell Journal of Economics*, 10, 74–91.

———, 1982, "Moral Hazard in Teams," *Bell Journal of Economics*, 13(2), 324–340.

Huddart, S., and M. Lang, 1996, "Employee stock option exercises an empirical analysis," *Journal of Accounting and Economics*, 21(1), 5–43.

Jenter, D., and F. Kanaan, 2008, "CEO Turnover and Relative Performance Evaluation," *Stanford University Graduate School of Business Research Paper*, (1992).

Jin, L., 2002, "CEO Compensation, Diversification, and Incentives," *Journal of Financial Economics*, 66(1), 29–63.

Johnson, S. A., and Y. S. Tian, 2000, "Indexed Executive Stock Options," *Journal of Financial Economics*, 57(1), 35–64.

Lambert, R. A., D. F. Larcker, and R. Verrecchia, 1991, "Portfolio Considerations in Valuing Executive Compensation," *Journal of Accounting Research*, 29(1), 129–149.

Maug, E., 2000, "The Relative Performance Puzzle," *Schmalenbach Business Review*, 52(1), 3–24.

Meulbroek, L. K., 2001, "Designing an Option Plan that Rewards Relative Performance: Indexed Options Revisited," *Harvard Business School Working Paper*, (02-022).

———, 2002, "Compensation at Level 3 Communications," *Harvard Business School Case*, (9-202-084).

Murphy, K. J., 1999, *Executive Compensation, in O. Ashenfelter, and D. Cards, eds.: Handbook of Labor Economics,*North-Holland, Amsterdam, pp. 2485–2563.

———, 2002, "Explaining Executive Compensation: Managerial Power vs. the Perceived Cost of Stock Options," *University of Chicago Law Review*, 69, 847–869.

Oyer, P., and S. Schaefer, 2005, "Why do Some firms Give Stock Options to all Employees?: An Empirical Examination of Alternative Theories," *Journal of Financial Economics*, 76(1), 99–132.

Rappaport, A., and T. H. Nodine, 1999, "New Thinking on How to Link Executive Pay with Performance," *Harvard Business Review*, 77(2), 91–101.

Ross, S. A., 2004, "Compensation, Incentives, and the Duality of Risk Aversion and Riskiness," *Journal of Finance*, 59(1), 207–225.

Weisbach, M. S., 2007, "Optimal Executive Compensation versus Managerial Power: A Review of Lucian Bebchuk and Jesse Fried's Pay without Performance: The Unfulfilled Promise of Executive Compensation," *Journal of Economic Literature*, 45(2), 419–428.

Appendix

Derivation of equation (12):

We rewrite P_T/H_T in (11) as

$$\begin{aligned}\frac{P_T}{H_T} = exp \times & \left\{ \left(\mu_P - \frac{\sigma_P^2}{2} \right) T + u_P \sigma_P \sqrt{T} \right\} \\ & \times \left\{ - \left(\mu_M - \frac{\sigma_M^2}{2} \right) \beta T - u_M \beta \sigma_M \sqrt{T} \right\} \times exp \left\{ - (1 - \beta) \left(r_f + \frac{1}{2} \rho \sigma_M \sigma_P \right) T \right\}\end{aligned} \tag{30}$$

We collect terms and observe that $\mu_P - \beta \mu_M = r_f(1 - \beta)$ from the CAPM equation (8). Then the terms in μ_P and μ_M cancel against $(1 - \beta) r_f$. Also, we can use $\beta \sigma_M = \rho \sigma_P$ from the definition of β to obtain:

$$-\frac{\sigma_P^2}{2} + \frac{\sigma_M^2 \beta}{2} - \frac{(1 - \beta) \rho \sigma_M \sigma_P}{2} = -\frac{\sigma_P^2 - \sigma_P^2 \rho^2}{2}.$$

Then:

$$\frac{P_T}{H_T} = exp \left\{ -\frac{\sigma_P^2 \left(1 - \rho^2\right)}{2} T + \left(u_P \sigma_P - u_M \rho \sigma_P\right) \sqrt{T} \right\}. \tag{31}$$

Using (13) and (14) in (31) and inserting the resulting expression into (11) gives (12).

Derivation of equations (27) and (28)

To derive (27), simply calculate

$$\begin{aligned} V'' &= U''(W')^2 + U'W'' = \underbrace{U'W'}_{=V'} \left[\frac{U''}{U'} W \frac{W'}{W} + \frac{W''}{W'} \right] \\ \Rightarrow \frac{V''}{V'} &= -\gamma \frac{W'}{W} + \frac{W''}{W'}. \end{aligned} \tag{32}$$

The last transformation uses the assumption that the utility function features constant relative risk aversion. Differentiating V'' again yields:

$$\begin{aligned}
V''' &= U'''\left(W'\right)^3 + 2U''W'' + U''W'W'' + U'W''' \\
&= \underbrace{U'W'}_{=V'}\left[\frac{U'''}{U'}\left(W'\right)^2 + \frac{W'''}{W'} + \frac{U''}{U'}\frac{W''}{W'}\left(2+W'\right)\right] \\
&= V'\left[\gamma\left(1+\gamma\right)\left(\frac{W'}{W}\right)^2 + \frac{W'''}{W'} - \frac{\gamma}{W}\frac{W''}{W'}\left(2+W'\right)\right],
\end{aligned} \tag{33}$$

which gives (28). Again, the last transformation uses the assumption of constant relative risk aversion.

Derivation of *UPPS* for risk-neutral CEOs

If the CEO is risk neutral, $\gamma = 0$ and marginal utility U' is a constant. The derivative of the wage function is $W'(P_T) = n_S + n_O I\left(P_T \geq K\right)$, where $I\left(\right)$ denotes the indicator function. Then $UPPS$ can be evaluated as

$$\begin{aligned}
UPPS &= \frac{U'}{P_0} E\left[\left(n_S + n_O I\left(P_T \geq K\right)\right) P_T\right] \\
&= \frac{U'}{P_0}\left(n_S E\left[P_T\right] + n_O E\left[P_T \left| P_T \geq K\right.\right] Pr\left(P_T \geq K\right)\right) \\
&= \frac{U'}{P_0}\left\{n_S P_0 exp\left(\mu_P T\right) + n_O P_0 exp\left(\mu_P T\right) N\left(d_1\right)\right\} \\
\text{with}: \ d_1 &= \frac{ln\left(P_0/K\right) + \mu_P T}{\sigma_P\sqrt{T}} + \frac{\sigma_P\sqrt{T}}{2},
\end{aligned} \tag{34}$$

where $N\left(d_1\right)$ is the cdf of the standard normal density. Note that μ_P replaces the risk-free rate in the standard expressions for the option delta and that the dividend yield is set to zero. Simplifying gives the expression in the text on page 26.

Tables

Table 1: Description of the data set

This table contains descriptive statistics for the variables in our data set. Share holdings and option holdings are based on end of year 2005 values from ExecuComp. Option holdings, n_O, are computed following the method of Core and Guay (2002). The number of restricted shares, n_{SR}, unrestricted shares, n_{SU}, and options are scaled by the total number of shares outstanding and presented as percentages. Base salary, ϕ, is the sum of salary, bonus, and "other compensation" from ExecuComp. The value of the CEO pay contract, π_0, is the sum of base salary, restricted and unrestricted shares, and options. CEO outside wealth, W_0, is estimated based on past income over at least 5 years reported in ExecuComp. The market capitalization is measured at the end of 2005. Volatilities and beta for each firm are estimated based on five years of monthly CRSP returns.

Variable	Symb.	Mean	Median	S.D.	25^{th} Perc.	75^{th} Perc.	N
Shares (res.)	n_{SR}	0.13%	0.02%	0.35%	0.00%	0.12%	755
Shares (unres.)	n_{SU}	1.74%	0.23%	5.04%	0.07%	0.81%	755
Options	n_O	1.49%	1.02%	1.79%	0.00%	1.87%	755
Base salary ($K)	ϕ	1,616	1,043	4,393	724	1,502	755
Contract ($M)	π	30.76	13.12	55.18	5.25	32.16	755
Wealth ($M)	W_0	63.83	13.49	654.87	6.13	33.36	755
Firm value ($M)	P_0	9,163	2,318	22,400	960	7,569	755
Maturity	T	8.14	6.17	6.47	4.51	9.11	755
Div. yield	d	1.24%	0.61%	2.24%	0.00%	1.81%	755
Tot. volatility	σ_P	38.82%	33.78%	18.93%	25.36%	47.99%	755
Mkt. volatility	σ_M	15.47%	15.41%	0.51%	15.41%	15.41%	755
Idio. volatility	σ_I	34.12%	30.52%	16.19%	22.38%	41.60%	755
Beta	β	1.08	0.89	0.82	0.50	1.46	755

Table 2: Full indexation of options

This table presents results for the case in which the the degree of indexation of options is constrained to $\psi = 1$. Firms can choose the fixed salary ϕ (in million dollars), and the number of options n_O. The firm's objective is to minimize contracting costs subject to the two constraints that the new contract provides the CEO (1) with at least the same utility as the observed contract, and (2) with at least the same effort incentives as the observed contract. Panel A shows our results for $\gamma = 1$, Panel B for $\gamma = 2$, and Panel C for $\gamma = 3$. Each panel shows the mean of the parameters across CEOs for five different values of the CEO's investment in the market portfolio ω. The table also shows the average efficiency gains from indexing expressed as a percentage of the observed value of the CEO's contract and the proportion of CEOs for whom these gains are positive. Base salaries are given in million dollars. All variables except γ, ϕ, and N are percentages.

Panel A: Results for $\gamma = 1$

				Mean		Median			
γ	ω	ϕ	n_O	ψ	S	ψ	S	$S > 0$	N
1	0	5.545	2.391	100.00	-24.82	100.00	-17.52	4.93	750
1	25	5.366	2.346	100.00	-22.56	100.00	-16.08	5.35	748
1	50	5.167	2.301	100.00	-20.80	100.00	-14.71	5.90	746
1	75	5.009	2.245	100.00	-18.98	100.00	-13.18	5.91	745
1	100	4.769	2.235	100.00	-17.56	100.00	-11.91	6.27	750

Panel B: Results for $\gamma = 2$

				Mean		Median			
γ	ω	ϕ	n_O	ψ	S	ψ	S	$S > 0$	N
2	0	3.452	4.045	100.00	-76.96	100.00	-21.66	9.33	697
2	25	3.242	3.661	100.00	-70.59	100.00	-17.44	11.67	711
2	50	3.051	3.404	100.00	-55.65	100.00	-13.19	15.33	711
2	75	2.873	3.192	100.00	-48.72	100.00	-10.01	17.66	719
2	100	2.654	3.177	100.00	-45.22	100.00	-7.34	24.55	721

Panel C: Results for $\gamma = 3$

				Mean		Median			
γ	ω	ϕ	n_O	ψ	S	ψ	S	$S > 0$	N
3	0	2.649	4.092	100.00	-116.73	100.00	-21.64	15.44	609
3	25	2.497	3.719	100.00	-87.08	100.00	-14.49	20.25	632
3	50	2.286	3.768	100.00	-75.35	100.00	-8.71	27.27	649
3	75	2.127	3.255	100.00	-65.41	100.00	-4.15	36.65	663
3	100	2.005	3.074	100.00	-46.64	100.00	-0.51	45.88	680

Table 3: Decomposing savings from the indexation of options

This table shows a decomposition of savings S from fully indexed options in Table 2. S_G are the gross savings that would result if the firm would only adjust ϕ to satisfy the participation constraint. $\Delta UPPS$ is the percentage change in UPPS from this step. $S_I = S - S_G$ are the implied additional savings if the firm also satisfies the incentive compatibility constraint and optimize of over ϕ and n_O. Each of these components is further decomposed into four effects which are computed sequentially: (1) the volatility effect (VOLE) reduces the volatility of the underlying asset from σ_P to σ_I; (2) the drift effect (DE) reduces the drift of the underlying from μ_P to r_f; (3) the strike price effect increases the strike price from P_0 to $P_0 exp\{r_f T\}$; (4) the market exposure effect (MEE) multiplies the number of options by a factor $b\, M_T^{\beta}$, where $b\, M_T^{\beta}$ is defined in equation (15). The sum of these effects equals the value for "Fully Indexed Options" in column 2 by construction. Options on indexed stock are the sum of VOLE and DE. All savings are percentages of the value of the observed contract π_d. The numbers of CEOs for whom we can compute all quantities are 627, 616, and 523 for Panels A, B, and C, respectively.

Panel A: Decomposition for $\gamma = 2$, $\omega = 0$.

	Fully Indexed Options (FIO)	Decomposing FIO				Options on Indexed Stock
		VOLE	DE	SPE	MEE	
S_G	11.6	11.7	-9.8	9.2	0.5	1.9
S_I	-99.1	16.8	-23.9	-98.5	6.5	-7.1
S	-87.5	28.5	-33.7	-89.3	7.0	-5.2
$\Delta UPPS$	-11.4	16.8	-18.2	-11.0	0.9	-1.3

Panel B: Decomposition for $\gamma = 2$, $\omega = 50\%$.

	Fully Indexed Options (FIO)	Decomposing FIO				Options on Indexed Stock
		VOLE	DE	SPE	MEE	
S_G	13.2	13.2	-9.3	9.2	0.2	3.9
S_I	-70.8	19.2	-18.8	-72.1	0.8	0.4
S	-57.5	32.4	-28.1	-62.9	1.0	4.3
$\Delta UPPS$	-9.8	20.6	-19.1	-11.6	0.2	1.5

Panel C: Decomposition for $\gamma = 2$, $\omega = 100\%$.

	Fully Indexed Options (FIO)	Decomposing FIO				Options on Indexed Stock
		VOLE	DE	SPE	MEE	
S_G	13.2	12.5	-7.5	8.3	-0.1	5.0
S_I	-42.7	19.3	-13.9	-42.3	-5.8	5.4
S	-29.4	31.8	-21.4	-33.9	-5.9	10.4
$\Delta UPPS$	-7.2	19.9	-16.0	-10.7	-0.5	3.9

Table 4: Sample splits and Correlations

This table shows how savings from indexation are related to firm, observed contract, and CEO characteristics. Panel A shows descriptive statistics for the group where indexation reduces costs ($S > 0$) and the group where indexation leads to higher costs for the firm ($S < 0$). $CE(W_T)/E(W_T)$ is the ratio of the certainty equivalent of W_T relative to the expected value of W_T under the observed contract. $\Delta Prob$ is defined as $Prob(P_T > H_T) - Prob(P_T > K)$. Unless otherwise indicated, all numbers are percentages. The reported z-statistic is from a Wilcoxon rank-sum test. Panel B reports correlations. S_{VOLE}, S_{DE}, and S_{SPE} are the savings S from the VOLE, DE, and SPE steps defined in Table 3. Pairwise correlations that are significant at at 5% level are reported in bold face.

Panel A: Sample Splits

	Mean			Median		
	$S > 0$	$S < 0$	t-stat	$S > 0$	$S < 0$	z-stat
S_G	15.3	12.9	2.34	16.9	12.0	2.41
S_I	-4.8	-80.4	3.67	-5.1	-36.4	11.96
S	10.4	-67.4	3.82	6.0	-22.5	14.28
$\Delta UPPS$	-6.9	-23.8	8.80	-3.6	-22.2	9.38
β	2.0	0.9	12.11	2.2	0.8	8.11
σ_I	42.2	35.0	3.60	40.5	31.0	3.72
n_O^d	1.2	1.6	-1.62	0.8	1.0	-2.47
n_{SR}^d	0.1	0.2	-2.39	0.0	0.0	-3.58
n_{SU}^d	5.5	1.5	6.25	0.2	0.3	1.15
ϕ_d (\$M)	1.3	1.4	-0.38	0.9	1.0	-2.22
T	4.6	7.7	-5.17	4.4	6.2	-6.18
W_0 (\$M)	58.0	32.0	2.87	15.0	13.0	1.03
$CE(W_T)/E(W_T)$	51.4	61.8	-4.19	50.5	64.1	-3.78
$Prob(P_T > K)$	48.3	54.3	-3.87	47.7	54.8	-4.18
$Prob(P_T > H_T)$	33.6	32.9	0.87	34.0	33.6	0.75
ΔProb	-14.6	-21.4	6.12	-13.2	-20.8	6.47
N	78	538		78	538	

Table 4: Sample splits and Correlations (Continued)

Panel B: Correlations

	S_G	S_I	S	$\Delta UPPS$	S_{VOLE}	S_{DE}	S_{SPE}	$\Delta Prob$
S_G	**1.00**				**0.60**	**-0.25**	**-0.15**	**-0.35**
S_I	**-0.22**	**1.00**			**-0.15**	**0.44**	**0.97**	**0.33**
S	**-0.17**	**1.00**	**1.00**		**-0.13**	**0.43**	**0.97**	**0.32**
$\Delta UPPS$	**-0.38**	**0.26**	**0.25**	**1.00**	-0.04	**0.25**	**0.20**	**0.51**
β	0.03	**0.11**	**0.11**	**0.37**	**0.66**	**-0.28**	0.08	**0.43**
σ_I	**-0.29**	0.05	0.04	**0.46**	**0.29**	**-0.19**	0.04	**0.70**
n_O^d	**0.08**	-0.04	-0.04	-0.03	**0.20**	**-0.26**	-0.02	**0.20**
n_{SR}^d	**-0.23**	0.07	0.05	**0.16**	**-0.22**	**0.18**	0.05	0.05
n_{SU}^d	**-0.14**	0.07	0.06	**0.37**	**-0.10**	**0.11**	0.05	0.00
ϕ_d	0.05	-0.03	-0.03	-0.06	-0.04	-0.01	-0.02	-0.06
T	**0.27**	**-0.51**	**-0.50**	**-0.28**	**0.12**	**-0.40**	**-0.48**	**-0.71**
W_0	**-0.10**	0.05	0.04	**0.13**	-0.06	0.04	0.03	-0.07
$CE(W_T)/E(W_T)$	**-0.42**	**0.34**	**0.32**	-0.03	**-0.71**	**0.59**	**0.28**	-0.02
$\Delta Prob$	**-0.35**	**0.33**	**0.32**	**0.51**	0.00	**0.23**	**0.30**	**1.00**

Table 5: Optimal indexation

This table presents results for the case in which the firm chooses the degree of indexation of options, ψ, fixed salary ϕ, and number of options n_O. Panel A shows our results for $\gamma = 1$, Panel B for $\gamma = 2$, and Panel C for $\gamma = 3$. Each panel shows the mean of the parameters across CEOs for five different values of the CEO's investment in the market portfolio ω. For the degree of indexation ψ, the median is also reported as well as the proportion of CEOs for whom $\psi = 0$ and $\psi = 1$ at the optimum, respectively. The table also shows the average and median efficiency gains from indexing expressed as a percentage of the value of the CEO's observed contract. Base salary is given in million dollars. All other variables except γ are percentages.

Panel A: Results for $\gamma = 1$

						Mean		Median		
γ	ω	ϕ	n_O	$\psi = 0$	$\psi = 1$	ψ	S	ψ	S	N
1	0	1.642	1.505	92.29	1.06	3.10	0.30	0.00	0.00	752
1	25	1.549	1.503	91.60	0.93	3.31	0.24	0.00	0.00	750
1	50	1.596	1.499	90.58	0.93	3.59	0.32	0.00	0.00	754
1	75	1.630	1.493	90.03	0.93	4.04	0.33	0.00	0.00	752
1	100	1.704	1.482	89.24	0.93	4.55	0.36	0.00	0.00	753

Panel B: Results for $\gamma = 2$

						Mean		Median		
γ	ω	ϕ	n_O	$\psi = 0$	$\psi = 1$	ψ	S	ψ	S	N
2	0	1.723	1.477	82.69	1.86	8.84	1.48	0.00	0.00	751
2	25	1.762	1.480	80.35	2.52	10.54	1.82	0.00	0.00	753
2	50	1.793	1.479	76.46	2.93	12.74	2.28	0.00	0.00	752
2	75	1.871	1.481	70.48	4.26	16.46	2.77	0.00	0.00	752
2	100	1.932	1.479	64.14	8.50	22.12	3.63	0.00	0.00	753

Panel C: Results for $\gamma = 3$

						Mean		Median		
γ	ω	ϕ	n_O	$\psi = 0$	$\psi = 1$	ψ	S	ψ	S	N
3	0	1.732	1.440	76.00	3.60	13.01	3.75	0.00	0.00	750
3	25	1.751	1.430	68.97	4.66	17.10	4.84	0.00	0.00	751
3	50	1.834	1.411	61.87	8.53	23.46	6.07	0.00	0.00	750
3	75	1.830	1.394	52.99	15.01	31.97	7.98	0.00	0.00	753
3	100	1.790	1.365	45.20	25.20	41.07	10.54	25.99	0.48	750

Table 6: Options on indexed stock

This table repeats the analysis in Table 5 for options on indexed stock. The firm chooses the fraction ψ of conventional options to be replaced by options on indexed stock, fixed salary ϕ, and number of options n_O to minimize compensation cost as in Table 5. The analysis is shown for ω between 0 and 1 and $\gamma = 2$.

						Mean		Median		
γ	ω	ϕ	n_O	$\psi = 0$	$\psi = 1$	ψ	S	ψ	S	N
2	0.00	1.859	1.390	61.30	6.65	19.30	5.48	0.00	0.00	752
2	0.25	1.879	1.375	54.91	7.43	22.72	6.46	0.00	0.00	754
2	0.50	1.911	1.349	47.61	8.36	27.37	7.61	8.45	0.08	754
2	0.75	1.975	1.330	39.31	11.29	34.24	9.05	25.00	1.00	753
2	1.00	1.937	1.290	32.45	16.36	42.73	11.08	41.03	2.60	752

Table 7: Rent extraction.

This table shows results for the rent extraction case. In this case, the firm optimizes only subject to the incentive compatibility constraint. Panel A reports results for the full indexation case, i.e. $\psi = 1$. Panel B presents results for the optimal indexation case $\psi \in [0, 1]$. All results are for $\gamma = 2$.

Panel A: Results for Full Indexation ($\psi = 1$)

				Mean		Median			
γ	ω	ϕ	n_O	ψ	S	ψ	S	$S > 0$	N
2	0	1,627	2.627	100.00	-23.64	100.00	-0.58	41.14	739
2	25	1,624	2.414	100.00	-18.86	100.00	-0.34	42.99	742
2	50	1,622	2.420	100.00	-23.24	100.00	0.00	45.95	740
2	75	1,618	2.438	100.00	-17.74	100.00	0.00	49.39	741
2	100	1,617	2.282	100.00	-9.86	100.00	0.40	52.16	740

Panel B: Results for Optimal Degrees of Indexation

				Mean		Median			
γ	ω	ϕ	n_O	ψ	S	ψ	S	$S > 0$	N
2	0	1,617	1.511	42.39	8.03	14.91	0.05	60.21	754
2	25	1,616	1.516	44.38	7.68	25.48	0.20	63.18	755
2	50	1,616	1.514	46.48	7.82	32.78	0.47	61.19	755
2	75	1,616	1.514	49.02	8.25	44.17	0.72	64.67	753
2	100	1,616	1.499	52.37	8.92	61.71	1.25	66.49	755

Table 8: Indexing restricted stock

This table shows results for the indexation of restricted stock. Firms can set fixed salary ϕ (in million dollars), and the number of restricted shares n_{SR} to minimize costs subject to the participation and incentive compatibility constraints. Panel A reports results for the full indexation case, i.e. $\psi = 1$. Panel B presents results for the optimal indexation case $\psi \in [0,1]$. All results are for $\gamma = 2$. Panel C reports rescaled savings (efficiency gains). $S_{SR}/n_{SR}^d P_0$ represents the efficiency gains from indexing restricted stock, expressed as a percentage of the total value of restricted stock in the observed contract. $S_O/n_O^d BS$ represents the efficiency gains from indexing options from Tables 2 and 5, expressed as a percentage of the total value of options in the observed contract.

Panel A: Results for Full Indexation ($\psi = 1$)

				Mean		Median			
γ	ω	ϕ	n_{SR}	ψ	S	ψ	S	$S > 0$	N
2	0	1,941	0.124	100.00	-0.63	100.00	0.00	17.35	755
2	25	1,888	0.121	100.00	-0.14	100.00	0.00	20.03	754
2	50	1,845	0.118	100.00	0.24	100.00	0.00	25.43	755
2	75	1,806	0.115	100.00	0.52	100.00	0.00	30.46	755
2	100	1,766	0.112	100.00	0.91	100.00	0.00	36.21	754

Panel B: Results for Optimal Degrees of Indexation

				Mean		Median			
γ	ω	ϕ	n_{SR}	ψ	S	ψ	S	$S > 0$	N
2	0	1,804	0.121	16.89	0.44	0.00	0.00	19.60	755
2	25	1,805	0.117	19.73	0.63	0.00	0.00	22.94	754
2	50	1,800	0.115	24.52	0.76	0.00	0.00	27.68	755
2	75	1,786	0.113	29.92	0.87	0.00	0.00	33.51	755
2	100	1,762	0.111	35.44	1.14	0.00	0.00	38.41	755

Panel C: Indexing Options Compared to Indexing Restricted Stock

		Full Indexation		Optimal Indexation	
γ	ω	$S_O/\left(n_O^d BS\right)$	$S_{SR}/\left(n_{SR}^d P_0\right)$	$S_O/\left(n_O^d BS\right)$	$S_{SR}/\left(n_{SR}^d P_0\right)$
2	0	-99.17	-1.63	1.78	2.21
2	25	-91.01	1.15	2.16	2.76
2	50	-70.66	3.73	2.64	3.44
2	75	-62.75	6.35	3.32	4.38
2	100	-57.43	9.23	4.31	5.62

Table 9: Optimal investment in the stock market

This table repeats the analysis in Table 5 when the fraction of outside wealth invested in the market is not restricted to be the same across CEOs. In a first step, the CEO chooses the investment in the stock market $\omega \in [0, 1]$ that maximizes her utility under the observed contract. This "quasi-optimal" investment level ω^* is used in a second step, in which the firm chooses the degree of indexation of options, ψ, fixed salary ϕ, and number of options n_O to minimize compensation costs as in Table 5. Finally, we compute the 2nd-stage "quasi-optimal" investment level ω^{**}, which is the utility maximizing stock market investment given the optimal contract from the first stage. The table shows the average ω^*, ω^{**}, and the resulting optimal contract parameters and savings for $\gamma = 1, 2, 3$.

							Mean		Median		
γ	ω^*	ω^{**}	ϕ	n_O	$\psi = 0$	$\psi = 1$	ψ	S	ψ	S	N
1	0.98	0.99	1.698	1.482	89.24	0.93	4.30	0.32	0.00	0.00	753
2	0.72	0.75	1.786	1.480	65.07	3.05	12.96	1.90	0.00	0.00	753
3	0.42	0.44	1.800	1.436	65.07	5.20	18.36	4.41	0.00	0.00	750

Table 10: Zero market risk premium

This table replicates results from Table 5 when the market risk premium is set to zero. Before running the main optimization, base salary ϕ^d is adjusted so that expected utility of the contract to the executive with a market risk premium of 4% (our baseline) case is equal to the expected utility with zero market risk premium. Panel A reports results for the full indexation case, i.e. $\psi = 1$. Panel B presents results for the optimal indexation case $\psi \in [0, 1]$. All results are for $\gamma = 2$.

Panel A: Results for Full Indexation ($\psi = 1$)

				Mean		Median			
γ	ω	ϕ	n_O	ψ	S	ψ	S	$S > 0$	N
2	0	18,160	2.247	100.00	-10.98	100.00	0.40	52.63	741
2	25	22,798	2.275	100.00	-13.33	100.00	1.31	59.38	746
2	50	26,785	2.201	100.00	-7.64	100.00	2.17	63.76	745
2	75	30,180	2.048	100.00	-3.34	100.00	2.85	66.85	745
2	100	32,790	2.000	100.00	-3.45	100.00	3.33	69.71	746

Panel B: Results for Optimal Degrees of Indexation

				Mean		Median			
γ	ω	ϕ	n_O	ψ	S	ψ	S	$S > 0$	N
2	0	17,590	1.464	52.90	6.27	66.23	1.21	70.57	741
2	25	22,384	1.454	59.01	7.06	85.10	1.87	73.47	746
2	50	26,347	1.435	63.49	7.80	99.98	2.47	76.06	745
2	75	29,728	1.406	66.57	8.54	100.00	2.97	77.53	745
2	100	32,383	1.383	69.33	9.37	100.00	3.59	77.79	746