Options, Option Repricing in Managerial Compensation: Their Effects on Corporate Investment Risk

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January 23, 2006

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Helpful comments from Nagpurnanand Prabhala and seminar participants at Temple University and Duke University are appreciated. Rajesh Aggarwal's written comments and conversation with us have been particularly useful. We especially thank an anonymous referee for many insightful comments.

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ABSTRACT

While stock options are commonly used in managerial compensation to provide desirable incentives, their adverse effects have not been widely appreciated. We show that a call-type contract creates incentives to distort the choice of investment risk. Relative to the risk level that maximizes firm value, a call option contract can induce too much or too little corporate risk-taking, depending on managerial risk aversion and the underlying investment technology. We show that inclusion of lookback call options in compensation packages has desirable countervailing effects on managerial choice of corporate risk policies and can induce risk policies that increase shareholder wealth. We argue that lookback call options are analogous to the observed practice of option repricing.

I. Introduction

Executive stock options have become an ever more important component of a manager's compensation. Hall and Murphy (2002) report that stock options account for 40% of total pay for the S&P 500 CEO's in 1998. Indeed, executive stock options are at the center of the ongoing debate surrounding crisis in corporate governance and spectacular failures, such as Enron, Worldcom, and Global Crossing. Thus, a deeper understanding of the managerial incentives induced by option-type contract is warranted. This paper examines the effects of options on corporate investment risk policies.

Options provide a basic link between a manager's pay and stock performance because the payoff function of a call is an increasing function of the terminal stock price. Since call values are increasing in volatility, the immediate implication is that an option-type contract encourages the manager to undertake excessively risky investments. However, this kind of reasoning ignores managerial risk-aversion. A risk-averse manager may be willing to sacrifice possible higher stock prices for lower uncertainties (risks).

Indeed, as we will show later, if the manager is risk-averse, she may take less risky investments than what would be optimal for the well-diversified stockholders. It is likely that well-diversified stockholders can balance and hedge their portfolios with little difficulty, and hence should only be concerned about maximizing their portfolio values. However, since most high level managers' portfolios are highly concentrated in company stock and options, it is essential to assume that they are risk-averse and, therefore, make choices to maximize their expected utilities.[1] Naturally, conflicts induced by shareholders' value maximizing and the manager's utility maximizing can arise.

The usual intuition that call options are increasing functions of the volatility depends on the assumption that changing a firm's risk level does not affect its stock price. However, we argue in Section III that the risk policy affects *both* the initial stock price *and* the terminal price distribution. Therefore, the manager chooses the risk level to control the initial stock price *and* its terminal distribution to maximize her utility. We examine the distortional effects of a call-type contract on the corporate risk policy controlled by a risk-averse manager.

[1]Note that unlike individual investors, executives cannot normally trade or hedge their stock options to eliminate the option risks. They are also usually explicitly or implicitly constrained from selling company stocks.

After we analyze the risk incentive costs associated with the call option contracts, we show how the inclusion of lookback calls in managerial contracts counteracts these effects. We argue that lookback calls have real world analogs, namely option repricing.

The major results of the paper can be summarized as follows.

1. Contrary to common intuition, a risk-averse manager may choose a lower risk level if more call options are included in her compensation package. This is because, even though more call options increase the expected payoff, they also increase the risk level of the payoff.[2] Thus, the distortionary effect of managerial risk aversion on optimal corporate risk is unlikely to be corrected through simple options in managerial compensation.

2. The costliness to deviate from the firm's optimal risk level depends on the investment risk technology. The more flexible the investment risk technology is, the greater is the propensity for the manager to depart from the optimal risk.

3. The structure (relative components) of the compensation package has a material impact on managerial incentives. It is not just how much a firm pays but how the firm pays that matters. Since utility maximization depends only on the relative value of each component, the structure seems to be more important than the total value of the compensation from an incentive standpoint. Given the participation constraint,[3] the compensation structure should be constructed in such a way as to minimize the cost to the firm.

4. Finally, an interesting and significant result is that lookback calls are shown to provide more desirable choices than regular calls. Though regular calls may provide reasonable *ex ante* incentives, they may not provide strong incentives *ex post*. For example, deep out of the money

[2]This result is consistent with Carpenter's (2000) finding that a money manager may choose safer portfolios if given more call options.

[3]The reservation utility can be satisfied by scaling the components of the compensation because the power utility function (that we use) is homogeneous of $1 - \Lambda$ degree in the different components of the manager's portfolio, where Λ is the risk-aversion coefficient. Therefore, we will only focus on the relative value of each component.

calls provide very weak pay-for-performance incentives and thus lead to option repricing. However, lookback calls are almost surely in the money all the time, and provide a strong positive link between firm value and the manager's utility because the delta[4] of a lookback call is always greater than 1 and thus greater than that of a regular call because its delta is always smaller than 1.[5]

One may argue that the fact that the delta of a regular call is always smaller than that of a lookback call does not necessarily make regular calls less desirable than lookback calls because one may be able to give the manager more (regular) call options since they are cheaper. However, there are three factors to be considered. First, even if the *ex ante* total delta of a portfolio of regular calls is matched with that of a portfolio of lookback calls by including more regular calls in the (regular call) portfolio, the *ex post* total delta of the regular call portfolio can still become very small when the calls are deep out of the money and option repricing is needed. However, if lookback calls are used, option repricing becomes unnecessary. Second, our calculations in Section IV indicate that including more regular calls in a compensation package may induce less desirable risk choices because of the risk-aversion effect as we have mentioned. Third, our calculations in Section V indicate that using lookback calls is more cost effective to achieving the same utility level for the manager. In sum, with their desirable *ex ante* (i.e. more cost effective) and *ex post* (i.e. strong performance incentive – delta always greater than 1) properties, we argue that lookback options can be a useful incentive component in compensation packages.

The rest of the paper is organized as follows. The next section discusses the most relevant literature and contrasts it with our main results. Section III characterizes the investment risk technology and the managerial risk decision problem. Section IV then provides simulation results that allow us to examine comparative statics. Section V explores the roles of lookback calls in mitigating the costs associated with suboptimal risk policies. Moreover, it provides an argument for lookback calls to have real world analogs, namely option repricing. Section VI concludes. In the Appendix, we prove that the delta of a lookback call is greater than that of a regular call.

[4]The delta of an option is the partial derivative of the option price with respect to the underlying stock price.

[5]See the Appendix for a formal proof that the delta of a lookback call is greater 1.

II. Related Literature and Positioning of the Paper

Since the seminal works of Jensen and Meckling (1976) and Myers (1977), there has been a large body of literature studying the agency costs associated with the conflict of interests among the firm's various claimants. Barnea, Haugen and Senbet (1985) provide a synthesis of the early literature on agency costs associated with corporate financing choices. Parrino and Weisbach (1999) estimate the magnitude of stockholder-bondholder conflict using Monte Carlo simulation. Mao (2002) considers the interaction of debt induced risk-shifting and under-investment. Parrino, Poteshman, and Weisbach (2005) consider the agency conflicts when a risk-averse manager decides whether to undertake a risky project when there is debt in place. To simplify the analysis of the agency costs of managerial compensation, we ignore the classic agency conflict between stockholders and bondholders and only consider that between the manager and stockholders, even though managerial actions also affect bondholders. Aggarwal and Samwick (2003) develop an agency model which relates managerial incentives to firm diversification. In contrast, our model relates managerial incentives to corporate risk policies.

Carpenter (2000) considers a money manager's risk incentive, given a call-type compensation contract. Her setting is different from ours. In our model, changing risk may also affect the value of the firm. In her setting, a money manager can change a portfolio's risk without any costs. There is no agency problem in her model, because the diversified owners can costlessly change their risk exposure through other investments. Ross (2004) examines risk incentive effects of common features such as puts and calls. He too finds that increasing call options may not induce more risk taking. But like in Carpenter (2000), the choice of risk level does not affect firm value. Meulbroek (2001) considers the cost to the firm of granting options to the management, but her concern is to identify the gap between managerial private value and the value of the options determined in the financial markets. She does not address incentive issues that may distort company risk policies.

Leland (1998) also considers costless shifting between two risk levels. He is concerned with the asset substitution problem between debtholders and stockholders. He argues that derivatives may be used to change a firm's risk level. We are concerned with risks associated with irreversible long term investments in real production processes such as like plants and machinery.

These investment policies not only affect the risk level but value of the firm.

Haugen and Senbet (1981) and Green (1984) are closely related to our paper in that they both consider the role options play in resolving agency problems. Haugen and Senbet (1981) consider the conflict between the owner-manager and outsider capital contributors and show that the agency problems of external financing can be resolved through options. In their model the owner-manager holds call options and outside investors hold put options. The agency problem is resolved, because outside investors are insured for bad states. Green (1984) considers the agency costs created by debt financing. He shows that conversion features and warrants can be used to control debt-induced agency conflicts, and such features can restore net present value maximizing, thus providing a rationale for the use of convertible bonds. We are concerned with the potential conflict of corporate investment risk induced by option-type compensations between the manager and shareholders.

Johnson and Tian (2000a, b) consider the value and incentive effects of various nonstandard options. The values of these options are the risk-neutral market prices, and the incentive effects are computed as the derivatives of the market price with respect to various model parameters. This kind of comparative statics holds all other variables constant and ignores the impact of the change of the underlying variable on the firm value. The incentives we consider are those relating to distortions in firm value and corporate risk policies, consistent with contemporary theories of agency. Furthermore, their study relies on risk-neutral pricing and applies to situations where the options can be dynamically hedged.

There are papers which look at the role of compensation structure in counteracting the risk-shifting problem arising from bondholder-stockholder conflict (e.g., John and John, 1993, John, Saunders and Senbet, 2000). John and John consider compensation structure consisting of equity participation, salary, and bonus/penalty schemes, and show how these features can be optimally structured to deal with the stockholder-bondholder risk-shifting problem. They argue that the pay-for-performance sensitivity is decreasing in leverage, mitigating somewhat the concern of Jensen and Murphy (1990) of observed low sensitivities. Aggarwal and Samwick (1999) provide empirical evidence that pay-for-performance is decreasing in the variance of firm value. John, Saunders and Senbet consider optimal compensation for the banking industry, and show how the pricing of deposit insurance, that includes incentive features of bank management compensation, can be used as a pre-commitment to an efficient bank investment policy and hence efficient banking regulation.

In this paper we deal with the agency problems between the manager and the stockholders associated with options in managerial compensation. In our model, the firm value is linked to the risk level the manager adopts, unlike the comparative statics commonly used in the literature. We find that the inclusion of lookback options in a compensation package is effective in aligning a risk-averse manager's interest with that of well-diversified stockholders. Lookback calls have positive payoffs in both good states and bad states, and thus have features similar to a combined portfolio of calls and puts. Unlike a combined portfolio of calls and puts, though, the delta of lookback calls is always greater than 1 and thus they provide reasonable incentives for both good states and bad states for the manager. In contrast, the delta of the repriceable options in Johnson and Tian (2000a) and Brenner, Sundaram and Yermack (2000) is negative for firm values close to the triggering boundary, thus providing the wrong incentives and calling for repricing.

In a different setting, Brenner, Sundaram, and Yermack (2003) show that, in many situations, rescindable options provide better incentives than regular stock options. Rescindable options allow their holders to rescind their exercise decisions. Thus, rescindable option holders obtain a put option upon their exercise of the option. In this case too an insurance feature like the put option implicit in a rescindable option provides the option holder stronger *ex ante* incentives than without it. Ross (2004) shows that the addition of put options to a compensation package moves the manager's portfolio into a less risk averse portion of the payoff domain and thus she is willing to take on more risk. However, inclusion of explicit or implicit put options (as in rescindable options) can lead to negative deltas for certain firm values, and thus provides the wrong incentive *ex post*. In a theoretic model, Acharya, John, and Sundaram (2000) examine the optimality and incentive effects of option repricing. They find that *ex ante* commitment of option repricing can be value-enhancing, but a negative effect on initial incentives exists. Lookbak options do not suffer these types of *ex ante* and *ex post* drawbacks.

Finally, while most papers on executive stock option incentives have focused on the sensitivity analysis of the risk-neutral (market) price of the options with respect to various underlying parameters,[6] we focus our analysis on the effects of stock-based compensations on risk-averse managers' choice

[6]For example, delta and vega of the option price. The vega of an option is the partial derivative of the option price with respect to the underlying volatility.

on corporate investment risk. In our framework, the cost of a compensation package does not only include the direct cost of the compensation itself, but also the cost of suboptimal investments. This is because changing risk can lower the value of the firm. Indeed, the numerical simulations in Section IV indicate that the direct cost of a typical compensation package is likely to be much smaller than the cost of potential suboptimal investments. The reason is that, as large as it is, the number of company shares and stock options in a typical compensation package is likely to be a very small fraction of the number of outstanding shares. However, previous work has focused on the discrepancy between private and market valuations of alternative compensation packages, ignoring the more important cost of suboptimal investments.

III. Compensation Structure and Corporate Investment Risk

A. Firm value as a function of risk: the real sector technology

In this section we address how alternative mixtures of company stock, stock options (including ordinary and lookback calls), and wealth unrelated to company stock (cash and stock holdings in other companies) affect the investment risk policy.

It is well-understood that a call option is an increasing function of the underlying volatility. However, the comparative statics of this type of analysis hold the firm value constant while changing the underlying asset's volatility. For example, Johnson and Tian (2000a, b), Hall and Murphy (2000, 20002), among others, examine the effects of executive stock options by considering comparative statics or certainty equivalent without taking into account the effects of stock options on a manager's decisions which affect the risk level, which in turn affects the firm value.

We assume the (initial) value of the firm as a single-peacked function of volatility, which we approximate by a quadratic function:[7]

$$V_0(\sigma) = V_0 - a\left(\frac{\sigma - \sigma_0}{\sigma_0}\right)^2, \tag{1}$$

where V_0 is the optimal firm value and a is a constant measuring the costliness of deviating from the optimal volatility level, σ_0.

While the assumption of single-peakedness (and its quadratic approximation in equation (1)) is strong, it is consistent with the idea that amongst choices in technologies available to the firm, the one with highest value will be achieved at a "best" level of risk, and that technologies with either higher or lower risks will involve value losses relative to this best level. Without making any more assumptions with regard to the curvature of $V_0(\sigma)$, for σ near σ_0, $V_0(\sigma)$ can be approximated by (1) since it has a maximum at σ_0.[8]

We do not include explicit effort incentive in our analysis. However, we emphasize that for a given level of risk σ, there may exist many other investment policies yielding the same level of risk but different firm values. $V_0(\sigma)$ in (1) is the highest among them. Given that a manager's compensation depends on the firm value, everything else equal, she prefers the highest firm value, $V_0(\sigma)$, for a given level of risk. Alternatively, we can regard $V_0(\sigma)$ as the firm value for risk level σ when the cost of effort is zero because with zero effort cost, the manager adopts the investment policy to achieve the highest firm value $V_0(\sigma)$ for risk level σ. Thirdly, we can also interpret $V_0(\sigma)$ as the firm value resulting from the manager's optimal effort choice. For example, suppose there are 100 different investment policies which yield the same risk level σ but different firm values. Each investment policy requires a different level of effort (and thus different effort cost). Given an effort-cost specification, the manager chooses a particular investment policy resulting a particular firm value, $V_0(\sigma)$. In this way we regard $V_0(\sigma)$ as the highest possible firm value for risk level σ resulting from a particular effort-cost specification.[9] In sum, we regard $V_0(\sigma)$ as the manager's opportunity set with or without effort cost.

[7]The characterization of the investment risk technology is in the same spirit as earlier papers (e.g., Haugen and Senbet, 1981, Green and Talmor, 1986). For instance, Green and Talmor (1986) assume that the firm value is a decreasing function of the firm's volatility, while examining the asset substitution problem between stockholders and bondholders.

[8]To the lowest order, $V_0(\sigma)$ is necessarily a quadratic function around its maximum.

[9]We do not attempt to specify the effort-cost function which results in $V_0(\sigma)$.

We further note that, even though in our model the risk level is observable (or computable from quadratic variation if the firm value process is observed continuously for a finite period.), a contract based on the risk level, σ, is not operational, because many policies with different (initial) firm values can have the same risk level. This is consistent with the agency paradigm that the private action is not observable, or in our framework, the specific levels of risk choices made by the manager are not contractible. A value-based contract is desired.

The value-based contract should be designed to give the manager the incentive to adopt more desirable risk level. In Section V we argue that lookback calls (in compensation packages) are superior inducing more desirable risk taking than regular calls. Lookback calls can be interpreted as calls with their strike price automatically reset whenever a new low of stock price is reached. The common practice of resetting options indicates that the incentives of resetting options (closely paralleling lookbacks) are (by revealed preference) superior to the incentives of ordinary call options that are not resetable. The intuition is that in contrast with ordinary options, the pay-for-performance incentives provided by lookback calls remain significant even after substantial price declines since a lookback call is always in the money and its delta is always greater than 1. When a regular call is deep out of the money, the link between firm value and the payoff of the call is very weak, because the option delta approaches zero. This weakness has been the strongest argument for option repricing in managerial compensation. Callaghan, Subramaniam and Youngblood (2003) report that for both the pre-repricing period and post-repricing period, repricing firms exhibit significantly positive industry-adjusted stock performance. Therefore, allowing repricing has a positive influence on a firm's stock performance.

B. Expected return as a function of risk: the financial sector

In the Black-Scholes framework, because the options can be dynamically hedged, they can be priced as if the return were the risk-free rate. Since they are normally not allowed to sell and hedge their stock options, risk-averse executives will need to use their subjective return distribution to compute their expected utilities. To this end, we consider the following specification:

$$\mu_V(\sigma) = r + \frac{\sigma}{\sigma_0}\left(\mu_V(\sigma_0) - r\right), \tag{2}$$

where $\mu_V(\sigma)$ is the expected return corresponding to risk level σ and r is the risk-free rate.

We motivate our choice in the following way. Within the CAPM framework,

$$\frac{\mu_V(\sigma) - r}{\mu_V(\sigma_0) - r} = \frac{\text{Cov}(\tilde{\mu}_V(\sigma), \tilde{\mu}_m)}{\text{Cov}(\tilde{\mu}_V(\sigma_0), \tilde{\mu}_m)}, \tag{3}$$

where $\tilde{\mu}_V(\sigma)$ is the (random) return corresponding to σ and $\tilde{\mu}_m$ the return of the market. Now if we make the assumption that the covariance is proportional to the risk level, σ, then we obtain 2.[10]

C. Firm value dynamics

For a given volatility level, we assume that the firm value evolves according to the following diffusion process,

$$\frac{dV_t(\sigma)}{V_t(\sigma)} = \mu_V(\sigma)dt + \sigma dB_t^V, \tag{4}$$

where B_t^V is a standard Wiener process. Note that the initial firm value $V_0(\sigma)$ is given by (1) and $\mu_V(\sigma)$ by (2).

For simplicity we assume that the value of her holdings in other companies follows another diffusion process given by

$$\frac{dS_t}{S_t} = \mu_S dt + \sigma_S dB_t^S, \tag{5}$$

where B_t^S is another standard Wiener process. Let ρ denote the correlation between B_t^V and B_t^S. The terminal values (at T) are given by

$$V_T(\sigma) = V_0(\sigma)e^{(\mu_V(\sigma)-\sigma^2/2)T+\sigma B_T^V}, \tag{6}$$

$$S_T = S_0 e^{(\mu_S-\sigma_S^2/2)T+\sigma_S B_T^S}. \tag{7}$$

[10]Unreported, we have also considered the case where the expected return does not change with the risk level. In this case the manager is more concerned about risk and adopts safer investments.

D. The executive's terminal wealth

Following Hall and Murphy (2002), we assume that the executive has risk-free investment F, holdings of shares of other companies S_0, N_S shares of company stock $V_0(\sigma)$, and N_C call options with strike price K and maturity T years in her portfolio.

To determine the executive's terminal wealth, we first obtain the value of her company holdings (shares and call options). If $V_T(\sigma) < K$, then the options will be out of the money, and the value of her company holdings is $N_S V_T(\sigma)$. If, on the other hand, $V_T(\sigma) > K$, she will exercise her options by paying the strike price K and the original shares will be diluted by the factor $1 + N_C$.[11] In this case the value of her company holdings is

$$N_S \left(\frac{V_T(\sigma) + N_C K}{1 + N_C} \right) + N_C \left(\frac{V_T(\sigma) + N_C K}{1 + N_C} - K \right) =$$
$$N_S V_T(\sigma) + \frac{N_C(1 - N_S)}{1 + N_C}(V_T(\sigma) - K).$$

Therefore, the executive's terminal wealth can be written as

$$W_T = Fe^{rT} + S_T + N_S V_T(\sigma) + \frac{N_C(1 - N_S)}{1 + N_C} \max(V_T(\sigma) - K, 0). \tag{8}$$

E. Optimal corporate risk policy

Given her terminal wealth, the executive makes her decision to maximize her expected utility. To this end, we assume that the manager has a constant relative risk-aversion utility function,

$$U(W_T) = \frac{W_T^{1-\Lambda}}{1 - \Lambda}, \tag{9}$$

where Λ is her relative risk-aversion coefficient. The executive chooses the volatility level by maximizing her expected utility,

$$\max_{\sigma} E \left[\frac{\left(Fe^{rT} + S_T + N_S V_T(\sigma) + \frac{N_C(1-N_S)}{1+N_C} \max(V_T(\sigma) - K, 0) \right)^{1-\Lambda}}{1 - \Lambda} \right], \tag{10}$$

[11] We normalize the original total number of shares outstanding to 1.

where $V_T(\sigma)$ and S_T are respectively given by (6) and (7).

The optimal risk choice by the manager may depart from the firm value maximizing strategy, σ_0. Problem (10) cannot be solved analytically. The first order condition can be expressed as an integral and the resulting risk policy can be obtained by solving the root of the first order condition. Alternatively, as it is done in this paper, the risk policy can be obtained as the solution of the maximization problem. It is obvious that the solution depends on the parameters of the problem. Numerical simulations are used to assess the comparative statics.

IV. Simulation Results

In this section we report results from numerical simulations. First, let NCW_0 be the initial non-company wealth and f_{NC} be the fraction of NCW_0 invested in other companies.[12] We adopt the following base values: $V_0 = 100$, $r = 5\%$, $\sigma_0 = 0.38$, $\mu_V(\sigma_0) - r = 7\%$, $\sigma_S = 0.3$, $\mu_S = 12\%$, $\Lambda = 2$, $NCW_0 = 0.32$, $f_{NC} = 0.8$, $T = 5$,[13] $N_S = 0.32\%$ and $N_C = 0.38\%$.[14] For the base case, we assume the parameter for the costliness to deviate from optimal risk, $a = 50$. This parameter value implies that if the risk level is twice as high as the optimal one, σ_0, the firm value will be reduced by one half. It also implies that if only risk-free investments ($\sigma = 0$) are made, the firm value will also be reduced by one half. Thus, future growth opportunities account for half of the firm's market value and the market to book is about two. The strike price of the call option is fixed at the initial stock price unless stated otherwise. The results are reported in Table 1. Several interesting features are noteworthy, and we discuss them below.[15]

[12] That is, investment in the riskless asset is $F = (1 - f_{NC})NCW_0$ and that in other companies is $S_0 = f_{NC}NCW_0$.

[13] Executive stock options have maturity up to ten years. Since they are normally exercised early, the effective maturity is shorter. See Hall and Murphy (2002) for details.

[14] Parrino, Poteshman, and Weisbach (2005) estimate that on a normalized basis the average manager among 1405 firms has 0.32% company shares and 0.38% calls. They also report that the volatility of a typical firm is 0.38.

[15] When we consider the optimal combination between company shares and regular calls in Table 2 and the optimal combination between company shares and lookback calls in Table 4 to minimize the total cost to the company, we keep the manager's utility level the same for each corresponding entry in Table 1. In Table 3, the number of lookback calls is chosen to yield the same utility as in Table 1.

A. Effect of risk-aversion

If $\Lambda = 0$, then the option analog applies. The risk-neutral manager always chooses a risk level higher than the firm value maximizing one. The reason is that the first order derivative of $V_0(\sigma)$ at σ_0 is zero, but that of the expected utility (expected payoff in this case) is positive. Therefore, the option effect dominates the decline of $V_0(\sigma)$ for σ near σ_0. On the other hand, if Λ is large, the manager is so risk-averse that she will only adopt very safe investments. For a given set of parameters, there is a particular Λ such that the manager will choose the optimal volatility level (0.38).

B. Effect of investment technology

For the base parameters, the easier it is to deviate from the optimal risk policy, the more the manager deviates. However, more deviation from the optimal risk level when a is small does not necessarily mean the agency cost[16] is larger because a smaller a means that it is less costly to deviate. It appears, in our examples, that the agency cost is most severe for moderate values of a. There are three factors at play. First, the manager wants to keep σ at σ_0. Any deviation lowers the initial firm value. Second, because she is risk-averse, she has an incentive to lower the risk level. Third, she wants to increase the risk level because of the call option in her portfolio. The resulting risk level the manager takes depends on the relative strength of these factors. For our parameters, the risk-aversion factor dominates.

C. Effect of increasing the portion of call option or company shares or non-company shares

Intuition suggests that the larger the call option portion in her portfolio, the higher the risk level the manager is going to take. Certainly, the intuition holds for a risk-neutral manger. However, the third group of results (changing the number of call options) shows that, if the manager is risk-averse, she may take lower risk level as the call option portion in her portfolio increases. The reason is that as the call portion becomes larger and larger, her overall portfolio becomes riskier and riskier for a given σ. Therefore, she may reduce the risk level of the firm to reduce her portfolio risk. The effect of increasing

[16] Agency cost is defined as the deviation of the firm value, $V_0(\sigma)$, from $V_0(\sigma_0) = V_0$.

the company stock component in a manager's portfolio is similar to that of increasing stock options and leads to lower risk taking. By increasing the portion of non-company wealth in shares of other companies, the resulting portfolio also becomes riskier, thus the manager will optimally choose safer investments.

D. Effect of option strike price

Table 1 shows that, for most of the cases we considered, the resulting σ is below the value maximizing σ_0. Now we consider the incentive implications if we change the strike price of the call option (the sixth group of results). Confirming our intuition, the higher the strike price, the higher the risk level the manager is going to take. For very low strike prices, the manager chooses low risk level, since the option is already deep in the money. For deep out of the money options, high volatility is needed to ensure that the options have a non-negligible probability to finish in the money. Note also that higher strike price has the effect of reducing the value of the option portion of the compensation, and thus reduces the overall risk level of the manager's portfolio. This is consistent with the conclusion from the previous paragraph.

E. Effect of diversification

If the relative portion of the company stock and call option is small in the manager's portfolio (large NCW_0),[17] the manager has incentives to increase risk to maximize her call option payoff, since she does not have much concern if the options finish out of the money.

The results with different f_{NC} in Table 1 seems to suggest that a significant flat fee component will induce the manager to take higher (more desirable) risk level, because lower f_{NC} corresponds to higher portion of riskless holdings. However, caution is needed. First, NCW_0 represents the manager's non-company wealth, mostly her well-diversified holdings of securities of other companies and riskless asset. Therefore, NCW_0 (and its investment) are not controllable by the firm. It is better to interpret that each different NCW_0 represents a different manager rather than the same

[17]Since NCW_0 can be regarded as the well-diversified portion of her portfolio which is independent of company performance, by changing the value of NCW_0, we change the diversification of her portfolio.

manager.[18] Second, as we have emphasized earlier, $V_0(\sigma)$ is not the only possible firm value for the risk level σ, but it happens to be the highest among different investment policies. If the manager's compensation is not tied to the firm's performance (e.g. via a flat fee), then the manager may adopt any one of many possible investment policies that can result in lower firm values for the same risk level even if the risk level is contractible.

F. Utility sensitivity with respect to the firm value

In column 6, we report the partial derivative of the expected utility with respect to the firm value (multiplied by 10^3). While a pay-for-performance sensitivity level or the derivative of the manager's utility with respect to the firm value can be optimized, we argue that minimizing the total cost to the firm is more critical. Basically, we have two choices. Given that a compensation package satisfies a given level of utility (reservation level), we could either minimize the total cost to the firm (including the agency cost of deviating from the optimal σ_0) or maximize the sensitivity level (either pay-for-performance or utility-performance). We have chosen to keep the utility level in Tables 2, 3, and 4 the same for each corresponding entry in Table 1 and minimize the total cost to the firm. The reason is that a sensitivity analysis on utility depends only on the value and structure of the compensation package and does not measure the magnitude of agency cost resulting from suboptimal choice of the risk level. Since the stock-based compensation of a typical manager is normally a very small fraction of a firm's capitalization, concentrating only on the compensation package severely underestimates the true cost to the firm, because the (neglected) agency cost can be a major component. Consequently, we have chosen to minimize the total cost to the firm by changing the mixture of the stock-based components (restricted stocks vs. regular calls or lookback calls) in Tables 2 and 4. For completeness, we have included the utility sensitivity in all tables and the utility level for each entry in Table 1.

G. Minimizing the total cost to the firm

Having examined the effects of various combinations of input values, we now consider the optimal combinations between the stock-based components of

[18] Similarly, different a's should be interpreted as representing different investment technologies (different firms).

the compensation (company shares and stock options). The optimal combination is the one that minimizes the total cost to the firm, while preserving the manager's utility. That is, we seek to choose combinations of the number of shares and number of calls such that the manager achieves the same utility as she would from the portfolio corresponding to each entry in Table 1.

The total cost to the firm is defined as the agency cost, $a((\sigma - \sigma_0)/\sigma_0)^2$, plus the value of shares and calls held by the manager. We do not include the non-company wealth as a choice variable, because it is beyond the control of the firm. We note from Table 1 that in most cases the value of shares and calls held by the manager is a small fraction of the total cost to the firm, and the agency cost of distortion from the first best optimal value predominates. Therefore, reducing the agency cost is more important than controlling the cost of the compensation. However, most papers on executive options have concentrated on the compensation's cost to the firm and/or certainty equivalent to a risk-averse manager. Ours, on the other hand, focuses on the potential conflicts between risk-averse managers and well-diversified shareholders generated by option-type compensations.

Table 2 indicates that, for most cases, it is more cost-effective to use company shares than regular options to achieve a given level of utility for the manager.[19] This is because, for a risk-averse manager, options are the most risky assets in her portfolio. Only in situations where the portfolio risk is already low (high non-company wealth NCW_0 and/or low company shares N_S or high option strike price), call options are needed to provide the manager the incentives to choose a more desirable risk level.

H. Section summary

Risk-aversion is an important consideration in managerial compensation design. Different mixtures of non-company wealth, company stock and call options with the same total market value can result in different investment policies. That is, the manager values these mixtures (certainty equivalent) differently. Therefore, the relative fractions of non-company wealth, company stock and call option play an important role in determining the risk level the manager takes and the cost of the compensation. Compensation contracts should be designed to encourage risk-averse managers to take on more desired risky investments. The mixture of the different compensation

[19]For easy comparison, we have included the total cost (TC) in all tables.

components is more important than the overall market value of the compensations. Excessive awarding of executive options in managerial compensation packages can lead to less desirable investment risk.[20]

V. The Roles of Lookback Calls in Reducing Managerial Incentive Costs

The previous section has explored the role of various combinations of three components in a manager's portfolio in reducing managerial incentive costs: non-company wealth, company shares and call options. Here we explore the roles played by lookback options, which we argue are analogous to observed option repricing.

We begin by providing a brief description of lookback call options. Let V_T^{min} be the minimum firm value from time zero to time T. Then the payoff function at maturity of a European lookback call is defined as the difference between the terminal firm value V_T and V_T^{min}, $V_T - V_T^{min}$. Note that since V_T^{min} is the minimum firm value during the life of the option, $V_T - V_T^{min}$ is always non-negative.[21] In the following, we first examine the impact on investment risk choice of using lookback calls in managerial compensation. We then explore the link between lookback calls and automatic strike price resetting and the advantages and possible disadvantages of lookback calls.

A. The impact of lookback calls on investment risk choice

Tables 1 and 2 indicate that risk aversion plays an important role in determining the risk level chosen by the manager. In fact, for all the entries, the risk level chosen by the risk-averse manager ($\Lambda = 2$) is below the optimal level. Table 2 further illustrates that, in most cases, the less risky company shares are more cost-effective than the more risky options. Therefore, how to provide the manager the desirable risk incentive is of central importance. Lookback calls play an effective role in providing the right risk incentives.

[20] Unreported results indicate that with longer horizon, the (risk averse) manager chooses to take on less risk. This is understandable, because bigger T means more volatile terminal firm value distribution for the same σ. Therefore, the holding period restriction of options and shares can also have important impacts on the manager's investment policy.

[21] For valuation of lookback options, see Goldman, Sosin and Gatto (1979).

Tables 3 and 4 replace the corresponding regular calls in Tables 1 and 2 with lookback calls. The number of lookback calls in Table 3 is chosen to yield the same utility level as each corresponding entry in Table 1. Comparing Table 1 and Table 3 indicates that loobback calls are more effective in reducing the agency costs associated with deviating from the optimal risk level. The reason is that, unlike regular calls, lookback calls are always in the money and thus the manager is willing to take a higher and more desirable risk level. Table 3 also indicates that the total cost to the firm is substantially lower when lookback calls are used instead of regular calls.

Interestingly, the entries corresponding to different Λ's indicate that when regular calls induce too little risk taking ($\Lambda = 4$), lookback calls induce more, and when regular calls induce too much risk taking, ($\Lambda = 0$), lookback calls induce less. This may seem puzzling because intuition suggests that lookback calls should always entail more risk taking than regular calls. However, we can appreciate these results using lookback delta. Note that, in the Appendix, we prove that the delta of a lookback call is always greater than that of a regular call. Compared with regular calls, when σ is below σ_0, lookback calls induce higher risk level, because higher risk results in higher firm value. The reason is that an increase in firm value yields a higher proportional increase in option value for lookback calls than for regular calls (delta effect). Similarly, when σ is above σ_0, relative to regular calls, lookback calls have a preference for lower σ (higher firm value), because their delta is higher than that of regular calls.

It should be recalled from Table 2 that regular calls were dominated by company shares in the compensation package. Such is not the case with lookback calls. Comparing Table 2 and Table 4 shows that lookback calls are very cost-effective in achieving the same utility level. Table 2 shows that, when the choice is between company shares and regular call options, a risk-averse manager prefers shares, because she is concerned that the calls may finish out of the money. Table 4 indicates that, when the choice is between company shares and lookback calls, the manager prefers lookbacks. There are two reasons. First, the manager is willing to choose a higher and more desirable risk level, because the lookbacks will never finish out of the money. Second, because the delta of a lookback call is greater than 1 (a share has a delta of 1), lookback calls have a stronger preference (than company shares) for higher firm value through higher risk level when the risk level is below σ_0. Comparing Table 2 and Table 4 shows that, when the choice is between company shares and lookback calls, the total cost to the firm is further reduced. Taking together, Tables 3 and 4 indicate that lookback calls are more effective than regular calls.

In our framework, portfolios with a higher portion of stock-based payments are riskier, and thus the risk-averse manager is more concerned about risks. Comparing Table 1 and Table 4 indicates that an insurance feature, such as option repricing (implicit in lookback calls), is effective in reducing the manager's risk concerns in situations where the manager's portfolio is highly concentrated in stock-based payments. This is consistent with the empirical finding in Chen (2004) where firms, that provide more stock-based incentives, such as stock and stock options, are more likely to reprice their executive stock options. Our result is also consistent with the empirical findings in Brenner, Sundaram, and Yermack (2000), Chance, Kumar and Todd (2000), Chidambaran and Prahbala (2003) that smaller, younger and rapidly growing firms are more likely to reprice their executive stock options, because these firms, on average, are riskier. Our story for option repricing is that it mitigates a risk-averse manager's concern for risks, and hence she is willing to adopt more desirable risk levels.

B. Interpreting lookback calls: Option strike resetting

The previous subsection clearly indicates that lookback calls can provide better incentives than either restricted stocks or regular call options. We note that a lookback call is identical to a call option whose exercise price is reset to the current stock price, whenever new stock price lows are reached. Thus, lookbacks are similar to ordinary executive stock options that are repriced automatically. In the following, we further explore the advantages and possible disadvantages of lookback call options.

First, the relative value of lookback calls increases more than the relative value of restricted stock, as the stock price increases because of the delta effect. Lookback calls provide stronger initial pay-for-performance incentives for management to increase firm value from the level at which they were granted. In most cases, lookback calls provide better risk-taking incentives for risk-averse managers as Tables 3 and 4 indicate.

Second, we argue that lookback calls are an effective vehicle for enhancing the pay-for-performance incentives without explicitly rewarding the manager for low stock prices as an option repricing decision seems to suggest. The reason is that, even though lookback calls can be regarded as regular calls with their strikes reset automatically whenever the stock price falls to a new low, the reset feature is part of the contract and its cost at grant date is properly accounted for. With lookback calls, explicit option repricing is not needed and the frequently heated debates associated with it are avoided. Hall and Murphy (2000) argue that the pay-for-performance incentives for risk-averse managers are typically maximized by at the money calls and thus provide an explanation why almost all executive options are granted at the money. While the grant date pay-for-performance incentives are maximized, the incentives are severely weakened when the options become deep out of the money after they are granted. This weakness has been the strongest argument for option repricing in managerial compensation. Callaghan, Subramaniam and Youngblood (2003) report that for both the pre-repricing period and post-repricing period, repricing firms exhibit significantly positive industry-adjusted stock performance. Therefore, allowing repricing has a positive influence on a firm's stock performance. If so, why not reprice the options whenever the pay-for-performance incentives are too weakened? The pay-for-performance incentives provided by lookback calls remain significant even after substantial price declines because they are always in the money and their deltas are always greater than 1. Furthermore, like ordinary call options, lookback calls are at the money when they are first issued. Thus, they are not subject to immediate tax consequences and there is no tax impediment of their adoption.

Third, if the (terminal) stock price V_T is positively correlated with any benchmark index, the (lookback call) strike price V_T^{min} is also positively correlated with the index. Consequently, the payoff, $V_T - V_T^{min}$, will filter out part of industry (or market-wide) component of the price movement in V_T. Option repricing is intended to restore incentives when the previously granted options are deep out of the money. Repricing can provide the right incentives when it can be determined that the negative shocks contributing to the stock price decline are beyond factors under the control of the manager. However, filtering out the managerial actions is a challenge, and it can be improved by the use of index options. It turns out that lookback options can provide a mechanism for automatic option strike resetting in a way consistent with indexation. Thus, the manager is not rewarded for stock price run-ups unrelated to actions taken by her and penalized for actions beyond her control. The added advantage is that lookback options do not require explicit knowledge of an index. Determining a well-defined index for indexation of options grants has been an issue when discussing the use of such options in contemporary compensation contracts.

Having explored some of the advantages of lookback calls, now we address one potential disadvantage. It might appear that lookback options will create disincentives in the short run. If managers could make decisions that temporarily depress stock prices to a new low, and subsequently could reverse such decisions, their options would be more valuable due to a lower strike price. If, however, such temporary decisions can be rationally anticipated, their short-run stock price impact will be small. More importantly, value creation typically is much more difficult than value destruction. While the manager may be able to lower the strike on a lookback by destroying value, restoring the lost value may be no easier than creating value prior to value destruction. Thus, while the manager may be able to create downward jumps or a downward path by destroying value, we do not think there is a symmetry on the upside. For example, for the same lookback payoff, a higher return is required when starting from a lower minimum. To see this, suppose the current price and minimum is \$100. It requires a 20% return to yield a payoff \$20 for the lookback. On the other hand, if the manager drives the price down to \$50, it would require a 40% return for the same payoff of \$20. It may not be easier to drive the price from \$100 to \$50 then back to \$70 than to raise it from \$100 to \$120.

Though our model does not include the reputation and career concern effects, they are something the manager needs to consider if she tries to follow the strategy of first destroying value and then subsequently trying to create it. Another reason that the manager may not want to drive down the firm value intentionally is that the company stock component of her own portfolio will suffer. Finally, we observe that the potential for abuse already has been noted when standard call options are repriced, but the continued practice of repricing suggests that the benefits outweigh these potential costs.

Before we leave this section, we emphasize again that while lookback calls are always in the money and the payoff from one lookback is higher than that from a regular stock option, the cost to the firm (or the market value of the options offered) is actually lower, because it requires fewer number of lookbacks to induce the same risk level. That is, for the same cost to the firm, lookback calls induce more desirable risk levels. Alternatively, to achieve the same utility level for the manager, the total cost to the firm is less. Thus, lookback calls are more cost effective than regular calls.

VI. Conclusions

Pay-for-performance is now a widely accepted dictum in the design of managerial compensation structure. Stock options are an integral part of managerial contracts in the hope of aligning management with shareholders. However, the adverse effects of options are not widely appreciated. Well-diversified shareholders' value maximizing and risk-averse managers' utility maximizing can lead to different desired actions. Relative to the optimal risk level for the firm, a call-type contract can induce both over or under investment in risk depending on managerial risk-aversion. Given a compensation package, we examine agency costs associated with deviating from the optimal corporate risk policies. In particular, we have shown that the inclusion of option repricing features has countervailing effects and is very effective in reducing these costs.

While deep out of the money call options may provide little incentive because the probability for the option to finish in the money is very small, a lookback call option is always in the money and provides the incentive for the manager to increase the stock price above the current level. Thus, lookback options not only provide the *ex ante* incentives but the *ex post* ones. In fact, a lookback call can be interpreted as a call with strike price reset whenever a new minimum price is reached. Moreover, we have argued that lookback calls have properties analogous to those embedded in indexed options, because both the terminal price and the minimum price are likely to be correlated with market returns and their difference (the payoff of a lookback call) filters out part of the market movement.

Appendix. The Lookback Call Delta is greater than 1

Here we prove that the delta (Δ) of a lookback call is always greater than 1 and thus greater than that of a regular call which is always smaller than 1. We make the usual assumption that the underlying asset price dynamics follow a standard Black-Scholes Geometric Brownian motion,

$$\frac{dS_t}{S_t} = \mu dt + \sigma dB_t, \tag{A1}$$

where μ and σ are constants and B_t is a standard Wiener process.

Let $m_t^T = \inf(S_u : u \in [t, T])$ be the minimum price during $[t, T]$. The terminal payoff of a lookback call is given by $S_T - m_0^T$. The market price of a lookback call at time t is given by the discounted risk-neutral expected value,

$$C_{LC}(S_t) = e^{-r(T-t)} E_t^Q[S_T - m_0^T] = S_t - e^{-r(T-t)} E_t^Q[\min(m_0^t, m_t^T)], \tag{A2}$$

where m_0^t is the minimum so far and m_t^T is the minimum in $[t, T]$, and Q denotes the risk-neutral measure.

Let $f(x)$ be the risk-neutral density of the minimum price during $[t, T]$ for the process in (A1). Using $f(x)$ we can write (A2) as

$$C_{LC}(S_t) = S_t - e^{-r(T-t)} \int_0^{m_0^t} x f(x) dx - e^{-r(T-t)} m_0^t \int_{m_0^t}^{S_t} f(x) dx. \tag{A3}$$

Closed form formula for $C_{LC}(S_t)$ has been obtained by Goldman, Sosin and Gatto (1979). Its delta can be obtained explicitly. However, the calculation is tedious and it is difficult to prove that the resulting Δ is greater than 1.

Here we follow a simpler strategy without explicitly computing the delta. If we change the price at t from S_t to $S_t + \epsilon S_t$, the terminal price will be $(1+\epsilon)S_T$ and the minimum during $[t, T]$ will be $(1+\epsilon)m_t^T$, where S_T and m_t^T are the corresponding values if the process in (A1) starts at S_t. The lookback call price can now be written as

$$\begin{aligned} C_{LC}(S_t + \epsilon S_t) &= (1+\epsilon)S_t - e^{-r(T-t)} \int_0^{\frac{m_0^t}{1+\epsilon}} x f(x) dx - \\ &\quad e^{-r(T-t)} m_0^t \int_{\frac{m_0^t}{1+\epsilon}}^{S_t} f(x) dx. \end{aligned} \tag{A4}$$

From (A4) and (A3) the change of the lookback call price is given by

$$C_{LC}(S_t + \epsilon S_t) - C_{LC}(S_t) = \epsilon S_t + e^{-r(T-t)} m_0^t \int_{\frac{m_0^t}{1+\epsilon}}^{m_0^t} f(x)dx - e^{-r(T-t)} \int_{\frac{m_0^t}{1+\epsilon}}^{m_0^t} x f(x)dx. \qquad \text{(A5)}$$

Thus, the delta of the lookback call is given by

$$\begin{aligned} \Delta &= \lim_{\epsilon \to 0} \frac{C_{LC}(S_t + \epsilon S_t) - C_{LC}(S_t)}{\epsilon S_t} \\ &= 1 + \lim_{\epsilon \to 0} \frac{e^{-r(T-t)}}{\epsilon S_t} \int_{\frac{m_0^t}{1+\epsilon}}^{m_0^t} (m_0^t - x) f(x)dx. \qquad \text{(A6)} \end{aligned}$$

Since $m_0^t > x$ for $x \in [m_0^t/(1+\epsilon), m_0^t]$, $\Delta > 1$. **Q.E.D.**

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Table 1: Risk Effects of Compensation Contracts with Regular Calls

	σ	$V_0(\sigma)$	VC	TC	$10^3 \frac{\partial E[U]}{\partial V}$	$E[U(W_T)]$
Base	0.251	94.275	30.735	6.142	5.599	-1.06219
$\Lambda = 0$	0.553	89.609	47.530	10.857	12.142	1.63697
$\Lambda = 4$	0.150	81.697	21.247	18.645	13.783	-0.74652
$a = 10$	0.150	96.329	25.035	4.073	5.691	-1.01563
$a = 30$	0.215	94.348	28.433	6.062	5.682	-1.04562
$a = 70$	0.275	94.612	32.353	5.813	5.509	-1.07262
$a = 90$	0.291	95.017	33.545	5.414	5.441	-1.07977
$N_C = 0.0\%$	0.270	95.802	32.450	4.505	5.784	-1.18375
$N_C = 0.2\%$	0.261	95.070	31.598	5.297	5.672	-1.11163
$N_C = 0.5\%$	0.245	93.721	30.164	6.729	5.554	-1.03447
$N_C = 1.0\%$	0.221	91.299	27.908	9.268	5.431	-0.94610
$N_S = 0.0\%$	0.316	98.596	36.570	1.543	2.846	-1.83694
$N_S = 0.2\%$	0.261	95.062	31.589	5.248	5.457	-1.25614
$N_S = 0.5\%$	0.244	93.557	30.000	7.024	5.378	-0.86553
$N_S = 1.0\%$	0.234	92.635	29.109	8.400	4.415	-0.57575
$f_{NC} = 0.0$	0.275	96.154	32.883	4.278	5.383	-1.06559
$f_{NC} = 0.5$	0.263	95.257	31.811	5.168	5.265	-1.04529
$f_{NC} = 1.0$	0.241	93.275	29.722	7.135	6.034	-1.08605
$K = 0.5V_0(\sigma)$	0.217	90.847	55.739	9.654	5.723	-0.92154
$K = 0.8V_0(\sigma)$	0.233	92.490	38.540	7.951	5.685	-1.01540
$K = 1.2V_0(\sigma)$	0.265	95.423	24.765	4.976	5.552	-1.09550
$K = 1.5V_0(\sigma)$	0.276	96.282	18.004	4.094	5.550	-1.12809
$NCW_0 = 0.2$	0.235	92.742	29.209	7.665	8.427	-1.31517
$NCW_0 = 0.5$	0.270	95.796	32.443	4.633	3.519	-0.83129
$NCW_0 = 1.0$	0.303	97.958	35.442	2.489	1.503	-0.52633

Column 1 represents the entries of Table 1. The other parameters are fixed at their base values. Columns 2-7 report the volatility chosen, the current firm value, the market value of one regular call, the total cost to the firm which is defined as the cost of deviating from the optimal σ_0, $a((\sigma - \sigma_0)/\sigma_0)^2$, plus the market values of company shares and regular calls in the compensation, and the partial derivative of the expected utility with respect to the initial firm value ($\times 10^3$), the expected utility, respectively.

Table 2: Minimizing the Total Cost with Company Shares and Regular Calls

	σ	$V_0(\sigma)$	$N_S(\%)$	VC	$N_C(\%)$	TC	$10^3 \frac{\partial E[U]}{\partial V}$
Base	0.263	95.299	0.399	31.859	0.000	5.081	5.747
$\Lambda = 0$	0.506	94.534	0.563	47.235	0.000	5.999	11.520
$\Lambda = 4$	0.181	86.236	0.365	24.047	0.000	14.078	13.295
$a = 10$	0.163	96.730	0.399	25.889	0.014	3.660	5.763
$a = 30$	0.228	95.211	0.401	29.533	0.000	5.170	5.801
$a = 70$	0.285	95.651	0.398	33.418	0.000	4.729	5.686
$a = 90$	0.301	96.070	0.397	34.584	0.000	4.312	5.627
$N_C = 0.0\%$	0.270	95.813	0.320	32.464	0.000	4.493	5.784
$N_C = 0.2\%$	0.266	95.505	0.365	32.098	0.000	4.843	5.774
$N_C = 0.5\%$	0.262	95.183	0.420	31.726	0.000	5.217	5.719
$N_C = 1.0\%$	0.258	94.812	0.494	31.312	0.000	5.657	5.599
$N_S = 0.0\%$	0.330	99.148	0.045	37.745	0.155	0.955	3.657
$N_S = 0.2\%$	0.274	96.125	0.281	32.847	0.000	4.145	5.757
$N_S = 0.5\%$	0.254	94.475	0.577	30.947	0.000	6.070	5.437
$N_S = 1.0\%$	0.241	93.300	1.072	29.746	0.000	7.700	4.418
$f_{NC} = 0.0$	0.287	96.991	0.409	33.986	0.000	3.406	5.648
$f_{NC} = 0.5$	0.275	96.161	0.404	32.892	0.000	4.227	5.461
$f_{NC} = 1.0$	0.254	94.470	0.395	30.942	0.000	5.903	6.125
$K = 0.5V_0(\sigma)$	0.256	94.708	0.518	58.515	0.000	5.783	5.559
$K = 0.8V_0(\sigma)$	0.261	95.097	0.434	40.886	0.000	5.316	5.700
$K = 1.2V_0(\sigma)$	0.266	95.537	0.349	24.908	0.164	4.837	5.670
$K = 1.5V_0(\sigma)$	0.279	96.456	0.292	18.247	0.844	3.977	5.339
$NCW_0 = 0.2$	0.252	94.282	0.393	30.742	0.000	6.088	8.523
$NCW_0 = 0.5$	0.277	96.311	0.406	33.082	0.000	4.080	3.661
$NCW_0 = 1.0$	0.303	97.971	0.332	35.464	0.328	2.470	1.514

Column 1 represents the entries of Table 1. The other parameters are fixed at their base values except the number of company shares and the number of regular calls which are chosen to minimize the total cost but yield the same utility level as each corresponding entry in Table 1. Columns 2-8 report the volatility chosen, the current firm value, the number of shares chosen, the market price of one regular call, the number of regular calls chosen, the total cost to the firm which is defined as the cost of deviating from the optimal σ_0, $a((\sigma - \sigma_0)/\sigma_0)^2$, plus the market values of company shares and regular calls in the compensation, and the partial derivative of the expected utility with respect to the initial firm value ($\times 10^3$), respectively.

Table 3: Risk Effects of Compensation Contracts with Lookback Calls

	σ	$V_0(\sigma)$	VLB	$N_L(\%)$	TC	$10^3 \frac{\partial E[U]}{\partial V}$
Base	0.284	96.814	47.376	0.222	3.600	5.355
$\gamma = 0$	0.541	90.996	63.598	0.368	9.528	12.730
$\gamma = 4$	0.189	87.373	34.004	0.052	12.924	11.210
$a = 10$	0.214	98.082	40.812	0.269	2.341	5.414
$a = 30$	0.258	96.887	44.820	0.238	3.529	5.404
$a = 70$	0.301	96.993	49.093	0.213	3.422	5.307
$a = 90$	0.313	97.222	50.328	0.206	3.192	5.266
$N_C = 0.0\%$	0.270	95.802	32.450	0.000	4.505	5.784
$N_C = 0.2\%$	0.281	96.629	47.021	0.125	3.739	5.442
$N_C = 0.5\%$	0.285	96.880	47.504	0.281	3.563	5.303
$N_C = 1.0\%$	0.286	96.937	47.616	0.503	3.610	5.114
$N_S = 0.0\%$	0.424	99.319	61.055	0.150	0.773	2.858
$N_S = 0.2\%$	0.305	98.046	49.971	0.201	2.250	5.144
$N_S = 0.5\%$	0.267	95.557	45.097	0.245	5.030	5.144
$N_S = 1.0\%$	0.247	93.834	42.336	0.286	7.224	4.379
$f_{NC} = 0.0$	0.303	97.957	49.766	0.211	2.461	5.390
$f_{NC} = 0.5$	0.292	97.344	48.436	0.244	3.085	5.277
$f_{NC} = 1.0$	0.277	96.293	46.397	0.188	4.101	5.478
$K = 0.5V_0(\sigma)$	0.286	96.956	47.652	0.576	3.626	5.053
$K = 0.8V_0(\sigma)$	0.286	96.912	47.566	0.323	3.551	5.263
$K = 1.2V_0(\sigma)$	0.282	96.702	47.160	0.156	3.681	5.415
$K = 1.5V_0(\sigma)$	0.280	96.551	46.874	0.098	3.804	5.465
$NCW_0 = 0.2$	0.267	95.605	45.180	0.226	4.802	8.160
$NCW_0 = 0.5$	0.302	97.873	49.575	0.208	2.543	3.307
$NCW_0 = 1.0$	0.330	99.151	52.932	0.163	1.252	1.335

Column 1 represents the entries of Table 1. The other parameters are fixed at their base values except that regular calls are replaced by lookback calls. Columns 2-7 represent the volatility chosen, the current firm value, the market price of one lookback call, the number of lookback calls which is chosen to yield the same utility level as each corresponding entry in Table 1, the total cost to the firm which is defined as the cost of deviating from the optimal σ_0, $a((\sigma - \sigma_0)/\sigma_0)^2$, plus the market values of company shares and lookback calls in the compensation, and the partial derivative of the expected utility with respect to the initial firm value ($\times 10^3$), respectively.

Table 4: Minimizing the Total Cost with Company Shares and Lookback Calls

	σ	$V_0(\sigma)$	$N_S(\%)$	VLB	$N_L(\%)$	TC	$10^3 \frac{\partial E[U]}{\partial V}$
Base	0.336	99.342	0.000	53.575	1.162	1.274	4.259
$\Lambda = 0$	0.503	94.752	0.600	63.814	0.000	5.816	12.237
$\Lambda = 4$	0.198	88.591	0.140	35.403	0.894	11.846	9.526
$a = 10$	0.307	99.627	0.000	50.945	1.285	1.019	4.286
$a = 30$	0.325	99.377	0.000	52.567	1.204	1.249	4.275
$a = 70$	0.344	99.361	0.000	54.247	1.136	1.249	4.243
$a = 90$	0.349	99.403	0.000	54.753	1.118	1.202	4.233
$N_C = 0.0\%$	0.349	99.663	0.000	54.875	0.871	0.810	4.270
$N_C = 0.2\%$	0.340	99.439	0.009	53.933	1.006	1.107	4.313
$N_C = 0.5\%$	0.334	99.252	0.000	53.264	1.241	1.401	4.241
$N_C = 1.0\%$	0.325	98.935	0.000	52.269	1.540	1.858	4.165
$N_S = 0.0\%$	0.381	100.00	0.041	57.849	0.070	0.081	3.101
$N_S = 0.2\%$	0.356	99.808	0.000	55.638	0.733	0.597	4.241
$N_S = 0.5\%$	0.316	98.593	0.000	51.320	1.883	2.356	4.061
$N_S = 1.0\%$	0.284	96.809	0.000	47.365	4.260	5.127	3.356
$f_{NC} = 0.0$	0.350	99.680	0.000	54.952	1.070	0.902	4.306
$f_{NC} = 0.5$	0.341	99.479	0.000	54.088	1.156	1.139	4.215
$f_{NC} = 1.0$	0.333	99.232	0.000	53.199	1.147	1.371	4.334
$K = 0.5V_0(\sigma)$	0.322	98.836	0.000	51.985	1.637	2.001	4.138
$K = 0.8V_0(\sigma)$	0.331	99.179	0.000	53.021	1.301	1.502	4.233
$K = 1.2V_0(\sigma)$	0.340	99.437	0.000	53.926	1.074	1.136	4.195
$K = 1.5V_0(\sigma)$	0.343	99.526	0.000	54.276	0.994	1.008	4.276
$NCW_0 = 0.2$	0.312	98.393	0.000	50.807	1.307	2.262	6.374
$NCW_0 = 0.5$	0.361	99.872	0.000	56.057	1.039	0.704	2.692
$NCW_0 = 1.0$	0.379	100.00	0.110	57.712	0.616	0.463	1.204

Column 1 represents the entries of Table 1. The other parameters are fixed at their base values except that regular calls are replaced by lookback calls. The number of company shares and number of lookback calls are chosen to minimize the total cost but yield the same utility level as each corresponding entry in Table 1. Columns 2-8 represent the volatility chosen, the current firm value, the number of shares chosen, the market price of one lookback call, the number of lookback calls chosen, the total cost to the firm which is defined as the cost of deviating from the optimal σ_0, $a((\sigma - \sigma_0)/\sigma_0)^2$, plus the market values of company shares and lookback calls in the compensation, and the partial derivative of the expected utility with respect to the initial firm value ($\times 10^3$), respectively.