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Probability Weighting and Employee Stock Options

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Abstract

This paper documents that riskier firms with higher idiosyncratic volatility grant more stock options to nonexecutive employees. Standard models in the literature cannot easily explain this pattern; a model in which a risk-neutral firm and an employee with prospect theory preferences bargain over the employee's pay package can. The key feature that makes stock options attractive is probability weighting. The model fits the data on option grants well when calibrated using standard parameters from the experimental literature. The results are the first evidence that risky firms can profitably use stock options to cater to an employee demand for long-shot bets.

I. Introduction

> In reality, people sometimes like to gamble, and a young engineer just out of college might well choose a job with a low salary but a chance to strike it rich. All the engineers I know are convinced that they are experts at picking winning technologies. —Varian (2004)

An estimated 9 million U.S. employees in 3,000 companies participate in broad-based stock option plans that grant options to at least 50% of their

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employees.[1] Firms with broad-based option plans include small technology firms as well as giant corporations such as PepsiCo, Cisco Systems, or Starbucks. Stock option grants to lower-level employees are intriguing because standard incentive arguments that motivate option grants to CEOs and other top managers do not easily carry over to rank and file employees who cannot meaningfully influence the stock price of their company.[2] Prior research has already made some progress in understanding broad-based stock option plans. One set of explanations focuses on the firm level. For example, cash constraints, the accounting treatment of options, investment opportunities, or the tax status of options may induce firms to grant stock options broadly (e.g., Yermack (1995), Core and Guay (2001), Hall and Murphy (2003), Babenko and Tserlukevich (2009), and Babenko, Lemmon, and Tserlukevich (2011)). A 2nd set of studies stresses the firm environment, highlighting competition for labor, industry effects, and geographical clustering (e.g., Ittner, Lambert, and Larcker (2003), Oyer (2004), and Kedia and Rajgopal (2009)).

While these and related theories are likely to explain some of the variation in stock option grants, there are at least two important unresolved challenges. First, in contrast to top managers, lower-level employees frequently seem to value stock options higher than the actuarially fair value (e.g., Hallock and Olson (2006), Devers, Wiseman, and Holmes (2007), Hodge, Rajgopal, and Shevlin (2009), and Sautner, Weber, and Glaser (2010)), which is at odds with any standard preference framework with risk-averse employees. Second, as I show in this paper, firms with more volatile stock returns (in particular, firms with higher idiosyncratic volatility) grant more employee stock options (ESOs). This is puzzling in standard preference frameworks since risk-averse and underdiversified employees would demand high risk premia to accept options from risky firms. Almost all standard models used in the literature would therefore predict, all else being equal, *fewer* options in risky firms (see below for exceptions).[3]

This paper departs from the existing literature by emphasizing the possibility that stock options are attractive to employees with "gambling preferences," which are defined here as preferences for skewed, lottery-like payoffs that offer small chances of large gains. Probably the most established framework to model such preferences is cumulative prospect theory (Tversky and Kahneman (1992), Barberis and Huang (2008)). The probability weighting function is an integral part of prospect theory and captures the attractiveness of lottery-like payoffs

[1]Source: National Center for Employee Ownership (version of Feb. 2010). The data are available at http://www.nceo.org/library/eo_stat.html. Stock options have continued to be an important part of compensation even after the mandatory expensing of stock options introduced in 2005. For example, the inflation-adjusted value of total stock options granted at the average ExecuComp firm from 2005 through 2009 is $7.7m, $8.7m, $7.9m, $7.1m, and $6.8m, respectively.

[2]This is now the conventional view (e.g., Hall and Murphy (2003), Oyer and Schaefer (2005), and Bergman and Jenter (2007)). Consistently, Aboody, Johnson, and Kasznik (2010) document that increasing stock option incentives for nonexecutive employees (in contrast to executives) does not lead to superior subsequent performance. Hochberg and Lindsey (2010) provide another perspective by suggesting that there might be mutual-monitoring incentives for small firms.

[3]Employees cannot trade or sell their options. Moreover, hedging the risk inherent in their options is difficult, costly, and therefore practically infeasible for lower-level employees. Hence, employees are left with firm-specific risk they cannot diversify, which leads to potentially substantial risk premia in standard models (see Oyer and Schaefer (2006) for an estimate of these risk premia).

(e.g., stock options) to decision makers. Two main contributions emerge from the paper. First, calibrations using available experimental data on preference parameters as an input show that probability weighting can explain *under plausible assumptions* why lower-level employees overvalue stock options relative to the Black-Scholes (1973) benchmark. Second, a prospect theory model yields new empirical predictions (in particular, the implication that *idiosyncratic* volatility is positively associated with ESO plans) that allow one to distinguish it from other models in the literature.

While gambling preferences are new to the literature on compensation, recent research in asset pricing suggests that they are an important driver of investment choices of retail investors and asset returns (e.g., Barberis and Huang (2008), Dorn and Sengmueller (2009), Kumar (2009), and Green and Hwang (2012)). Motivated by this evidence I conjecture that gambling preferences are also an important factor for understanding why one sees stock option grants to lower-level employees. This is consistent with anecdotal evidence (see, e.g., the opening quote). Moreover, strong survey evidence exists to support this conjecture. Hodge et al. (2009) survey 192 entry- and middle-level managers and conclude that “over 40% of managers value options at greater than their Black-Scholes value and such managers view options as a *lottery ticket* [my emphasis].”

This paper has two main parts. In the 1st part of the paper, I develop a simple model of efficient pay setting between a risk-neutral firm and an employee with cumulative prospect theory preferences, where the firm tries to minimize compensation cost subject to the employee’s participation constraint. The model has the straightforward implication that if employees are subject to probability weighting, and if probability weighting raises the certainty equivalent sufficiently, an economic rationale for the use of stock options to compensate nonexecutive employees is that firms can reduce their personnel cost by granting overvalued stock options and by simultaneously reducing base salaries. This implies that firms can use stock options to benefit from catering to an employee demand for lottery-like payoffs.[4]

In addition to formalizing the intuition concerning why probability weighting can explain the use of stock options, the real benefit of the model lies in the fact it can be calibrated conveniently. This has several advantages. First, probability weighting by itself makes lottery-like payoffs (e.g., stock options) attractive, while the kink of the value function at the reference point and the concavity of the value function in the domain of gains make them unattractive. The calibrations show which effects dominate and when they dominate. Second, the calibrations can use the comparatively precise estimates of prospect theory preference parameters from the large experimental literature to examine if the model predicts options under quantitatively plausible assumptions. Third, the calibrations allow for estimates of the dollar benefit to firms from granting ESOs. Fourth, the calibrations generate testable empirical predictions.

[4]An important precondition for this rationale, pointed out by Bergman and Jenter (2007), is that firms can offer employees a financial claim that they cannot otherwise obtain in the market. Since there is effectively no outside market for the 10-year options usually awarded, stock options fulfill this condition.

The main variables of interest in the calibrations are the volatility of the stock price and the degree of probability weighting, since they govern the thickness of the right tail of the payoff distribution and the subjective overweighting of the tail, respectively. The 1st central insight from the calibrated model is that broad-based stock option plans should exist in companies with high volatility, but not in companies with low volatility. In the benchmark specification, the cutoff level is at about 40%, which I show to be broadly consistent with the data. The 2nd central insight is that the value of stock options granted per employee increases in firm risk. Finally, the calibrated model predicts that a broad-based ESO plan is more likely and that stock option grants are larger if the degree of probability weighting is higher.

In the 2nd part of the paper, I test the predictions from the model on the universe of ExecuComp firms from 1992 to 2005. The main finding is that firm volatility (and in particular the idiosyncratic part of volatility that cannot be explained by industry-year effects) has significant explanatory power for both the presence of broad-based ESO plans and the number of stock options granted to nonexecutive employees. Increasing firm risk by 1 standard deviation increases the probability of seeing a broad-based stock option plan at a given firm by 5.9%, and the number of stock options granted in firms with a stock option plan increases by 32.1%.

These findings are not driven by existing explanations in the literature. In particular, firm volatility does not simply capture small firms, firms in special industries (e.g., technology stocks), cash-constrained firms, or firms with convex tax schedules. More generally, I show using fixed effects regressions that unobserved invariant factors on the industry-year level, the metropolitan statistical area (MSA)-year level, and the firm level cannot explain the positive relation between firm volatility and stock option grants. My results are not explained by alternative models based on agency theory, employee retention motives, or employee optimism. Overall, the findings are consistent with the theoretical model and suggest that employee preferences for lottery-like payoffs can explain a significant fraction of both the time-series and cross-sectional variation in ESO grants.

An implicit assumption of my model setup is that probability weighting is particularly relevant inside the firm-employee relationship; that is, I assume that lottery tickets and options on other firms (even if they existed with similar features) are not a perfect substitute for the option on the own firm. As is also reflected in the opening quote, prior research documents that individuals like to gamble on things they are familiar with, projects they are directly involved in, and stocks they feel competent about (see Heath and Tversky (1991), Kahneman and Lovallo (1993), and Graham, Harvey, and Huang (2009)).[5] I therefore argue that this is a plausible assumption.

[5]Similarly, there may be frictions (behavioral or based on transaction costs) that make it easier for employees to accept their own company's options instead of engaging in active decisions. See, for example, Babenko and Sen (2011) for evidence of employee inertia in employee stock purchase plan participation.

My work is related to previous papers in the literature. Like my paper, Bergman and Jenter (2007) emphasize that employee demand may drive the existence of broad-based stock option plans. They find evidence for the hypothesis that employees extrapolate past stock returns and that ESO grants are timed to take advantage of positive employee sentiment. Note that this is entirely distinct from the effects of probability weighting. Under the sentiment hypothesis, employees erroneously expect stock price trends to continue. Probability weighting, on the other hand, does not imply errors in beliefs. It is simply a modeling tool to capture most individuals' preference for a 5% chance to win $100 over a sure win of $5, even if there is no uncertainty about the winning probability of 5%.[6] An important difference to Bergman and Jenter is that their model predicts the number of options to *decrease* in firm volatility, while the probability weighting model predicts the opposite.[7]

Another related paper is Oyer and Schaefer (2005), who provide an empirical investigation of Oyer's (2004) model of employee retention. The retention model predicts a positive relationship between industry volatility and stock option grants, and Oyer and Schaefer (2005) find this pattern in the data. An important difference that I will test using my much larger data set is that the retention model predicts a *negative* relationship between idiosyncratic volatility and stock option grants (as pointed out by Oyer and Schaefer (2005)), while a *positive* relationship is predicted by the probability weighting model.

Support for a model with gambling preferences comes from a related paper by Kumar, Page, and Spalt (2011). Motivated by my model, they show that the fraction of Catholics to Protestants in a region where the firm is headquartered predicts the size of ESO grants. They argue that this reflects the impact of religiously induced gambling norms. This is consistent with my model if their proxy captures variation in the degree of probability weighting δ.

My paper contributes to the compensation literature by providing a gambling-preference-based solution to the puzzle of why nonexecutive employees frequently value options higher than the risk-neutral benchmark, and why riskier firms grant more ESOs.

My paper also contributes to a growing literature that incorporates cumulative prospect theory preferences into otherwise standard economic models and then uses calibrations to assess the quantitative relevance. The two papers most closely related are Barberis and Huang (2008), who analyze the impact of cumulative prospect theory and probability weighting on asset prices, and Polkovnichenko (2005), who shows that probability weighting is quantitatively consistent with

[6]Consistent with the theoretical difference, I find in my regressions that including past stock returns as a proxy variable for investor sentiment, as in Bergman and Jenter (2007), has no effect on the positive relation between stock options and firm volatility predicted by the probability weighting model.

[7]Oyer and Schaefer (2006) calibrate a related model in which employees are optimistic about their firm's returns and find that such a model predicts that firms with lower stock volatility can more efficiently grant stock options. Even if one were willing to make the additional assumption that employees in volatile firms are systematically more optimistic, the required degree of optimism (Oyer and Schaefer (2006) report that for the typical firm in their sample an employee with constant relative risk aversion utility and $\rho = 2.5$ (a very low estimate) would need to overestimate expected returns by 200%) appears too large to be plausible for average companies.

observed household investment patterns.[8] To the best of my knowledge, my study is the first to formally analyze probability weighting in a corporate finance context.

Lastly, my study contributes to the catering literature by highlighting employees as an additional and important group that managers might cater to. Prior literature has established that managers may cater to shareholder demands by adjusting their payout policy (e.g., Baker and Wurgler (2004), Becker, Ivković, and Weisbenner (2011)), their capital structure (e.g., Baker and Wurgler (2002)), their investment policies (e.g., Polk and Sapienza (2009)), or their stock-split decisions (e.g., Baker, Greenwood, and Wurgler (2009)). In my study, managers cater *within-firm* to an employee preference for receiving stock option pay. My calibration results suggest that exploiting employee gambling preferences can be very profitable for firms. Hence, catering theories might be even more economically relevant than previously thought.

II. The Model

This section presents a static model in which a risk-neutral firm makes a take-it-or-leave-it offer of a pay contract, denoted by w, to a representative employee. Contract negotiations take place in $t=0$, and the contract pays off in $t=T$. The contract is a function of the time T stock price of the company, denoted by P_T.

The aim is twofold. First, the model will formalize the intuition that probability weighting makes stock options attractive to lower-level employees. Second, the model can be calibrated, and it can answer two important questions: Does the model predict options for *plausible* parameter values? What are the testable cross-sectional implications from the model? The model is able to answer these questions very precisely. It will be very simple and parsimonious otherwise.

Employee Preferences. The employee has preferences according to cumulative prospect theory (Tversky and Kahneman (1992)). For continuous probability distributions, cumulative prospect theory preferences imply that an employee evaluates the risky payoffs from her compensation contract according to

$$\text{(1)} \qquad \mathrm{E}^{\psi}\left[v\left(w\left(P_T\right)-RP\right)\right] \;=\; \int v\left(w\left(P_T\right)-RP\right)d\psi\left(F(P_T)\right).$$

Here, $F(P_T)$ is the cumulative distribution function of the stock price P_T. The value function is given by

$$\text{(2)} \quad v\left(w\left(P_T\right)-RP\right) \;=\; \begin{cases} \left(w\left(P_T\right)-RP\right)^{\alpha}, & \text{if } w\left(P_T\right)\geq RP \\ -\lambda\left(-\left(w\left(P_T\right)-RP\right)\right)^{\alpha}, & \text{if } w\left(P_T\right)< RP \end{cases},$$

where $0<\alpha\leq 1$, and $\lambda\geq 1$. It assigns a value to payoffs from the pay contract relative to a reference point RP. If the payoff is greater than the reference point, it is called a gain; otherwise, a loss. The function is convex over losses

[8]Other related papers include Benartzi and Thaler (1995), Barberis, Huang, and Santos (2001), Barberis and Xiong (2009), and Dittmann, Maug, and Spalt (2010).

and concave over gains, which captures diminishing sensitivity with respect to outcomes further away from the reference point. The loss aversion parameter λ governs the steepness of the function in the loss space. If $\lambda > 1$, then employees dislike losses more than they are attracted by equal-sized gains.

The probability weighting function transforms cumulative probabilities into decision weights via the function

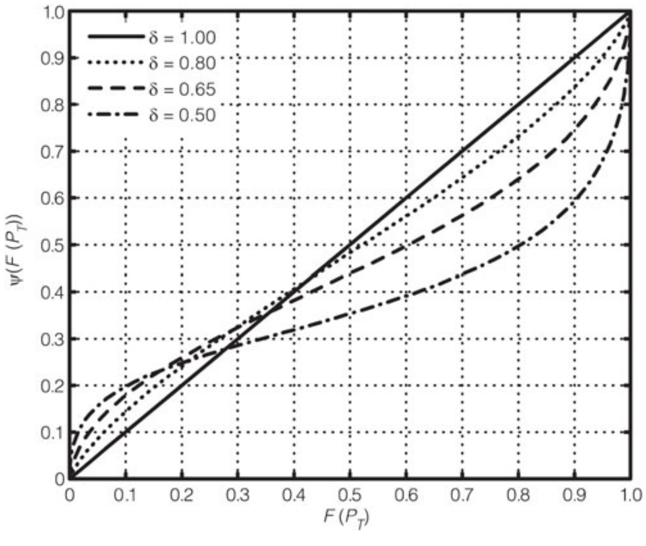
$$\psi\left(F(P_T)\right) = \begin{cases} \frac{-(1-F(P_T))^{\delta}}{\left(F(P_T)^{\delta}+(1-F(P_T))^{\delta}\right)^{\frac{1}{\delta}}}, & \text{if } w\left(P_T\right) \geq RP \\ \frac{F(P_T)^{\delta}}{\left(F(P_T)^{\delta}+(1-F(P_T))^{\delta}\right)^{\frac{1}{\delta}}}, & \text{if } w\left(P_T\right) < RP \end{cases}, \tag{3}$$

where $0.28 < \delta \leq 1$ measures the degree of probability weighting.[9] The weighting function is applied to gains and losses separately. Figure 1 shows the probability weighting function for different degrees of probability weighting δ.

FIGURE 1

The Probability Weighting Function

Figure 1 shows the probability weighting function as proposed by Tversky and Kahneman (1992) for different values of the weighting parameter δ.



The Problem of the Firm. The problem of the firm is to offer a compensation contract w such that the cost to the firm is minimized while providing the employee at least with her reservation value. The pay contract w, which pays out in $t = T$, consists of a fixed salary ϕ and n_o options with maturity T and strike price K on the company stock with random stock price P_T:

$$w\left(P_T\right) = \phi + n_o \max\left(P_T - K, 0\right).$$

[9]The lower bound at 0.28 is a technical assumption to keep $\partial\psi\left(F\left(P_T\right)\right)/\partial P_T$ positive. All experimental evidence suggests that δ is substantially above 0.28. For a more detailed discussion, see Ingersoll (2008).

The firm wants to minimize compensation costs subject to the standard participation constraint of the employee and thus offers the combination of salary and options to the employee that solves

$$
\begin{aligned}
(4) \qquad & \min_{n_o,\phi} \phi e^{-rT} + n_o BS, \\
\text{s.t.} \qquad & \mathrm{E}^{\psi}\left[v\left(w\left(P_T\right) - RP\right)\right] \geq v\left(\overline{V} - RP\right), \\
& n_o \geq 0.
\end{aligned}
$$

Here, BS is the Black-Scholes (1973) value of one option, which following the prior literature is used to approximate the cost of the option to a well-diversified firm, and E^{ψ} are expectations with respect to the weighted probabilities according to equation (1). Here, $\overline{V}$ denotes the (nonnegative) outside opportunity of the employee,[10] and $\overline{V}$ should be thought of as the certainty equivalent of a pay contract offered at another firm that is evaluated in the light of the proposed contract by comparing it to the reference point. I assume that employees cannot write options on the firm and hence $n_o \geq 0$. [11]

An empirical regularity is that almost all stock options to both executives and nonexecutive employees are granted an at-the-money (ATM). There is a debate in the literature about the underlying reasons (e.g., Hall and Murphy (2002), Bebchuk and Fried (2005)). It is not the aim of the model to contribute to this debate. Instead, consistent with observed practice, the model takes ATM strike prices as exogenous. Of course, conceptually, the strike price could be endogenized, as it is a variable the firm can control. This might lead to optimal strike prices that are higher than the observed strike prices; options would become more lottery-like, which might make them even more attractive to employees. Fixing K exogenously at the observed level is therefore a conservative assumption if the aim of the model is to show that probability weighting can lead to ESO plans.

On a broader level, endogenizing K in my model requires that one is willing to assume that strike prices for lower-level employees are set independently of strike prices for executives. This may be a strong assumption given the almost universal use of ATM options across both groups. For example, under the managerial power view of Bebchuk and Fried (2005), executives strongly oppose options with higher strike prices because this would reduce their ability to expropriate rents. If executives want ATM options for rent extraction purposes, they may have little incentive to grant options with higher strike prices to their employees. Finally, there might be a negative relation between the size of the gamble and the degree of probability weighting (after all, except for pathological cases, people do

[10]For tractability, it is assumed to be independent of the proposed contract. This is defensible if $\overline{V}$ is determined some time before the actual contract negotiations. In reality, it seems plausible that employees get an idea about competitive salaries in cash equivalents from statements like, "Typically employees in industry X (and position Y, etc.) can expect to get a pay package worth $\overline{V}$ dollars."

[11]Note that not allowing for compensation in restricted stock is not a serious limitation of my model. Bergman and Jenter (2007) show that firms will not use stock trading at fair market value to take advantage of employee biases. Since employees can always buy the stock at market prices on their own, they will not accept pay cuts in lieu for stock in excess of the market value. Hence, it does not pay for the firm to issue traded equity instruments like company stock. For nontraded instruments like stock options, on the other hand, the absence of an outside market makes exploiting employee preferences for company equity feasible.

not spend very large amounts of money on extremely skewed payoffs like lottery tickets). Endogenizing the contractual shape in a more complex model allowing for such effects is left for future research.

Reference Point. One needs to make an assumption about the reference point RP of the employee. Unfortunately, prospect theory is largely silent on this parameter, and while the status quo has often been used in simple settings, Kahneman and Tversky (1979) themselves note that "there are situations in which gains and losses are coded relative to an expectation or aspiration level that differs from the status quo." In the absence of clear guidance from previous research, I make the following general assumption:

Assumption 1. The reference point RP, over a pay package of n_o options and a fixed salary of ϕ, is linear in n_o and ϕ and has the functional form

(5) $$RP = n_o\theta + \phi,$$

where θ is a constant with $\theta \geq 0$.

Assumption 1 is intuitive: θ represents any payoff expectation or aspiration level the employee holds for one option. This could be, for example, the Black-Scholes (1973) value. Since she gets n_o of these options, $n_o\theta$ represents the expectations on the risky part of the portfolio. Since the fixed wage ϕ is nonrandom, it is simply added to any expectation the employee holds on the risky part of the pay package.[12] Consider, for example, an employee who receives 10,000 options and \$200,000 base salary over a planning horizon of 4 years. She anticipates that her options pay off \$5 per option in T. Hence, her reference point is $10{,}000 \times \$5 + \$200{,}000 = \$250{,}000$.

Assumption 1 is consistent with findings in the prior literature. Hodge et al. (2009) conduct a survey to analyze how employees value their stock options. Their results provide evidence that employees use simple heuristics, like subtracting the strike price from the best guess of the future stock price, as a basis for attaching a value to options. Such a reference point is a special case of Assumption 1, and I will use it as a candidate reference point in the calibrations in the next section.

This set of assumptions leads to the following proposition (proven in Appendix A):

Proposition 1. Let BS be the Black-Scholes (1973) value of one option and CE denote the certainty equivalent the employee holds for one stock option, which is implicitly defined as

$$\mathrm{E}^{\psi}\left[v\left(\max\left(P_T - K, 0\right) - \theta\right)\right] = v\left(CEe^{rT} - \theta\right).$$

Then the firm has a broad-based ESO plan if and only if $CE > BS$.

[12]Although I do not incorporate outside wealth here to focus on the main trade-offs in the model, this omission is far less consequential than it would be in a standard expected utility model. The reason is that in prospect theory, risk attitudes are relative to the reference point and therefore not necessarily dependent on wealth. One simple case that would be fully captured by the present setup would be existing outside wealth W_0 that is invested in risk-free assets. Just like base salary, this sure payment would be fully absorbed in the reference point and therefore inconsequential for the decision.

Proposition 1 is straightforward (although less straightforward than the wording of the proposition would suggest). It states that firms grant stock options to nonexecutive employees if and only if the certainty equivalent of the employee for options exceeds the value of the options to an outside investor, which is the cost of the options to the firm. If the certainty equivalent of an option is lower, the company is better off paying the reservation wage in cash and not issuing options at all. The proposition captures the idea that ESO plans are driven by employees who, in line with recent survey and empirical evidence, subjectively value options higher than outside investors. Firms can exploit the probability assessments by replacing fixed salary worth $n_o^* CE$ by stock options that are worth less, $n_o^* BS$, to an outside investor. Hence, lower-level employees in companies with broad-based ESO plans allow firms to lower their overall personnel cost.

The detail, that Proposition 1 is stated in terms of a single option only, deserves comment. By virtue of the power form of the value function and the linear specification of the reference point, the setup implies that the certainty equivalent is homogeneous of degree 1 in the number of granted options. In analyzing the implications from the model, it is thus sufficient to look at the value of a single option for employees and outside investors, respectively. In addition, the existence of a stock option plan does not depend on the (unobservable) outside option $\overline{V}$. These properties are extremely convenient for calibrating the model and for numerically developing the predictive content of Proposition 1 in the next section.

Proposition 1 is a very parsimonious way of characterizing the *existence* of broad-based ESO plans. However, it is not helpful in analyzing how many options the firm will grant, since (in this simplest version of the model) the employee would be willing to substitute an *infinite* number of options for base salary once $CE > BS$. If one wants more realistic implications for the number of granted stock options, one has to enrich the model by defining the boundaries of the firm's willingness to grant options and/or the employee's willingness to receive them as part of the compensation package.

Costs that Limit Plan Size. Obviously, the size of actual stock option plans is limited by a number of factors. For firms, the willingness to grant options may be constrained by the documented concerns about diluted earnings per share and the inability to repurchase a large fraction of shares (e.g., Kahle (2002), Bens, Nagar, Skinner, and Wong (2003)), by the desire to maintain good relationships with employees that could be severely impaired if employees end up with a lot of underwater options (e.g., Akerlof and Yellen (1990), Bewley (1999)), or by the cost of securing shareholder approval from shareholders who do not want their share in the company to be diluted (e.g., Hall and Murphy (2003)).[13] Employees' willingness to accept options as part of their compensation will be limited by the

[13]For example, Intel CEO Craig Barrett states in a filing to the Securities and Exchange Commission (SEC), "Intel stockholders are concerned about their ownership in the company being 'reduced' or 'diluted' by our stock option program. If we don't take some measured action, the stockholders will not support our option plan." (Available as part of a filing with the SEC at http://www.secinfo.com/d14D5a.12dJc.htm.) Such "measured actions," for example, the time and effort involved for persuading large shareholders that the proposed plan is a good idea, are costly and likely to put a limit on plan size.

base salary needed to meet living expenses and mortgage payments. Also, the willingness to take a gamble is likely to decrease as stakes get very high (even in Las Vegas, except for pathological cases, people gamble for sizable but not huge amounts relative to their total wealth).[14] Lastly, the cost from underdiversification increases in the size of the stock option grant.

It is beyond the scope of this paper to determine which of the many potential constraints on plan size are most binding. To model the many potential factors above in the most parsimonious way possible, I make the following assumption:

Assumption 2. The costs limiting the size of the ESO plan can be described by a strictly increasing convex function $c(n_o)$, with $c(0) = 0$.

This leads to the following prediction (proven in Appendix A):

Proposition 2. The number of stock options granted increases in $CE - BS$.

III. Calibration of the Model

A. Parameterizing the Model

I calibrate the model by calculating, for various combinations of firm volatility and probability weighting, the difference between the certainty equivalent of one option for an employee and the value of one option to an outside investor, which is equal to the cost of the option to the firm. For the stock price P_T, I assume a lognormal distribution, which depends on the risk-free rate of interest r, the length of the period T, firm volatility σ, and a standard normally distributed random variable u:[15]

$$P_T \quad = \quad P_0 \exp\left\{\left(r - \frac{\sigma^2}{2}\right) T + u\sigma\sqrt{T}\right\}.$$

Following Dittmann and Maug (2007), I assume risk-neutral pricing throughout. This ensures that if the preferences of the employee approach risk neutrality ($\alpha = 1, RP = 0$, or $\alpha = \lambda = 1$), and without probability weighting ($\delta = 1$), the certainty equivalent of one option approaches the Black-Scholes (1973) value.[16]

[14]This could be modeled in principle by making δ a function of the stakes. Other approaches in the literature include augmenting the value function by a term that makes marginal utility decline as employee wealth gets sufficiently small (Gomes (2005)) or augmenting a standard concave utility function with a loss-aversion term (Barberis et al. (2001)). The cost of such modifications is that the model loses much of its ability to be calibrated based on reliable experimental data.

[15]The median dividend yield in the sample of companies analyzed below is 0.25%. I thus set dividend yields to 0 in what follows. Incorporating sensible dividend yields would be straightforward and does not alter the main results.

[16]Introducing a risk premium in the model (i.e., $\mu \geq r$) would lead to the paradoxical outcome that a strictly risk-averse employee (a limiting case of the model when $RP = 0$) would value options higher than the Black-Scholes (1973) value for sufficiently low degrees of risk aversion *even without probability weighting*. This results because the employee's investment in the stock market is not explicitly modeled (Cai and Vijh (2005)). While this can be done in principle, it would dramatically reduce the tractability of the model. The present approach, following Dittmann and Maug (2007), guarantees internal consistency in a tractable way.

I set r to 5% and T to 4 years.[17] Setting T to 4 years is motivated by the observation that most employees exercise most of their options shortly after they become exercisable (Huddart and Lang (1996)).[18] Consistent with essentially all actual ESO plans, the strike price of the option, K, is equal to the grant date stock price, P_0.

To parameterize the value function, I set the curvature parameter α and the coefficient of loss aversion λ to the standard values of 0.88 and 2.25, respectively (Tversky and Kahneman (1992)). As indicated above, there is to date little research on how people set reference points for complex distributions like payoffs from stock options. I propose two candidate reference points, which are special cases of Assumption 1. The first assumes a simplified intrinsic option value calculation and is based on interview evidence reported by Hodge et al. (2009). This approach suggests the reference point to be the expected future stock price less the strike price of the option. To focus on the impact of probability weighting, I assume that the stock price expectation of the employee is today's stock price compounded over T years at a rate of r. As an alternative reference point, I also consider the Black-Scholes (1973) option value with maturity equal to T. The Black-Scholes value may be particularly salient among the more financially literate employees, since companies routinely use the Black-Scholes formula to estimate the value of their stock option grants for financial reporting purposes. Both reference points differ because the simplified intrinsic value specification is invariant to volatility, while using the Black-Scholes value implies a reference point that increases with volatility. Intuition offers little guidance on which is the more appropriate. My results show that they lead to similar results.[19]

The remaining two parameters are the volatility of the firm's stock return and the degree of probability weighting, which is captured by the parameter δ in the weighting function. These parameters are of particular interest, since they govern the thickness of the tail of the payoff distribution and the subjective overweighting of the tail, respectively. Table 1 presents experimental results on the value of the weighting parameter δ. These estimates are reasonably homogeneous and suggest that values at about $\delta = 0.65$ are plausible, which is consistent with values used in the literature (e.g., Barberis and Huang (2008)).[20] I analyze the fit of the model for a grid of values for δ that encompasses the most plausible values, as well as the case of no probability weighting, $\delta = 1$. I also use a grid for the volatility of the firm.

[17] Setting $r = 10\%$, $r = 15\%$, or $T = 7$ does not alter the main results presented here.

[18] Other common vesting schedules that stipulate the right to exercise a maximum of 25% of the options per annum over the first 4 years of the option's life are thus assumed here to be evaluated as if all of options would become exercisable at $T = 4$. A more complex model with different time periods would have to specify an aggregation rule across time. I abstract from pro-rata vesting to keep the model tractable.

[19] Appendix B shows that the results are robust to sensible changes in the proposed reference point specifications.

[20] In a large study on individual decision making, Gonzalez and Wu (1999) document that there is considerable heterogeneity in probability weighting across individuals. They conclude, however, that the Tversky and Kahneman (1992) weighting function "provide[s] an excellent, parsimonious fit to the median data."

TABLE 1

The Degree of Probability Weighting

Table 1 summarizes estimates of the parameter δ in the Tversky and Kahneman (1992) probability weighting function in prior studies.

Study	Parameter Estimate
Tversky and Kahneman (1992)	δ = 0.61 (gains), δ = 0.69 (losses)
Camerer and Ho (1994)	δ = 0.56 (gains)
Wu and Gonzales (1996)	δ = 0.71 (gains)
Abdellaoui (2000)	δ = 0.60 (gains), δ = 0.70 (losses)
Bleichrodt and Pinto (2000)	δ = 0.67 (gains)

B. Calibration Results

Table 2 presents the difference between certainty equivalent and the Black-Scholes (1973) value (scaled by the share price P_0) for a reference point equal to the Black-Scholes value (Panel A) and for the simplified intrinsic value calculation (Panel B). The certainty equivalent is calculated according to the definition in Proposition 1. In both panels, the results confirm the intuition: The more individuals overweight small probabilities (captured by δ) and the more small chances of large gains there are (captured by firm volatility), the more attractive options become. For all but the highest values of δ, the difference between certainty equivalent and Black-Scholes value increases in the firm volatility, which, by Proposition 2, implies more options at high-volatility firms, as long as $CE > BS$.

In Panel A of Table 2, for $\delta = 0.65$, if the reference point equals the Black-Scholes (1973) value, no options are predicted for firms with stock price volatility less than 40%. In Panel B, when the reference point is based on the expected intrinsic value, the predicted volatility cutoff is only slightly lower. There is nothing

TABLE 2

Calibration Results

Table 2 presents the difference of certainty equivalent and the Black-Scholes (1973) value for one option, scaled by the share price P_0, for different combinations of probability weighting and firm volatility. The model predicts employee stock option plans if $CE > BS$ (cells with bold numbers in the table). Larger stock option grants are predicted for larger values of $CE - BS$. The calculations assume a lognormal stock price distribution with T = 4 years and r = 5%. The strike price of the option, K, is set equal to the grant date stock price P_0. Preference parameters are $\alpha = 0.88$ and $\lambda = 2.25$. Panel A gives results when the reference point for one option is the Black-Scholes value (i.e., $\theta = BS$). Panel B gives results when the reference point for one option is $\theta = P_0 e^{rT} - K$.

Probability Weighting	Firm Volatility									
δ	20%	25%	30%	35%	40%	45%	50%	60%	70%	80%
Panel A. $CE - BS$ Scaled by P_0 When $\theta = BS$										
0.40	**0.093**	**0.175**	**0.289**	**0.443**	**0.650**	**0.926**	**1.290**	**2.394**	**4.268**	**7.406**
0.50	**0.024**	**0.068**	**0.126**	**0.204**	**0.306**	**0.436**	**0.602**	**1.074**	**1.807**	**2.925**
0.60	−0.028	−0.012	**0.010**	**0.041**	**0.083**	**0.136**	**0.204**	**0.392**	**0.669**	**1.067**
0.63	−0.037	−0.028	−0.012	**0.010**	**0.041**	**0.081**	**0.133**	**0.276**	**0.488**	**0.790**
0.65	−0.045	−0.041	−0.032	−0.017	**0.004**	**0.033**	**0.070**	**0.176**	**0.334**	**0.559**
0.68	−0.048	−0.052	−0.049	−0.041	−0.028	−0.010	**0.016**	**0.091**	**0.204**	**0.367**
0.70	−0.052	−0.056	−0.059	−0.061	−0.056	−0.046	−0.031	**0.017**	**0.094**	**0.206**
0.75	−0.058	−0.065	−0.071	−0.076	−0.081	−0.085	−0.088	−0.091	−0.073	−0.035
0.80	−0.064	−0.073	−0.082	−0.091	−0.099	−0.107	−0.114	−0.126	−0.135	−0.141
0.90	−0.074	−0.088	−0.102	−0.117	−0.131	−0.146	−0.161	−0.191	−0.220	−0.249
1.00	−0.082	−0.100	−0.119	−0.138	−0.157	−0.177	−0.198	−0.240	−0.284	−0.327

(continued on next page)

TABLE 2 (continued)

Calibration Results

Probability Weighting	Firm Volatility									
δ	20%	25%	30%	35%	40%	45%	50%	60%	70%	80%
Panel B. CE − BS Scaled by P_0 When $\theta = P_0 e^{rT} - K$										
0.40	**0.089**	**0.170**	**0.284**	**0.442**	**0.655**	**0.938**	**1.313**	**2.447**	**4.362**	**7.553**
0.50	**0.026**	**0.075**	**0.142**	**0.231**	**0.347**	**0.494**	**0.679**	**1.197**	**1.986**	**3.172**
0.60	−0.024	**0.000**	**0.036**	**0.083**	**0.143**	**0.217**	**0.308**	**0.550**	**0.890**	**1.359**
0.63	−0.035	−0.015	**0.014**	**0.053**	**0.103**	**0.165**	**0.240**	**0.438**	**0.713**	**1.086**
0.65	−0.044	−0.030	−0.007	**0.025**	**0.066**	**0.117**	**0.179**	**0.340**	**0.561**	**0.856**
0.68	−0.053	−0.043	−0.025	0.000	**0.033**	**0.074**	**0.124**	**0.254**	**0.430**	**0.662**
0.70	−0.060	−0.055	−0.043	−0.023	**0.002**	**0.035**	**0.075**	**0.178**	**0.316**	**0.497**
0.75	−0.071	−0.077	−0.073	−0.064	−0.051	−0.033	−0.010	**0.049**	**0.130**	**0.234**
0.80	−0.076	−0.094	−0.099	−0.099	−0.096	−0.089	−0.080	−0.053	−0.014	**0.036**
0.90	−0.084	−0.109	−0.135	−0.151	−0.164	−0.175	−0.185	−0.202	−0.216	−0.228
1.00	−0.092	−0.119	−0.146	−0.174	−0.202	−0.230	−0.253	−0.297	−0.341	−0.384

in the model that would ex ante guarantee that it can produce any quantitatively reasonable prediction as to which firms should grant options. Its ability to produce such predictions that can be tested directly on the data is a clear strength. Remarkably, a cutoff level of about 40% is what I find in analyzing the universe of ExecuComp firms below.

For all specifications considered, the importance of probability weighting is striking. Without it ($\delta = 1$), the certainty equivalent is never high enough for the model to predict options, irrespective of firm volatility. To understand this, note that if the employee were risk neutral, her certainty equivalent would equal the Black-Scholes (1973) value. Hence, the values for $\delta = 1$ in Table 2 show that without probability weighting the employee is effectively risk averse, despite the convex part in the value function over losses. As a consequence, the relation between volatility and stock options reverses: If there is no probability weighting, the difference between *CE* and *BS* is negative and decreases in firm volatility, just as standard concave utility models would predict. I will show in the next section that this is actually counterfactual, which further strengthens the case for the probability weighting model.

The argument presented so far implies that firms can benefit from catering to employees who overweight small probabilities. To get an idea of the magnitude of this benefit in dollar terms, assume a typical company with 20,000 nonexecutive employees, which grants options with a Black-Scholes (1973) value of $5,000 per employee annually.[21] For $\delta = 0.65$ and firm volatility of 45%, the value by which reduced base salaries exceed the Black-Scholes cost of options can be estimated from Panel A of Table 2 to be about $11 million.[22] For the reference point in Panel B, benefits are $39 million. Hence, for typical firms, benefits from options are sizable but not huge. The magnitude of the benefits increases quickly for firms with higher stock return volatility. A firm with volatility of 60% can reduce base

[21]These values are close to the mean values for firms in the ExecuComp universe over the years 1992–2005, as will be shown in Table 3.

[22]This is calculated as 20,000 × \$5,000 × $[(CE - BS)/BS]$.

salaries by about \$49 million to \$94 million more than what it grants to employees in Black-Scholes value. For the largest granters of ESOs, this value-cost differential can be enormous. For example, some large companies in the sample I analyze below have granted per annum on average roughly \$50,000 worth of options per employee for 25,000 employees at a firm volatility of 45%. Depending on the reference point, this implies a value-cost gap of between \$99 million and \$354 million per year.

One important caveat is that the calculations do not take into account the external cost of granting stock options discussed in Section II. If these costs accrue mostly to the firms, then the values overstate the benefit to firms. If the costs accrue mainly to the employees, the above calculations give an accurate estimate of the savings firms can generate from taking advantage of employee preferences for long-shot gambles. In any case, the results suggest that probability weighting of employees can have quantitatively important economic consequences for compensation practices in high-volatility corporations.

IV. Empirical Tests of the Model

Three testable implications emerge from the calibrated model. First, all else being equal, higher-volatility firms should be more likely to have a broad-based stock option plan. Second, the number of stock options granted per employee should, all else being equal, be higher for firms with higher volatility. Third, for a given level of firm volatility, the number of stock options and the probability of the existence of a broad-based plan is increasing in the degree of probability weighting. I will test these implications below.

A. Data Set and Construction of Variables

Following Desai (2003) and Bergman and Jenter (2007), I estimate the number of options granted to nonexecutive employees based on the ExecuComp variable “pcttotopt,” which provides for each executive option grant the percentage this grant represents of the total number of options granted to all employees of the firm in the fiscal year. I average the estimates for all executives in 1 firm-year and eliminate outliers by dropping all firm-years for which the standard deviation of the estimates is greater than 10% of the mean. The variable “pcttotopt” is available in ExecuComp until 2005, and my sample period is therefore from 1992 to 2005.

As I want to focus exclusively on nonexecutive employees for whom incentive considerations are negligible, I follow Oyer and Schaefer (2005) and use what I label a “narrow” definition of employees, which requires an additional assumption about how far options are spread into the organization. I assume that the number of executives increases for larger firms at a decreasing rate, and I take the square root of the total number of employees as an estimate of the number of high and top executives in the firm.[23] To be able to quantify the number of

[23]Oyer and Schaefer (2005) use an estimate of the number of executives within a firm that is linear in the total number of employees. Since the total number of employees in my sample is much more dispersed, this linear estimate is likely to overstate the number of executives in large firms. For a

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options to high executives, I further assume, following Oyer and Schaefer (2005), that 10% of the average number of options to the top executives in the ExecuComp database, excluding the CEO, are awarded to the average high executive not listed in the ExecuComp database.[24] The number of options to top executives can be obtained from ExecuComp directly by summing over individual grants in the firm-year. The number of options to nonexecutive employees is then calculated by subtracting the number of options to top executives and the number of options to high executives from the total number of options. The number of employees reported in ExecuComp is used to calculate per employee values, adjusted for top and high executives, where appropriate.

I define a variable ESOPlan (employee stock option plan) that is 1 if the number of granted options in the firm-year is positive and greater than 0.5% of the number of shares outstanding, and 0 otherwise. The latter assumption follows Oyer and Schaefer (2005) and intends to ensure that I indeed capture firms with broad-based plans.

All data are taken from the Center for Research in Security Prices (CRSP) Compustat merged database. I drop all companies with fewer than 40 employees or fewer than 2 reported executives to exclude firms for which the above adjustment for other high executives is not sufficient to rule out incentive motives for option grants. The main variable of interest is firm volatility, which I compute using 3 years of daily CRSP returns.[25] Following Bergman and Jenter (2007), I control for size using the log of sales and for investment opportunities using Tobin's Q (calculated as book assets minus book equity plus market value of equity, all over assets), the 3-year average of research and development (R&D) expense scaled by total assets, and a dummy variable that indicates the existence of long-term debt to proxy for access of the firm to debt markets. I winsorize firm volatility and Tobin's Q at the 1% and 99% levels. I further drop all companies in the financial sector (Standard Industrial Classification (SIC) codes 6000–6999) and all company-years where one of the above variables was missing. The resulting data set has 14,612 firm-year observations for 2,228 unique firms.

I define a number of additional variables suggested by the prior literature. As measures of cash constraints I include the Kaplan and Zingales (KZ) (1997) index.[26] As additional measures of cash constraints, I follow Core and Guay (2001) and include cash flow shortfall, defined as a 3-year average of common and preferred dividends plus cash flow used in investing activities less cash flow from operations, all divided by total assets, and interest burden, defined as the 3-year average of interest expense scaled by operating income before depreciation.

large firm with 100,000 employees, the original Oyer and Schaefer (2005) estimate of high executives would be 10,000, whereas under the approach taken here, the estimate of high executives is 316. All results are qualitatively unchanged when using the linear estimate.

[24]All results continue to hold if this percentage is set to 5% or 20%.

[25]The main results are not sensitive to the definition of volatility. Using volatility estimates based on 1 year of daily returns or 5 years of monthly returns gives very similar results.

[26]Following Bergman and Jenter (2007), I do not include Tobin's Q, as this is already included as a control variable in the regression. Hence the KZ (1997) index is calculated as (all components winsorized at the 1% and 99% levels): KZ-Index $= -1.002 \times$ Cash Flow $- 39.368 \times$ Cash Dividends $- 1.315 \times$ Cash Balances $+ 3.139 \times$ Leverage.

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Interest burden is censored from above at 1. All measures are constructed at the end of year $t-1$.

To control for higher grants at new-economy firms, I include a dummy variable for new-economy firms, which are defined, following Oyer and Schaefer (2005), as firms in SIC code industries 3570–3579, 3661, 3674, 5045, 5961, and 7370–7379. I also control for contemporaneous return, Return$(t-1,t)$, defined as the stock return excluding dividends from the end of year $t-1$ to the end of year t, and Return$(t-3,t-1)$, the annualized stock return excluding dividends from the end of year $t-3$ to the end of year $t-1$. Lastly, following Babenko and Tserlukevich (2009), I use the absolute coefficient of variation of earnings before interest and taxes (EBIT) over the last 10 years as a measure of the convexity of a firm's tax schedule.

Panel A of Table 3 presents descriptive statistics for the pooled sample. The average firm has 18,814 employees and sales of $4.0 billion. Median (mean) firm volatility is 41.3% (46.3%), and Tobin's Q is 1.60 (2.11). About 14% of firms do not have long-term debt in their capital structure, and 16% of firms in the sample are in new-economy industries. A broad-based ESO plan is in place in the majority of firm-years (58.5%) and, for the average firm-year, 42.8% (70.6%) of all options granted go to employees if employee is narrowly (broadly) defined.[27] In each fiscal year, average companies in the sample grant options on 3.2% of their shares outstanding.

For the typical company that grants options, the Black-Scholes (1973) value of option grants to nonexecutive employees is modest, with a median per employee value of $1,212.[28] The distribution is skewed, and the per employee mean value at $7,020 is higher. It should be noted, however, that these numbers are biased downward if (as is probably the case in almost all companies) not all employees in the company receive options. Clearly, for some companies in the sample, stock option grants to nonexecutive employees are anything but modest. For example, one of the largest granters of ESOs in the sample, Cisco Systems Inc., is estimated to grant options worth on average about $50,000 per employee, with an average total annual value of option grants to nonexecutive employees in excess of $1 billion.

B. Univariate Results

The calibrated model predicts that ESO plans are more common among high-volatility firms and that higher-volatility firms grant more options per employee. Pooling the data and sorting firms into volatility quintiles strongly confirms these predictions (Table 4). The median firm in the 2 lowest volatility quintiles does not have a broad-based plan, while the median firm in quintiles 3–5 does. Firm

[27]Under this broad definition, all individuals employed by the company, except for the top executives reported in ExecuComp, are counted as employees.

[28]Black-Scholes (1973) values are calculated based on the average of the grant date stock price reported in ExecuComp for all grants in a given firm-year. Option maturity and risk-free rate of interest are uniformly set to 7 years and 5%, respectively. Since the main part of the analysis is based on the number of options and not their Black-Scholes value, these assumptions are not substantial for what follows.

TABLE 3

Summary Statistics

The original data set includes all firms with more than 40 employees listed in ExecuComp over the period from 1992 to 2005. Firms in the financial sector are excluded (SIC codes 6000–6999). The final data set has observations on 2,228 firms. The table presents summary statistics for the pooled sample. Volatility is the annualized total volatility computed from 3 years of daily stock returns. R&D is a 3-year average of research and development expenses scaled by total assets. Long-Term Debt is a dummy variable that is equal to 1 for firm-years where the firm has long-term debt. P_0 is the log of the average grant-date stock prices reported in ExecuComp. KZ-Index is the Kaplan-Zingales (1997) measure of financial constraints defined in Section IV. CF shortfall is cash flow shortfall defined as a 3-year average of common and preferred dividends plus cash flow used in investing activities less cash flow from operations, all divided by total assets. Interest Burden is the 3-year average of interest expense scaled by operating income before depreciation, with interest burden set to 1 when interest expense is greater than operating income before depreciation. New Economy Firm is a dummy variable equal to 1 for firms with SIC industry codes 3570–3579, 3661, 3674, 5045, 5961, and 7370–7379. Contemporaneous return, Return($t-1, t$), is defined as the stock return excluding dividends from the end of year $t-1$ to the end of year t. Return($t-3, t-1$) is the annualized stock return excluding dividends from the end of year $t-3$ to the end of year $t-1$. Earnings volatility is calculated as the absolute coefficient of variation using 10 years of EBIT data. ln(1 + n_o) is the natural log of 1 plus the number of employee stock options (ESOs) (narrowly defined) per employee. ESOPlan is a dummy variable that indicates a broad-based stock option plan in the firm-year. ESOPlan is 1 if the number of nonexecutive ESOs is positive and greater than 0.5% of the number of shares outstanding. Nonexecutive employees are defined "broadly" as all employees of the firm except those listed in ExecuComp. Nonexecutive employees are defined "narrowly" by correcting the total number of employees by the executives listed in ExecuComp and other high-ranking executives. The correction is based on estimating the total number of executives in a firm by taking the square root of the total number of employees. Black-Scholes (1973) values are calculated based on the average of the grant date stock price reported in ExecuComp for all grants in a given firm-year. Maturity of the options and risk-free rate of interest is uniformly set to 7 years and 5%, respectively.

Variable	Mean	SD	25th Pctl.	Median	75th Pctl.	N
Panel A. Firm Characteristics						
Employees	18,814	54,901	1,700	5,080	15,234	14,612
Sales ($m)	3,990	11,700	359	1,000	3,000	14,612
Volatility	46.28	21.66	30.35	41.26	57.58	14,612
Tobin's Q	2.11	1.48	1.21	1.60	2.39	14,612
R&D (in % of Assets)	3.82	7.21	0.00	0.18	5.04	14,612
Long-Term Debt > 0	86.70	33.96	100.00	100.00	100.00	14,612
ln(P_0)	3.08	0.73	2.70	3.17	3.58	14,612
Dividend Yield	1.17	1.62	0.00	0.24	1.98	14,612
KZ-Index	0.22	1.20	−0.50	0.26	0.97	14,500
CF Shortfall	−0.18	0.15	−0.25	−0.17	−0.11	14,543
Interest Burden	0.10	1.38	0.04	0.11	0.20	13,306
New Economy Firm	16.03	36.69	0.00	0.00	0.00	14,612
Return($t-1, t$)	22.36	138.16	−14.90	8.98	37.55	14,584
Return($t-3, t-1$)	15.36	42.51	−7.25	9.59	29.72	13,795
Earnings volatility	96.53	252.87	29.97	49.48	81.54	11,025
Panel B. Stock Option Plan Characteristics						
Total granted options to shares outstanding	3.19	16.89	1.05	1.88	3.45	14,612
ln(1 + n_o)	3.22	3.02	0.00	3.62	5.72	14,612
ESOPlan	58.47	49.28	0.00	100.00	100.00	14,612
Percent of options to CEO	13.92	11.62	6.06	10.79	18.06	14,612
Percent of options to other reported executives	15.46	10.52	7.53	13.30	21.18	14,612
Percent of options to employees (broad)	70.62	18.91	60.15	74.26	85.00	14,612
Percent of options to employees (narrow)	42.83	28.48	18.20	45.47	66.37	14,612
BS-Value to CEO ('000)	1,417	2,536	193	544	1,426	14,612
BS-Value to other reported executives ('000)	447	778	73	183	463	14,612
BS-Value to employees (broad)	4,652	11,662	158	543	2,698	14,612
BS-Value to employees (narrow)	4,105	11,168	0	167	1,942	14,612
BS-Value to employees (broad) if $n_o > 0$	7,664	14,486	487	1,658	7,441	8,544
BS-Value to employees (narrow) if $n_o > 0$	7,020	13,887	316	1,212	6,547	8,544

volatility of the median firm in quintile 3 is 39.4% (mean = 41.8%) and thus remarkably close to the cutoff levels predicted by the calibration results for plausible degrees of probability weighting in Table 2. Moving to quintiles with higher volatility, the average per employee Black-Scholes (1973) option value increases monotonically and at an increasing rate from $353 in the bottom quintile to $13,032 in the top quintile. The number of options per employee increases likewise. If I do not correct for other high executives and use the broad definition of employees instead, I find the same monotonic relation between firm volatility, per employee Black-Scholes value, and number of options, which shows that the results are not an artifact of introducing a narrow employee definition. The proportion of firms with a broad-based plan increases at an increasing rate from 41.1% to 83.6%. All differences are statistically significant.[29]

TABLE 4

Sorting Results

Table 4 presents employee stock option (ESO) grants sorted by firm volatility. Volatility is the annualized total volatility computed from 3 years of daily stock returns. A firm has a broad-based stock option plan in the firm-year (ESOPlan = 1) if the number of nonexecutive ESOs is positive and greater than 0.5% of the number of shares outstanding. The per employee number of options is the number of options granted per nonexecutive employee. The number of nonexecutive employees are computed by correcting the total number of employees by the executives listed in ExecuComp and other high-ranking executives. The correction is based on estimating the total number of executives in a firm by taking the square root of the total number of employees. Nonexecutive employees are defined "broadly" as all employees of the firm except those listed in ExecuComp. Black-Scholes (1973) values are calculated based on the average of the grant date stock price reported in ExecuComp for all grants in a given firm-year. Maturity of the options and risk-free rate of interest are uniformly set to 7 years and 5%, respectively. The *t*-test and Wilcoxon rank-sum test are used to test the difference in the per employee number of granted options across adjacent quintiles.

Panel A. Mean

Firm Volatility Quintile	Firm Volatility	Percentage of Firms with ESO Plan	Per Empl. BS-Value	Per Empl. No. of Options	*t*-Test of Difference [*p*-value]	Per Empl. BS-Value (broad)	Per Empl. No. of Options (broad)
1	25.01%	41.14%	$353	63	—	$571	112
2	33.37%	46.85%	$989	124	0.00	$1,349	209
3	41.76%	52.89%	$1,731	213	0.00	$2,206	289
4	54.29%	68.00%	$4,448	526	0.00	$5,175	787
5	77.10%	83.57%	$13,032	1,967	0.00	$13,987	2,741

Panel B. Median

Firm Volatility Quintile	Firm Volatility	ESO Plan at Median Firm	Per Empl. BS-Value	Per Empl. No. of Options	Wilcoxon Test of Difference [*p*-value]	Per Empl. BS-Value (broad)	Per Empl. No. of Options (broad)
1	23.88%	No	$0	0	—	$201	55
2	31.35%	No	$0	0	0.00	$279	55
3	39.39%	Yes	$71	17	0.00	$456	76
4	52.05%	Yes	$564	97	0.00	$1,089	176
5	72.66%	Yes	$4,844	842	0.00	$5,670	989

C. Firm Volatility and Existence of Broad-Based Stock Option Plans

To confirm the univariate predictions, I first run multivariate regressions to establish that firms with higher stock return volatility are more likely to have a broad-based ESO plan. As a baseline, I estimate different versions of a linear probability model (LPM). The dependent variable in these regressions is ESOPlan, which is 1 if the firm has a broad-based ESO plan in the year. The regressions include a large set of control variables suggested by the prior literature, as well as different fixed effects. Standard errors allow for clustering on the firm level. I also report results for a corresponding probit model.

[29]Note that the increase in per employee Black-Scholes (1973) value is not mechanically caused by using higher volatilities in the Black-Scholes formula, because together with the Black-Scholes value, the number of options per employee increases with the volatility quintiles. This is not easily reconciled with any standard concave utility model. In such a model, higher volatility would decrease the value of options to the employee, since she has to be compensated for bearing additional risk. As a consequence, it would likely be optimal for the firm to substitute some of the options with cash. This would (inconsistent with the data presented here) lead to fewer options, not more.

Table 5 presents results. The variable of interest is firm volatility, and the baseline set of control variables includes the log of sales to control for firm size, Tobin's Q, and R&D expenses to capture investment opportunities and cash constraints, as well as a dummy variable that indicates if the firm has long-term debt. Across all specifications, the regressions indicate that higher firm volatility is associated with a greater likelihood of a broad-based stock option plan. Smaller firms are more likely to grant ESOs, and so are firms with high Tobin's Q and high R&D expenditures. The positive relation between firm risk and ESO plans suggests that agency considerations (which would predict the opposite) are unlikely to be a major driver of ESO grants.

TABLE 5

Existence of ESO Plans

Table 5 presents regressions of an indicator variable for the existence of a broad-based employee stock option plan on firm volatility and control variables. ESOPlan is equal to 1 if there is a broad-based stock option plan at the firm in the respective firm-year. Volatility is the annualized total volatility computed from 3 years of daily stock returns. All variables have been previously defined in Table 3. Industry dummy variables are based on the 3-digit SIC code. Marginal effects computed at the mean are reported for the probit models. Robust *t*-statistics (for the LPM) and *z*-statistics (for the probit model) with clustering at the firm level are given below the coefficient estimates.

	Dependent Variable							
	ESOPlan (dummy variable)							
Variable	(1)	(2)	(3)	(4)	(5)	(6)	(7)	Probit
Volatility	0.244	0.262	0.229	0.245	0.233	0.272	0.190	0.244
	3.61	3.51	4.38	4.26	3.23	2.95	2.48	2.54
ln(Sales)	−0.010	−0.008	−0.017	−0.015	−0.006	0.002	−0.005	−0.009
	−1.39	−1.11	−2.96	−2.37	−0.75	0.27	−0.61	−0.92
Tobin's Q	0.012	0.010	0.012	0.015	0.010	0.008	0.000	0.002
	2.51	1.79	2.99	3.05	1.52	0.89	−0.02	0.14
R&D	0.382	0.695	0.349	0.401	0.517	0.821	0.809	2.867
	2.68	4.55	2.99	3.03	3.04	4.05	4.65	6.04
Long-Term Debt > 0	−0.022	−0.011	−0.016	−0.024	−0.045	−0.029	−0.009	−0.065
	−1.14	−0.54	−1.01	−1.40	−2.04	−1.00	−0.37	−1.68
KZ-Index	−0.004					0.002	−0.010	0.003
	−0.54					0.20	−0.99	0.27
CF Shortfall		−0.212				−0.228	−0.271	−0.300
		−3.46				−2.89	−3.86	−2.88
Interest Burden		−0.002				−0.002	0.011	0.000
		−0.66				−0.41	1.28	−0.09
New Economy Firm			0.159			0.161	0.102	0.296
			3.45			2.54	1.53	3.72
Return($t-1$, t)				−0.005		−0.004	−0.008	−0.022
				−2.02		−0.40	−0.80	−1.57
Return($t-3$, $t-1$)				−0.005		−0.037	−0.046	−0.055
				−0.58		−1.83	−2.40	−2.24
Earnings volatility					0.003	0.004	0.003	0.010
					1.72	2.13	1.41	2.12
Industry dummies							Yes	Yes
Year dummies								Yes
MSA × Year dummies							Yes	
Industry × Year dummies	Yes	Yes	Yes	Yes	Yes	Yes		
Pseudo/Adj. R^2	0.286	0.276	0.283	0.278	0.248	0.260	0.284	0.232
N	10,716	9,800	14,612	13,795	11,025	7,936	7,713	7,826

One possibility is that time-varying labor market conditions induce firms to grant more options, for example, if labor markets are tighter (e.g., Oyer and Schaefer (2005)). Therefore, specifications (1)–(6) in Table 5 control for this by including dummy variables for each industry-year combination. Hence, the results are not driven by the state of the labor market, industry volatility, or other factors specific to certain industries and years. In this setting, the coefficient on volatility measures the *idiosyncratic* component of volatility unexplained by the average volatility in an industry-year. The well-known retention model of Oyer (2004) would then predict a *negative* coefficient on volatility. The results in specifications (1)–(6) therefore show that they cannot be explained by the retention model.

The regressions show the effects of including several additional control variables suggested by prior research. I first control for cash constraints using the KZ (1997) measure (specification (1)), as well as cash flow shortfall and interest burden (specification (2)). While both the KZ index and interest burden are not significant, the negative coefficient on cash flow shortfall indicates that *less* cash-constrained firms are more likely to grant stock options. Not finding evidence that cash constraints matter for ESO grants is consistent with findings in the previous literature (Bergman and Jenter (2007)) but inconsistent with the hypothesis that stock options are mainly used to compensate employees when cash is scarce. The main result on firm volatility is not affected by including these measures of cash constraints. I next include a dummy variable for new-economy firms that confirms prior findings that these companies grant more ESOs (Ittner et al. (2003)). Again, the volatility coefficient is unaffected.

Next, I include measures of past stock returns to make sure that I am not capturing effects related to trend extrapolation or optimism (Bergman and Jenter (2007)). Consistent with the theoretical distinction between biased beliefs and a preference for long shots, the positive relation between firm risk and ESO plans remains essentially unchanged when controlling for contemporaneous and prior 2-year stock returns. In the next check, I include a measure of tax convexity used in Babenko and Tserlukevich (2009). Consistent with their findings, broad-based ESO plans are more common among firms with volatile earnings. Again, this effect cannot explain the positive connection between stock return volatility and ESO plans. Specification (6) in Table 5 includes all additional control variables. Specification (7) runs the complete specification with MSA-year effects and industry effects to control for neighborhood effects that might be related to geographical industry clustering (Kedia and Rajgopal (2009)). Specification (8) shows that a probit model with industry and year dummy variables yields very similar results.

The results are economically significant. For example, based on specification (6), a 1-standard-deviation increase in firm volatility increases the chance of seeing a broad-based option plan by 5.9% ($= 0.272 \times 0.217$), or 10.1% relative to the sample mean of ESOPlan ($= 0.059/0.585$). Overall, the results strongly support the prediction of the calibrated model that risky firms are more likely to have a broad-based ESO plan.

D. Firm Volatility and the Size of Stock Option Grants

The 2nd main hypothesis from the calibrated model is that riskier firms should grant more ESOs. I therefore regress the per employee number of stock options to nonexecutive employees on control variables suggested by the prior literature and fixed effects.[30] The main regressions I run will be ordinary least squares (OLS) regressions on the subsample of firms that grant options (controlling for sample selection), as well as Tobit regressions. Standard errors in all regressions are clustered at the firm level.

In addition to the baseline controls used in Table 5, I include the dividend yield and the log of the average grant-date stock prices reported in ExecuComp, because these variables influence the Black-Scholes (1973) value of the option, and because a firm with a much higher stock price or much lower dividend must grant fewer options to deliver the same value. To address the issue of sample selection for the OLS regressions, I use a Heckman (1976) 2-stage approach. I compute the inverse Mills ratio from the fitted values of the probit model in Table 5, and I then include this variable, which I report as "Heckman's lambda," as an additional regressor in 2nd-stage OLS regressions.

Table 6 presents results. Across all specifications, higher volatility is associated with more ESOs. As before, these regressions include industry-year effects, so they indicate that labor market conditions or other, potentially unobservable

TABLE 6

Size of Option Grants

Table 6 presents regressions of the number of employee stock options (ESOs) on firm volatility. All variables have been previously defined in Table 3. "Heckman's Lambda" is a self-selection variable from a 1st-stage probit model. Industry dummy variables are based on the 3-digit SIC code. Marginal effects computed at the mean for firms with ESO plans are reported for the Tobit model. Robust *t*-statistics (for the OLS model) and *z*-statistics (for the Tobit model) with clustering at the firm level are given below the coefficient estimates.

	Dependent Variable								
	$\ln(1+n_O)$								
Variable	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	Tobit
Volatility	1.796	1.742	1.629	1.491	1.059	1.483	1.166	0.705	0.696
	8.22	6.95	9.05	7.36	4.35	4.72	4.65	3.15	3.89
ln(Sales)	−0.031	−0.061	−0.077	−0.065	−0.036	−0.046	−0.126	−0.174	−0.030
	−1.17	−2.06	−3.38	−2.68	−1.30	−1.36	−4.22	−2.78	−1.56
Tobin's Q	0.153	0.172	0.173	0.213	0.197	0.207	0.193	0.097	0.051
	8.61	8.77	11.74	11.34	9.24	6.85	7.36	4.87	2.65
R&D	1.173	2.036	0.722	0.682	0.833	1.374	1.162	0.506	2.774
	1.87	3.17	1.36	1.16	1.35	1.98	1.71	0.65	5.99
Long-Term Debt > 0	−0.158	−0.387	−0.304	−0.308	−0.397	−0.234	−0.205	−0.097	−0.142
	−2.17	−4.70	−4.89	−4.71	−4.67	−2.27	−2.37	−1.55	−2.51
$\ln(P_0)$	−0.317	−0.288	−0.263	−0.304	−0.326	−0.363	−0.430	−0.417	−0.094
	−6.76	−5.53	−6.84	−6.88	−6.41	−5.39	−7.97	−9.00	−2.56
Dividend Yield	−8.774	−2.569	−0.845	−0.590	−1.602	−11.385	−14.061	−8.866	−6.430
	−2.42	−0.71	−0.27	−0.18	−0.45	−2.94	−4.17	−2.70	−3.04
Heckman's Lambda	−2.044	−1.887	−2.040	−2.306	−2.403	−1.598	−0.491	0.720	
	−4.86	−4.45	−6.10	−6.13	−6.07	−3.43	−1.23	2.05	
KZ-Index	−0.207					−0.156	−0.156	−0.068	−0.037
	−8.54					−4.98	−5.94	−2.81	−1.68
CF Shortfall		−0.675				−0.423	−0.368	−0.192	−0.593
		−3.20				−1.61	−1.78	−0.99	−3.54
Interest Burden		−0.006				−0.002	−0.060	−0.038	−0.003
		−0.32				−0.11	−2.40	−5.92	−0.61

(continued on next page)

[30]I use the number of options, rather than the Black-Scholes (1973) value of options, because there is a mechanical relation between Black-Scholes value and volatility that might confound my inferences.

TABLE 6 (continued)

Size of Option Grants

Variable	Dependent Variable								
	$\ln(1+n_O)$								
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	Tobit
New Economy Firm			0.899			0.979	0.862		0.543
			5.37			4.35	4.80		5.07
Return($t-1$, t)				−0.138		−0.152	−0.133	−0.087	−0.065
				−5.24		−2.98	−2.77	−3.10	−3.14
Return($t-3$, $t-1$)				0.011		−0.155	−0.055	0.038	−0.110
				0.27		−2.25	−0.97	0.89	−2.64
Earnings volatility					0.004	0.004	0.000	−0.006	0.011
					0.60	0.49	0.03	−1.15	2.54
Firm fixed effects								Yes	
Year dummies								Yes	Yes
Year × MSA dummies							Yes		
Industry dummies							Yes		Yes
Industry × Year dummies	Yes	Yes	Yes	Yes	Yes	Yes			
Pseudo/Adj. R^2	0.710	0.693	0.708	0.696	0.682	0.706	0.751	0.906	0.342
N	6,309	5,583	8,510	7,926	5,966	4,296	4,205	4,296	7,936

factors on the industry level cannot explain my findings (even if these factors are time varying). Again, since the industry-year effects take out all systematic components at this level, the volatility coefficient is effectively measuring the idiosyncratic component of volatility. Hence, the positive sign is consistent with the probability weighting model, but not with the retention model. Controlling for neighborhood effects by introducing MSA × year effects along with industry fixed effects also does not change my results. These results indicate a very robust cross-sectional relationship between firm volatility and stock option grants to nonexecutive employee, which is consistent with the calibrated model developed in the previous sections.

A testable time-series prediction from the model is that stock option grants should increase when the firm becomes more volatile. Specification (8) in Table 6 tests this prediction by including firm fixed effects. The coefficient on volatility decreases but continues to be highly statistically significant (t-stat. = 3.15). These regressions also show that my results are not driven by time-invariant unobserved heterogeneity at the firm level. To further ensure that sample selection is not an issue, I estimate a Tobit model. The results are essentially unchanged.

The results are again economically significant. For example, a 1-standard-deviation increase in firm volatility (21.7%) increases the number of stock options per nonexecutive employee by about 32.1% in the model with industry × year fixed effects (specification (6)), and 15.3% in the model with fixed effects. Overall, these results provide strong support for the 2nd main prediction of the calibrated model: Riskier firms grant more ESOs.

E. Stock Option Grants and the Degree of Probability Weighting

The 3rd prediction of the calibrated model is that stock option grants increase in the degree of probability weighting. This prediction is particularly hard to test, since the variation of the degree of probability weighting across employees is very hard to measure. In this section I propose 2 variables to capture the degree of probability weighting δ.

The 1st variable I use is an indicator for new-economy firms. Anecdotal evidence suggests that many employees chose to leave better-paying jobs in more traditional industries to work for high tech start-up firms during the 1990s in the hope of making a fortune. Similarly, students from elite universities frequently preferred employment in the new-economy sector to more traditional lines of work such as investment banking, with prospects to "strike it rich" through stock options being one of the reasons (e.g., Varian (2004)). I therefore conjecture that employees in the new-economy sector on average place more emphasis on small chances of large gains (i.e., they are likely to have a higher degree of probability weighting).

The results from the previous sections are consistent with this conjecture (Tables 5 and 6). I test another prediction of the model in Table 7: The number of stock options should be increasing in the interaction between firm volatility and probability weighting (because the difference between certainty equivalent and the Black-Scholes (1973) value increases toward the top right corner in both panels in Table 2). I therefore look at the interaction effect between volatility and the new-economy firm dummy variable. Columns 1 and 2 of Table 7 report that this prediction is borne out by the data. The impact of volatility on ESO grants is about twice as high for new-economy firms than for old-economy firms, using both the baseline set as well as the extended set of variables as controls.

A 2nd variable I consider has been suggested by Kumar et al. (2011). These authors present extensive evidence to suggest that the ratio of Catholics to Protestants in a county (CPRATIO) is a good proxy for gambling attitudes of the average inhabitant of the county. The underlying rationale is very different views on gambling expressed in Catholic and Protestant teachings (see their paper for evidence). In one of their applications, Kumar et al. show that the proportion of Catholics and Protestants in the county of the firm's headquarters predicts the size of stock option grants.

In the next set of tests, I incorporate their religion-based gambling proxy into the specifications used in Tables 5 and 6. These tests are closely related to Kumar et al. (2011), but I use a different dependent variable (n_O vs. the Black-Scholes (1973) value of options), a different set of control variables, and different estimation techniques (LPM and 2-stage least squares). The central difference is that they focus on CPRATIO, while I focus on firm risk.[31] Specifications (7) and (8) are new to my paper. My results complement their evidence.

[31]Kumar et al. (2011) do not control for volatility in their baseline regressions. In one of their additional tests, they split their baseline sample into high- and low-volatility firms. They do not control for volatility, and they do not test if the coefficient on CPRATIO is significantly different across the subsamples. In another test, they report county fixed effects regressions with an interaction between volatility and CPRATIO. Because CPRATIO is defined on the county level, these tests speak to the difference between high- and low-volatility firms within one county, but the baseline effect of CPRATIO cannot be separately determined. Hence, this regression cannot determine how stock option grants change with the degree of probability weighting for a *given* level of firm risk (the vertical dimension in Table 2).

TABLE 7

Option Grants and the Degree of Probability Weighting

Table 7 presents regressions of the number of employee stock options on firm volatility and proxies for the degree of probability weighting. The dependent variable in the LPMs in columns (3) and (4) is ESOPlan. The dependent variable in all other regressions is $\ln(1 + n_O)$. CPHIGH is an indicator variable that is high if the ratio of Catholics to Protestants in the county population where the firm is headquartered is above median in a given year. "Heckman's Lambda" is a self-selection variable from a 1st-stage probit model. All other variables have been previously defined in Table 3. Additional control variables are the control variables used in Table 6. Industry dummy variables are based on the 3-digit SIC code. Robust t-statistics with clustering at the firm level are given below the coefficient estimates.

Variable	OLS (1)	OLS (2)	LPM (3)	LPM (4)	OLS (5)	OLS (6)	OLS (7)	OLS (8)
Volatility	1.196	1.021	0.172	0.180	1.731	1.470	1.329	0.913
	6.82	3.64	3.97	2.58	12.53	7.14	7.17	3.23
Volatility × New Economy Firm	1.081	0.996						
	5.28	3.07						
New Economy Firm	−0.180	−0.045		0.162		1.028		1.001
	−1.19	−0.22		2.93		5.67		5.67
CPHIGH			0.048	0.040	0.223	0.156	−0.084	−0.215
			3.45	2.16	4.93	2.69	−0.91	−1.79
Volatility × CPHIGH							0.583	0.800
							3.51	3.01
ln(Sales)	−0.180	−0.163	−0.023	−0.007	−0.115	−0.094	−0.111	−0.087
	−8.35	−5.67	−4.56	−0.90	−5.83	−3.53	−5.64	−3.23
Tobin's Q	0.159	0.246	0.007	0.003	0.176	0.224	0.176	0.223
	11.77	9.82	1.99	0.40	14.44	9.42	14.64	9.49
R&D	2.250	3.271	0.415	0.907	1.224	1.776	1.056	1.535
	5.21	5.59	3.59	5.06	2.28	2.77	1.97	2.45
Long-Term Debt > 0	−0.127	−0.121	−0.016	−0.032	−0.329	−0.247	−0.321	−0.244
	−2.15	−1.39	−1.10	−1.32	−6.41	−3.12	−6.30	−3.13
$\ln(P_0)$	−0.160	−0.182			−0.251	−0.403	−0.256	−0.408
	−4.56	−3.25			−8.30	−8.34	−8.52	−8.61
Dividend Yield	3.993	3.875			−4.153	−11.526	−3.801	−10.902
	1.73	1.33			−1.74	−4.24	−1.59	−4.02
Heckman's Lambda	−1.168	−0.857			−1.165	−0.666	−1.259	−0.826
	−9.53	−6.07			−4.48	−2.05	−4.80	−2.50
Additional controls	No	Yes	No	Yes	No	Yes	No	Yes
Year dummies	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Industry dummies	No	No	Yes	Yes	Yes	Yes	Yes	Yes
Adj. R^2	0.580	0.541	0.269	0.259	0.718	0.735	0.719	0.737
N	8,510	4,296	14,612	7,936	8,510	4,296	8,510	4,296

In specifications (3) and (4), I reestimate the LPM from Tables 5 and 6 and include a dummy variable, CPHIGH, that equals 1 if the county in which the firm is headquartered has an above-median CPRATIO (i.e., high gambling propensity) in the year. Specifications (5)–(8) use the number of stock options as a dependent variable. These results show that, conditional on firm volatility, stock option plans are more common, and stock option grants are larger, for firms located in areas where employees are more likely to have a higher degree of probability weighting. Lastly, the interaction between firm risk and CPHIGH is positively related to the size of stock option grants, which is consistent with moving more into the top right corner of Table 2. Consistent with intuition, firms can profit most if both their employees are more likely to find long shots attractive, and if their stock looks attractive as a gamble.

Overall, the evidence from two different proxies for the degree of probability weighting provides additional support to the prediction of the theoretical model developed in the previous sections.

V. Conclusion

In this paper I show empirically, using a sample of over 2,200 U.S. firms over the years 1992–2005, that firms with high stock return volatility grant more stock options to their nonexecutive employees. These findings are not driven by existing explanations in the literature. In particular, firm volatility does not simply capture small firms, firms in special industries (e.g., technology stocks), cash-constrained firms, or firms with convex tax schedules. More generally, I show using fixed effects regressions that unobserved invariant factors on the industry-year level, the MSA-year level, and the firm level cannot explain the positive relation between firm volatility and stock option grants. The results are not driven by alternative models based on employee retention motives or employee optimism. Overall, the findings suggest that employee preferences for lottery-like payoffs can explain a significant fraction of both the time-series and cross-sectional variation in ESO grants. A calibrated model in which a risk-neutral firm bargains with employees with cumulative prospect theory preferences can explain the empirical findings remarkably well. The results suggest that risky firms can profitably use stock options to cater to an employee demand for long-shot bets, which adds a new dimension to the debate on the effectiveness of stock option compensation.

Since this is the first paper to introduce probability weighting into the compensation literature, there are some limitations. First, the lack of available experimental and psychological guidance on how individuals set reference points for complex distributions like payoffs from stock options is a clear obstacle for using prospect theory in applied work. Second, my approach is in reduced form, and I do not solve for the optimal contract. Instead, I model contracts based on the structure observed in the data. Third, my model implies potentially large savings in wage costs for firms with broad-based option plans. Good wage data for individual firms are not publicly available for most corporations, so this implication is hard to test. Empirically establishing that firms lower their wage bills by catering to an employee preference for stock options and more accurately quantifying the wealth transfers in the process would be very valuable.

Appendix A. Proofs

1. Proof of Proposition 1

In order to prove Proposition 1, the following two lemmas will be useful:

Lemma 1. The prospect value of the contract (n_o, ϕ_o) does not depend on the base salary received and is homogeneous of degree α in the number of options n_o if the reference point is given by $RP = n_o\theta + \phi$ (Assumption 1).

Proof.

$$\begin{aligned} \mathrm{E}^{\psi}(n_o, \phi) &\equiv \mathrm{E}^{\psi}\left[v\left(n_o \max\left(P_T - K, 0\right) + \phi - RP\right)\right] \\ &= \mathrm{E}^{\psi}\left[v\left(n_o\left(\max\left(P_T - K, 0\right) - \theta\right)\right)\right] \\ &= \mathrm{E}^{\psi}\left(n_o\right), \end{aligned}$$

where the 2nd equality follows from using the definition of the reference point in Assumption 1. This proves the 1st part of Lemma 1. To prove the 2nd part, note that

$$\begin{aligned}
\mathrm{E}^{\psi}(n_o) &= -\lambda \int_0^{\theta+K} \left(-\left(n_o\left(\max\left(P_T - K, 0\right) - \theta\right)\right)\right)^{\alpha} d\psi\left(F(P_T)\right) \\
&\quad + \int_{\theta+K}^{\infty} \left(n_o\left(\max\left(P_T - K, 0\right) - \theta\right)\right)^{\alpha} d\psi\left(F(P_T)\right) \\
&= n_o^{\alpha} \cdot \left(-\lambda \int_0^{\theta+K} \left(-\left(\max\left(P_T - K, 0\right) - \theta\right)\right)^{\alpha} d\psi\left(F(P_T)\right)\right. \\
&\quad \left. + \int_{\theta+K}^{\infty} \left(\max\left(P_T - K, 0\right) - \theta\right)^{\alpha} d\psi\left(F(P_T)\right)\right) \\
&= n_o^{\alpha} \cdot \mathrm{E}^{\psi}(1). \qquad \square
\end{aligned}$$

Lemma 2. There does not exist an optimal contract $\left(n_o', \phi'\right)$ such that the participation constraint does not hold as an equality.

Proof. The proof will proceed by contradiction. Suppose there exists an optimal contract (n_o', ϕ') such that

$$\text{(A-1)} \qquad \mathrm{E}^{\psi}\left[v\left(n_o' \max\left(P_T - K, 0\right) + \phi' - RP\right)\right] \quad > \quad \mathrm{E}^{\psi}\left[v\left(\overline{V} - RP\right)\right].$$

Using the definition of the reference point in Assumption 1 and noting that the outside option $\overline{V}$ is received with certainty, I get

$$\text{(A-2)} \qquad \mathrm{E}^{\psi}\left[v\left(n_o'\left(\max\left(P_T - K, 0\right) - \theta\right)\right)\right] \quad > \quad v\left(\overline{V} - n_o'\theta - \phi'\right).$$

The left-hand side does not depend on the fixed wage ϕ', while

$$\frac{\partial}{\partial \phi} v\left(\overline{V} - n_o'\theta - \phi'\right) \quad < \quad 0.$$

Since the right-hand side of expression (A-2) is continuous in ϕ, the value function has unbounded support, since $v(x) \to \infty$ as $x \to \infty$, and since there are no restrictions on ϕ, there exists $\phi'' < \phi'$, such that

$$\mathrm{E}^{\psi}\left[v\left(n_o'\left(\max\left(P_T - K, 0\right) - \theta\right)\right)\right] \quad = \quad v\left(\overline{V} - n_o'\theta - \phi''\right).$$

Since the number of options is unchanged and since $\phi'' < \phi'$, the firm pays strictly less for the contract (n_o', ϕ''), while still satisfying the participation constraint. Hence, (n_o', ϕ') cannot be optimal. $\square$

It follows immediately from Lemma 2 that for any optimal contract (n_o^*, ϕ^*) it must be true that

$$\text{(A-3)} \qquad \mathrm{E}^{\psi}\left[v\left(n_o^*\left(\max\left(P_T - K, 0\right) - \theta\right)\right)\right] \cdot v\left(\overline{V} - n_o^*\theta - \phi^*\right) \quad \geq \quad 0.$$

Hence, one needs to consider two cases:

Case 1. $\quad \mathrm{E}^{\psi}\left[v\left(n_o^*\left(\max\left(P_T - K, 0\right) - \theta\right)\right)\right] \geq 0.$

The certainty equivalent CE, which depends on both n_o^* and ϕ^*, is implicitly defined by

$$\begin{aligned}
\text{(A-4)} \qquad \mathrm{E}^{\psi}\left[v\left(n_o^*\left(\max\left(P_T - K, 0\right) - \theta\right)\right)\right] &\equiv \overline{\mathrm{E}^{\psi}\left(n_o^*\right)} \\
&= \left(CE\left(n_o^*, \phi^*\right) e^{rT} - n_o^*\theta - \phi^*\right)^{\alpha}.
\end{aligned}$$

Rewriting the participation constraint using expression (A-4) gives

$$\left(CE\left(n_o^*, \phi^*\right) e^{rT} - n_o^*\theta - \phi^*\right)^{\alpha} \quad = \quad \left(\overline{V} - n_o^*\theta - \phi^*\right)^{\alpha},$$

which implies

$$CE\left(n_o^*, \phi^*\right) = \overline{V}e^{-rT}. \tag{A-5}$$

From expression (A-4) I get for the certainty equivalent

$$CE\left(n_o^*, \phi^*\right) = \overline{\mathrm{E}^{\psi}\left(n_o^*\right)}^{1/\alpha} \cdot e^{-rT} + n_o^* \theta \cdot e^{-rT} + \phi^* e^{-rT},$$

and since prospect value is homogeneous of degree α, I have

$$\begin{aligned} CE\left(n_o^*, \phi^*\right) &= n_o^* \cdot \overline{\mathrm{E}^{\psi}\left(1\right)}^{1/\alpha} \cdot e^{-rT} + n_o^* \theta \cdot e^{-rT} + \phi^* e^{-rT} \\ &= n_o^* \cdot CE\left(1, 0\right) + \phi^* e^{-rT}. \end{aligned}$$

Thus, any contract that satisfies the original participation constraint must also satisfy

$$n_o^* \cdot CE\left(1, 0\right) + \phi^* e^{-rT} = \overline{V}e^{-rT}. \tag{A-6}$$

Case 2. $\mathrm{E}^{\psi}\left[v\left(n_o^*\left(\max\left(P_T - K, 0\right) - \theta\right)\right)\right] < 0.$

The certainty equivalent CE, which depends on both n_o^* and ϕ^*, is implicitly defined by

$$\begin{aligned} \mathrm{E}^{\psi}\left[v\left(n_o^* \left(\max\left(P_T - K, 0\right) - \theta\right)\right)\right] &\equiv \overline{\mathrm{E}^{\psi}\left(n_o^*\right)} \\ &= -\lambda\left(-\left(CE\left(n_o^*, \phi^*\right) \cdot e^{rT} - n_o^* \theta - \phi^*\right)\right)^{\alpha}. \end{aligned} \tag{A-7}$$

Rewriting the participation constraint using expressions (A-7) and (A-3) gives

$$-\lambda\left(-\left(CE\left(n_o^*, \phi^*\right) \cdot e^{rT} - n_o^* \theta - \phi^*\right)\right)^{\alpha} = -\lambda\left(-\left(\overline{V} - n_o^* \theta - \phi^*\right)\right)^{\alpha},$$

and thus analogous to equation (A-5),

$$CE\left(n_o^*, \phi^*\right) = \overline{V}e^{-rT}. \tag{A-8}$$

From expression (A-7) I get for the certainty equivalent

$$CE\left(n_o^*, \phi^*\right) = -\left(-\lambda^{-1} \cdot \overline{\mathrm{E}^{\psi}\left(n_o^*\right)}\right)^{1/\alpha} \cdot e^{-rT} + n_o^* \theta \cdot e^{-rT} + \phi^* e^{-rT},$$

and since the subjective value is homogeneous of degree α, I have

$$\begin{aligned} CE\left(n_o^*, \phi^*\right) &= n_o^* \cdot \left[-\left(-\lambda^{-1} \cdot \overline{\mathrm{E}^{\psi}\left(1\right)}\right)^{1/\alpha} + \theta\right] \cdot e^{-rT} + \phi^* e^{-rT} \\ &= n_o^* \cdot CE\left(1, 0\right) + \phi^* e^{-rT}, \end{aligned}$$

which together with equation (A-8) leads to the formulation for the participation constraint as given in equation (A-6).

Replacing the participation constraint in expression (4) with equation (A-6), and substituting, the maximization problem simplifies to

$$\min_{n_o} \overline{V}e^{rT} - n_o^*\left(CE - BS\right),$$

where CE and BS are the Black-Scholes (1973) values for one stock option. If $CE > BS$, then $n_o^* > 0$ and $n_o^* = 0$ otherwise, which proves Proposition 1. □

2. Proof of Proposition 2

Introducing a strictly convex cost function $c(n_o)$, the maximization problem becomes

$$\min_{n_o} \quad \overline{V}e^{rT} - n_o^* \left(CE - BS\right) + c(n_o).$$

The 1st-order condition is

$$CE - BS \quad = \quad c'(n_o).$$

Since $c(\cdot)$ is strictly increasing, n_o increases in $CE - BS$, which proves Proposition 2. □

Appendix B. Robustness of the Reference Point Specification

Appendix B shows that the calibration results are robust to sensible changes in the proposed reference point specifications.

Figure B1 shows the impact of changing the reference point assumptions by changing the parameter θ in equation (5). If the reference point is the Black-Scholes (1973) value, I multiply this value by a scalar $\nu \in [0, 2]$. Hence, an employee with $\nu = 2$ has an aspiration level for stock option payoffs that is 100% higher than in the base case with $\nu = 1$. For $\nu = 0$, all option payoffs are coded as gains, and the value function of the employee becomes concave over all payoffs from the pay contract. Likewise, if the reference point stems from an intrinsic value heuristic, I allow for a higher (or lower) expected level of future stock prices by multiplying the growth rate of the stock r by $\nu \in [0, 2]$. Figure B1 shows the difference between certainty equivalent and Black-Scholes value scaled by P_0 for different combinations of ν with the degree of firm volatility (Graphs A and B) and probability weighting δ (Graphs C and D).

From Graphs A and B of Figure B1 one sees that for all values of ν the benefit of granting options, as measured by $(CE - BS)/P_0$, is highest for high-volatility firms. Hence, the prediction of more options at riskier firms is generally robust to different reference point specifications. More interesting are the effects on the predicted presence of broad-based option plans from changing the baseline aspiration level. For small to moderate changes (roughly about $\pm 50\%$), the model predicts no plans at low-volatility firms. For large changes, however, the model predicts options for all firms. To understand this, note that ν governs whether payoffs fall into the loss space or the gain space and whether or not the kink in the value function (a point of locally extreme risk aversion) is in the center of the payoff distribution. For very high reference points (high values of ν), most payoffs from the contract fall into the loss space. Since the employee is risk loving over this range, she will be attracted by risky gambles. For very low reference points, only the gain space is relevant. Since the curvature of the value function over gains is small (since most of the aversion toward risky gambles is captured by the kink in the value function), even small degrees of probability weighting are enough to overcome the risk premia demanded by the employee for bearing option risk. Hence, observed instances of broad-based plans at low-volatility firms may be related to extreme aspiration levels (both positive and negative) of a few representative employees.

Graphs C and D of Figure B1 show that the benefit of granting options strictly increases as the degree of probability weighting increases. As in the base case, the driving force behind broad-based option plans in my model is probability weighting. The convexity of the loss space by itself is not sufficient to generate certainty equivalents in excess of the Black-Scholes (1973) value, even if the reference point is relatively large (high values of ν in Figure B1).

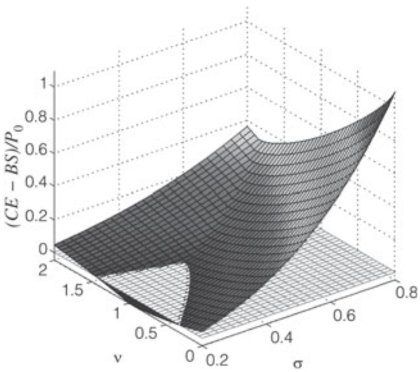
Overall, Figure B1 shows that the main implications from the model are generally robust to sensible variations in the reference point specification.

FIGURE B1

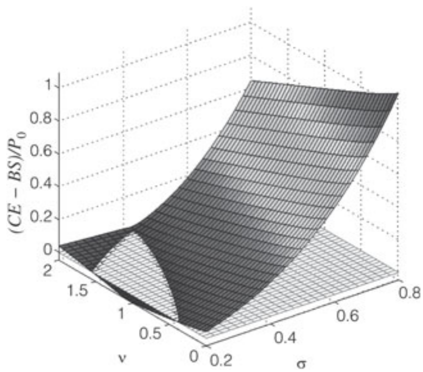
Robustness with Respect to Reference Point

Figure B1 shows the difference between certainty equivalent to the employee, *CE*, and Black-Scholes (1973) value, *BS*, scaled by the share price P_0, when the reference point is decreased or increased by a factor ν. Graphs A and B show results for 2 different reference points when the volatility, σ, of the stock returns of the firm is changed simultaneously. Graphs C and D show the same results varying the degree of probability weighting, δ. Broad-based ESO plans are predicted whenever $CE > BS$ and the size of the plan increases in $CE - BS$.

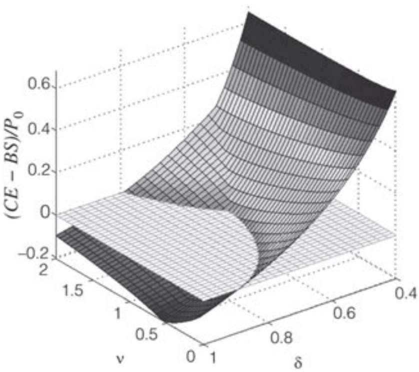
Graph A. $\theta = vBS$; $\delta = 0.65$



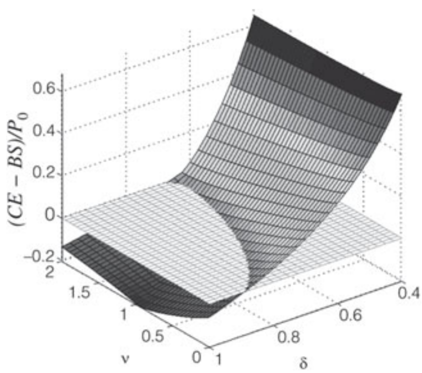
Graph B. $\theta = P_0 e^{\nu rT} - K$; $\delta = 0.65$



Graph C. $\theta = vBS$; $\sigma = 0.40$



Graph D. $\theta = P_0 e^{\nu rT} - K$; $\sigma = 0.40$



Appendix C. Probability Weighting and Stock Option Exercises

The paper shows that a simple model based on employees who have cumulative prospect theory preferences generates predictions that are surprisingly consistent with the data on stock option grants. In this Appendix, I show that a model with probability weighting is not incompatible with early exercise of ESOs.[32]

[32]Other papers in the literature have suggested that early exercise behavior is also consistent with rational explanations (e.g., Bettis, Bizjak, and Lemmon (2005)). The purpose of this section is thus not to argue that more traditional models cannot explain exercise behavior. The purpose is to argue that early exercise does not per se constitute an argument against a probability weighting model.

The key idea is that, as a default, individuals evaluate investment decisions over short horizons (they are "myopic"). This builds on the work by Benartzi and Thaler (1995), who argue that for a typical investment portfolio the relevant horizon is about 1 year. Heath, Huddart, and Lang (1999) and Odean (1998) find that option exercises are significantly related to short-term stock price run-ups, which suggests that for stock options even horizons shorter than 1 year may be relevant. Typical vesting schedules preclude exercising options for a period of several years, and it thus seems reasonable to assume that the evaluation horizon is extended accordingly. Once the options are vested, however, the shorter "default" horizon becomes relevant again. I argue that the shorter this horizon, the more likely is an option exercise, consistent with empirical studies that find that ESOs are usually exercised quickly after the vesting date (Huddart and Lang (1996)).

To fix ideas, let the grant date be $T=0$, let T_1 be the vesting date, and let T_2 be called the horizon date. In T_1 the employee decides whether or not to exercise the options. If she is myopic in the sense of Benartzi and Thaler (1995), she will base this decision on the possible payoffs from exercising the stock options in T_2, which are dependent on the stock price P_{T_2} given by

$$P_{T_2} \quad = \quad P_{T_1} \exp \left\{ \left(r - \frac{\sigma^2}{2} \right) (T_2 - T_1) + u\sigma\sqrt{T_2 - T_1} \right\}.$$

She will exercise in T_1 if the payoff from exercising, $P_{T_1} - K$, is positive and greater than the certainty equivalent for holding the options until T_2, which is implicitly defined by

$$\mathrm{E}^{\psi} \left[v \left(\max \left(P_{T_2} - K, 0 \right) - RP \right) \right] \quad = \quad v \left(CE - RP \right).$$

The intuition is now that the longer the option is held, the more skewed the payoff distribution will become. Since the employee overweights small probabilities of large gains, this tends to increase the certainty equivalent and hence decreases the probability of an option exercise in T_1.

I again test the intuition by calibrating a simple benchmark model. I assume that $T_1 = 4$ and that the stock price at P_0 has increased to $P_{T_1} = P_0 e^{rT_1}$, the expected value. The option is thus in the money as $K = P_0$ and so $P_0 e^{rT_1} - K > 0$. The reference point of the employee is denoted, without loss of generality, by $RP = P_{T_1} - K + \theta$, where θ is any number with $\theta > K - P_{T_1}$. I assume $\theta = P_{T_1}(e^{rT_2} - 1)$ in the calibrations, which implies that the employee's best guess about the stock price in T_2 is the expected value as seen from time T_1. I report results only for a degree of probability weighting of $\delta = 0.65$. All other parameters are the same as in Section III.

Panel A of Table C1 reports that the intuition is borne out by the model. For all levels of firm volatility, the ratio of certainty equivalent to intrinsic value at time T_1 is strictly increasing in T_2. A ratio smaller than 1 indicates option exercise. Hence, for evaluation horizons smaller than 6 months, the model predicts exercises for all volatilities. The model also generates another plausible result: The more the options are in the money in T_1 (i.e., the higher P_{T_1} relative to the strike price), the more likely is an exercise decision (Panel B). Intuitively, a higher stock price at the vesting date ceteris paribus increases the reference point for the option payoff at the horizon date, which implies that more option payoffs fall into the loss space. Hence, a higher ratio of actual stock price to strike price tends to make options unattractive to employees with cumulative prospect theory preferences.

Heath et al. (1999) have documented that empirical exercise behavior of employees is sensitive to reference points, most notably whether or not the stock price exceeds the 52-week high stock price. They also argue that prospect theory is largely consistent with their findings. While a truly dynamic cumulative prospect theory model that could integrate such reference point effects is still unavailable, the results presented here on stock option grants and exercises and the complementary work by Heath et al. (1999) suggest that prospect theory has the potential to explain individual behavior in stock option programs in a unified framework.

TABLE C1

Exercise Decisions

Table C1 presents the influence of the evaluation horizon and the moneyness of options on exercise decisions. Panels A and B show the ratio of certainty equivalent when holding the option, *CE*, to the intrinsic value obtained by exercising, $P_{T_1} - K$. The option is not exercised if this value is greater than 1 (cells with bold numbers in the table). The evaluation horizon is $T_2 - T_1$. Panel A assumes $P_{T_1} = P_0 e^{rT_1}$. For Panel B an evaluation horizon of 6 months is assumed. The calculations use a lognormal stock price distribution with $T_1 = 4$ years and $r = 5\%$. The strike price of the option K is set equal to the grant date stock price P_0. Preference parameters are $\alpha = 0.88$, $\lambda = 2.25$, and $\delta = 0.65$. The reference point is taken to be equal to the statistically expected value of P_{T_2} less the strike price K.

Panel A. Influence of the Evaluation Horizon on Option Exercise

	Firm Volatility									
Horizon (years)	20%	25%	30%	35%	40%	45%	50%	60%	70%	80%
0.10	0.232	0.287	0.337	0.381	0.419	0.454	0.485	0.540	0.588	0.633
0.25	0.371	0.436	0.489	0.535	0.576	0.614	0.649	0.714	0.775	0.833
0.50	0.505	0.571	0.628	0.678	0.725	0.770	0.812	0.894	0.973	**1.047**
0.75	0.599	0.668	0.728	0.784	0.837	0.888	0.938	**1.034**	**1.124**	**1.250**
1.00	0.677	0.748	0.813	0.874	0.933	0.990	**1.046**	**1.153**	**1.278**	**1.562**
2.00	0.925	**1.011**	**1.092**	**1.172**	**1.251**	**1.329**	**1.402**	**1.722**	**2.232**	**2.857**
4.00	**1.321**	**1.430**	**1.541**	**1.654**	**1.766**	**1.928**	**2.255**	**3.114**	**4.247**	**5.702**

Panel B. Influence of the Moneyness on Option Exercise

	Firm Volatility									
P_{T_1}/K (%)	20%	25%	30%	35%	40%	45%	50%	60%	70%	80%
105.00	**1.297**	**1.421**	**1.554**	**1.840**	**2.165**	**2.514**	**2.883**	**3.674**	**4.535**	**5.465**
110.00	0.838	0.924	**1.003**	**1.078**	**1.147**	**1.211**	**1.285**	**1.615**	**2.005**	**2.439**
120.00	0.542	0.609	0.667	0.720	0.769	0.815	0.860	0.947	**1.029**	**1.104**
130.00	0.402	0.466	0.520	0.566	0.608	0.647	0.684	0.754	0.820	0.885
150.00	0.254	0.310	0.360	0.403	0.441	0.475	0.507	0.563	0.615	0.664
200.00	0.126	0.157	0.190	0.222	0.254	0.284	0.311	0.360	0.403	0.441

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