Probability Weighting and Employee Stock Options

JOB MARKET PAPER

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Abstract

This paper documents that riskier firms grant more stock options to non-executive employees using a large panel of US firms from 1992 to 2005. A simple model in which a risk-neutral firm and an employee with cumulative prospect theory preferences bargain over the employee's pay package can provide an explanation for this otherwise puzzling behavior. The key feature which makes stock options attractive is the well-established tendency of individuals to overweight small probabilities of large gains. I calibrate the model using standard parameters from the experimental literature and find that it fits the data remarkably well. In addition, I show that probability weighting, when combined with the assumption of myopic employees, generates predictions that are quantitatively consistent with observed patterns of stock option exercises.

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1 Introduction

An estimated 9 million US employees in 3,000 companies participate in broad-based stock option plans which grant options to at least 50% of their employees.[1] This is surprising since these stock options are risky contracts and employees cannot sell or hedge them.[2] Hence, according to standard economic theory, risk-averse employees should demand a substantial risk premium for this kind of compensation. The fact that stock options are used so widely suggests that there must be offsetting benefits accruing to firms that grant options. For CEOs and other top executives, such benefits might stem from mitigating agency problems (Jensen and Meckling, 1976, Holmström, 1979). For non-executive employees, however, the widespread use of stock options is puzzling because it is not clear exactly which benefits outweigh the cost from risky option payoffs. In particular, standard incentive arguments that motivate executive compensation are unlikely to carry over to lower-level employees who cannot influence the stock price by their individual actions, and who cannot coordinate their actions easily because of the free-rider problem.[3] Adding to the puzzle is the empirical finding in this paper that companies with broad-based stock option plans are predominantly risky firms with high stock price volatilities.

This paper explores the ability of cumulative prospect theory (Tversky and Kahneman, 1992) to explain the widespread use of stock options to compensate non-executive employees. In particular, I concentrate on the role of probability weighting. Probability weighting is a non-linear transformation of objective probabilities and captures the well-documented tendency of individuals to overweight small probabilities and underweight medium to large probabilities in evaluating risky gambles.[4] This leads to both a preference for skewness and risk-seeking behavior for gambles involving small probabilities of large gains. The key proposition in this paper is that the lottery-like nature of stock options – their asymmetric payoff profile which combines large gains with small probabilities – makes them attractive to employees and thus allows firms to minimize compensation costs. I

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[1] Source: National Center for Employee Ownership (version of February 2008). The data is available at: http://www.nceo.org/library/eo_stat.html.

[2] Employees can only exercise their options (after the vesting period) but not sell them. Hedging is precluded either explicitly, through contracts with the granting firm, or implicitly because of trading costs, short-sale constraints or cognitive limitations. One possible exception are a small number of top executives with access to investment banks who provide specifically structured products to reduce exposure to company risk (Bettis, Bizjak, and Lemmon, 2001).

[3] See also Hall and Murphy (2003), Oyer and Schaefer (2005), and Bergman and Jenter (2007).

[4] The seminal work on probability weighting is Kahneman and Tversky (1979) and Tversky and Kahneman (1992). Gonzales and Wu (1999), Bleichrodt and Pinto (2000), and Abdellaoui, Vossmann, and Weber (2005) provide additional evidence. Applications of overweighting small winning probabilities include Thaler and Ziemba (1988), Cook and Clotfelter (1993), Hausch and Ziemba (1995), Loughran and Ritter (1995) and Jullien and Salanie (2000). Kachelmeier and Shehata (1992) provide direct evidence for risk-seeking behavior in gambles involving small probabilities and large monetary stakes. See also Camerer (2000) for a review of some of the literature.

start analyzing this proposition by developing a simple model of efficient pay-setting between a risk-neutral firm and an employee with cumulative prospect theory preferences. I then calibrate the model using standard parameter estimates from the experimental literature and show that it predicts that broad-based employee stock option plans are more common among firms with more volatile stock prices and that the per employee number of granted stock options increases with stock price volatility. In the second part of the paper, I test these predictions on the universe of ExecuComp firms from 1992 to 2005. I estimate the number of options granted to lower-level employees at the individual firm level and find that the theoretical predictions are strongly supported by the data, even after controlling for a large number of variables previously found to be important in the literature, and after including industry or firm effects.

The work in this paper is motivated by recent empirical research which shows that a sizeable subset of retail investors gamble in the stock market by investing into stocks with lottery-like features. In particular, these investors are willing to trade off skewness for lower average returns.[5] If retail investors want lottery-like stocks in their investment portfolios, a natural question to ask is whether they like stock options in their compensation packages because they come with a small chance of large gains. I operationalize the preference for lottery-like gambles by incorporating probability weighting in an otherwise standard wage bargaining model, where the firm tries to minimize compensation cost subject to the employee's participation constraint. The model predicts that options are granted if and only if the certainty equivalent of the first option for the employee exceeds the value of the option to a well-diversified outside investor, which is the economic cost of granting the stock option for the firm. Hence, if employees are subject to probability weighting, and if probability weighting raises the certainty equivalent sufficiently (which is, of course, not a given), an economic rationale for the use of stock options to compensate non-executive employees is that firms can reduce their personnel cost by granting overvalued stock options and by simultaneously reducing base salaries.[6] Such a mechanism is consistent with a growing body of empirical and survey evidence documenting that employees frequently value options in excess of the Black-Scholes value.[7] Standard concave utility models are in stark contrast to these findings since the value of options for

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[5] See Kumar (2008) and Han and Kumar (2008). Of course, the idea that gambling preferences can be important is not new to economics. For example, Markowitz (1952) hypothesizes that individuals who gamble prefer to "take large chances of a small loss for a small chance of a large gain" and that they like positive skewness in payoffs.

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

[7] See Lambert and Larcker (2001), Hodge, Rajgopal, and Shevlin (2006), Sawers, Wright, and Zamora (2006), Hallock and Olson (2006), and Devers, Wiseman, and Holmes (2007).

a risk-averse individual can never exceed the value to well-diversified outside investors. The model proposed in this paper, on the other hand, can easily explain why surveys find subjective values in excess of the Black-Scholes value by appealing to a preference for skewness based on probability weighting as an underlying driver. An implicit assumption of my model set-up is that probability weighting is particularly relevant inside the firm-employee relationship.[8] This is consistent with research in decision sciences showing that individuals like to gamble on things they know and on projects they are directly involved in (see Heath and Tversky, 1991, Kahneman and Lovallo, 1993, an the discussion in Section 8).

In calibrations, using available experimental evidence to pin down the parameters of cumulative prospect theory preferences, I show that my model generates predictions that are quantitatively important. My main variables of interest are the volatility of the stock price and the degree of probability weighting since they govern the thickness of the tails of the payoff distribution and the subjective overweighting of the tails, respectively. As expected I find that for a given volatility the certainty equivalent is increasing in the degree of probability weighting. For a given level of probability weighting, the ratio of certainty equivalent to objective option value is increasing in stock price volatility. In the benchmark specification, the model predicts that broad-based stock option plans exist in companies with high volatility, but not in companies with low volatility, with a cutoff level at about 40%. It also predicts that the number of employee stock options granted per employee increases in firm risk. I show that both predictions are consistent with data on stock option grants for firms in the ExecuComp universe. Without probability weighting these predictions change fundamentally: the objective value is always higher than the certainty equivalent and so employees always prefer cash compensation over equity-based compensation.

As an extension I explore implications of the model for stock option exercises. In the spirit of Benartzi and Thaler (1995), I propose a connection between the horizon over which an individual evaluates the option and the value attached to it. Myopic employees will exercise their option whenever the value of holding it for another period is less than the intrinsic value obtained by immediate exercise. In such a setting the vesting period becomes a crucial feature of option design. At the time of grant, the vesting period (often three years) is likely to lengthen the evaluation horizon used by the employee, which makes the payoff distribution from the options more skewed.

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[8] I do not make the claim that probability weighting is not relevant outside the firm-employee relationship. The literature on retail investors' preference for lottery-like stocks is an example where individuals (who are likely to be employees) make skewed gambles in the market. Conversely, Titman (2002) argues that in the late 1980s firms in Hong Kong issued overpriced warrants in response to investor demand for levered bets. What I argue is that there are good reasons to believe that firms are in a particularly good position to profit from probability weighting among their employees (see Section 8).

This results in a preference for options over cash compensation. After the vesting period, however, employees are likely to resort to their "default" evaluation horizon which is shorter (Benartzi and Thaler, 1995, argue that one year is plausible for equity investments). Since the payoff distribution of options is less skewed for shorter horizons, this increases the relative benefit of exercising early. Again, I show in calibrations of a probability weighting model that this idea is quantitatively meaningful: employees with short evaluation horizons (one year and less) tend to exercise their options early and the tendency to exercise early increases in the moneyness of the options – consistent with stylized facts of option exercise behavior.

My paper 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. Benartzi and Thaler (1995) propose a solution to the equity premium puzzle based on prospect theory and myopically loss-averse agents. Barberis, Huang, and Santos (2001) study the broader implications of loss aversion on asset prices. Hens and Vleck (2005) and Barberis and Xiong (2008) use a calibrated version of prospect theory to understand the disposition effect. Polkovnichenko (2005) shows that probability weighting is quantitatively consistent with observed household investment patterns. Barberis and Huang (2008) focus on probability weighting in the context of portfolio decisions. They show that cumulative prospect theory preferences can be consistent with the CAPM and explain why investors may hold underdiversified portfolios and prefer skewness in individual securities. In corporate finance, calibrated prospect theory models include Dittmann, Maug, and Spalt (2008), who explain the observed mix of stock and options in CEO compensation contracts by introducing loss-averse CEOs into the principal-agent model of Holmström (1979), and Maug and Spalt (2008) who use the same framework to analyze the optimal design of executive stock options. My contribution is to introduce a calibrated model with probability weighting into the corporate finance literature by analyzing an economically important domain: stock option compensation for lower-level employees.

Section 2 reviews the relevant literature on stock option compensation for non-executive employees. The model is developed and solved in Section 3. Section 4 presents calibrations and derives testable hypotheses on option grant behavior which are confirmed empirically in a large dataset for US firms in Section 5. Section 6 presents robustness checks. The relation between option grants and option exercises is investigated in Section 7. Section 8 presents arguments why firms may be in a particularly good position to exploit behavioral biases of employees. Section 9 concludes.

2 Related literature on stock options for non-executive employees

A standard argument for the use of stock options for top executives is that they align the interests of shareholders and managers by providing an incentive for managers to take actions that maximize shareholder value. In a similar vein, firms might issue options to incentivize non-executive employees. A serious caveat with this agency view of equity-based employee compensation is that actions of lower-level employees are unlikely to move stock prices at all, let alone substantially. Stock prices are an uninformative signal of an individual employee's effort and possible free-riding is bound to dwarf any incentive effect of equity-based compensation for non-executives.[9] Oyer and Schaefer (2005) calibrate a principal-agent model and conclude that, even without the free-rider problem, observed stock option packages are much too small to provide meaningful incentives. Moreover, the empirical evidence in Oyer and Schaefer (2005) and in this paper, that stock option grants to employees are larger for firms in riskier industries (or riskier firms, respectively) is at odds with standard agency-theoretic models. Incentives will thus play no role in my theoretical model.

Bergman and Jenter (2007) develop the theoretical argument under which circumstances firms can profit from employees who overvalue their firm's equity. They make the important observation that the ability of firms to exploit employees is limited by the ability of employees to buy equity claims in the market, which can explain why firms usually grant stock options instead of restricted stock to compensate lower-level employees. An important difference to the present treatment is that their model explicitly predicts the number of options to decrease in firm volatility.[10] In the empirical part of their paper, Bergman and Jenter (2007) find evidence for the hypothesis that employees extrapolate past stock returns and that employee stock option grants are timed to take advantage of positive employee sentiment. Note that this is logically 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

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[9] For related claims on the ineffectiveness of options to incentivize non-executive employees see Hall and Murphy (2003), Oyer and Schaefer (2005) and Bergman and Jenter (2007). Consistently, Kedia and Mozumdar (2002) document that granting employee stock options does not lead to superior stock market performance. Hochberg and Lindsey (2008) find that broad-based option plans lead to subsequent increases in accounting returns, which they argue is consistent with an incentive effect from options due to mutual monitoring. Note, however, that these results are also consistent with a model in which firms can lower personnel cost by granting options to lower-level employees, as is suggested in this paper.

[10] 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. They also show that this is empirically counterfactual. 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 CRRA utility and $\rho = 2.5$ would need to overestimate expected returns by 200% – appears too large to be plausible for average companies.

simply a modelling 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%. Following Bergman and Jenter (2007) I include past stock return as a proxy variable for investor sentiment in my regressions in the empirical part of the paper and find that this has no effect on the positive relation between stock options and firm volatility predicted by the probability weighting model.

Employee stock options could be a way to provide retention incentives, as their value is high in exactly those states of the world where demand for labor is highest (Oyer, 2004).[11] Hence, labor market conditions and industry specific factors may be first-order drivers of grant behavior. Oyer and Schaefer (2005) provide some evidence for this view. However, it is not obvious why risky instruments such as stock options should be the most efficient mechanism to provide retention incentives to risk-averse employees when alternatives such as retention bonuses, pension benefits as a function of years at the firm and the possibility of creating level-of-pay paths that benefit employees that stay with the firm, are available alternatives (see Hall and Murphy, 2003, for a more extensive discussion). I incorporate both industry volatility (as a measure of labor market competition) and industry fixed effects in my empirical analysis below and find some evidence consistent with the hypothesis that retention motives affect stock option grants on the industry level.

Stock options may be used in particular by cash-constrained firms (Yermack, 1995, Core and Guay, 2001). I include proxies for cash constraints in the empirical part of the paper and find mixed evidence, which is consistent with recent results in the literature (Ittner, Lambert, and Larcker, 2003, Bergman and Jenter, 2007).

Hall and Murphy (2003) advance the hypothesis that, prior to the new laws on option expensing which came into effect in 2005, options were perceived by boards as a cheap way to remunerate employees, since they did not carry an accounting charge. Analyzing the costs and potential benefits of option compensation, Oyer and Schaefer (2006) find that if stock option compensation was driven only by accounting considerations, firms would be willing to incur between \$0.5 to \$1 in real economic cost in order to boost pre-tax net income by \$1. They conclude that accounting considerations are "not the sole (or even the main) driver of option grants."

Babenko and Tserlukevich (2008) show that companies can obtain tax savings if their marginal tax rates are positively correlated with their taxable income. Employees tend to exercise stock options in good states of the world, which leads to a tax advantage for stock option compensation over fixed wage compensation if the company's tax schedule is convex. Babenko and Tserlukevich

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[11] Inderst and Mueller (2007) use a related idea on firm-specific human capital.

(2008) document a positive relation between tax convexity and stock option grants. At the same time they state that despite the documented tax advantage, tax considerations are not the main driver of stock option grants. I include a proxy for the convexity of the tax schedule in my regressions.

There are a number of additional empirical studies on factors influencing the existence or adoption of broad-based employee stock option plans. For the US, using cross-sectional data for 1998, Oyer and Schaefer (2005) provide some evidence for a positive relation between stock price volatility and existence of broad-based employee stock option plans. They also show, however, that in their sample firm volatility becomes insignificant when industry volatility is added as an additional explanatory variable. They conclude that industry volatility, and not firm volatility, drives option compensation.[12] Ittner, Lambert, and Larcker (2003), using survey data from the years 1999 and 2000, document that new economy firms are particularly likely to grant employee stock options. Krumova and Sesil (2006) find weak evidence that broad-based plans are positively associated with sales volatility. Outside the US, Nagaoka (2005) and Jones, Kalmi, and Mäkinen (2006) find some support for a positive relation between stock price volatility and employee stock option grants in Japan and Finland, respectively.

The dataset I use in this paper is considerably larger than the datasets used in previous studies. In contrast to most prior papers I use firm-specific estimates of the number of granted employee stock options and exclusively focus on non-executive employees. I pay particular attention to ruling out any potentially confounding effects – in particular incentive effects – which are likely to be relevant for executives but not for non-executive employees.

3 The model

3.1 Model set-up

This section presents a simple 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.

Employee preferences. The employee has preferences according to cumulative prospect theory (Tversky and Kahneman, 1992), which is a refinement of Kahneman and Tversky's (1979) prospect

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[12] The difference between their results and mine most likely stem from the fact that they analyze a small cross-sectional sample, while I analyze a much larger panel dataset.

theory. To develop an intuition, consider the original version of prospect theory first. There, a gamble which offers a payoff of x with a probability $f(x)$ and zero otherwise is evaluated according to

$$E^{\psi}[x] = v(x)\,\psi(f(x)), \tag{1}$$

which combines two separate functions: the value function $v(\cdot)$ and the probability weighting function $\psi(\cdot)$. To focus on probability weighting, assume for the moment that $v(x) = x$. Kahneman and Tversky (1979) derive the form of $\psi(\cdot)$ from observed choices. First, they show that most individuals prefer a 0.1% chance to win $5,000 to a sure $5 ("lotteries"). Setting $f(x) = 0.001$, $x = 5,000$, this choice is consistent with the preferences in (1) if $\psi(0.001) > 0.001$. At the same time most individuals prefer paying $5 over a lottery in which they loose $5,000 with probability 0.1% ("insurance"). Setting $\psi(0.001) > 0.001$ can again explain the observed choice. Hence, probability weighting is consistent with the simultaneous demand for lotteries and insurance. In the context of stock options, small probabilities are unambiguously associated with large gains. So probability weighting makes stock options attractive.[13] Note that there is no uncertainty about either payoffs or probabilities in the above examples. Hence, $\psi(\cdot)$ does not capture mistaken beliefs about probabilities. The function $\psi(\cdot)$ should rather be thought of as decision weights – a modelling tool to capture observed preferences.

Tversky and Kahneman (1992) have refined the original version of prospect theory. The main differences between the two versions are that the probability weighting function is now applied to the cumulative probabilities instead of the actual probabilities, and that cumulative prospect theory is applicable to gambles with any number of outcomes. Transforming cumulative probabilities ensures that preferences satisfy first order stochastic dominance – a weakness of the original version – while retaining the general implication that probability weighting leads to a preference for skewed lottery-like payoffs. For continuous probability distributions cumulative prospect theory preferences imply that an employee evaluates the risky payoffs from her compensation contract according to

$$E^{\psi}[v(w(P_T) - RP)] = \int v(w(P_T) - RP)\, d\psi(F(P_T)). \tag{2}$$

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

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[13] For financial claims with symmetric payoff structure it is not ex ante clear whether transforming probabilities by $\psi(\cdot)$ makes the claim more or less attractive, since both large gains and large losses are overweighted.

is given by

$$v\left(w\left(P_T\right)-RP\right)=\begin{cases}\left(w\left(P_T\right)-RP\right)^{\alpha} & , if\ \ w\left(P_T\right)\geq RP\\ -\lambda\left(-\left(w\left(P_T\right)-RP\right)\right)^{\alpha} & , if w\left(P_T\right)<RP\end{cases}\tag{3}$$

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 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

$$\psi\left(F(P_T)\right)=\begin{cases}\frac{-(1-F(P_T))^{\delta}}{\left(F(P_T)^{\delta}+(1-F(P_T))^{\delta}\right)^{\frac{1}{\delta}}} & , if\ \ w\left(P_T\right)\geq RP\\ \frac{F(P_T)^{\delta}}{\left(F(P_T)^{\delta}+(1-F(P_T))^{\delta}\right)^{\frac{1}{\delta}}} & , if w\left(P_T\right)<RP\end{cases}\tag{4}$$

where $0.28<\delta\leq 1$ measures the degree of probability weighting.[14] The weighting function is applied to gains and losses separately. Figure 1 shows the probability weighting function. It is inverse-S-shaped and intersects the 45 degree line from above. This reflects the fact that individuals are generally more sensitive to changes in probabilities from 1% to 2%, or from 98% to 99%, as they are to changes from 32% to 33%. That is, individuals tend to perceive probabilities in a non-linear fashion. Various studies have shown that the inverse-S-shape describes choice behavior well.[15] The degree of probability weighting, i.e. the extend to which the tail of the payoff distribution is overweighted is governed by the weighting parameter δ. The lower δ, the more will small probabilities be overweighted and medium to large probabilities underweighted. For $\delta=1$, which is the benchmark case of no probability weighting, the weighting function approaches the 45 degree line and cumulative probabilities are mapped into themselves.

The cost of granting stock options. I assume that there exist externalities from granting stock options such that the total cost to the firm exceeds the price of the option to an outside investor and that these external costs from granting options increase with the size of the grant. This is consistent with the limits on the number of stock options awarded to individual employees and with

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

[15] For example Tversky and Kahneman (1992), Gonzales and Wu (1999), Bleichrodt and Pinto (2000), and Abdellaoui, Vossmann, and Weber (2005).

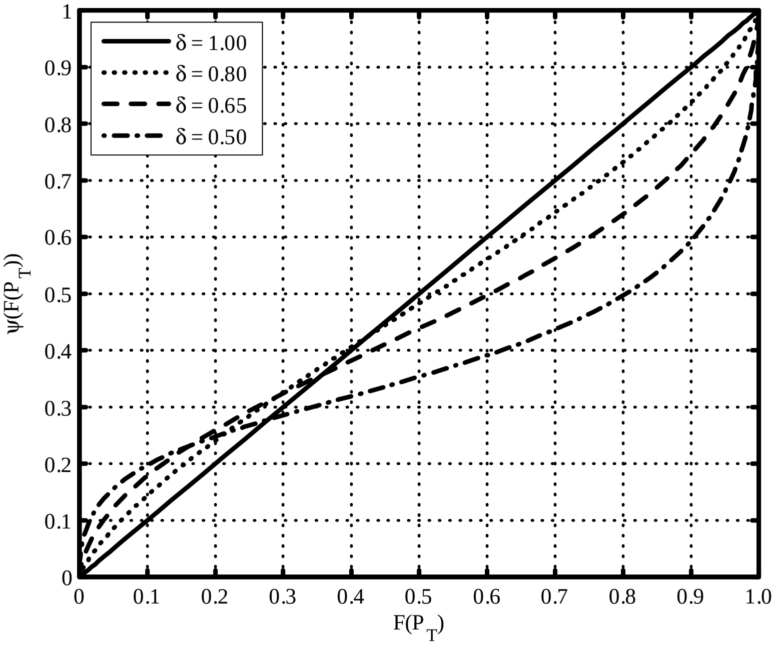

Figure 1: The probability weighting function as proposed by Tversky and Kahneman (1992) for different probability weighting parameters δ.

limits on the maximum dilution from option grants that are used by many companies. There are at least three possible sources of such costs.

First, securing shareholder approval for stock option plans becomes harder for larger plans. For example, Intel's CEO Craig Barrett states in a filing to the SEC that: "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."[16] 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.

Second, there is evidence that firms engage in repurchases of shares in the open market to fund option exercises, and to counter the impact of stock option exercises on diluted earnings per share (Kahle, 2002, Bens, Nagar, Skinner, and Wong, 2003). If stock option grants get large, firms may have to repurchase a large number of shares, which gets increasingly difficult and costly. Hall and Murphy (2003) report that managers perceive both, securing shareholder approval and dilution as substantial costs associated with stock option grants, which lends additional support for assuming that larger grants get increasingly costly.

Third, if a large part of employee pay is tied to stock options, underwater options may foster

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[16] Available as part of a filing with the SEC at: http://www.secinfo.com/d14D5a.12dJc.htm.

employee discontent and thus impair firm productivity. There is evidence that employees regard large wage reductions brought about by low payoffs from variable pay components like stock options as breach of an implicit agreement of mutual trust between company and employee, and that employees partly blame the company for their losses (Bewley, 1999). Employees may reciprocate in a variety of ways such as not putting in extra effort, spreading rumors, lowering morale of fellow workers, or even committing sabotage (Akerlof and Yellen, 1990). All this lowers firm productivity. Ex post, taking costly measures to keep morale up, for example bailing out underwater options, may be necessary. I assume that the firm will already anticipate this cost ex ante when designing a stock option program.[17]

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 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:

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

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:

$$\begin{aligned} \min_{n_o,\phi} \quad & E[\phi + n_o \max\left(P_T - K, 0\right)] + c\left(n_o\right) \\ s.t. \quad & E^{\psi}\left[v\left(w\left(P_T\right) - RP\right)\right] \geq v\left(\overline{V} - RP\right) \\ & n_o \geq 0. \end{aligned} \tag{5}$$

Here E is the standard expectation operator, and E^{ψ} are expectations with respect to the weighted probabilities according to equation (2).[18] $\overline{V}$ denotes the outside opportunity of the employee.[19] I assume that employees cannot write options on the firm and hence $n_o \geq 0$. To keep the model tractable, externalities from granting stock options are captured by a standard increasing

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[17] This argument is likely to affect larger companies more: effective pay reductions are correlated among the firm's workers and larger firms cannot easily substitute a large number of discontent or disappointed workers in the labor market because labor supply is likely limited in most industries. My empirical results will show that this reasoning is consistent with the data: smaller firms grant more options per employee.

[18] The interest rate is set to zero in this section to simplify notation but it is included in the numerical work below.

[19] For tractability, $\overline{V}$ is assumed to be independent of the proposed contract. This is defendable if $\overline{V}$ is determined some time before the actual contract negotiations and thus predetermined. Alternatively $\overline{V}$ can be taken to be a pure cash payment. 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."

and convex cost function $c(n_o)$ with $c(0) = 0$.

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 non-traded instruments like stock options, on the other hand, the absence of an outside market makes exploiting employee preferences for company equity feasible.

Reference point. We need 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:*

$$RP = n_o\theta + \phi, \tag{6}$$

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 value, or the intrinsic option value for her best-guess future stock price. 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 non-random, it is simply added to any expectation the employee holds on the risky part of the pay package. Consider, for example, an employee who receives 10,000 options and \$200,000 base salary over a planning horizon of four years. She anticipates that her options pay off \$5 per option in T. Hence her reference point is $10,000 \times \$5 + \$200,000 = \$250,000$.

There is also empirical support for Assumption 1. Hodge, Rajgopal, and Shevlin (2006) conduct a survey among 77 current mid-level managers and 111 future entry-level managers 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.

3.2 Theoretical results

The model from the previous section admits an intuitive solution, which is summarized in the following proposition. I prove it in the appendix.

Proposition 1. *The optimal contract* (ϕ^*, n_o^*) *from program (5) and a reference point of the form (6) is given by*

$$(i) \quad n_o^* = 0 \quad \textit{and} \quad \phi^* = \overline{V},$$

if $CE \leq E[\max(P_T - K, 0)]$, *and*

$$(ii) \quad c'(n_o^*) = CE - E[\max(P_T - K, 0)] \quad \textit{and} \quad \phi^* = \overline{V} - n_o^* CE,$$

if $CE > E[\max(P_T - K, 0)]$. *The certainty equivalent the employee holds for one stock option, denoted by* CE, *is implicitly defined as*

$$E^{\psi}[v(\max(P_T - K, 0) - \theta)] = v(CE - \theta).$$

Proposition 1 states that firms grant stock options to non-executive employees if and only if the certainty equivalent of the employee for options exceeds the value of the options to an outside investor. Under risk-neutral valuation this value is the Black-Scholes value of the option. 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 (Part (i)). Part (ii) shows that employee stock option plans are driven by employees who, in line with recent survey and empirical evidence, subjectively value options higher than outside investors.[20] Firms can exploit the probability assessments by replacing fixed salary worth $n_o^* CE$ by stock options which are worth less, $n_o^* E[\max(P_T - K, 0)]$, to an outside investor. Hence, lower-level employees in companies with broad-based employee stock option plans allow firms to lower their overall personnel cost.

It follows from Part (ii) that the predicted number of granted stock options increases with the difference in option value to employees and to outside investors, and that firms will grant options as

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[20] See references in the Introduction.

long as the benefit from granting options exceeds option-related negative externalities captured by the cost function $c(n_o)$. The cost function thus affects how much options are granted, and captures the simple idea that if firms benefit more per option, then they will grant more of them. For the existence of stock option plans, which depends only on the sign of $CE - E[\max(P_T - K, 0)]$, the cost function is irrelevant.

Proposition 1 is stated in terms of one single option only. By virtue of the power form of the value function and the linear specification of the reference point, the set-up implies that the certainty equivalent is homogenous in the number of granted options. In analyzing the implications from the model, it is thus sufficient to look at the value of one single stock option for employees and outside investors, respectively. In addition, both, the optimal number of options granted, and the existence of stock option plans, are not dependent on the outside option $\overline{V}$. These properties, although they can only be an approximation to reality, are extremely convenient for calibrating the model and for numerically developing the predictive content of Proposition 1 in the next section.

A direct implication of the modeling assumptions as reflected in Proposition 1 is that employee stock option grants are only limited by the firm's willingness to supply more options. This is consistent with anecdotal evidence of employees "clamoring" for stock options during the internet boom (Hall and Murphy, 2003) and with Bergman and Jenter (2007) who propose that equity compensation of employees is driven by "exuberant employees who *demand* to be paid in options".[21] Direct empirical evidence on this conjecture (as well as direct evidence to the contrary) is scarce. The closest empirical finding to my knowledge is Sautner and Weber (2005), who analyze in detail the behavior of 70 high-ranking employees of a large German company in an employee stock option plan between 2003 and 2004. They find that the median individual demands 100% of the options she is eligible to – consistent with the conjecture that option grants are limited by firms' supply.

4 Calibration of the model

Proposition 1 predicts stock options for non-executive employees whenever the certainty equivalent for employees exceeds the value of the options to an outside investor. An advantage of modeling the underlying preferences explicitly is that it allows me to calibrate the model and investigate whether it

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[21] It is possible to model explicitly the unwillingness of employees to hold a very large number of options or similarly the unwillingness to accept pay cuts by altering the preferences or constraints imposed on the employee. Examples in the literature include augmenting the value function by a term which 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, Huang, and Santos, 2001). The cost of such modifications is that the model looses much of its ability to be calibrated based on reliable experimental data.

predicts options under reasonable assumptions about preference parameters and firm characteristics. Because the experimental literature provides some guidance on values to parameterize cumulative prospect theory preferences, the calibration exercise below is a comparatively strict test of the validity of the model. Moreover, I can derive hypotheses on which firms are likely to grant options to non-executive employees.

4.1 Parameterizing the model

I calibrate the model by calculating, for different combinations of firm volatility and probability weighting, the ratio of the certainty equivalent of one option for an employee, to the value of the option for an outside investor. 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:[22,23]

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

I set r to 5% and T to 4 years.[24] Setting T to 4 years is motivated by the observation that most employees exercise most of their options shortly after they become exercisable (Huddard and Lang, 1996). In addition, Benartzi and Thaler (1995) argue that in evaluating equity portfolios, individuals routinely use a one year horizon. Since employee stock options cannot be exercised in the vesting period, it seems natural to assume that the evaluation period is extended until options become exercisable.[25] The strike price of the option, K, is equal to the grant date stock price, P_0. In this set-up the value of one option to an outside investor is equal to the Black-Scholes value.

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,

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

[23] 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 value. This implies that all risk in the model is firm specific.

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

[25] Other common vesting schedules which stipulate the right to exercise a maximum of 25% of the options per annum over the first four years of the options 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.

Table 1: Estimates of the parameter δ in the Tversky and Kahneman (1992) probability weighting function.

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)

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, Rajgopal, and Shevlin (2006). 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 equal to the statistical expectation. As an alternative reference point I also consider the Black-Scholes 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.[26]

The remaining two parameters are the volatility of the firm's stock price 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 relatively homogenous and suggest that values at about $\delta = 0.65$ are plausible.[27] I analyze the fit of the model for a grid of values for δ which 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.

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[26] Additional robustness checks regarding the reference point specification are provided in Section 6.

[27] In a large study on individual decision making, Gonzales 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."

4.2 Calibration results

It is the key idea of this paper that overweighting small probabilities of large gains makes options attractive. Thus, for a given degree of probability weighting, we would expect higher evaluations of options if the underlying stock price distribution is more skewed, which is captured by firm volatility given our lognormal distributional assumption. Likewise, for a given level of firm volatility, we would expect option valuations to increase in the degree of probability weighting.

Table 2 shows the ratio of certainty equivalent to Black-Scholes value 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 ratio of certainty equivalent to Black-Scholes value increases in the firm volatility, which, by Proposition 1 implies more options at high-volatility firms, as long as the ratio is greater than 1.

In Panel A, for $\delta = 0.65$, if the reference point equals the Black-Scholes 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 cut-off is only slightly lower. There is nothing 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 which can be directly tested on the data is a clear strength. A cut-off 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 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 scaled certainty equivalent 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 employees who overweight small probabilities can

Table 2: Calibration results. The table shows the ratio of certainty equivalent and Black-Scholes value for one option for different combinations of probability weighting and firm volatility. The model predicts employee stock option plans if this ratio exceeds one (shaded fields in the table). 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: Ratio of certainty equivalent to Black-Scholes value for one option when the reference point equals the Black-Scholes value.

Probability weighting (δ = 1 implies no weighting)	**Firm volatility**									
	20%	*25%*	*30%*	*35%*	***40%***	*45%*	*50%*	*60%*	*70%*	*80%*
0.40	**1.37**	**1.62**	**1.91**	**2.27**	**2.70**	**3.24**	**3.90**	**5.73**	**8.57**	**12.98**
0.50	**1.10**	**1.24**	**1.40**	**1.58**	**1.80**	**2.05**	**2.35**	**3.12**	**4.20**	**5.73**
0.60	0.89	0.96	**1.03**	**1.12**	**1.22**	**1.33**	**1.46**	**1.77**	**2.19**	**2.73**
0.63	0.85	0.90	0.96	**1.03**	**1.11**	**1.20**	**1.30**	**1.55**	**1.86**	**2.28**
0.65	0.82	0.85	0.90	0.95	**1.01**	**1.08**	**1.16**	**1.35**	**1.59**	**1.90**
0.68	0.81	0.82	0.84	0.88	0.93	0.98	**1.04**	**1.18**	**1.36**	**1.59**
0.70	0.80	0.80	0.81	0.83	0.85	0.89	0.93	**1.03**	**1.17**	**1.33**
0.75	0.77	0.77	0.78	0.78	0.79	0.80	0.80	0.82	0.87	0.94
0.80	0.75	0.74	0.74	0.74	0.74	0.74	0.74	0.75	0.76	0.77
0.90	0.71	0.69	0.68	0.67	0.66	0.65	0.64	0.62	0.61	0.60
1.00	0.67	0.65	0.63	0.61	0.59	0.57	0.56	0.53	0.50	0.47

Panel B: Ratio of certainty equivalent to Black-Scholes value for one option when the reference point equals the expected intrinsic value $P_0 e^{rT} - K$.

Probability weighting (δ = 1 implies no weighting)	**Firm volatility**									
	20%	*25%*	*30%*	*35%*	***40%***	*45%*	*50%*	*60%*	*70%*	*80%*
0.40	**1.35**	**1.60**	**1.90**	**2.27**	**2.72**	**3.27**	**3.95**	**5.83**	**8.73**	**13.22**
0.50	**1.10**	**1.26**	**1.45**	**1.66**	**1.91**	**2.19**	**2.53**	**3.36**	**4.52**	**6.13**
0.60	0.90	**1.00**	**1.11**	**1.24**	**1.37**	**1.53**	**1.69**	**2.09**	**2.58**	**3.20**
0.63	0.86	0.95	**1.04**	**1.15**	**1.27**	**1.40**	**1.54**	**1.87**	**2.26**	**2.76**
0.65	0.83	0.90	0.98	**1.07**	**1.17**	**1.28**	**1.40**	**1.67**	**2.00**	**2.39**
0.68	0.79	0.85	0.92	1.00	**1.09**	**1.18**	**1.28**	**1.50**	**1.76**	**2.07**
0.70	0.76	0.81	0.87	0.93	**1.01**	**1.08**	**1.17**	**1.35**	**1.56**	**1.80**
0.75	0.72	0.73	0.77	0.82	0.87	0.92	0.98	**1.10**	**1.23**	**1.38**
0.80	0.70	0.67	0.69	0.72	0.75	0.78	0.82	0.90	0.97	**1.06**
0.90	0.67	0.62	0.57	0.57	0.57	0.58	0.59	0.60	0.62	0.63
1.00	0.64	0.58	0.54	0.50	0.47	0.44	0.43	0.41	0.40	0.38

be exploited by firms. To get an idea of the magnitude of this benefit in dollar terms, assume a typical company with 20,000 non-executive employees, which grants options with a Black-Scholes value of $5,000 per employee annually.[28] For $\delta = 0.65$ and firm volatility of 40% the value by which reduced base salaries exceed the Black-Scholes cost of options can be calculated from Panel A of Table 2 to be $1 million.[29] For the reference point in Panel B, benefits are slightly higher ($17 million). Hence, for typical firms, benefits from options are small, although maybe sizeable enough to cover for expenses related with setting up and administering a broad-based plan. This changes quickly for firms with higher stock price volatility. A firm with volatility of 60% can reduce base salaries by about $50 million more than what it grants to employees in Black-Scholes value. For the largest granters of employee stock options, this value-cost differential can become enormous. Over the last decade, a company like Cisco has roughly granted per annum on average $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 and $354 million per year. To be sure, these are back-of-the-envelope calculations and have to be treated as such. They suggest clearly, however, that individual biases can have important economic consequences.

4.3 Hypotheses

The results in Table 2 deliver testable predictions regarding employee stock option plans. If employees are subject to probability weighting, the model predicts:

Hypothesis 1. *If a firm has a broad-based employee stock option plan, then per employee stock option grants are higher for higher volatility firms.*

Hypothesis 2. *Firms are more likely to have a broad-based stock option plan in place if the volatility of their stock price is high.*

I test these hypotheses on the universe of ExecuComp firms in the next section.

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[28] These values are the mean values for firms in the ExecuComp universe over the years 1992 to 2005 as shown in Table 3.

[29] This is calculated as

$$20,000 \times \$5,000 \times \left[\frac{CE}{BS} - 1\right].$$

This calculation disregards externalities from granting options because I have no good way of specifying the cost function. The benefits reported are thus upper bounds for the net "profit" from granting options to employees.

5 Empirical tests of the model

5.1 Dataset and construction of variables

Firms do not have to disclose details about their stock option programs to non-executive employees, which poses a challenge for empirical research in the field. Following Desai (2003) and Bergman and Jenter (2007) I estimate the number of options granted to non-executive 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 one 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.

Some papers have used what I label a "broad" definition of employees (Core and Guay, 2001, Bergman and Jenter, 2007). Under this broad definition, all individuals employed by the company, except for the top executives reported in ExecuComp, are counted as employees.[30] For typical companies, employees defined in such a way almost certainly include a number of employees for which incentive motives for equity compensation cannot be dismissed easily (I call them "high executives"). As I want to focus exclusively on non-executive employees for which 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. Hence, a company with 100 employees has an estimated 10 executives for which options could have an incentive effect, whereas for a company with 10.000 employees this is the case for 100 executives.[31] To be able to quantify the number of 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, is awarded to the average high executive not listed in the ExecuComp database.[32] 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 non-executive employees is then calculated by subtracting the number of options to

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[30] The median company reports equity compensation for the top 5 executives (min: 1, max: 9).

[31] Oyer and Schaefer (2005) use an estimate of the number of executives within a firm which 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 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.

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

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.

I define a variable *ESOplan* which indicates whether there exists a broad-based employee stock option plan for a given firm-year. *ESOplan* is 1 if the number of non-executive employee stock options is positive and greater than 0.5% of the number of shares outstanding, and zero otherwise. The latter assumption follows Oyer and Schaefer (2005) and intends to ensure that I indeed capture firms with broad-based plans.

My initial sample consists of all companies in the ExecuComp database for the years 1992 to 2005. All balance sheet data is taken from Compustat and all stock return data is taken from the CRSP Compustat merged database. I drop all companies with less than 40 employees or less than two 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 take directly from ExecuComp. ExecuComp calculates this variable on the basis of stock prices over the prior 60 months.[33] In all regressions 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) and the three year average of research and development expense scaled by total assets. Since, all else equal, firms with lower stock prices have to grant more options to grant an option package with the same Black-Scholes value, I use the log of the average grant-date stock prices reported in ExecuComp for all grants in a respective firm-year as an additional control variable in regressions involving the number of options granted. I winsorize firm volatility and Tobin's Q at the 1% and the 99% level. I further drop all companies in the financial sector (SIC codes 6000 to 6999) and all company-years where one of the relevant parameters for the baseline specification (Table 5) was missing. The resulting dataset has 14,967 firm-year observations for 2,238 unique firms.

For my robustness checks, I define a number of additional variables along the lines suggested by prior papers on the subject. "Contemporaneous stock return" is the return (excluding dividends) from the beginning to the end of period t. "Prior 2 year stock return" is the return (excluding dividends) from the beginning of period $t-2$ to the end of the period $t-1$. Industry volatility is defined as the median stock price volatility for all firms in one three digit SIC code industry. As measures of cash constraints I include cash flow (Compustat data items 14 + 18), cash dividends (data items 19 + 21), cash balances (data item 1), all over lagged assets, and leverage ((data items

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[33] If the stock trades for less than 60 months, ExecuComp uses the maximum number of monthly observations available. If the firms trades for less than a year, then the average S&P 1,500 volatility number is imputed.

9 + 34) / (data items 9 + 34 + 216)).[34] All controls for cash constraints are winsorized at the 1% and 99% level.[35] Lastly, following Babenko and Tserlukevich (2008) and Graham and Smith (1999) I use the absolute coefficient of variation of EBIT over the last ten years as a measure of the convexity of a firm's tax schedule.

For Table 3 and Table 4, Black-Scholes 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 my analysis is mainly based on the number of options and not their Black-Scholes value, these assumptions are not substantial for what follows.

Table 3 shows descriptive statistics for the pooled sample. The median firm has 5,121 employees, a market capitalization of $1.01 billion and sales of $1.09 billion (Panel A). Median (mean) firm volatility is 38.9% (44.4%) and Tobin's Q is 1.60 (2.11). Panel B shows stock option plan characteristics. A broad-based employee stock option plan is in place in the majority of firm-years (58.1%) and, for the median firm-year, 45.2% (74.2%) of all options granted go to employees if employee is narrowly (broadly) defined. In each fiscal year, average companies in the sample grant options on 1.9% to 3.2% of their shares outstanding.

For the typical company, the Black-Scholes value of option grants to non-executive employees is modest, with a median per employee value of $160. The distribution is skewed and the per employee mean value at $5,852 is higher. Looking only at firms with a broad-based plan, these numbers are larger, but still not very high. 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 non-executive employees are anything but modest. For example, one of the largest granters of employee stock options 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 non-executive employees in excess of $1 billion.

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[34] These are the constituents of a measure of cash constraints based on work by Kaplan and Zingales (1997), Lamont, Polk, and Saa-Requejo (2001), and Baker, Stein, and Wurgler (2003) which is also used in Bergman and Jenter (2007). Using the Kaplan-Zingales-index instead of the constituents leaves all main results unchanged.

[35] I have also used cash flow and capital expenditure over lagged assets (as in Oyer and Schaefer, 2005), as well as interest burden and cash flow shortfall (as in Core and Guay, 2001) as measures of cash constraints. Results concerning the influence of cash constraints on option grants are weaker under these measures, while the main results relating to firm volatility remain basically unchanged.

Table 3: Descriptive statistics. Original dataset 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 to 6999). Also excluded are firm-years for which any relevant items for the base regressions (Table 5) were missing. Firm volatility is the 60 month stock price volatility reported by ExecuComp. R&D is a three year average scaled by total assets. Prior 2 year stock return is the annualized stock return from the beginning of year $t-2$ to the end of year $t-1$. Both contemporaneous and prior 2 year returns are calculated excluding dividends. Earnings volatility is calculated as the absolute coefficient of variation using ten years of EBIT data. Employees are defined "broadly" as all employees of the firm except those listed in ExecuComp. 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 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.

Time period	*1992 - 2005*			
Number of firms in sample	*2,238*			
	Mean	Median	Std. Dev.	Firm-Years
Panel A: Firm characteristics				
Number of employees	19,053	5,121	54,939	14,967
Market value of equity (millions)	\$4,050	\$1,010	\$12,000	14,967
Sales (millions)	\$5,520	\$1,090	\$19,000	14,967
Firm volatility	44.4%	38.9%	21.4%	14,967
Tobin's Q	2.11	1.60	1.48	14,967
R&D	3.8%	0.2%	7.2%	14,967
Contemporaneous stock return	22.9%	8.9%	145.0%	14,902
Prior 2 year stock return	15.2%	9.5%	42.5%	14,107
Cash flow$_{t-1}$ / Assets$_{t-2}$	10.6%	10.9%	12.4%	14,702
Cash dividends$_{t-1}$ / Assets$_{t-2}$	1.3%	0.5%	1.9%	14,723
Cash balances$_{t-1}$ / Assets$_{t-2}$	17.9%	6.5%	27.7%	14,751
Leverage$_{t-1}$	32.8%	32.6%	25.7%	14,715
Earnings volatility	98.4%	49.8%	259.1%	11,321
Panel B: Stock option plan characteristics				
Total granted options to shares outstanding	3.2%	1.9%	16.7%	14,967
Percentage of firms with ESO plan	58.1%	-	-	14,967
Percent of options to CEO	14.0%	10.8%	11.7%	14,967
Percent of options to other reported executives	15.5%	13.3%	10.5%	14,967
Percent of options to employees (broad definition)	70.5%	74.2%	19.0%	14,967
Percent of options to employees (narrow definition)	42.6%	45.2%	28.5%	14,967
BS-value of options to CEO	\$1,722,098	\$543,374	\$7,063,028	14,967
Per capita BS-value to other reported executives	\$499,884	\$182,924	\$1,392,593	14,967
Per employee BS-value (broad definition)	\$6,408	\$537	\$50,203	14,967
Per employee BS-value (narrow definition)	\$5,852	\$160	\$50,336	14,967
Per employee BS-value (broad definition) if $n_o>0$	\$10,731	\$1,617	\$65,521	8,695
Per employee BS-value (narrow definition) if $n_o>0$	\$10,073	\$1,191	\$65,719	8,695

Table 4: Employee stock options grants sorted by firm volatility. Original dataset 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 to 6999). Also excluded are firm-years for which any relevant items for the base regressions (Table 5) were missing. Firm volatility is the 60 month stock price volatility reported by ExecuComp. Employees are defined "broadly" as all employees of the firm except those listed in ExecuComp. 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 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.

Mean

Firm volatility quintile	Firm Volatility	Percentage of firms with ESO plan	T-test for equality with previous quintile [P-value]	*Narrow definition:* Per employee		*Broad definition:* Per employee	
				BS-value	n_O	BS-value	n_O
1	21.7%	36.5%	[-]	$253	57	$423	103
2	30.8%	47.4%	0.00	$652	94	$963	148
3	39.2%	55.5%	0.00	$2,123	220	$2,585	323
4	51.2%	69.1%	0.00	$6,606	576	$7,335	850
5	79.2%	82.2%	0.00	$19,723	1,934	$20,835	3,369

Median

Firm volatility quintile	Firm Volatility	ESO plan at median firm in quintile	Wilcoxon rank-sum test for equality with previous quintile [P-value]	*Narrow definition:* Per employee:		*Broad definition:* Per employee:	
				BS-value	n_O	BS-value	n_O
1	22.1%	no	[-]	$0	0	$138	48
2	30.8%	no	0.00	$0	0	$296	57
3	39.0%	yes	0.00	$107	23	$492	82
4	50.8%	yes	0.00	$675	108	$1,238	195
5	74.5%	yes	0.00	$4,672	760	$5,532	928

5.2 Empirical results

5.2.1 Univariate results

According to Hypotheses 1 and 2, the model predicts that employee stock option 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 two lowest volatility quintiles does not have a broad-based plan, while the median firm in quintiles 3 to 5 does. Firm volatility of the median firm in quintile 3 is 39.0% and thus surprisingly close to the cut-off 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 option value increases monotonically and at an increasing rate from \$253 in the bottom quintile to \$19,723 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 artefact of introducing a narrow employee definition. The proportion of firms with broad-based plan increases at an increasing rate from 36.5% to 82.2%. The differences between means and medians of the distribution of the *ESOplan* variable between adjacent quintiles are all statistically significant at the 1% level, using t-tests and Wilcoxon rank-sum tests, respectively.

Note that the increase in per employee Black-Scholes 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.[36]

5.2.2 Firm volatility and the size of stock option grants

To confirm the univariate predictions, the first set of regressions I run are OLS regressions on the subsample of firms with broad-based employee stock option plans in place according to the *ESOplan* variable. (Potential concerns about selection bias are addressed in Section 6.) I estimate various specifications of the regression equation

$$\ln\left(1+n_{o,ikt}\right)=\alpha+\beta\cdot\sigma_{ikt}+\Gamma\cdot X_{ikt}+\lambda_t+\lambda_k+\lambda_i+\varepsilon_{ikt},\tag{7}$$

which predicts the log of the number of options per non-executive employee in firm i, in industry k at time t. For each firm-year, firm volatility is denoted by σ_{ikt}, X_{ikt} is a vector of controls, λ_t is a year dummy, λ_k is an industry dummy based on the firm's three digit SIC code and λ_i is a fixed or, depending on the specification, random firm effect. As dependent variable, I use the number of

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[36] See for example Holmström and Milgrom (1987).

Table 5: Regressions of the log of the number of employee stock options on firm volatility and control variables. Dataset is based on all firms with more than 40 employees listed in ExecuComp over the period from 1992 to 2005. Regressions consider only the subsample of firms with employee stock option plan. Firm volatility is the 60 month stock price volatility reported by ExecuComp. Log of grant-date stock price is the log of the average grant-date stock prices reported in ExecuComp for all grants to reported executives in a given firm-year. R&D is the three year average of research and development expense scaled by total assets. Industry dummies are based on the three digit SIC code. Robust standard errors with clustering at the firm level are reported in parentheses. Overall-R^2 is reported for specification (3).

	Dependent variable: log of the number of employee stock options per employee			
Independent variable	(1)	(2)	(3)	(4)
Firm volatility	**2.39** ***	**1.76** ***	**1.16** ***	**0.53** ***
	(0.17)	(0.13)	(0.12)	(0.14)
Log of grant-date stock price	**-0.09** **	**-0.26** ***	**-0.21** ***	**-0.27** ***
	(0.04)	(0.03)	(0.02)	(0.03)
Log of sales	**-0.22** ***	**-0.20** ***	**-0.28** ***	**-0.19** ***
	(0.02)	(0.02)	(0.02)	(0.03)
Tobin's Q	**0.21** ***	**0.22** ***	**0.08** ***	**0.07** ***
	(0.02)	(0.01)	(0.01)	(0.01)
R&D	**4.56** ***	**2.23** ***	**1.03** ***	**-0.79** ***
	(0.65)	(0.56)	(0.40)	(0.30)
Firm fixed effects				Yes
Firm random effects			Yes	
Industry dummies		Yes		
Year dummies	Yes	Yes	Yes	Yes
(Adjusted) R^2	0.522	0.699	0.455	0.896
N	8,695	8,695	8,695	8,695

*** Significant at 1% level; ** significant at 5% level; * significant at 10% level.

stock options instead of the Black-Scholes value to avoid a mechanical relation between volatility and option value.[37] All regressions use robust standard errors that allow for clustering at the firm level.

Table 5 confirms the univariate predictions. Firms with higher stock price volatility grant significantly more stock options per employee. This relationship is robust to including year dummies, industry dummies, firm random effects and firm fixed effects. It is also economically significant. Increasing firm volatility by one standard deviation (21.4 percentage points) increases per-employee stock option grants by 37.6%, when controlling for industry effects, and 11.4%, when controlling

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[37] If despite the concern about the mechanical relationship between Black-Scholes value and volatility, I run regressions using the log of per employee option value as dependent variable, results remain basically unchanged and, if anything, get even stronger.

for firm fixed effects. Table 5 also shows that firms that grant more employee stock options per employee are significantly smaller, have higher Tobin's Q, and have higher R&D expense as a fraction of total assets. Such companies are also the companies which are most likely to deliver very high stock option payoffs. Hence, overall, results are consistent with the proposition that employee stock option grants are driven by employees who overweight small chances of large stock option gains.

Table 6 adds further control variables which were suggested to influence employee stock options grants in related work. First, Bergman and Jenter (2007) suggest that employee stock option grants are driven by employee sentiment and use past stock returns as a proxy variable. Second, Oyer (2004) suggests in a model which focuses on employee retention that the variability of outside opportunities of employees are positively related to employee stock option grants. Hence, following Oyer and Schaefer (2005), I include industry volatility as a proxy for labor market conditions. Third, I control for cash constraints since firms with investment opportunities but little cash available may be more likely to compensate their employees with stock options that require no cash outlay today. Lastly, I use the absolute coefficient of variation of EBIT (Graham and Smith, 1999, and Babenko and Tserlukevich, 2008) to account for tax effects due to the convexity of the tax schedule.

Table 6 shows that controlling for these additional variables does not change the main empirical result: firms with higher stock price volatility grant significantly more employee stock options. This is true for specifications with industry dummies as well as for specifications with firm fixed effects.[38] I find mixed evidence for the influence of past returns on the number of stock options granted, with a positive relation only in specification (1). Consistent with the retention model of Oyer (2004), I find a significant and positive relation between industry volatility and option grants. However, in contrast to Oyer and Schaefer (2005), who analyze a much smaller sample, I find no evidence that either the magnitude, or the significance of firm volatility is affected when including industry volatility as an additional control variable (the same holds true for the linear probability and probit models below). Consistent with the results in Ittner, Lambert, and Larcker (2003) and Bergman and Jenter (2007) I find little evidence for a systematic relation between cash constraints and option grants. To the contrary, firms with higher cash balances, and firms that need less cash to pay interest on their debt grant more, not less, stock options. There is some, albeit statistically weak, evidence for a positive relation between tax volatility and option grants.

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[38] Earnings volatility is insignificant (p-value 0.616) when included in the set of regressors for the fixed effects specification (6). Since the earnings volatility variable is only available for companies that are in the sample for at least 10 years, including it leads to a loss of 19.5% of the observations in the sample. The coefficient of sigma in regression (6) including earnings volatility is essentially unchanged (0.361), while the standard error is somewhat higher (0.202). Even with the insignificant earnings volatility included, the coefficient of sigma is still significant with a p-value of 0.074.

Table 6: Regressions of the log of the number of employee stock options on firm volatility and enlarged set of control variables. Prior 2 year stock return is the annualized stock return from the beginning of year $t-2$ to the end of year $t-1$. Both contemporaneous and prior 2 year returns are calculated excluding dividends. Industry volatility is the median volatility of firms within the same three digit SIC code industry. Earnings volatility is calculated as the absolute coefficient of variation using ten years of EBIT data. All other variables are defined as in Table 5. Industry dummies are based on the three digit SIC code. Robust standard errors with clustering at the firm level are reported in parentheses.

	Dependent variable: log of the number of employee stock options per employee					
Independent variable	(1)	(2)	(3)	(4)	(5)	(6)
Firm volatility	**1.71** ***	**1.74** ***	**1.41** ***	**1.32** ***	**1.13** ***	**0.35** **
	(0.14)	(0.14)	(0.13)	(0.16)	(0.16)	(0.16)
Log of grant-date stock price	**-0.33** ***	**-0.26** ***	**-0.42** ***	**-0.34** ***	**-0.46** ***	**-0.38** ***
	(0.04)	(0.03)	(0.03)	(0.04)	(0.04)	(0.03)
Log of sales	**-0.18** ***	**-0.20** ***	**-0.10** ***	**-0.17** ***	**-0.08** ***	**-0.15** ***
	(0.02)	(0.02)	(0.02)	(0.02)	(0.02)	(0.03)
Tobin's Q	**0.25** ***	**0.22** ***	**0.18** ***	**0.25** ***	**0.23** ***	**0.08** ***
	(0.02)	(0.01)	(0.01)	(0.02)	(0.02)	(0.01)
R&D	**2.14** ***	**2.24** ***	**2.05** ***	**1.96** ***	**1.61** ***	**-0.71** **
	(0.60)	(0.56)	(0.47)	(0.67)	(0.53)	(0.31)
Contemporaneous return	**-0.11** ***				**-0.07** **	**-0.04** *
	(0.04)				(0.03)	(0.02)
Prior 2 year return	**0.07** **				**-0.13** ***	**0.05** **
	(0.03)				(0.04)	(0.03)
Industry volatility		**0.17**			**0.55** **	**0.58** **
		(0.23)			(0.26)	(0.23)
Cash flow$_{t-1}$ / Assets$_{t-2}$			**-0.03**		**0.12**	**-0.13**
			(0.13)		(0.19)	(0.11)
Cash dividends$_{t-1}$ / Assets$_{t-2}$			**0.30**		**-1.15**	**2.70** **
			(1.19)		(1.38)	(1.26)
Cash balances$_{t-1}$ / Assets$_{t-2}$			**0.95** ***		**1.21** ***	**0.27** ***
			(0.06)		(0.10)	(0.05)
Leverage$_{t-1}$			**-0.65** ***		**-0.72** ***	**-0.33** ***
			(0.09)		(0.10)	(0.08)
Earnings volatility				**0.01** *	**0.01**	
				(0.01)	(0.01)	
Firm fixed effects						Yes
Industry dummies	Yes	Yes	Yes	Yes	Yes	
Year dummies	Yes	Yes	Yes	Yes	Yes	Yes
(Adjusted) R^2	0.697	0.699	0.725	0.684	0.718	0.899
N	8,082	8,695	8,472	6,096	6,024	8,012

*** Significant at 1% level; ** significant at 5% level; * significant at 10% level.

In sum, the results in Tables 5 and 6 strongly support Hypotheses 1 and show that riskier firms grant more employee stock options even when controlling for industry effects, firm effects and a number of variables found important in the prior literature.

Table 7: 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 one if there is a broad-based stock option plan at the firm in the respective firm-year. Industry dummies are based on the three digit SIC code. Marginal effects are reported for the probit models. Some observations for the probit model in specification (4) are lost because of no within-industry variation in the ESOplan variable. Overall-R^2 and McFadden's R^2 is reported for the linear and probit random effects model, respectively. Robust standard errors with clustering at the firm level are given in parentheses.

	Dependent variable: ESOplan (dummy variable)				
	Linear Probability Model			Probit Model	
Independent variable	(1)	(2)	(3)	(4)	(5)
Firm volatility	**0.36** ***	**0.16** ***	**0.21** ***	**0.23** ***	**0.34** ***
	(0.04)	(0.04)	(0.03)	(0.05)	(0.05)
Log of sales	**-0.02** ***	**-0.02** ***	**-0.04** ***	**-0.03** ***	**-0.07** ***
	(0.01)	(0.00)	(0.00)	(0.01)	(0.01)
Tobin's Q	**0.03** ***	**0.01** ***	**0.01** **	**0.01** **	**0.01** **
	(0.00)	(0.00)	(0.00)	(0.01)	(0.01)
R&D	**1.23** ***	**0.47** ***	**0.85** ***	**2.27** ***	**3.78** ***
	(0.17)	(0.12)	(0.09)	(0.32)	(0.22)
Firm random effects			Yes		Yes
Industry dummies		Yes		Yes	
Year dummies	Yes	Yes	Yes	Yes	Yes
Percent correctly predicted	0.670	0.734	0.647	0.684	0.654
(Adjusted or Pseudo) R^2	0.161	0.267	0.151	0.238	0.150
N	14,967	14,967	14,967	14,843	14,967

*** Significant at 1% level; ** significant at 5% level; * significant at 10% level.

5.2.3 Firm volatility and existence of broad-based stock option plans

To investigate whether higher firm volatility increases the probability of broad-based employee stock option plans at firms (Hypothesis 2), I estimate different versions of a linear probability model of the form

$$ESOplan = \alpha + \beta \cdot \sigma_{ikt} + \Gamma \cdot X_{ikt} + \lambda_t + \lambda_k + \mu_i + \varepsilon_{ikt},$$

where μ_i is a random firm effect. The dependent variable is now *ESOplan*, an indicator variable which is one if there is a broad-based plan. The remaining covariates I consider are the same as in the previous regressions, except for the stock price, which I drop from the set of control variables since it only determines the number of options granted but not whether or not any options are granted at all. I also report results for a corresponding probit model.

Table 7 shows that Hypothesis 2 is borne out by the data: high volatility firms are more likely to have a broad employee stock option plan. This finding is robust to including year, industry and firm effects. The signs on the control variables are as expected and robust across specifications. The impact of firm volatility is again economically significant: increasing firm volatility by one standard deviation increases the probability of a broad-based plan in the firm by between 3.4 and 7.7 percentage points in the linear probability model, while the probit model predicts changes of 5.0 and 7.4 percentage points (baseline probability 58.1%).

Table 8 shows results for the larger set of control variables. The positive and significant relation between firm volatility and the number of granted stock options is robust to controlling for past returns, industry volatility, cash constraints, and tax convexity. I conclude that there is strong support in the ExecuComp universe for the hypothesis that broad-based employee stock option plans are significantly more common in high volatility firms (Hypothesis 2).

6 Additional robustness checks

6.1 Reference point specification

So far I have documented that my model fits the data on option grant behavior remarkably well. There is still some heterogeneity in granting practices across firm volatility quintiles, however: about 36% of firms in the lowest volatility quintile grant employee stock options although my baseline model would predict no option grants for these companies (Table 4). For the highest quintile, 80% instead of the predicted 100% grant options. It may of course well be that a substantial part of this variation is simply noise. Moreover, other factors may well contribute to grant decisions. The purpose of this section is to offer an explanation for some of this variation by allowing for heterogeneity of reference points across firms. By doing so, I will also show that the main results are robust to sensible changes to the proposed reference point specifications.

Figure 2 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 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.

Table 8: Regressions of an indicator variable for the existence of a broad-based employee stock option plan on firm volatility and enlarged set of control variables. All variables are defined as in Table 5. For the probit model, marginal effects computed at the mean are reported. Some observations for the probit model are lost because of no within-industry variation in the ESOplan variable. For the random effects probit model, McFadden's R^2 is reported. Robust standard errors with clustering at the firm level are given in parentheses.

	Dependent variable: ESOplan (dummy variable)					
	Linear Probability Model					Probit
Independent variable	(1)	(2)	(3)	(4)	(5)	(6)
Firm volatility	**0.18** ***	**0.17** ***	**0.16** ***	**0.14** ***	**0.19** ***	**0.22** ***
	(0.04)	(0.04)	(0.04)	(0.05)	(0.06)	(0.08)
Log of sales	**-0.02** ***	**-0.02** ***	**-0.02** ***	**-0.01** **	**-0.01**	**-0.01** *
	(0.01)	(0.00)	(0.01)	(0.01)	(0.01)	(0.01)
Tobin's Q	**0.01** ***	**0.01** ***	**0.00**	**0.01**	**0.00**	**0.00**
	(0.00)	(0.00)	(0.00)	(0.01)	(0.01)	(0.01)
R&D	**0.46** ***	**0.47** ***	**0.55** ***	**0.60** ***	**0.64** ***	**2.47** ***
	(0.12)	(0.12)	(0.12)	(0.16)	(0.15)	(0.40)
Contemporaneous return	**-0.01** ***				**-0.01** ***	**-0.01** *
	(0.00)				(0.00)	(0.01)
Prior 2 year return	**-0.01**				**-0.06** ***	**-0.07** ***
	(0.01)				(0.01)	(0.02)
Industry volatility		**-0.05**			**-0.01**	**0.04**
		(0.07)			(0.09)	(0.11)
Cash flow$_{t-1}$ / Assets$_{t-2}$			**0.13** ***		**0.21** ***	**0.21** **
			(0.04)		(0.06)	(0.10)
Cash dividends$_{t-1}$ / Assets$_{t-2}$			**-1.09** ***		**-0.73**	**-0.96**
			(0.40)		(0.48)	(0.63)
Cash balances$_{t-1}$ / Assets$_{t-2}$			**0.05** ***		**0.07** **	**0.15** **
			(0.02)		(0.03)	(0.06)
Leverage$_{t-1}$			**-0.03**		**-0.03**	**-0.02**
			(0.03)		(0.03)	(0.04)
Earnings volatility				**0.00**	**0.00**	**0.00**
				(0.00)	(0.00)	(0.00)
Industry dummies	Yes	Yes	Yes	Yes	Yes	Yes
Year dummies	Yes	Yes	Yes	Yes	Yes	Yes
Percent correctly predicted	0.732	0.735	0.733	0.720	0.725	0.654
(Adjusted or pseudo) R^2	0.266	0.267	0.268	0.244	0.247	0.217
N	14,107	14,967	14,634	11,321	11,175	11,063

*** Significant at 1% level; ** significant at 5% level; * significant at 10% level.

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 2 shows the ratio of certainty equivalent to Black-Scholes value for different combinations of ν with the degree of firm volatility (top panel) and probability weighting δ (bottom panel).

From the top panel we see that for all values of ν the benefit of granting options as measured by CE/BS 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 from

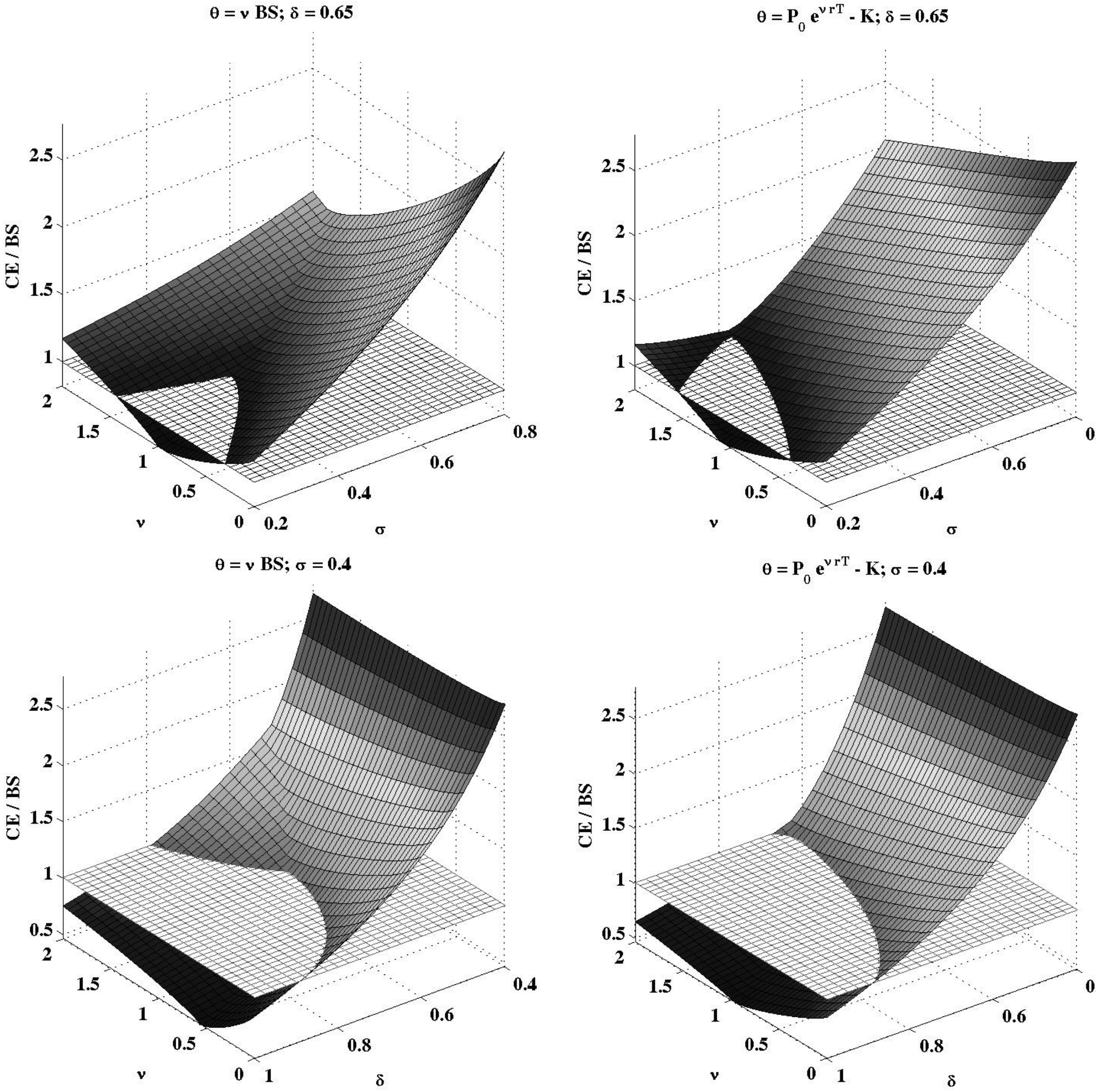

Figure 2: Robustness with respect to reference point specification. This figure shows the ratio of certainty equivalent to Black-Scholes value for one stock option using different reference point specifications. The left panel shows values for $\theta = \nu BS$. The right panel shows values for $\theta = P_0 e^{\nu r T} - K$. Resulting changes in CE/BS are presented for various levels of firm volatility σ (top panel) and various degrees of probability weighting δ (bottom panel). Options are predicted by the model for $CE/BS > 1$.

changing the aspiration level on the predicted presence of broad-based option plans. For small to moderate deviations (roughly about plus/minus 50%), the model predicts no plans at low volatility firms. For large deviations, 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 only small (since most of the aversiveness towards risky gambles is captured by the kink in the value function), even small degrees of probability weighting are enough to overcome the small 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 of a few representative employees.[39]

The lower panel of Figure 2 shows 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 value, even if the reference point is relatively large (high values of ν in Figure 2).

6.2 Robustness of empirical results

I perform a number of additional robustness checks. First, I replace the log-specification of my dependent variable in equation (7) with the level of per employee stock options $n_{o,ikt}$. The results are basically unchanged (results not reported). Second, the strong support for Hypothesis 1 in the data is based on OLS regressions on the subsample of firms that grant employee stock options. This may introduce sample selection bias. To investigate how severe this bias is, I run a Tobit model on the full sample of firms (Table 9). The impact of firm volatility is still highly significant in all specifications and implies a change of 10.2-31.6% in the number of granted options per employee for a one standard deviation increase in firm volatility (marginal effects for non-censored observations computed at the mean). Third, Ittner, Lambert, and Larcker (2003) present evidence that stock options are used in particular by new economy firms (defined by SIC codes 3570-3579, 3661, 3674, 5045, 5961 and 7370-7379). To rule out that my results are driven by new economy firms, I run separate regressions on the subsample of new economy firms and on the complement (results not reported). I also run regressions which include a dummy for new economy firms (results not reported). As expected both the proportion of firms granting options and the number of granted options per employee is markedly higher for new economy firms. All results on stock price volatility hold for new economy firms as well as for the remaining firms. Lastly, splitting my sample into an earlier sample (years

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[39] Note that by incorporating past returns, my empirical analysis may control for a potentially large part of this heterogeneity in aspiration levels.

Table 9: Tobit regressions of the log of the number of stock options per employee on the set of control variables used in Table 6. The table shows marginal effects for non-censored observations computed at the mean. Industry dummies are based on the three digit SIC code. Robust standard errors with clustering at the firm level are given in parentheses. The reported Pseudo-R^2 is the squared correlation between actual and fitted values.

	Dependent variable: log of the number of employee stock options per employee					
Independent variable	(1)	(2)	(3)	(4)	(5)	(6)
Firm volatility	**1.48** ***	**1.43** ***	**1.14** ***	**0.95** ***	**1.09** ***	**0.48** ***
	(0.19)	(0.19)	(0.18)	(0.22)	(0.24)	(0.15)
Log of grant-date stock price	**-0.08** *	**-0.09** **	**-0.21** ***	**-0.13** ***	**-0.17** ***	**-0.11** ***
	(0.04)	(0.04)	(0.04)	(0.04)	(0.05)	(0.03)
Log of sales	**-0.16** ***	**-0.18** ***	**-0.10** ***	**-0.10** ***	**-0.05** *	**-0.18** ***
	(0.02)	(0.02)	(0.03)	(0.03)	(0.03)	(0.02)
Tobin's Q	**0.14** ***	**0.12** ***	**0.10** ***	**0.11** ***	**0.10** ***	**0.04** **
	(0.02)	(0.02)	(0.02)	(0.02)	(0.02)	(0.02)
R&D	**2.97** ***	**3.11** ***	**3.20** ***	**3.14** ***	**3.04** ***	**5.33** ***
	(0.67)	(0.64)	(0.59)	(0.73)	(0.65)	(0.43)
Contemporaneous return	**-0.08** ***				**-0.06** **	**-0.03** ***
	(0.03)				(0.03)	(0.01)
Prior 2 year return	**-0.04**				**-0.27** ***	**-0.17** ***
	(0.04)				(0.06)	(0.04)
Industry volatility		**-0.28**			**0.00**	**1.42** ***
		(0.32)			(0.37)	(0.19)
Cash flow$_{t-1}$ / Assets$_{t-2}$			**0.45** **		**0.74** ***	**0.15**
			(0.18)		(0.25)	(0.17)
Cash dividends$_{t-1}$ / Assets$_{t-2}$			**-4.80** **		**-3.52** *	**-2.79** **
			(1.87)		(2.03)	(1.19)
Cash balances$_{t-1}$ / Assets$_{t-2}$			**0.69** ***		**0.76** ***	**0.74** ***
			(0.07)		(0.12)	(0.10)
Leverage$_{t-1}$			**-0.38** ***		**-0.38** ***	**-0.28** ***
			(0.12)		(0.14)	(0.08)
Earnings volatility				**0.01** **	**0.01** **	**0.01**
				(0.01)	(0.01)	(0.01)
Firm random effects						Yes
Industry dummies	Yes	Yes	Yes	Yes	Yes	
Year dummies	Yes	Yes	Yes	Yes	Yes	Yes
Pseudo R^2	0.129	0.130	0.133	0.116	0.120	-
N	14,107	14,967	14,634	11,321	11,175	11,175

*** Significant at 1% level; ** significant at 5% level; * significant at 10% level.

1992 to 2000) and a later sample (years 2001 to 2005) shows that neither economic, nor statistical significance is lost (results not reported).

7 The relation between stock option grants and exercises

So far I have documented that a simple model based on employees who have cumulative prospect theory preferences generates predictions which are surprisingly consistent with the data. In this section I show that such a model has the potential to provide a unified framework for thinking about both stock option grants and exercises.

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 portfolio of stocks and bonds the relevant horizon is about one year. Heath, Huddard, 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 shorter horizons than one 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 employee stock options are usually exercised quickly after the vesting date (Huddard and Lang, 1996).

To fix ideas let the grant date be $T = 0$, let T_1 be the vesting date and T_2 be called the horizon date. In T_1 the employee decides on 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

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

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

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

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 $\theta = P_{T_1}\left(e^{rT_2} - 1 \right)$ in the calibrations which implies that the employee's best guess about

Table 10: 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 to the intrinsic value obtained by exercising. The option is not exercised if this value is greater than one (shaded cells). 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 exercises of employee stock options.

Evaluation horizon (in years)	**Firm volatility**									
	20%	*25%*	*30%*	*35%*	***40%***	*45%*	*50%*	*60%*	*70%*	*80%*
0.10	0.23	0.29	0.34	0.38	0.42	0.45	0.48	0.54	0.59	0.63
0.25	0.37	0.44	0.49	0.53	0.58	0.61	0.65	0.71	0.77	0.83
0.50	0.51	0.57	0.63	0.68	0.73	0.77	0.81	0.89	0.97	**1.05**
0.75	0.60	0.67	0.73	0.78	0.84	0.89	0.94	**1.03**	**1.12**	**1.25**
1.00	0.68	0.75	0.81	0.87	0.93	0.99	**1.05**	**1.15**	**1.28**	**1.56**
2.00	0.93	**1.01**	**1.09**	**1.17**	**1.25**	**1.33**	**1.40**	**1.72**	**2.23**	**2.86**
4.00	**1.32**	**1.43**	**1.54**	**1.65**	**1.77**	**1.93**	**2.25**	**3.11**	**4.25**	**5.70**

Panel B: Influence of the moneyness of the option on exercises of employee stock options.

Ratio P_{T1} / K [%]	**Firm volatility**									
	20%	*25%*	*30%*	*35%*	***40%***	*45%*	*50%*	*60%*	*70%*	*80%*
105	**1.30**	**1.42**	**1.55**	**1.84**	**2.17**	**2.51**	**2.88**	**3.67**	**4.53**	**5.46**
110	0.84	0.92	**1.00**	**1.08**	**1.15**	**1.21**	**1.29**	**1.61**	**2.01**	**2.44**
120	0.54	0.61	0.67	0.72	0.77	0.82	0.86	0.95	**1.03**	**1.10**
130	0.40	0.47	0.52	0.57	0.61	0.65	0.68	0.75	0.82	0.89
150	0.25	0.31	0.36	0.40	0.44	0.48	0.51	0.56	0.61	0.66
200	0.13	0.16	0.19	0.22	0.25	0.28	0.31	0.36	0.40	0.44

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 4.

Table 10 Panel A shows 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 one indicates option exercise. Hence, for evaluation horizons smaller than a year, 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, Huddard, and Lang (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 yet unavailable, the results presented here on stock option grants and exercises and the complementary work by Heath, Huddard, and Lang (1999) suggest that prospect theory has the potential to explain individual behavior in stock option programs in a unified framework.

The cumulative prospect theory model predicts that employees from riskier firms should be less likely to exercise their options early. This appears to be in contrast to findings from Bettis, Bizjak, and Lemmon (2005) and Huddard and Lang (1996). The study by Bettis, Bizjak, and Lemmon (2005), however, focuses on executives, which are explicitly not the focus of this study. Since it is likely that top executives and rank-and-file employees differ along many dimensions (financial literacy, expertise in assessing risks etc.), it is not clear that the results for executives carry over to non-executives. Huddard and Lang (1996) find that across their seven firms, exercises are positively related to firm volatility. Closer inspection reveals, however, that four out of seven firms in their sample have coefficients in regressions which predict a negative relation, as suggested by the present model. These coefficients are significant for two of these companies – companies which also happen to be the most volatile in the sample. It would be valuable to see results for non-executive employees on a large sample basis to accurately assess the predictions of the cumulative prospect theory model with respect to exercises.

8 Are firms in a special position to exploit the bias?

Firms that grant stock options do so because – as employees overvalue small probabilities of large gains – they can reduce base salaries by more than one for one. Of course, in principle, anybody can offer skewed payoffs to individuals. Indeed, lottery tickets, long-shot race-track betting or individual investments into risky option portfolios at online brokers are examples of lottery companies, bookmakers and brokers profiting from individuals desire to "hit the jackpot."[40] There are good reasons to believe, however, that firms are in a particularly good position to take advantage of employees subject to probability weighting.

First, there is ample evidence that individuals are greatly overinvested in their own company stock in their retirement savings plans. Some authors attribute this to a default bias (Carroll, Choi, Laibson, Madrian, and Metrick, 2005). In the present case, if the default setting in a pay contract is that it includes options, individuals are likely to be reluctant to exchange the default (options) against an alternative (no options).

Second, it is known at least since Ellsberg (1961), that individuals' willingness to bet on uncertain events depends not only on the degree of uncertainty but also on the source of uncertainty. Important for the firm-employee relationship is the finding that individuals like to bet on things they feel confident and knowledgeable about (Heath and Tversky, 1991, Keppe and Weber, 1995). Moreover, they may adopt the so called "insider-view" (Kahneman and Lovallo, 1993), which is a tendency to favorably judge the likely success of a project if one is directly involved in it. Hence, an employee may overweight the possibility of her stock options paying of a large amount because she is an insider in the firm. At the same time she may focus on her employer's stock options as opposed to other skewed gambles since she feels especially knowledgeable about her own company, thus showing a preference for the more familiar source of uncertainty.

Lastly, firms have the opportunity to exchange stock options for *future pay increases.* While from a classical economic perspective reducing salary increases and cutting base salary by the same amount are the same thing, there is evidence that individuals are much more sensitive to the latter (Kahneman, Knetsch, and Thaler, 1986, Bewley, 1999). This can also explain why it may be hard for an investment bank to step in and offer stock options on a company's stock to the company's employees: the employees would have to pay cash to the bank and thus suffer a nominal loss of cash. The firm, on the other hand, can cut real wages by reducing nominal pay increases – a small procedural change that can have profound impact on the perceived attractiveness of an offered prospect.

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[40] For literature that links probability weighting with these phenomena, see for example, Cook and Clotfelter (1993), Hausch and Ziemba (1995), and Jullien and Salanie (2000).

9 Conclusion

In this paper I show empirically, using a sample of over 2,200 US firms over the years 1992 to 2005, that firms with a high stock price volatility grant more stock options to their non-executive employees. The finding that higher firm volatility is associated with more options is at odds with standard agency models of compensation. The results are robust to including industry effects, showing that labor market competition or special circumstances in new economy firms are not sufficient to explain broad-based employee stock option compensation.

A model in which risk-neutral firms bargain with employees with cumulative prospect theory preferences can explain the empirical findings remarkably well. The key intuition is that probability weighting, and in particular the tendency of individuals to overweight small probabilities of large gains, makes options attractive since they come with a highly skewed payoff distribution of bounded losses and unbounded low-probability upside. This intuition is shown to be consistent with the data when the model is calibrated using parameter values from the experimental literature. An attractive feature of the model is that it avoids specifying an ad hoc bias to explain a perceived empirical anomaly. Instead, it is a direct application of cumulative prospect theory, the most firmly established alternative to expected utility theory to date.

This article explores the ability of probability weighting to explain the widespread use of employee stock options and shows that this concept is remarkably powerful in explaining an important part of the empirical evidence. Of course, it is still possible and likely that other factors also play a role in firms' decisions to issue options. Future research may show that there are interesting complementarities between the explanations. For example, Hall and Murphy (2003) argue that accounting considerations are important for stock option grants, while Oyer and Schaefer (2005) cast serious doubt on this notion on the basis of the large implied risk premium which results from pushing risky claims onto employees who are risk averse. My paper could potentially add to this debate, since my results show that if employees overweight small probabilities, the implied risk premium is much smaller than in standard concave utility models.

Given the non-standard nature of the preference and modelling structure, this work has some natural 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. In the absence of such guidance I propose two plausible reference points – an intrinsic value heuristic in which the employee forecasts the stock price and then subtracts the strike price, as well as the Black-Scholes value of the option. I show that the main results hold for both specifications and that they are robust to sensible deviations from these reference points. A benefit of the proposed reference point assumptions is that they are testable, but further research on the nature of reference points for non-trivial gambles would be clearly valuable. Second, in order to keep the model tractable I impose several restrictions. In particular, I assume that the representative employee has a power value function (as suggested by Tversky and Kahneman, 1992), that the reference point is a linear function of base salary and the number of granted options and that the cost of granting options increases in the number of granted options. These restrictions allow me to show that the concept of probability weighting alone can go a long way towards both qualitatively and, importantly, quantitatively explaining features of option granting behavior that are not easily reconciled with existing theories. Relaxing some of these assumptions is left to further research.

The model and results in this paper suggest a number of promising avenues for future research. It may be interesting, for example, to explore whether employees sort into companies based on their degree of probability weighting, and investigate the strategic implications of such a sorting mechanism. Also, employees rise through the ranks of their corporations. So, if employees are subject to probability weighting, what degree of probability weighting is desirable for top-managers; and how should we design mechanisms to promote the right employees to the top? On a more general level, probability weighting could have a profound impact on firm policies if CEOs are also subject to it. Investigating the relevance and implications of probability weighting for the interaction of firms and markets is an important task for future research.

Appendix

A Proof of Proposition 1

In the main text, the interest rate was set to zero to simplify the exposition. In this appendix, I incorporate interest rates. 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 homogenous of degree* α *in the number of options* n_o *if the reference point is given by* $RP = n_o\theta + \phi e^{rT}$ *(Assumption 1).*

Proof.

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

where the second equality follows from using the definition of the reference point in Assumption 1. This proves the first part of the Lemma. To prove the second part note that

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

□

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 $\left(n_o^{'}, \phi^{'}\right)$ such that

$$E^{\psi}\left[v\left(n_o^{'} \max(P_T - K, 0) + \phi^{'} e^{rT} - RP\right)\right] > E^{\psi}\left[v\left(\overline{V} e^{rT} - RP\right)\right]. \tag{8}$$

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

$$E^{\psi}\left[v\left(n_o^{'}\left(\max\left(P_T-K,0\right)-\theta\right)\right)\right] > v\left(\overline{V}e^{rT}-n_o^{'}\theta-\phi^{'}e^{rT}\right). \tag{9}$$

The left-hand side does not depend on the fixed wage $\phi^{'}$, while

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

Since the RHS of (9) is continuous in ϕ, the value function has unbounded support and since there are no restrictions on ϕ, there exists $\phi^{''}<\phi^{'}$, such that

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

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

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

$$E^{\psi}\left[v\left(n_o^{*}\left(\max\left(P_T-K,0\right)-\theta\right)\right)\right]\cdot v\left(\overline{V}e^{rT}-n_o^{*}\theta-\phi^{*}e^{rT}\right)\geq 0. \tag{10}$$

Hence we have to consider two cases:

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

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

$$E^{\psi}\left[v\left(n_o^{*}\left(\max\left(P_T-K,0\right)-\theta\right)\right)\right]\equiv\overline{E^{\psi}\left(n_o^*\right)}=\left(CE\left(n_o^*,\phi^*\right)e^{rT}-n_o^*\theta-\phi^*e^{rT}\right)^{\alpha}. \tag{11}$$

Rewriting the participation constraint using (11) gives

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

which implies

$$CE\left(n_o^*,\phi^*\right)=\overline{V}. \tag{12}$$

From (11) we get for the certainty equivalent

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

and since prospect value is homogenous of degree α, we have

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

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

$$n_o^* \cdot CE\left(1, 0\right) + \phi^* = \overline{V}. \tag{13}$$

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

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

$$E^{\psi}\left[v\left(n_o^*\left(\max\left(P_T - K, 0\right) - \theta\right)\right)\right] \equiv \overline{E^{\psi}\left(n_o^*\right)} = -\lambda\left(-\left(CE\left(n_o^*, \phi^*\right) \cdot e^{rT} - n_o^*\theta - \phi^* \cdot e^{rT}\right)\right)^{\alpha}. \tag{14}$$

Rewriting the participation constraint using (14) and (10) gives

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

and thus analogous to (12),

$$CE\left(n_o^*, \phi^*\right) = \overline{V}. \tag{15}$$

From (14) we get for the certainty equivalent

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

and since the subjective value is homogenous of degree α, we have

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

which together with equation (15) leads to the formulation for the participation constraint as given in equation (13).

Replacing the participation constraint in (5) with (13) and solving this maximization problem in the usual way gives the optimal contract parameters (n_o^*, ϕ^*) stated in Proposition 1. ■

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