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The Risk Preferences of U.S. Executives

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In this paper, I elicit risk attitudes of U.S. executives by calibrating a subjective option valuation model for option exercising data (1996 to 2008), yielding approximately 65,000 values of relative risk aversion (RRA) for almost 7,000 executives. The observed behavior is generally consistent with moderate risk aversion and a median (mean) RRA close to one (three). Values are validated for chief executive officers (CEOs) by testing theory-based predictions on the influence of individual characteristics on risk preferences such as gender, marital status, religiosity, and intelligence. Senior managers such as CEOs, presidents, and chairpersons of the boards of directors are significantly less risk averse than non-senior executives. RRA heterogeneity is strongly correlated with sector membership and firm-level variables such as size, performance, and capital structure. Alternative factors influencing option exercises are tested for their influence on RRA values.

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1. Introduction

Recently, researchers have made significant advances in estimating the distribution of risk preferences in a variety of contexts. As a result, we are equipped with adequate tools to elicit risk preferences by observing behavior in the lab (e.g., Holt and Laury 2002, Andersen et al. 2008), in securities markets (Bliss and Panigirtzoglou 2004, Bollerslev et al. 2011), in labor markets (e.g., Chetty 2006), and in insurance markets (e.g., Cohen and Einav 2007). However, little evidence exists on the distribution of risk preferences of key decision makers such as senior managers. Since managers play a pivotal role in our economic system, this lack of insight limits us from addressing a number of important research questions. For example, researchers testing contract theory face a predicament when the heterogeneity of risk preferences is not observed because individuals exhibiting different risk preferences are likely to choose different contracts (Ackerberg and Botticini 2002, Allen and Lueck 1995). Hence, any study that relates executive incentives to managerial behavior (such as earnings management, the choice of capital structure, or accounting fraud) should be viewed under the proviso that the sorting effect of individuals into contracts is of low empirical relevance.

Although some evidence on the risk preferences of executives of primarily private firms has been presented recently (Graham et al. 2013), the question remains open as to whether executives of listed firms tend to exhibit high or low degrees of risk aversion.[1] Simply extrapolating from studies on nonexecutives may not be feasible because executives represent a demographic group associated with a select set of socioeconomic characteristics and psychological traits, all of which may correlate with risk preferences (e.g., MacCrimmon and Wehrung 1990, Locke et al. 1991, Borghans et al. 2009, Dohmen et al. 2010). Second, executives undergo a selection process, and the probability of success of surpassing rivals during this process may itself be a function of risk aversion (Skaperdas and Gan 1995). Third, executives have made human capital investments in the past that allow them to perform managerial tasks, and the propensity to make such investments is related to risk aversion (Shaw 1996).

Obviously, it is difficult to measure risk preferences of executives whose behavior cannot be studied in controlled experiments and whose private financial choices are typically opaque. In this paper, I propose a method for recovering risk-aversion measures from exercising patterns of employee stock options and I apply it to a large, widely available set of data. In general, option valuation models are not helpful for recovering risk preferences since the value of an option is independent of the risk preferences of the option holder when hedging is unconstrained (Black

[1] Further indirect evidence is provided by Becker (2006), who reports that CEO equity incentives are correlated with personal wealth levels, suggesting that risk aversion plays a role in designing incentive schemes.

and Scholes 1973, Merton 1973). However, since executives are forced to hold more of a firm's stock than they would voluntarily choose to, they assign a lower value to a portfolio comprising employee options than an unconstrained investor, and methods of *subjective* valuation that reflect individual risk aversion can be applied (Hall and Murphy 2002, Ingersoll 2006). Since subjective option values are not directly observed, I use an indirect approach to estimate executives' risk aversion. I assume that the option holder chooses the stock price at which to exercise the option such as to maximize its subjective value. Subsequently, I identify the value of relative risk aversion (RRA, or henceforth denoted γ) consistent with the observed trigger share price under this assumption. For the first-order approach suggested here, I derive a set of conditions under which the method is guaranteed to provide γ-values consistent with subjective option value maximization. Those conditions define a parameter space that covers the large majority of the observations used in this study.

I apply the method to employee stock option exercise data reported to the Securities and Exchange Commission (SEC) under insider trading regulations (SEC Form 4). By tapping into this public source, I obtain approximately 65,000 estimates of relative risk aversion from around 7,000 executives during the period 1996 to 2008, comprising a variety of managerial functions and hierarchy levels at U.S. firms. A pooling of all executives shows that the large majority of transactions imply risk-averse preferences. Reassuringly for calibration studies such as Murphy (1999) and others, we find a median value of risk aversion of approximately one and a mean value of three, which are close to the values used by these studies. The largest concentration of mass of the empirical distribution occurs between zero and one. The share of transactions yielding estimates suggesting risk-loving preference is below 1%.

Unfortunately, no other risk preference measures are available to directly validate the parameters derived in this paper. Instead, I use the fact that certain individual characteristics were hypothesized and empirically shown to predict differences in risk preferences such as gender, marital status, intelligence, and religious affiliation. To gather this information, I use biographic information from Marquis *Who's Who* for the chief executive officer (CEO) cohort. For all characteristics, I find the differences in risk preferences to have the expected sign. Most of these results are associated with some level of statistical significance, lending support to the validity of the risk-aversion measures. From the same source, I use data on further individual characteristics such as political affiliation and military experience and find plausible values of correlations with risk aversion.

As a further check for whether the method produces plausible estimates for risk preferences, I examine the extent of within-individual variation by performing an analysis of variance (ANOVA). The results show that 50%, 2%, and 48% of the variance in risk preferences are associated with between-individual, year-based, and within-individual variations, respectively. Hence, the preference measures still contain a substantial amount of unexplained fluctuations within individuals. Since risk preference data are skewed and p-values from F-tests are highly sensitive to deviations from normality, an ANOVA might not be appropriate. Hence, I test the stability of the ranking of executives' median risk preferences across years and find that approximately 70% of executives remain in two adjacent quartiles of the yearly risk-aversion distributions across the entire observation period.

Finding substantial within-individual variation is not surprising given the many factors besides risk aversion that are outside the model and yet may affect the option-exercise decision. Beyond risk aversion, one might be concerned that executives wish to signal information to the market by holding on to options for longer than they would otherwise. Because the model would misinterpret these long holding periods as low risk aversion rather than signaling, the risk-aversion estimates may be too low. However, estimated risk aversion is only weakly related to bid–ask spreads (a proxy for information asymmetry), suggesting that the bias is not severe. Furthermore, I test the impact of factors such as liquidity-driven exercises and reference points not accounted for in Ingersoll's (2006) option model and find no evidence that reference points generate significant biases in preference estimates. However, there is evidence that within individual heterogeneity is associated with liquidity-driven exercises.

Another factor that potentially distorts option-implied risk preferences is managerial overconfidence. Malmendier and Tate (2005, 2008) introduced overconfidence measures based on option exercising behavior that are by design correlated with the risk-aversion parameters derived in this paper.[2] Since the option-exercising patterns consistent with these definitions of overconfidence often give rise to low levels of risk aversion in Ingersoll's (2006) model, one may suspect that risk preferences are downward biased when overconfidence is not accounted for. By removing those observations that are categorized as overconfident in Malmendier and Tate (2005), I find that the median estimated risk aversion increases from 0.911 to 1.017. Further tests indicate that overconfidence might not represent a severe

[2] For example, executives who only exercise in the year before the option expires or who do not exercise options even though they are well in the money are categorized as overconfident.

issue for the entire distribution of risk preferences; however, this paper could not resolve the issue of whether a general tendency exists for executives to exhibit overconfidence.

One primary motivation to compute risk preferences is to relate them to corporate outcomes. Without aiming to find causal relationships, I examine the distribution of risk preferences across firm-level variables and detect a number of plausible patters. First, regulated industries host managers that are more averse to risk than their peers in unregulated industries. Second, larger firms employ more risk-averse managers than smaller ones. Third, more risk-averse executives work at less levered companies. Fourth, even though the relationship is not monotone for all measures, higher-performing firms are associated with less risk-averse executives. Finally and unsurprisingly, higher total and systematic risk tends to be related to lower managerial risk aversion.

This paper is the first to provide (partially) validated risk preferences for the large majority of executives of listed U.S. firms that can be readily employed in empirical research.[3] This paper is closely related to the work of Graham et al. (2013), who elicit risk aversion from survey experiments. However, the data sets do not substantially overlap because Graham et al. (2013) primarily sample private firms, whereas we exclusively analyze public firm executives. Moreover, this paper is distinguished by measuring revealed preferences instead of stated preferences as in paper by Graham et al. (2013). Second, this study's measure is continuous, whereas the Graham et al. (2013) measure is dichotomous. Finally, for most executives, this paper provides estimates that are based on a series of transactions at different time points and not a cross-section as in the work of Graham et al. (2013).

This study is also related to a number of papers that use calibration techniques of option pricing models, such as by eliciting subjective option values from calibrating utility models to observed exercise pattern by employees (e.g., Lambert et al. 1991, Carpenter 1998, Dittmann and Maug 2007). One of the distinguishing features of Ingersoll's (2006) model is that it allows the computation of the marginal subjective value of an option instead of the average value of all options that mature on the date on which utility is evaluated. Moreover, none of these papers calibrate models explicitly to back out managerial risk aversion.[4]

However, note that the results of this study indicating that managers tend to be moderately risk averse are consistent with calibration studies such as Bettis et al. (2005), Armstrong (2007), and others that find that subjective option values are lower than the respective risk-neutral values.[5]

2. Methodology

The valuation of executive stock options is associated with several problems that prevent standard tools such as the Black and Scholes model to be employed.[6] First, executives might be averse to risk exposure. In general, although risk preferences do not affect asset values when investors can freely hedge their positions, risk-sharing arrangements require employees to hold securities such as stock options in excess of the voluntary level. As a result, option holders are exposed to firm-specific risk that they cannot entirely diversify away. In this case, risk-averse individuals will attach lower (subjective) values to their portfolios that contain larger proportions of these assets (Hall and Murphy 2002, Ingersoll 2006). Another reason for why the Black–Scholes model for European call options is not appropriate in this context is the observed exercising behavior. Heath et al. (1999), Klein and Maug (2009), and other empirical studies have reported that executives exercise options well before they expire. Models such as the standard Black–Scholes model do not predict early exercising and therefore might be inappropriate to be employed to calculate option values for executives. Ingersoll (2006) addressed both problems of risk aversion and early exercising, on which the following exposition is based.

Ingersoll (2006) makes a number of assumptions that are standard in portfolio-consumption models. First, the stock price of the company and the prices of other primary assets follow a multidimensional Brownian motion of portfolio-based factors with constant parameters. Second, he assumes away taxes and transactions costs, constraints on borrowing or short selling or any other frictions in the market. Ingersoll's (2006) main nonstandard ingredient is the assumption that managers need to hold a constant minimum share $\theta > 0$ of wealth in their firms' stock. He imposes a factor model of risk to identify the residual risk of the firm that the executive cannot hedge away under the given constraint on θ. This is the risk that the employee otherwise would have avoided

[3] The data on managerial risk preferences are available from the author's personal website (https://sites.google.com/site/steffenhbrenner/).

[4] Dittmann et al. (2010) calibrate and compare principal–agent models with expected utility and loss aversion. Observed CEO pay contracts seem a better fit with models based on loss-averse preferences than simple CRRA utility functions. Hence, a useful extension of this study would be to compute implied measures of risk aversion based on more general utility functions.

[5] One exception is Hallock and Olson (2006), who estimate a random utility model for a single-firm sample and find that subjective option values exceed Black–Scholes values. However, Armstrong (2007) points out a number of problems with this study, arriving at opposite results.

[6] For an excellent survey of option valuation models, see Broadie and Detemple (2004).

because it is unpriced. Furthermore, Ingersoll (2006) uses a constant relative risk-aversion (CRRA) function to describe utility u given by $u_t = (1/(1-\gamma))c_t^{(1-\gamma)}$ where c_t is the level of consumption at time t and γ is the parameter of relative risk aversion. The individual is said to be risk averse if $\gamma > 0$, risk neutral if $\gamma = 0$, and risk loving otherwise.[7]

Unfortunately, no closed-form solution is available to value American call options with early exercise under this set of assumptions.[8] However, Ingersoll (1998) develops a barrier-derivative approximation method that has been shown to perform well compared with other commonly employed techniques.[9] The option value depends on the exercise policy $k(t)$ that denotes the share price that triggers the exercise of the option the first time it is reached. Essentially, Ingersoll (1998) derives the subjective value of an option for a given exercise strategy, and then searches for the one that maximizes the option value. The option value is approximate because the set of exercise strategies comprise only constant policies k that do not change ex post in response to changes in parameters. Ingersoll (1998) shows that for reasonable parameters, the true option values are close to the option values based on the optimal constant exercise strategy.

Let us call the approximative subjective option value when exercise strategies are constrained to constant-barrier strategies such as $\tilde{C}$ that is given by Ingersoll (2006) as follows:

$$\begin{aligned}
\tilde{C}&(k \mid \gamma) \\
&= Se^{-\hat{q}\Delta T}\Bigg\{\Phi(h_X^+) - \Phi(h_k^+) \\
&\qquad - \left(\frac{k}{S}\right)^{2(\xi+1)}\left[\Phi(h^+_{(XS^2)/k^2}) - \Phi(h^+_{S^2/k})\right]\Bigg\} \\
&\quad - Xe^{-\hat{r}\Delta T}\Bigg\{\Phi(h_X^-) - \Phi(h_k^-) \\
&\qquad - \left(\frac{k}{S}\right)^{2\xi}\left[\Phi(h^-_{(XS^2)/k^2}) - \Phi(h^-_{S^2/k})\right]\Bigg\} \\
&\quad + (k - X)\left[\left(\frac{k}{S}\right)^{\xi-\kappa}\Phi(H_k^+) + \left(\frac{k}{S}\right)^{\xi+\kappa}\Phi(H_k^-)\right], \quad (1)
\end{aligned}$$

where S is the current share price, X is the exercise price, and $k \geq S$ is a share price threshold that defines the constant-barrier exercising strategy. Furthermore,

$$h_Y^{\pm} \equiv \ln(S/Y)\big(\xi + \tfrac{1}{2} \pm \tfrac{1}{2}\big)\sigma\sqrt{\Delta T},$$

$$H_k^{\pm} \equiv \frac{\ln(S/k) \pm \kappa\sigma^2\Delta T}{\sigma\sqrt{\Delta T}}, \quad \kappa \equiv \sqrt{\xi^2 + 2\hat{r}/\sigma^2},$$

$$\xi \equiv (\hat{r} - \hat{q})/\sigma^2 - \tfrac{1}{2}, \quad \hat{r} \equiv r - \gamma\theta^2\nu^2, \quad \hat{q} \equiv q + \gamma(1-\theta)\theta\nu^2,$$

where r is the expected riskless rate, σ is the firm's total risk, ν is the firm's residual risk, ΔT represents the time remaining until the option matures, and q is the expected dividend yield. As previously mentioned, γ is the parameter of relative risk aversion, and θ is the share of the managers' wealth tied to firm equity *in excess* of what the executive would hold voluntarily. The terms h, H, $\hat{r}$, and $\hat{q}$ are functions of the risk aversion γ, the stock price volatility σ, the risk-free rate r, the dividend yield q, and residual risk ν; Φ is the standard cumulative normal distribution function. In this model, future income streams are discounted at the subjective interest rate $\hat{r}$ and the subjective dividend yield $\hat{q}$ instead of the unadjusted rates, which is the point at which the managers' risk aversion becomes relevant for the valuation of the option.

One may wonder how the timing of option exercises can be affected by risk aversion, given that θ—the share of wealth invested in firm equity—is assumed to be constant. Option exercises affect risk exposure because they are dictated by the optimal path of consumption of a risk-averse individual. More risk-averse individuals may favor current consumption over risky investments, and hence the "absolute" rather than the "relative" risk exposure can be influenced by option exercises in this model.[10]

How can we use (1) to infer the option holder's risk preferences? Because subjective option values are not observable, we cannot directly calibrate this model to the data. One alternative is to take a first-order condition approach to back out γ from the model. Since $\tilde{C}(k)$ is continuously differentiable, the first derivative of (1) can be taken with respect to the choice of k, $\partial\tilde{C}(k,\gamma)/\partial k$. Assuming that the executive is maximizing the option value when choosing to exercise, for the day of exercise we obtain

$$\frac{\partial\tilde{C}(k, \gamma \mid k_o = S)}{\partial k} = 0 \quad (2)$$

[7] The assumption of constant relative risk aversion is supported by empirical evidence (Chiappori and Paiella 2011) and tremendously facilitates the analysis in a dynamic context since it makes relative risk aversion independent from the individual's wealth level.

[8] A Black–Scholes-like closed-form solution for European call options is available from Ingersoll (2006, §II).

[9] Early exercise is often taken into account by valuing the option based on a European call option and reducing the time to maturity. In addition to other problems, this approach fails to capture heterogeneity in risk preferences.

[10] Empirical evidence by Ofek and Yermack (2000) and data derived for this paper support the notion that, on average, incentives and the share of wealth invested in firm equity do not change much over time. However, these findings do not rule out that in some cases executives experience big drops in θ after selling substantial amounts of firm equity, for example, because boards do not always replenish those incentives (Ladika 2013). In those cases, individuals might appear more risk averse than they really are because there is the potential benefit of early exercises of reducing risk exposure.

when the current share price S equals k_o. Equation (2) implicitly defines γ. In words, if we observe the share price k_o at which the option was exercised, then we obtain an implied measure of risk aversion γ by finding the null of the first order condition (2). Hence, $\gamma = f(k_0, X, \sigma, \nu, q, r, \Delta T, \theta)$ is a function of the observed price when the option was exercised and all other input variables for the option value (1).

Since there is no closed-form solution given for γ that could be derived from (2), we use a numerical approach. Unfortunately, for a given value of γ, $\tilde{C}(k,\gamma)$ it is not guaranteed to be concave in k. In other words, for γ returned by any numerical procedure, we cannot be sure that the observed trigger price k_o indeed maximizes the option value. Hence, it then remains to be proven that the solution γ to the previous first-order condition above is indeed consistent with subjective option value maximization. In the online appendix (available at https://sites.google.com/site/steffenhbrenner/home/research), I provide sufficient conditions for the parameter space to imply local concavity of $\tilde{C}(k,\gamma)$. Additionally, I numerically check the second order condition for (1) to ensure a local maximum for every observation.

I provide some intuition for how the model identifies risk aversion. Unfortunately, general comparative statistics are difficult to obtain given that a closed-form solution of the function defining γ is not available. However, I provide some numerical results on the relationships between input variables and the implied risk preferences for three scenarios. One is based on the "median option" of the sample used in this paper, that is, the input values for the model equal the sample median values displayed in §3. For these parameters, the model implies $\gamma = 0.872$. Furthermore, I performed the same test for two options with similar parameters except for the exercise price and the dividend yield, giving rise to lower ($\gamma = 0.1$) and higher ($\gamma = 2.5$) values of relative risk aversion, to examine whether the results are sensitive to the levels of risk aversion. All results are displayed in Table 1. First, ceteris paribus, increasing total risk (σ^2) by 1% increases relative risk aversion by 0.8% to 2.9%. Note that when we increase total risk, firm-specific risk remains constant. Then, a small increase in total risk increases the subjective value of the option and, therefore, makes the marginal option holder better off by not exercising the option at this point in time. Hence, the option holder who decides to exercise the option after an increase in σ^2 is endowed with a higher aversion to risk. In contrast, increasing firm-specific risk (ν^2) uniformly decreases risk aversion by approximately 1%. This condition holds because keeping the other transaction parameters such as share and exercise prices and time to maturity constant prevents a higher exposure of firm-specific risk from being hedged by portfolio transactions. Hence, a higher risk tolerance entails option exercising at higher levels of firm-specific risk. Furthermore, increasing the share of wealth θ invested in firm equity by 1% leads to lower risk-aversion values (by 0.2% and 0.8%), which follows from a similar logic as the result on firm-specific risk ν. In contrast, a 1% increase in the time to maturity ΔT represents a more cautious exercising behavior, and therefore it induces higher values of risk aversion (0.1% to 1.3%). Furthermore, the riskless rate and the dividend yield determine the structure and discount rate for future cash flows. An increase in the riskless rate and a decrease in the dividend yield would decrease the option value, and hence the same exercising patterns would suggest a lower level of risk aversion. Consistent with that explanation, I find that a 1% increase in the riskless rate r induces an increase in γ by 0.2% to 3.0%, and an increase in the dividend yield q implies an increase by 0.1% to 2.7%. Finally, we consider the impact of an increase in the current share price S and the exercise price X on implied risk aversion. Increasing the first and decreasing the latter would both lead to an increase in the ratio S/X at the time of the exercise, indicating that the individual exhibits a more tolerant attitude toward risk bearing. In line with these thoughts, we find that implied risk aversion changes by −1.5% to −4.3% (1.6% to 4.4%) when $S(X)$ increases by 1%.

Table 1 **Numerical Comparative Statics**

	$\gamma = 0.1$	$\gamma = 0.872$	$\gamma = 2.5$
	$S = 78.65$	$S = 39.30$	$S = 21.82$
σ^2	2.88	0.77	0.97
ν^2	−0.96	−0.96	−0.96
θ	−0.23	−0.53	−0.76
ΔT	1.30	0.40	0.14
r	3.04	0.52	0.23
q	−2.66	—	−0.07
S	−4.32	−1.52	−2.60
X	4.38	1.55	2.71

Notes. This table shows the percentage changes in the implied risk aversion as a result of a 1% increase in the input variables listed in the corresponding row of the first column. Three scenarios are considered where S takes the values shown at the top of each column, and $q = 0.01$ for the calculations for the first and third rows, and $q = 0$ otherwise. All other variables take the median values displayed in Table 2.

3. Data

In this study, the unit of observation is a single option transaction for which I calibrate Ingersoll's (2006) subjective option value model. To obtain the necessary input for the calibration method, I match data from a variety of sources. First, I use Thomson Reuters' Insider Filings data that cover all reports to the SEC on Form 4 for share and option-related transactions by corporate insiders. Specifically, the data contain transaction-specific information such as the date on which the transaction was executed, the number of exercised options, the exercise and market prices of the company's stock on the transaction day, and the time to maturity. The initial sample covers 36,000 different individuals for whom we observe employee option exercises between 1996 and 2008.

Another model parameter that enters Ingersoll's (2006) model is the share of the manager's wealth invested in firm equity higher than the voluntary level, denoted by θ. Nonfirm wealth of U.S. executives is difficult to measure. For the subset of executives covered by the Execucomp database, Dittmann and Maug (2007) constructed a nonfirm wealth measure based on previous income streams, observable investment decisions, and assumptions about consumption and taxation. Dittmann (2010) provides recent estimates.[11] The measure θ is defined as the ratio of wealth tied to firm equity, which is computed as the sum of the values of the stock and Black–Scholes option values following Core and Guay's (2002) approach for the equity holdings before 2006 and the total wealth of the executive. Note that this measure is imprecise because Dittmann and Maug's (2007) assumption about the path of consumption does not account for differences in risk aversion. Furthermore, it ignores human capital.[12] Furthermore, in Ingersoll (2006), this value θ is not what enters the model, but is the share of firm-related equity investments *in excess* of what an executive voluntarily holds. Although we do not observe the true value of θ, for a typical executive, the share of voluntarily held equity should be small and close to their weight in the market portfolio. Furthermore, θ may not literally measure contractual obligations to hold a certain share of wealth in firm equity, but also tacit pressure or the intrinsic desire to appear loyal. Given that compensation data from which Dittmann and Maug (2007) derive their wealth estimates are available only for executives represented in Compustat's Execucomp database, the sample considerably shrinks when matching the data on individual wealth information. We obtain about 9.3 observations on average per individual, for 6,983 individuals for which we have all the required information to perform the calibration.[13]

[11] The wealth estimates can be downloaded from Ingolf Dittmann's website, which had the following URL at the time this study was conducted: http://people.few.eur.nl/dittmann/data.htm.

[12] Whether our approach systematically over- or underestimates the true value of θ is unclear because firm-specific human capital enters the nominator and unobserved assets and general human capital enter the denominator of θ.

Table 2 Descriptive Statistics for Input Variables

		Mean	Median	Std. dev.
Volatility	σ	0.432	0.376	0.228
Residual risk	ν	0.391	0.338	0.220
Time to maturity	ΔT	4.462	4.783	2.657
Dividend yield	q	0.002	0.000	0.039
Riskless rate	r	0.043	0.045	0.013
Ratio of share price (S) to exercise price (X)	S/X	10.399	2.588	271.227
Ratio of nonfirm to total wealth	θ	0.555	0.579	0.239

Notes. This table shows descriptive statistics for model variables from a sample of 64,994 observations. The volatility and residual risk are annualized values based on standard capital asset pricing model estimations on daily share price data for the past 36 months counted from the transaction. The dividend yield is the ratio of the dividend paid for the current financial year and the closing share price on the day of the transaction. As the riskless rate, U.S. Treasury bills with a maturity of three months are used. The ratio θ is the ratio of firm-related to total executive wealth and based on nonfirm wealth estimates provided by Dittmann and Maug (2007) and estimates for firm-related wealth (equity holdings), which is based on the Black and Scholes formula for options. Financial data are taken from CRSP and Compustat. Note that values are not shown in percentage terms.

Regarding further inputs into the valuation function such as volatility σ and residual risk ν, I use standard measures based on daily stock price data from the Center for Research in Security Prices (CRSP). I compute volatility σ and derive the residual risk ν based on the estimation of a simple capital asset pricing model from daily data over the past 36 months from the day of the transaction using S&P 500 returns as the market returns. As the riskless rate r, I use the three-month Treasury bill rate provided by CRSP.

Table 2 presents descriptive statistics for these variables. The volatility has a median of approximately 0.37 and a mean of approximately 0.43. The average residual risk is smaller by approximately 0.04 than the estimated volatility. The average time to maturity is 4.46 years. Provided that option contracts run 7 to 10 years and vesting typically occurs after 3 to 5 years, many options seem to get exercised relatively quickly after vesting. The median value for the dividend rate is 0, whereas the average is 0.2%. For the riskless rate, values are approximately 4.3% (mean) and 4.5% (median) for the given time period. The mean of relative wealth invested in firm equity for those executives is 56%, and the median is 58%.

Table 3 sheds light on the managerial functions and the hierarchy levels represented in the data set of self-reported option exercises. The categories surveyed by the SEC include managers from the top echelon, such as CEOs, chief financial officers (CFOs), chief operating officers (COOs), and chief technology officers. The

[13] I further eliminate 6.5% of observations with θ_i-values outside the closed unit interval.

Table 3 **Number of Observations Across Managerial Categories (Primary and Nonprimary Role-Code Entries)**

	Function	No. of obs.
O	Officer	38,899
CEO	Chief executive officer	16,400
P	President	13,969
OX	Divisional officer	10,811
CFO	Chief financial officer	9,760
OD	Officer and director	5,639
CB	Chairman of the board and officer	5,248
EVP	Executive vice president	5,071
VP	Vice president	4,732
CO	Chief operating officer	3,926
SVP	Second vice president	3,757
GC	General counsel	2,889
OS	Officer of subsidiary	1,402
OT	Officer and treasurer	1,207
CT	Chief technology officer	888

Notes. This table shows frequencies of managerial categories that are reported in Form 4 to the SEC. Up to four categories can be entered per filing. Typically, multiple role codes are reported.

categories also cover lower hierarchy levels, including second vice presidents, executive vice presidents, and divisional managers, and include some observations from general counsels and secretaries. Senior executives such as CEOs, presidents, and CFOs clearly belong to the class of managers most heavily represented in this sample.

4. Results

The risk preferences computed in this paper yield from applying the first-order condition of subjective option value maximization (Equation (2)). Unfortunately, a closed-form representation of the risk-aversion parameter γ cannot be derived from this condition. Hence, I use Equation (2) as an implicit function of γ and implement a numerical approach to elicit the preference parameter from it.[14] Let us call $\hat{\gamma}$ the value returned by the numerical procedure. It is not guaranteed that the option value function (1) is concave for all values of γ or that the procedure arrives at a result sufficiently close to the solution within the given number of iterations. Hence, I additionally compute the second derivative of the value function for the given model parameters at $\hat{\gamma}$ and check whether it is negative. In the online appendix to this paper, I provide a set of sufficient conditions that guarantee concavity of (1) and show that approximately 81% of the observations in our sample satisfy these conditions. Furthermore, since the numerical procedure naturally produces inexact solutions, I verify that $\hat{\gamma}$ is close to the exact risk-aversion parameter by testing for deviations of 0.1 from this value whether the corresponding subjective option values are lower than those for $\hat{\gamma}$; that is, I examine whether $\max[\tilde{C}(\hat{\gamma}-0.1), \tilde{C}(\hat{\gamma}+0.1)] < \tilde{C}(\hat{\gamma})$. For those transactions that do not satisfy these two conditions, I rerun the procedure with a larger number of iterations and recheck the conditions.

Table 4 provides an overview over the risk preference measures obtained from option exercise data and reports percentiles and other statistics for the entire sample. The median of approximately 0.9 indicates a moderate level of risk aversion for the typical executives. This value is broadly within the range of parameters derived by previous research for nonexecutives (see, for example, the survey in Bliss and Panigirtzoglou 2004). Outliers do not appear to play an important role. Cochrane and Hansen (1992) view CRRA values larger than 50 as implausible. Approximately 1% of all observations are from this range. I continue the analysis based on winsorized data and assign the value 50 to every observation from the set of outliers. Even after winsorizing, the distribution of γ-values is skewed right, resulting in the mean of approximately 2.9 being more than three times as large as the median. Note that right-skewness appears to be a typical feature of the distribution of risk preferences (see, e.g., Cohen and Einav 2007).

I also compute the share of observations that give rise to risk-loving, risk-neutral, and risk-averse preferences. I define risk neutrality as $|\gamma| < 0.1$. Of course, the size of the interval defining risk neutrality is

Table 4 **Percentiles of the Distribution of Implied Risk-Aversion Parameters and Other Descriptives**

10th percentile	0.110
20th percentile	0.237
30th percentile	0.409
40th percentile	0.630
Median	0.911
60th percentile	1.339
70th percentile	1.969
80th percentile	3.149
90th percentile	6.170
Mean	2.918
Standard deviation	7.664
Share of risk-loving individuals	0.006
Share of risk-neutral individuals	0.087
Share of risk-averse individuals	0.897
Share of outliers (risk averse)	0.010

Notes. The percentiles are computed based on the entire distribution; the mean and the standard deviation are based on the sample in which outliers are assigned the value 50. As outliers, we treat all observations with $\gamma > 50$. In the lower part of the table, the relative share of three categories of risk aversion are reported. The shares are calculated as the number of observations consistent with the corresponding risk preferences relative to the total number of observations.

[14] I use the *findroot* procedure in Mathematica with a starting value for $\gamma = 2$ and compute 200 iterations.

arbitrary. However, others have used similar values ($|\gamma| < 0.15$ in Holt and Laury 2002). Around 9% of the observations fall into the narrow band associated with risk neutrality. Not surprisingly, most of the derived parameters are larger than 0.1, indicating that at least some degree of risk aversion is prevalent at the risk preferences of executives. More than 90% of the observations belong to this category. Even the executives at the upper end of the distribution (90th percentile) exhibit plausible values of relative risk aversion of approximately six.

Some of the transactions seem to be in line with risk-loving preferences. However, note that in these cases, the assumption of θ taking values substantially larger than zero is likely misplaced. To satisfy their appetite for risk, risk-loving executives may themselves choose a more substantial risk exposure by holding larger portions of firm equity. If this statement holds, then the true level of θ is probably close to zero, and Ingersoll's (2006) valuation model does not apply. For this reason, we henceforth ignore solutions with $\gamma < -0.1$. However, note that only approximately 0.6% of the transactions suggest risk-loving behavior; therefore, this problem is of low practical importance.

Our results are potentially biased because we are only able to derive implied measures of risk aversion for option holders who exercise their options before the day they expire. For last-day exercisers, we compute an upper bound of risk aversion from observations during previous periods when the executive chose not to exercise the option, but there is no way to recover more information. Obviously, these cases are more likely to be associated with executives endowed with a low aversion to risk, and hence observing their risk preferences probably pushes down the overall level of risk aversion. However, last-day option exercises are rare. During the entire period from 1996 to 2008, there are only 474 such cases, representing 0.7% of all observations.

Insider trading reports contain information on the function that the manager performs in the company (role code). I report descriptive statistics on these data in Table 5. The first columns are reserved for senior executives such as CEOs, CFOs, officers that serve as board chairpersons, presidents, and COOs. CEOs and chairpersons of the board display the lowest aversion to risk (median values less than 0.6). The vast majority of board chairpersons in our sample are in fact CEOs. Substantial variation exists in the mean and median of risk aversion across executives. Generally, the level of risk aversion tends to be substantially smaller at higher levels of the corporate hierarchy. For non-senior executives (defined as individuals whose title does not contain "chief" and who are not board members), the model implies values of risk aversion between 2.3 and 4.5 (mean) and 0.7 and 1.9 (median). The difference in mean and median between these two groups is strongly significant (results not reported). The exercise behavior for lower-level officers such as divisional managers (OXs) and those performing specific functions such as general counsels (GCs) generally implies much higher γ-values.

In the next step, we analyze the distribution of risk preferences across economic sectors. Table 6 reports descriptive statistics for CEO risk aversion (upper panel) and non-CEO risk aversion (lower panel) across 11 sectors. First note that employee options are much more important in some sectors than in others. The technology, healthcare, finance, and consumer services sectors cover the majority of all observations, both for CEOs and non-chief executives. Furthermore, considerable heterogeneity exists in CEO risk preferences across sectors. The median RRA is approximately 0.4 for healthcare and consumer nondurables, and reaches 1.8 for the public utilities sector. Additionally, CEOs in the technology and consumer services sectors exhibit relatively low values of risk aversion, whereas the finance sector and the basic industries sector on the other side are associated with more risk-averse chief executives. One potential explanation for this pattern is that more risk-averse managers prefer to work for firms protected from competition by market power such as in the financial and utilities Sectors, which is called the Galbraith–Caves hypothesis (see Galbraith 1967, Chaps. 3 and 7; Caves 1970; Edwards and Heggestad 1973; Christofides and Tapon 1979). However, note

Table 5 Implied Risk-Aversion Parameters Across Managerial Categories

	Top executives							Non-top executives							
	CEO	CFO	CB	P	CO	CT	OD	OX	VP	SVP	EVP	GC	OS	O	OT
Mean	1.92	3.26	2.30	2.20	2.80	4.07	2.50	3.70	2.30	2.90	3.94	3.22	4.45	3.42	3.00
Median	0.59	0.94	0.57	0.66	0.96	0.92	0.78	1.26	0.74	0.97	1.53	1.29	1.89	1.13	0.90
Standard deviation	5.50	7.63	5.75	5.59	5.98	9.44	6.27	7.77	6.05	6.54	7.64	6.78	7.70	7.35	7.12

Notes. The mean, median, and standard deviation are computed excluding individuals with $\gamma < -0.1$. Outliers with $\gamma > 50$ are assigned a value of 50. The full names of the managerial categories can be found in Table 3.

Table 6 Risk Preferences Across Economic Sectors

Sector	Mean	Median	Std. dev.	Mean θ	No. of obs.
CEOs					
Finance	3.06	1.06	6.74	0.63	1,447
Healthcare	0.98	0.35	2.30	0.62	2,055
Consumer nondurables	1.55	0.38	4.85	0.49	2,121
Consumer services	1.84	0.57	4.58	0.57	2,471
Consumer durables	2.44	0.72	6.29	0.54	546
Energy	2.47	0.75	7.41	0.57	967
Transportation	2.25	0.66	4.99	0.55	147
Technology	1.80	0.45	5.94	0.58	3,848
Basic industries	3.05	1.42	5.73	0.56	810
Capital goods	2.42	0.91	5.32	0.59	1,315
Public utilities	4.75	1.83	7.37	0.56	485
Non-chief executives					
Finance	4.22	1.94	7.48	0.62	4,674
Healthcare	2.11	0.73	5.15	0.58	6,070
Consumer nondurables	4.28	1.49	8.73	0.51	3,229
Consumer services	2.92	0.91	6.63	0.56	6,814
Consumer durables	2.88	0.90	6.58	0.51	1,682
Energy	1.82	0.82	4.33	0.55	3,117
Transportation	2.30	0.97	5.01	0.58	750
Technology	3.09	0.89	7.47	0.52	12,732
Basic industries	5.28	2.08	9.49	0.49	2,826
Capital goods	2.69	1.20	5.88	0.56	4,457
Public utilities	6.95	3.33	10.13	0.51	1,985

Notes. This table lists the mean, median, and standard deviation of risk aversion for the economic sectors reported in Form 4 to the SEC. The upper panel displays values for CEOs, and the lower panel displays values for non-chief executives. The two rightmost columns show sector averages for the ratio of firm-related to total wealth (θ) and the number of observations.

that these numbers represent simple averages or medians for executives in these industries and do not take into account any structural differences across the sectors such as firm size or differences in financing. The lower panel of Table 6 shows risk attitudes for all non-chief executives. Although the overall level of risk aversion is higher, the differences between sectors are largely persistent.

Option-implied risk preferences might help explain managerial choices on behalf of their companies. In the following section, I examine how managerial risk preferences relate to a variety of firm characteristics. However, note that my purpose is not to identify causal relationships, but rather to reveal empirical patterns to motivate further in-depth research. I tabulate the mean and median values for γ across the quartiles of some of the most common measures of firm size, capital structure, performance, and risk derived from Compustat (see Table 7). A number of monotone relationships emerge between observed risk attitudes of managers and firm-related outcome measures. Beginning with three size measures (number of employees, sales, and total assets), I consistently find that larger companies employ more risk-averse executives than smaller companies. The most plausible interpretation is that risk-averse managers are matched with larger, typically more diversified, and less risky companies. However, alternative mechanisms may be at work to generate this pattern.

Table 7 Risk Preferences and Firm Characteristics

	Quartiles			
	Q1	Q2	Q3	Q4
Employees				
Median	0.69	0.87	0.94	1.35
Mean	2.49	2.69	3.00	3.68
Sales				
Median	0.58	0.79	0.93	1.39
Mean	2.25	2.53	2.87	3.85
Total assets				
Median	0.55	0.85	1.14	1.49
Mean	2.14	2.56	3.29	3.88
R&D/assets				
Median	1.03		1.05	0.65
Mean	3.26		3.07	2.28
Leverage				
Median	0.58	0.89	1.08	1.38
Mean	2.08	3.01	3.05	3.72
Market-to-book				
Median	1.67	1.15	0.72	0.45
Mean	5.00	3.00	2.12	1.38
Return on assets				
Median	1.28	1.09	0.68	0.64
Mean	4.30	3.15	2.17	1.88
Return on equity				
Median	1.11	0.95	0.73	0.77
Mean	4.14	2.70	2.22	2.44
Volatility (3 years)				
Median	2.16	0.89	0.65	0.48
Mean	4.94	2.91	2.21	1.81
Beta (3 years)				
Median	1.04	1.12	1.00	0.75
Mean	3.22	3.29	3.13	2.52

Notes. Relative risk preference values of executives are matched to firm-level data comprising information on size, capital structure, profitability, and risk from the corresponding financial year. For these variables, I compute samplewide quartiles. This table shows median and mean risk-aversion levels within these quartiles. The firm-level variables are taken from Compustat and CRSP. For missing values of R&D expenditures, I impute a value of zero.

Regarding investment policies, the data show that firms with research and development (R&D) expenditures over assets that are larger than the sample median employ less risk-averse executives. Note that the relationship between R&D intensity and risk aversion is not monotone across quartiles. Furthermore, with respect to capital structure, less risk-averse individuals tend to work at less levered firms. The difference is substantial. Relative risk aversion is approximately twice as high for the upper quartile compared with the lower quartile of the leverage distribution. This pattern could be the outcome of the larger control of debt holders over levered firms (Jensen and Meckling 1976, Ortiz-Molina 2007).

However, note that this result is not consistent with Graham et al. (2013), who report for primarily private firms that highly risk-averse managers tend to be employed by firms with high debt ratios and high proportions of short-term debt over total debt.

A monotone and negative relationship exists between risk aversion and the market-to-book measure. Regarding other performance measures, the corresponding relationship is not monotone, but as a tendency, the top two quartiles are still associated with the least risk-averse executives. Finally, we examine the distribution of risk aversion across quartiles of firm-specific risk measures. Considering stock return volatility, the relationship between these two variables is negative. However, since volatility is a model parameter, such a pattern might mechanically result from the application of our procedure. Nevertheless, a very similar pattern emerges even for beta, which measures the firm's exposure to systematic risk. Finding that risk-averse managers are more often observed at low-risk firms may not be surprising, provided that the risk preferences of managers and the riskiness of the firm are parameters that determine the value of a match between the manager and the company. However, note that theory does not unambiguously predict such a negative assortative matching (Legros and Newman 2007).

Table 8 Risk Preferences and Individual Characteristics of CEOs

	Median risk aversion		Difference	Wilcoxon test
Gender	Male	Female		
	0.75	1.98	-1.23^{*}	$p = 0.09$
Married	Yes	No		
	0.95	0.76	0.19^{*}	$p = 0.09$
Children	0.94	0.79	0.15	$p = 0.22$
Top college	0.69	0.93	-0.24	$p = 0.27$
Religion	1.14	0.84	0.30^{***}	$p = 0.01$
Military service	0.92	0.85	0.07	$p = 0.30$
MBA	1.01	0.88	0.13^{*}	$p = 0.06$
Political affiliation	Republican	Democrat		
	1.76	0.70	1.06	$p = 0.68$
Age	In years	Median RRA		
	[29–40)	0.72		
	[40–50)	0.70		
	[50–60)	0.80		
	[60–∞)	0.86		

Notes. This table shows median values of implied risk aversion across some individual characteristics collected from Marquis *Who's Who* (all variables except *gender* and *age*) and Execucomp (*gender* and *age*). The Marquis *Who's Who* sample covers 1,122 individuals. *Married* and *Children* are only considered if executives enter information into the category "family" in Marquis' form. *Top college* refers to an undergraduate degree from either Harvard University, Massachusetts Institute of Technology, Princeton University, Stanford University, or Yale University. The fourth column shows the differences of risk aversion between two categories. The significance level from a Wilcoxon rank sum test is reported in the fifth column.

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

5. Validation

Unfortunately, no other risk preference measures are available that could help directly validate the option-based measure of risk aversion. An alternative validation method is to examine whether the preference measures exhibit cross-sectional properties such as predicted by (economic) theory and supported by empirical and experimental research. For this purpose, I use data from Marquis *Who's Who*, which contains an array of individual information on CEOs such as family background (for example, whether CEOs have children and are married), birth year, educational achievements (e.g., MBA degrees and the colleges they attended), whether they served in the military, and religious and political affiliations.[15] I match risk-aversion data for 1,122 chief executives with data from Marquis *Who's Who*. Age information is gathered from Compustat's Execucomp data set. Table 8 displays how the median of risk aversion is related to a variety of individual characteristics.

Probably the most well-documented fact on risk preferences is the gender gap (e.g., Jianakoplos and Bernasek 1998, Croson and Gneezy 2009, Powell and Ansic 1997, Eckel and Grossman 2008). Consistent with these papers, I find that female CEOs are substantially more risk averse than male CEOs (see the first row of Table 8). Female CEOs' median risk aversion is more than twice as high as the parameter for male CEOs. However, note that given to the low number of top female executives (below 2%), any statistical test on the difference in the medians of both groups is problematic. Still, the Wilcoxon test suggests that the difference in the medians of both groups is significantly different from zero at the 10% level.

Furthermore, the decision on when and whether to marry has often been linked to risk aversion (Chiappori and Reny 2006, Spivey 2010). Hypotheses and empirical results suggest that because of risk sharing and uncertainty reduction, married CEOs exhibit substantially higher levels of risk aversion. This result can be replicated for our CEO cohort. Married CEOs display an option exercise behavior that gives rise to a substantially higher aversion to risk than single CEOs. The difference between the median values is 0.19 ($p < 10\%$). Perhaps as the result of a stronger inclination of risk-averse managers to live in a stable relationship, having children is also associated with stronger risk aversion. However, the difference in risk aversion between executives with and without children is statistically not significant at the usual levels.

Previous research has documented a negative relationship between certain intelligence measures and

[15] These data were originally collected for a paper by Brenner and Wernicke (2013) on the moral constraints of CEO pay.

risk aversion (e.g., Dohmen et al. 2010). For many decades, college admission in the United States has been based on standardized testing along different domains (the SAT), and Frey and Detterman (2003) show that performance in these tests is highly correlated with general mental ability, a factor that accounts for a large share of the variance in IQ tests. Because admission to top colleges is very competitive, individuals granted admission to these institutions tend to have very high SAT test scores. Hence, as a proxy for mental ability or intelligence, I use an indicator variable for whether the individual has acquired an undergraduate degree from one of the "big five" colleges: Harvard University, Massachusetts Institute of Technology, Princeton University, Stanford University, and Yale University. Again, in line with our expectations, risk aversion tends to be markedly lower for graduates from these universities. The median risk-aversion measure for top college graduates is approximately 0.24 lower, but the difference between both groups is statistically not significant.

Risk preferences have also been linked to the religious beliefs of individuals. Miller and Hoffmann (1995) argue that the choice of religious acceptance versus religious rejection could be viewed as a lottery, called Pascal's Wager, after the philosopher who famously discussed this argument. As a result, Miller and Hoffmann (1995) argue that the choice of whether to keep or adopt religious beliefs should be related to individual attitudes toward risk. In our sample, 161 executives revealed their religious orientation. When comparing this group with those executives who did not mention a religious affiliation, the median of risk aversion for believers is substantially larger ($\Delta = 0.30$), and the difference is statistically significant at the 1% level.

I elaborate on patterns of risk preferences across other individual characteristics, which I contrast with related empirical evidence. First, CEOs who served in the military exhibit option-exercising behavior in line with substantially greater aversion to risk. This finding is consistent with Benmelech and Frydman (2014), who report lower levels of corporate investment and R&D by military CEOs, perhaps triggered by their specific risk preferences. Furthermore, CEOs with an MBA degree (about one-third of the subsample) exhibit a slightly higher level of risk aversion than the remaining CEOs, but the difference is only weakly significant ($p < 10\%$). This result is consistent with the notion that individuals pursuing an MBA not only carefully plan their professional career, but also tend to avoid financial risk exposure. In contrast, Graham et al. (2013) find that MBA graduates are slightly underrepresented among very risk-averse individuals. Few executives reveal their political affiliation in Marquis *Who's Who*. For those who do, the large majority of executives lean toward the Republicans. These executives show dramatically higher levels of risk aversion than those who disclose preferences for the Democrats. Higher levels of risk aversion corroborate recent evidence on the positive relationship between Republican CEOs and conservative corporate policies (Hutton et al. 2014).

Finally, I investigate the effect of age on risk preferences. Because the literature on this topic is undecided, we cannot use age to validate the measure of risk preference.[16] For example, Riley and Chow (1992) and Halek and Eisenhauer (2001) find that risk aversion decreases with age until the age of 65, from which point it starts to increase again. Jianakoplos and Bernasek (1998) do not detect any significant relationship. Using age information from Compustat's Execucomp data set, Table 8 shows median risk preferences for four age brackets. For our sample, risk aversion increases with age, which is in line with the study by Graham et al. (2013), who report that managers who are older than the sample median are more likely to be highly risk-averse individuals.

6. Robustness

Previous research on employee options has identified a number of factors that drive option exercises, which are not accounted for in Ingersoll's (2006) model. In this section, I first examine the robustness of the implied risk preferences by fundamentally asking to what extent risk preferences are stable within individuals and then test specifically to what extent the preference measures might be distorted because of those factors. Specifically, I analyze how behavioral biases such as overconfidence and attention to reference prices distort risk preferences, and I test the effects of other economic mechanisms such as exercises motivated by the manager's desire to signal beliefs or to generate liquidity.

6.1. Temporal Persistence

The question of the reliability of the implied preference parameters computed in this paper is closely connected to their stability over time. Although some models predict nonstatic risk preferences (Barberis et al. 2001), using preference parameters that wildly fluctuate for the same individual is discouraged. Because most individuals enter our sample with a series of transactions spanning multiple (on average, 3.25) years, sufficient longitudinal data exist to examine within-individual variation. I use two approaches to examine persistence. First, I examine persistence at absolute levels by performing an ANOVA to shed light on the relative importance variation in risk aversion within and between subjects.

[16] For a recent survey of this literature, see Mather et al. (2012).

Table 9 ANOVA F-Tests for the Equality of Means Across Individuals and Time

	Share of variance	F-statistic	Probability value
Individual effects	0.50	8.80	0.00
Year effects	0.02	231.15	0.00
Residuals	0.48		
Number of observations	64,470		

Note. This table presents an analysis of variance with individual and calendar year effects.

Second, I focus on the relative stability of executives' preferences by considering changes in the positions of preference rankings over time.

Table 9 displays the p-values from an ANOVA F-test and the share of variance explained by individual and year effects. The F-test allows rejection of the null hypothesis of equal means across executives at the 1% level of significance. Note that even though the p-values indicate significant variation in the time series, the share of variance that can be attributed to year effects is relatively small (approximately 2%). In contrast, individual effects substantially contribute to explaining the variance in risk preferences. Approximately half of the variance in relative risk aversion is associated with between-subject variation. The remaining variation is related to within-subject variance and errors. Hence, a larger part of the variation is not explained by fixed-year or individual effects.

Given the skewed distribution of risk preferences, they are not well described by the normal distribution; thus, the ANOVA results may not be very informative about the temporal stability of preferences. I make another attempt to analyze the stability that should be immune to this problem by considering the relative position of the median of individual preference parameters across years. Specifically, I compute the median risk aversion for every executive in every year and identify the corresponding quartile along the yearly distribution of preference parameters. If preferences are stable, individuals should remain in the same quartile across multiple years. Note that all observations are included for establishing the yearly preference distributions, but some individuals are not represented in this analysis because they did not report transactions for at least two different years.

The first column of Table 10 shows the number and share of individuals who remain in the same quartile across all years. The second column displays the number of individuals who only change within two adjacent quartiles, and so on. For an impression of what numbers to expect when quartile membership is entirely random and every individual is in the sample for three years, note that approximately 6% remain in the same quartile throughout, and approximately 28% only switch between two neighboring quartiles. In fact, approximately 70% of all executives do not change quartile membership by more than one position (see Table 10). Thus, the large majority of individuals exhibit strongly persistent positions in the rankings. Only 9% of all individuals eventually turn up in both the highest and the lowest quartiles. Given that a representative manager is in the sample for around three and a quarter years, this pattern suggests a high level of persistence in the rankings of the preferences, providing support for stable relative preferences.

Table 10 Persistence of Relative Risk-Aversion Measures Across Yearly Rankings

	Maximum difference across quartiles			
	0	1	2	3
Number	1,194	1,517	804	331
Share	0.31	0.39	0.21	0.09

Notes. For this table, I first compute the yearly distributions of relative risk aversion, and for every executive, the median risk aversion for every year in which a transaction is reported. Then, based on these numbers, I identify the quartile membership for each individual in each year with at least one transaction. Finally, considering the location of the individual yearly median risk-aversion values across all years, I compute the largest jump across quartiles. Hence, the number of executives who stay in the same quartile across all years is reported in Column 2 (maximum difference between quartiles is equal to zero). On average, executives report transactions over 3.25 years.

6.2. Overconfidence

Some scholars have suggested that managers might be too optimistic in their expectations about corporate performance and their own ability to improve it. As a result, overconfidence leads managers to exhibit specific biases in their capital structure and other corporate policy choices. For example, Malmendier and Tate (2005) demonstrate that firms headed by overconfident CEOs have higher investment cash flow sensitivities and issue less equity than their peers. Furthermore, they are more likely to overpay for target companies and undertake value-destroying mergers (Malmendier and Tate 2008). For the same reasons, these executives may also wait longer before exercising their options. Hence, room for concern exists that Ingersoll's (2006) approach is inappropriate for modeling the preferences of overconfident executives and that the distribution of risk aversion across individuals derived in §4 partially reflects differences in the degree of overconfidence rather than in the degree of risk aversion. Moreover, the link between individual risk-aversion measures and firm-level variables might be the result of decision-making biases arising from overconfidence rather than differences in risk aversion. In the following section, I argue that overconfidence is not the driving factor behind the results derived in the previous sections. Specifically, ignoring

Table 11 Overconfidence and Implied Risk-Aversion Parameters

# longholdings	RRA	# execs.	% cumulative	% longholdings	RRA	# execs.	% cumulative
0	1.28	4,256	62.5	0.00	1.28	4,256	62.5
1	0.94	914	75.9	(0, 0.1]	1.21	271	66.4
2	0.91	529	83.6	(0.1, 0.2]	1.34	363	71.8
3	0.74	293	87.9	(0.2, 0.3]	1.12	278	75.9
4	0.74	199	90.9	(0.3, 0.4]	0.91	256	79.6
5	0.68	149	93.1	(0.4, 0.5]	0.82	246	83.2
6	0.66	114	94.7	(0.5, 0.6]	0.60	93	84.6
7	0.47	85	96.0	(0.6, 0.7]	0.43	114	86.3
8	0.55	60	96.9	(0.7, 0.8]	0.47	116	88.0
9	0.72	31	97.3	(0.8, 0.9]	0.43	56	88.8
10+	0.44	183	100.0	(0.9, 1]	0.50	764	100.0

Notes. This table shows the individuals' median risk aversion depending on how many incidences of "longholdings" are reported for an individual (second column) and depending on the share of longholdings relative to the number of all reported option exercises (sixth column). The cumulative share of executives in the corresponding Longholder categories is displayed in the fourth and eighth columns. The third and seventh columns show the corresponding number of executives. The total number of executives is 6,813.

all individuals who may potentially be categorized as overconfident does not materially affect any of the relationships between the risk-aversion measure and firm-level variables such as presented in Table 7.

Before analyzing the relationship between risk aversion and overconfidence, we need to decide how to measure overconfidence. Many established measures of overconfidence are derived from option exercise data. The first option-based measure used by Malmendier and Tate (2005) is called *Longholder*, which identifies individuals as overconfident when they hold options until the last year before they expire. The other measure assumes overconfidence when individuals keep an option package unexercised even though the option is at least 67% in the money in the fifth year after it was granted (called *Holder* 67). Whereas the Longholder measure is simple to calculate for every individual in our sample, Holder 67 is more problematic because it requires tracking individuals and their option exercises for multiple consecutive years. Consequently, the additional data requirement reduces Malmendier and Tate's (2005) sample by 72% of the observations. Because both measures of overconfidence are strongly correlated (Malmendier and Tate 2005), I continue to analyze the relationship between overconfidence and risk aversion by concentrating on the Longholder measure.

Table 11 shows the relationship between risk preferences and the Longholder measure of overconfidence. The first three columns display the distribution of median risk preferences by the number of option transactions of the individuals that are in line with the definition of Longholder. First, observe that approximately 62% of all executives in our sample exercised none of their options in the last year before maturity, and therefore are not categorized as overconfident under any definition of Longholder.[17] Another 14% are "longholders" only for one of their transactions. Less than 10% of the executives exhibit notorious long-holding behavior (more than four incidences of late exercises). A comparison of the median levels of risk aversion between all longholders and the nonlongholders shows a marked difference (0.775 for longholders versus 1.049 for nonlongholders). However, given that any transaction qualifying as a late exercise often generates low numbers of risk aversion for typical parameters, this result is not surprising.

The number of late exercises may not be informative about overconfidence without taking into account the total number of transactions reported for an individual. The share of late exercises of options among all recorded transactions shows no substantial difference in the median risk-aversion levels of executives who were never longholders and those who choose to exercise only in the last year before option expiry in up to 30% of all of their transactions (see the three rightmost columns of Table 11). Naturally, risk aversion decreases when the share of option long holdings increases. According to Table 11, less than 14% of all executives appear to exhibit persistently late exercising behavior (being a longholder in at least 70% of all transactions).

Dismissing the hypothesis that some executives are temporarily or permanently overconfident and, therefore, make different choices than their peers for private financial or corporate decisions is difficult. The important questions are (a) whether overconfidence has a strong effect on the distribution of risk-aversion measures elicited from option exercises and (b) whether the patterns that we find between risk

[17] For pragmatic reasons, Malmendier and Tate (2005) assume overconfidence for every individual who held an option at least once until the final year before expiration.

aversion and corporate-level variables are potentially driven by variations in overconfidence rather than by differences in risk aversion. In principle, accounting for variations in return expectations is possible (see Ingersoll 2006, §II.C). Unfortunately, measuring beliefs about returns and, thus, appropriately adjusting the implied risk-aversion parameter for those executives who show signs of overconfidence is difficult. However, one simple way to examine whether overconfidence really shapes the distribution of risk preferences and their relationship with firm-level variables is to remove individuals who would be categorized as overconfident according to the Longholder measure and to test whether any substantial differences emerge in the distribution of risk preferences and with regard to the correlations with firm-level variables.

To examine the effect of potentially overconfident executives on the distribution of risk preferences, I eliminate all risk preference parameters associated with a late (final year) option exercise. The distribution of risk-aversion parameters changes slightly. The 10th, 50th, and 90th percentiles are 0.139, 1.017, and 6.399, respectively (instead of 0.110, 0.911, and 6.170; see Table 4). Furthermore, I partially reconstruct Table 7, which shows risk preferences across the quartiles of certain firm-level variables, including size, performance, and risk excluding all individuals who have been longholders in at least one of their transactions (see Table 12). Additionally, I show the share of longholders across the same quartiles. Compared with Table 7, risk aversion increases across the board in Table 12, a consequence of dropping longholders. However, none of the patterns displayed in Table 7 is materially altered. Hence, overconfidence does not appear to generate the (correlational) links between risk preferences and firm outcomes.

Table 12 **Risk Preferences and Firm Characteristics (Excluding Longholders) and the Distribution of Longholders**

	Quartiles			
	Q1	Q2	Q3	Q4
Employees				
RRA (median)	0.75	1.02	1.09	1.53
Share of longholders	0.39	0.46	0.47	0.55
Sales				
RRA (median)	0.65	0.96	1.16	1.42
Share of longholders	0.37	0.47	0.50	0.50
Total assets				
RRA (median)	0.63	1.02	1.28	1.69
Share of longholders	0.39	0.51	0.45	0.52
R&D/assets				
RRA (median)	1.25		1.14	0.71
Share of longholders	0.49		0.52	0.36
Leverage				
RRA (median)	0.65	1.02	1.17	1.62
Share of longholders	0.39	0.46	0.53	0.49
Market-to-book				
RRA (median)	2.12	1.38	0.89	0.47
Share of longholders	0.52	0.49	0.49	0.34
Return on assets				
RRA (median)	1.49	1.29	0.72	0.66
Share of longholders	0.46	0.48	0.42	0.49
Return on equity				
RRA (median)	1.28	1.04	0.82	0.80
Share of longholders	0.45	0.42	0.45	0.53
Volatility (3 years)				
RRA (median)	2.40	1.01	0.84	0.53
Share of longholders	0.43	0.44	0.36	0.24
Beta (3 years)				
RRA (median)	1.22	1.32	1.08	0.74
Share of longholders	0.38	0.38	0.38	0.32

Notes. I use the firm-level data matched to risk preference values derived for Table 7 and eliminate all individuals with "Longholding transactions." As in Table 7, I compute samplewide quartiles for the firm-level variables and show the median risk-aversion levels across these quartiles. I also show the share of individuals at least once reporting a "Longholding" incidence as a share of all executives in this quartile (second row for every firm variable).

6.3. Signaling Effects

Although securities laws prohibit corporate insiders from trading on private information, investors pay attention to equity-related transactions in their search for cues about future share performance. Given investors' attention, top executives may use option exercises to signal positive or negative beliefs about future stock returns (Damodaran and Liu 1993), implying that risk-aversion values might be biased because of this mechanism. Because signaling most likely induces later exercises, risk aversion should be biased downward. I use two methods to examine whether and to what extent signaling might bias the risk-aversion measures. First, because monitoring is more costly with high information asymmetry, one may expect that signaling becomes more important and risk-aversion measures become lower when information asymmetry between managers and outside investors increases. Second, signaling becomes more effective the higher the expected information advantage of the executive relative to investors. Hence, since CEOs tend to be among the best-informed executives, the trading behavior of chief executives in firm equity is typically under high public scrutiny, and one would expect CEOs to have stronger incentives to use signaling through their option exercise policy than less visible executives. As a result, signaling should become more important for individuals once they are promoted to the CEO position, and the implied risk preferences should decrease once an executive becomes the CEO.

As a measure of information asymmetry, I choose the relative bid–ask spread of the closing share price based on CRSP daily stock data. This measure is computed as the ratio of the bid–ask spread and the bid price—an established measure of information asymmetry—and has been applied in a series

Table 13 **Risk Preferences and Annual Bid–Ask Spreads**

	Median RRA	
Relative bid–ask spread	All executives	CEOs
First quartile	1.173	0.645
Second quartile	1.057	0.674
Third quartile	0.823	0.505
Fourth quartile	0.749	0.578

Note. This table shows the median risk-aversion levels for all executives (second column) and only CEOs (third column) across the quartiles of the annual firm-level averages of closing share price bid–ask spreads relative to bid prices as a measure for information asymmetry.

of papers, including Hasbrouck (1991), Venkatesh and Chiang (1986), and Coller and Yohn (1997).[18] One expects that, ceteris paribus, higher degrees of information asymmetry are associated with greater scrutiny of executives' equity transactions, inducing managers to hold on to their options to signal optimism and excess future performance to outside investors. For the relative bid–ask spreads, I find that, indeed, median risk aversion continuously falls from the lowest to the highest quartile by approximately 0.42 (see Table 13, second column). One problem with this result is that the composition of executives may differ across the quartiles for the relative bid–ask spread distribution. This problem holds, for example, because firms with smaller bid–ask spreads issue options to a broader population of executives, and managers who are further from senior positions have different risk preferences. Hence, I performed the analysis again and covered only chief executives (see Table 13, third column). Although the difference between the median RRA for the first and the fourth quartiles is still positive, it is much smaller than for the entire sample (approximately 0.07). Moreover, for CEOs, risk aversion does not fall continuously with the relative bid–ask spreads. The maximum value is associated with the second quartile, and the minimum value is associated with the third quartile. Thus, no clear pattern exists suggesting an unambiguous link between this measure of information asymmetry and risk preferences, a pattern that should emerge if signaling is a substantial factor in exercise decisions.

The second attempt to check whether signaling distorts our results involves a comparison of intraindividual differences in implied risk preferences for managers who appear in our sample as CEOs and as non-chief executives at different points in time. Such transactions exist for 339 individuals. A comparison of the median risk aversion for every individual as CEO and as non-CEO reveals an increase in risk aversion of 0.107 when moving to the CEO position. Because one expects a decrease in risk aversion when moving to the top executive position, this result also fails to provide support for the signaling hypothesis.

6.4. Reference Points

Another psychological bias affecting employees' option exercising behavior that received significant attention is the influence of recent share price developments. Heath et al. (1999) first identified this bias, which was later confirmed by Core and Guay (2002), Klein and Maug (2009), and others. These papers report that exceeding the maximum share price over a certain period significantly increases the likelihood of option exercise. Heath et al. (1999) suggest that prospect theory (Kahneman and Tversky 1979) can well explain this specific pattern of option exercising behavior. They argue that individuals use previous stock price realizations as reference points, making them more risk averse when the current stock price is higher than the reference point, and more risk seeking when it is lower. For various reasons, the maximum share price in the previous 12 months appears to be the best pragmatic choice as the reference point.[19] In relation to our model, whether the implied values of risk aversion are biased is unclear, but one might expect intraindividual variation in risk preferences depending on how sensitive individuals respond to the current share price relative to the reference price when contemplating the exercise decision.

First, note that exercising options after reaching a 12-month high does not represent the dominating behavior in our sample. From the subsample that covers a complete history of closing share price data for the 12 months before the transaction takes place, in only about 14% of all cases was the current price on the day of exercise equal to or higher than the maximum price during the previous year. However, when comparing the median risk preferences derived for transactions from these 14% of all transactions to the preferences derived for the remaining transactions, we find at least a modest risk-aversion premium of 0.072 for the first category. In other words, exercising behavior that might be consistent with a higher responsiveness to reference points is associated with slightly higher levels of risk aversion. Moreover, options exercised after the share price reached a 52-week high on average have more than a four month longer time to maturity. At first sight, one might be tempted to interpret this result in the sense

[18] Previous studies used a wide variety of measures for information asymmetry between managers and investors, such as analysts' followings, analysts' forecast accuracy, trading volume, bid–ask spread, stock return volatility, corporate diversification, and firm size. Many of those measures, including volatility, are problematic in our context because they enter the option value model directly or they might be correlated with some of the model parameters.

[19] For example, Benartzi and Thaler (1995) find that investors evaluate their portfolio over a period of one year.

that responding sensitively to the ratio of reference price to current share price leads, on average in our sample, to faster exercising, and therefore to (slightly) higher values of relative risk aversion. However, I also find that options exercised after a 52-week high have, on average, slightly lower moneyness and volatility, both of which contribute to greater risk aversion. Hence, it is unclear whether the gap in risk aversion related to reference points might be caused by some model variables being correlated to the incidence of hitting a 52-week high or whether there is a substantial deviation from the simple utility model underlying Ingersoll (2006) with regard to the influence of reference prices.

One problem with the preceding analysis is that it does not effectively capture the fact that prospect theory predicts within-individual variation in risk preferences as a result of the share price relative to the reference price. A substantial number of individuals are covered whose exercises exclusively cover points in time from one of the two categories (either hitting a 52-week high or not). Henceforth, I only consider individuals for whom we observe both exercises after hitting and not hitting a 52-week high (2,152 individuals), and I compute the difference in the median from both categories. Across these individuals, the median difference is only -0.021. Hence, although executives exist whose risk preferences are responsive to recent share price development, this response seems not to be typical in our sample.

6.5. Liquidity-Driven Exercises

Finally, when contemplating whether to exercise options, executives may not be guided only by concerns about maximizing option values constrained by risk preferences, but also by providing liquidity for consumption. Both explanations for when employee options are exercised produce divergent predictions of the temporal distribution of exercises. The subjective valuation model suggests that, at a certain point in time, one should observe single packages or multiple packages with similar characteristics (for example, time to maturity and moneyness) to be exercised. Clusters of exercises of option packages with varying characteristics within a short window give rise to different risk-aversion measures as in Ingersoll (2006) and, therefore, are inconsistent with this framework. However, liquidity-based explanations allow for clusters of exercises of packages with different parameters.

I do not track specific option packages over time and thus cannot observe whether the same package is exercised multiple times. Rather, to address the problem of liquidity-driven option exercises, I consider (a) the frequency of clustered option exercises and (b) the median spread of risk aversion within those clusters. I consider a cluster to encompass all option exercises performed by an executive within one calendar week. First, note that from the approximate 65,000 transactions recorded in our sample, 36,146 were singular transactions not accompanied by others in the same week or by transactions involving packages with exactly the same parameters. Hence, multiple transactions of nonidentical packages within the same week are not rare. The question is how similar those packages are and whether they are associated with similar risk-aversion estimates. Conditional on the fact that there are multiple transactions of different packages within one week, the median maximum spread of the implied RRA values for the same individual in one calendar week is 0.359, indicating moderate differences in risk aversion. However, in light of the skewness of the risk-aversion distribution, considering the spread across different values of risk aversion might be important. I find a spread of 0.048 if the minimum value of γ is in the narrow band defining risk neutrality ($[-0.1, 0.1]$). If $\gamma \in [0.1, 1]$, the median spread becomes 0.205. If the relative risk aversion is larger than one, the median spread becomes 0.966. Hence, for a substantial portion of the observations, multiple option exercises within a short window yield relatively large spreads of risk aversion. In particular, this concept holds for executives with greater risk aversion. Thus, the argument that liquidity-driven exercises (or other factors that induce clustering of option exercises) affect risk preference estimates receives some support.

Finally, note that the other possibility of behavior that is incongruent with regard to Ingersoll's (2006) model is the partial exercise of options. Partial exercises may also be driven by liquidity-based motivations or other portfolio considerations. The within-individual variation measured in §6.1 might be partially explained by exercising in multiple installments. Unfortunately, I cannot estimate the significance of this alternative because I do not track individual options. However, studying similar data, Klein and Maug (2009) find that partial exercises exist but play a minor role.

7. Conclusion

This paper measures executives' risk aversion from data on the exercising of employee stock options. The calibration method makes use of the hedging constraint that accompanies stock option programs for executives and is based on an argument over the optimal choice of the share price that triggers the option exercise. Applying the method yields approximately 65,000 values of relative risk aversion for U.S. executives for the period between 1996 and 2008. Even though I find that risk-averse preferences dominate for managers at all levels of the corporate hierarchy, substantial heterogeneity exists across this group.

Moreover, up to 9% of all observations are consistent with risk-neutral option exercising behavior. Note that executives in senior positions in the firm are, on average, less risk averse. To validate the measure, I test whether risk preferences differ along individual characteristics for a subsample of CEOs as predicted by theory and as documented in empirical and experimental research. Individual characteristics for the validation include gender, marital status, religious affiliation, top college degree, and others. All differences are as predicted, and most results are significant at least at the 10% level.

To obtain an impression on how risk preferences relate to firm-level outcome variables, I perform a preliminary analysis and find that risk aversion is associated with the firm's sector membership and corporate characteristics such as size, performance, capital structure, R&D intensity, and risk. However, a causal analysis must be relegated to future research. The risk-aversion data may also help calibration studies for managerial behavior at public firms that previously relied on conjectures about risk preferences that were not empirically grounded (e.g., Hall and Murphy 2002, Haubrich 1994, Dittmann and Maug 2007).

One caveat to this study is that the analysis is conducted within the expected utility framework that has received much criticism (Tversky and Wakker 1995, Rabin and Thaler 2001). Even though conducting a similar analysis using a less restrictive framework might be worthwhile, I have conducted a number of tests to examine whether implied measures of risk aversion are biased given certain behavioral distortions such as using reference prices or because of signaling effects. Although I do not find substantial support for such concerns, the tests may not be strong enough to rule out these effects. In particular, further analyses should be undertaken regarding the effects of overconfidence and liquidity-based exercises.

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