The Incentives of Equity-Based Compensation and Wealth

Christopher S. Armstrong

Stanford University
Graduate School of Business
518 Memorial Way
Stanford, CA 94305

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Abstract:
This study estimates chief executive officers' (CEO) subjective valuation of their equity holdings using their revealed preferences conveyed by their decisions to hold or exercise their stock options and to hold or sell their equity shares. Using a random utility framework, I find that the subjective value of equity holdings is associated with both economic and behavioral factors, and that the impact of these factors varies considerably across CEOs. In addition, I find that most CEOs value their equity holdings below the corresponding risk-neutral value, which provides new insight relative to prior literature that examines how insiders value equity-based compensation. This study also provides preliminary evidence regarding the relationship between the sensitivity of CEOs' subjective value of their equity holdings to changes in stock price (subjective delta) and volatility (subjective vega) and future operating performance, investment and financial risk, and stock price performance. The results frequently diverge from those of prior studies that examine the relationship between risk-neutral equity portfolio deltas and these future performance measures. Collectively, the results of this study highlight the complexity of measuring the equity incentives construct and suggest that an executive's subjective valuation of equity is a critical component.

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1. Introduction

Equity-based compensation is the most prominent component of remuneration for chief executive officers (CEOs) of most publicly-traded corporations in the U.S. (e.g., Frederic W. Cook & Co. Inc., 2006). Hall and Liebman (1998), Core, Guay, and Verrecchia (2003), and others suggest that an executive's equity portfolio (consisting of stock options, restricted stock, and unrestricted personal stockholdings) produces the vast majority of incentives for most CEOs. Therefore, researchers have naturally been interested in better understanding to what degree equity holdings provide incentives by examining the association between executives' equity and corporate governance structure, accounting choice, and future performance.

Measurement of the incentives produced by stock and option holdings is typically computed using a risk-neutral valuation model (e.g., the Black-Scholes delta or vega).[1] However, as discussed by Lambert, Larcker, and Verrecchia (1991), vesting restrictions, nontransferrability, and short-sale constraints coupled with executives' risk-aversion and lack of wealth diversification can cause executives to value equity differently than risk-neutral, diversified investors. These factors can also substantially affect how executives value their equity holdings and, by extension, the incentives provided by these equity holdings. Thus, in order to understand the relation between equity and incentives it is critical to distinguish between the subjective value of equity (i.e., the value to the executive) and objective value of equity (i.e., the value to a well-diversified, risk-neutral investor).

The purpose of this paper is threefold. First, I estimate the subjective value of stock and option holdings for a broad sample of CEOs by exploiting the information conveyed by their stock sales and option exercises. The subjective value of these holdings is estimated using a revealed preferences approach (within a random utility framework) that allows for a rich specification of company-, executive-, and grant-specific determinants that capture both economic and behavioral factors that affect the subjective value of these equity holdings. Second, I develop new incentive measures using the change in the subjective value of the executives' equity holdings with respect to the change in stock price and volatility (i.e., delta sensitivity and vega sensitivity, respectively). Third, I assess the association between these revealed preferences incentive measures and future research and development expenditures, stock price volatility, operating performance, and stock price performance.

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[1] The Black-Scholes delta and vega are the partial derivatives of the (risk-neutral) Black-Scholes value of an option with respect to the underlying stock price and stock price volatility, respectively. These computations are widely used in studies of equity incentives.

The results indicate that the subjective value of stock options and stock is generally below the corresponding risk-neutral valuation. For example, the average CEO in my sample values a grant of stock options at approximately 70% of its Black-Scholes value. However, approximately 14% of the CEOs value their stock options above their Black-Scholes value. Thus, there is substantial heterogeneity across CEOs in terms of their subjective valuation and the accompanying incentives to increase stock price and volatility.

In an attempt to provide insight into prior literature, I disaggregate the dollar holdings measure of equity portfolio incentives (both delta and vega) into its two components which I label the "equity wealth component" and the "sensitivity component." Equity wealth is constant across subjective and risk-neutral measures of incentives and exhibits a high degree of cross-sectional variation simply as a result of differences in the level of holdings across executives. The sensitivity component captures the equity portfolio's average change in (subjective or objective) value for a change in stock price and is not highly correlated across incentive measures.

Preliminary results indicate a statistically positive relationship between the equity portfolio vega sensitivity and future research and development (R&D) expenditures. In contrast, the association between future R&D expenditures and the equity wealth component of the portfolio vega is negative (and generally significant). The revealed preference delta sensitivity exhibits a positive association with future R&D, while the risk-neutral delta sensitivity exhibits a negative association. I find very little evidence of an association between the various incentive measures and future operating performance. Finally, the revealed preference delta sensitivities exhibit a statistically positive association with future stock price returns. However, neither the risk-neutral equity portfolio sensitivity nor the equity wealth component is significant in either specification. These results provide some preliminary evidence that incentive measures developed using a subjective valuation approach have an incremental ability to explain subsequent CEO investment decisions and stock price performance.

Overall, the results illustrate the sensitivity of inferences regarding equity incentives to whether subjective or risk-neutral equity value is estimated. The results also demonstrate that the equity incentives construct is not easily captured by a single variable such as the risk-neutral equity portfolio delta or vega. Finally, the results highlight the importance of accounting for differences in contracting environments and executives' preferences when estimating measures of their equity incentives.

The remainder of this paper is organized in six sections. The next section reviews the prior literature on the subjective value of equity-based compensation and the related topic of measuring the objective equity incentives provided by these instruments. Section 3 describes the revealed preferences model of subjective value of stock and options and the random utility framework within which it is derived. This section also discusses the specification of alternative models of subjective value and the simulated maximum likelihood estimation techniques. Section 4 discusses the sample and variable measurement. Section 5 presents the estimates of the subjective value of the executives' equity holdings and the accompanying incentives, along with a comparison to their risk-neutral counterparts. Section 6 provides the preliminary results of three applications of the revealed preferences measure of incentives. Section 7 summarizes the results, highlights the limitations of the random utility model, and discusses several directions for future research.

2. Background

2.1. Subjective Value of Equity

Although prior studies have noted the distinction between the cost of equity compensation and its subjective value to the recipient, most research has focused on estimating the cost to the company. More recently, however, there has been an increased emphasis on estimating the value of equity compensation to the recipient primarily to answer questions about the efficiency of compensation arrangements. These studies can be roughly classified as either theoretical, survey-based, or empirical.

The theoretical papers typically analyze the features of the contracting environment that can cause an employee's subjective value of equity (or any form of risky compensation in general) to diverge from its value to a risk-neutral, well-diversified investor (and thus the cost to the granting company).[2] One of the first theoretical studies is Lambert, Larcker, and Verrecchia (1991) which calculates the certainty equivalent of a stock option grant to a risk-averse, undiversified employee. They assume power utility (in order to accommodate wealth effects), that stock options are held to maturity (i.e., no early exercise), and that the employee cannot affect the evolution of the firm's stock price (i.e., no incentive effects). Within this framework, Lambert, Larcker, and Verrecchia (1991) show that the subjective value (i.e., certainty equivalent) of a new option grant is always less than its risk-neutral value and that depending on the degree of risk-aversion and the fraction of the manager's outside wealth correlated with the firm's stock price, the discount placed on a new option grant can be very large. In some cases, the manager's

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[2] The cost of an executive's equity-based compensation to the granting company is the amount that a well-diversified, risk-neutral investor would pay for the cash flows generated by the equity instrument with the timing of the cash flows determined by the executive's decisions (e.g., when the executive decides to exercise stock options).

subjective value can be less than 10% of the option's risk-neutral Black-Scholes value. They also show that in certain settings, the subjective value of options is actually decreasing in the volatility of the underlying stock price, which is contrary to the comparative statics for a risk-neutral valuation (i.e., the Black-Scholes value of an option is always increasing in volatility).

Hall and Murphy (2002) extend the analysis of Lambert, Larcker, and Verrecchia (1991) by incorporating early exercise of the stock options within their certainty equivalence framework. With similar assumptions about the contracting environment, they show that it is possible to trace a boundary on the price of the underlying stock (as a function of time), above which the executive prefers to exercise the options early, thereby foregoing any remaining time value. They conclude that allowing for early exercise always increases the subjective value of the options because it results in fewer constraints on the executive's behavior (i.e., the executive could always choose to hold the option to maturity even if permitted to exercise it early). Similarly, Hodder and Jackwerth (2005) show that when a risk-averse, undiversified manager can affect the firm's risk profile (i.e., stock price volatility) the subjective value of an option can exceed its risk-neutral Black-Scholes value. One important contribution of Hall and Murphy (2002) and Hodder and Jackwerth (2005) is that they explicitly incorporate the endogenous nature of incentives in their respective valuation frameworks. Thus, both studies show that the subjective value (and therefore the incentives provided by) equity is a function of certain managerial choices (i.e., exercise decisions in the case of the former, and managerial decisions about firm risk in the case of the latter). I return to this point in the next section when I discuss the revealed preferences model of incentives.

The survey-based studies typically examine how lower- and middle-level executives value equity-based compensation. Hodge, Rajgopal, and Shevlin (2006) survey a sample of 193 middle-level managers and future entry-level managers (i.e., executive / evening and daytime MBA students) and find that these employees, on average, value stock options 34% higher than their Black-Scholes value. They also report that their survey participants undervalue restricted stock relative to its market value. Larcker and Lambert (2001) survey 122 participants and they find a similar magnitude of overvaluation relative to the Black-Scholes value of the options (about 50% higher than the Black-Scholes value for at-the-money options). In contrast, Farrell, Krische, and Sedatole (2006) find that 75% of their sample of 210 managers at five mid- to large-size companies outside of the manufacturing sector valued their actual option holdings at less than their Black-Scholes value.

Finally, the empirical studies attempt to infer subjective option values from the associated exercise pattern exhibited by employees. For example, Bettis, Bizjak, and Lemmon (2005) calibrate a utility-based model of early option exercise similar to the one developed by Carpenter (1998). They report that the subjective value of the stock options for their sample of Section 16 Insiders is lower than the corresponding objective (i.e., Black-Scholes) value and that the difference is increasing in stock price volatility. Hallock and Olson (2006) also infer the subjective value of options from employee exercise behavior, but within a more flexible framework that allows for non-economic determinants of value. In particular, their methodology is based on a random utility model of discrete choice, coupled with the observation that employees will exercise their options when the intrinsic value exceeds the subjective value – otherwise they will continue to hold the options. Hallock & Olson (2006) conclude that their sample of middle-level executives at a single large firm value their options at substantially more than their Black-Scholes value.

Overall, the theoretical evidence suggests that risky equity-based compensation is more valuable to employees with (1) more wealth, (2) a lower degree of risk aversion, and (3) less of their wealth tied to the value of the their firm. In addition, Hodder and Jackwerth's (2005) analysis suggests that options might be more valuable to an executive than to an outside investor if the executive's ability to affect the evolution of his or her firm's stock price more than outweighs any loss in value that results from trading restrictions, risk-aversion, and undiversification. But a review of the existing literature reveals difficulties in assigning a subjective value to equity-based compensation and wealth for executives capable of affecting the stock prices of their firms, as well as difficulties in assessing whether the subjective value of executives' equity-based compensation is above or below its risk-neutral value. Despite inroads made by the current literature, assigning absolute and relative valuations to executives' equity-based compensation is both theoretically and empirically ambiguous, reflecting a need for better methods of quantification.

2.2. Equity Incentives

There are three primary components of executive compensation: (1) flow compensation (i.e., the executive's annual salary, bonus, restricted stock and option grants, and other forms of explicit remuneration), (2) changes in the value of the executive's stock and option portfolio, and (3) the change in the value of the executive's human capital. Hall and Liebman (1998) find that the change in value of equity holdings dwarfs the other two components for the typical CEO and that this differential is even more pronounced in recent periods.[3] Similarly, Core, Guay, and Verrecchia (2003) report that for their sample, the average change in CEO wealth due to changes in the value of their equity portfolio is more than thirty times larger than the annual salary and bonus components of their compensation. For this reason, many studies simply focus on changes in the value of equity holdings as their measure of executive incentives.[4,5]

In order to construct a measure of executive equity incentives it is therefore necessary to (1) measure the executive's wealth (which includes the subjective value of any equity holdings), (2) understand how the executive's wealth covaries with the firm's stock price, and (3) specify the appropriate unit of change in stock price. The measurement of executive wealth is problematic because although we can observe flow compensation and equity holdings (from annual proxy statements and other regulatory filings), other financial wealth and human capital are not observed. As discussed above, most of the literature uses equity and stock option holdings as a proxy for executive wealth. However, if senior executives are risk-averse and hold a large portion of their wealth in their respective companies' stock, it is necessary to measure the subjective value of wealth and determine how this changes with shifts in the firm's stock price.

There is some agreement in the literature on how to measure the change in firm value at which to evaluate an executive's wealth. Baker and Hall (2004) discuss two popular approaches that are used as the unit change in firm value. The first is the <u>dollar change</u> in the value of the executive's stock and option portfolio for a <u>dollar change</u> in firm value.[6] This measure is typically calculated as the change in the value of the executive's stock and option portfolio with respect to a $1,000 change in the firm's market value. The computation is commonly done by first adding (1) the number of shares of stock and restricted stock held by the CEO divided by the total number of

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3 Based on this evidence, Hall and Liebman (1998) conclude that the cash component of compensation contracts is a "second order effect" and thus exclude it from their analysis.

4 In addition, the incentives literature has traditionally examined the CEO where upward promotions are less frequent than for other senior executive positions. Thus, the change in value of human capital as a source of compensation and incentives is likely to be less important for a CEO than for other senior-level executives.

5 This sentiment is also apparent in most empirical definitions of incentives, which deliberately exclude variation in flow compensation and changes in the value of human capital. In particular, Core, Guay, and Larcker (2003) define incentives as "the sensitivity of the manager's wealth to stock price changes" and Jin (2002) provides a related definition of incentives as "the degree to which CEO wealth is linked to stock market performance." Core and Guay (1999) supply a more precise definition by explicitly focusing on equity incentives which they define as "the change in the dollar value of the CEO's stock and options for a 1% change in the stock price." As discussed below, this is referred to in the literature as the "dollar holdings" measure of equity incentives.

6 This measure is also known as the "pay for performance sensitivity," which was originally defined by Jensen and Murphy (1990) as "the dollar change in the CEO's wealth associated with a dollar change in the wealth of shareholders."

shares outstanding and (2) the number of options held by the CEO, each of which is multiplied by its "delta."[7] This total is then divided by the total number of shares outstanding and multiplied by $1,000, and is referred to as the "fractional holdings" measure of equity incentives.

The second measure is the dollar change in value of the executive's stock and option portfolio for a percentage change in firm value. This measure is calculated using the total incentives from the CEO's option portfolio plus the total incentives from the CEO's stock and restricted stock portfolio. The former is measured as the sum of the deltas of each of the CEO's options multiplied by 1% of the stock price. The latter is measured by simply multiplying the number of shares of stock and restricted stock owned by the CEO by 1% of stock price.[8] The sum of the two components is referred to as the "dollar holdings" measure of equity incentives.

Baker and Hall (2004) contend that the suitability of each measure is context specific depending on how the CEO's actions affect firm value. When the CEO's actions affect the dollar returns of the firm (e.g., consuming perquisites), then the CEO's percentage ownership is the appropriate measure of incentives (i.e., the fractional holdings measure). When the CEO's actions affect the percentage returns of the firm (e.g., decisions about corporate strategy), the appropriate measure of CEO incentives is the dollar holdings in the firm (i.e., the dollar holdings measure). Core and Guay (1999) further distinguish between these two measures by noting that the fractional holdings measure (i.e., the dollar change in CEO wealth for a $1,000 dollar change in firm value) assumes that the manager's incentives increase with his fractional ownership of the firm. In contrast, the dollar holdings measure (i.e., the dollar change in CEO wealth for a percentage change in firm value) assumes that incentives increase with a manager's dollar ownership of the firm.[9]

Given that equity provides the dominant source of incentives for most senior-level executives, the literature has examined a wide-range of issues related to the effects (whether intended or not)

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[7] The "delta" of an option is the partial derivative of its value with respect to the price of the underlying stock. The delta indicates the sensitivity of the option's value (whether objective of subjective) to changes in the price of the underlying stock. If the appropriate option valuation model is the Black-Scholes (1973) model, then the delta is the partial derivative of the Black-Scholes formula with respect to price. An option delta of 0.7, for example, implies that the value of the option increases by $0.70 for every dollar increase in the price of the underlying stock. In this context, the delta indicates the fraction of shareholder wealth creation captured by the option holder.

[8] Core and Guay (1999) point out that there is an obvious one-to-one mapping between the dollar holdings measure and the fractional holdings measure. In particular, starting with the fractional measure of equity incentives, one can recover the dollar holdings measure by multiplying the fractional holdings measure by the value of the firm divided by $100,000.

[9] As I discuss in Section 5, the dollar holdings measure of incentives can be disaggregated into two separate components – an equity wealth component and a sensitivity component – and, although the two are related, they can have different implications for measuring incentives.

of equity incentives using both measures. Table 1 summarizes several recent studies in order to highlight the breadth of issues examined and the variety of measures used to estimate equity incentives. Given the difficulties of properly measuring equity incentives, it is not surprising that research on equity-based compensation has not reached a consensus on the appropriate measure. Indeed, a number of authors have noted the importance of properly measuring this key construct in order to draw valid and reliable inferences from empirical incentives studies such as those in Table 1. In particular, Core and Guay (2003) note that "an important empirical and theoretical issue in [executive compensation] studies is the appropriate method of measuring the value of stock-based compensation and the incentives provided by these securities." Core, Guay, and Larcker (2003) make a similar point by observing that "a fundamental question for the compensation literature is the measurement of incentives in general, and equity incentives in particular."[10] The next section develops a model of subjective value and incentives that incorporates features of the contracting environment that prior theoretical and empirical work suggests are important for understanding an executive's subjective value of his equity holdings.

3. Revealed Preferences Model of Subjective Equity Valuation

This section develops a revealed preferences model of equity value to infer executives' subjective valuation of their stock and option holdings from their sale and exercise behavior. In particular, the model is developed within a random utility framework where an executive's utility over his or her stock and option holdings is specified as a function of various behavioral, economic, and other factors that jointly affect the subjective value and resulting exercise behavior. There are a number of advantages of the revealed preference approach relative to the (theoretical and survey-based) methods discussed in the previous section.

First, the revealed preferences approach neither requires nor assumes completely rational exercise behavior. Thus the model admits both behavioral biases that affect the executive's exercise decision (e.g., benchmark heuristics) and other systematic determinants of option exercise (e.g., seasonal selling to satisfy consumption) that have been documented in prior

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[10] Coles, Daniel, and Naveen (2006) discuss how many studies adopt measures of this important construct that are removed from the theoretical work. In particular, they note that "nearly all prior empirical experiments use a relatively rudimentary representation of compensation structure as the basis for explanatory variables. Such right-hand side variables include transformed, scaled, unscaled, and/or untransformed measures… These measures are disconnected from the characteristics of compensation, specifically delta and vega, that theoretical models suggest are important." Similarly, Hall and Murphy (2002) note that "although academics and practitioners sometimes note the shortcomings of Black-Scholes, academics routinely use Black-Scholes to measure the value, cost, and pay/performance sensitivity of non-tradable executive options…".

research (e.g., Heath, Huddart, and Lang (1999) and Armstrong, Jagolinzer, and Larcker (2006)). Second, the revealed preference approach indirectly captures both executive risk-aversion and their degree of undiversification in a very flexible fashion. Specifically, the revealed preferences approach does not require an assumption about the functional form of the executives' utility (e.g., power) or the risk aversion parameter, which is needed for current measures such as those developed by Lambert, Larcker, and Verrecchia (1991) and Hall and Murphy (2002). Finally, if executives understand the mapping between their actions and firm value, this will influence their stock sale and option exercise decisions. If these decisions are correlated with covariates included in the model (e.g., prior returns, future returns and prior volatility) then the outcome of the incentive effects will manifest in the coefficient estimates.[11]

3.1. Random Utility Model of Option Exercises [12,13]

The revealed preferences model of equity valuation is developed within a random utility framework that is common in the discrete choice literature (e.g., McFadden (1999), McFadden and Train (2000), Hallock and Olsen (2006)).[14] In a multi-period setting with repeated choices over time, the decision maker (indexed by i) faces a variety of alternative choices (indexed by j) in each period (indexed by t), each of which provides him with a certain level of utility $U_{i,j,t}$ that is known to the decision maker but not to the researcher. This unobserved utility is then decomposed into two parts so that total utility is $U_{i,j,t} = V_{i,j,t} + \varepsilon_{i,j,t}$, where $V_{i,j,t}$ is the systematic component which represents the observable factors that affect utility and $\varepsilon_{i,j,t}$ is the stochastic component that represents unobservable factors that affect utility. The systematic component $V_{i,j,t}$ (sometimes called "representative utility") is typically specified as a (linear) function of observable attributes of either the decision maker (e.g., age or wealth) or the choice set. Since the $\varepsilon_{i,j,t}$ terms are unknown, they are treated as random with joint density $f(\varepsilon_{i,j,t})$, and it is this density

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[11] Train (Chapter 7, 2003) further discusses the relative advantages and disadvantages of revealed preference and stated preference research designs.
[12] The discussion in this and the following three subsections draw heavily on the framework and methodology described in Train (2003).
[13] The random utility model of option exercise developed in this section also applies to stock sales. As discussed in the next section, I group each executive's stockholdings together and treat them as separate option grant with an exercise price of zero and an indefinite maturity. In order to facilitate the discussion, I simply refer to option exercises throughout the remainder of this section and this should be taken to include both the stock and option holdings of an executive.
[14] The nature of the decision maker's choice set (i.e., discrete or continuous) dictates whether the model is a discrete choice model or a continuous choice model. As discussed below, I model the fraction of the option grant exercised as a continuous variable, so the revealed preferences model in this setting is characterized as a continuous choice model. However it shares many features with models of discrete choice.

that enables the researcher to make probabilistic statements about the decision maker's choices. Thus, the utility of each alternative choice is modeled as a random variable and the probability that any given alternative (or sequence of alternatives in a multi-period setting) is defined as the probability that it provides the decision maker with the greatest utility among the available alternatives.

Within this framework, I model an executive's utility over his stock and option holdings by assuming each executive has the following utility function for each outstanding option grant:[15]

$$U_{i,k,t} = IV_{i,k,t}E_{i,k,t} + SV_{i,k,t}H_{i,k,t} - \tfrac{1}{2}D_i H_{i,k,t}^2 \tag{1}$$

where $U_{i,k,t}$ is the utility of executive i from grant k in period t, $IV_{i,k,t}$ is the intrinsic value of the option grant (which is greater than or equal to zero), $E_{i,k,t}$ is the fraction of the total option grant exercised during the period, $SV_{i,k,t}$ is executive subjective value of the options in the grant during the period, $H_{i,k,t}$ is the fraction of the option grant available to exercise (i.e., the fraction of the grant vested less the cumulative fraction exercised) that is held by the executive during the period, and D_i is a parameter that reflects the executive's disutility from continuing to hold the options rather than exercising them during the period.[16] The form of this utility function is motivated by a mean-variance certainty equivalence representation that is common in agency models.[17] However, since this utility function does not have a direct correspondence to a formal utility function (e.g., power, negative exponential, etc.), it is best described as a "reduced-form" representation rather than a structural model of utility maximization.

The parameter D_i in equation (3) is intended to capture the cost to the executive of holding the options rather than exercising them immediately and receiving cash equal to the intrinsic value. As discussed in the following section, a number of covariates are included in the model to capture various explicit sources of disutility from holding the options, such as the executive's risk-aversion, degree of undiversification, and (unfavorable) forward looking information about the

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[15] The previous notation uses j to index the choice set in a discrete choice setting. However in this case, since I model the executive's choice (i.e., the fraction of the option grant to exercise) as a continuous variable I do not index over the choice set. Instead, I introduce an index for each of the executive's separate option grants.

[16] This setup assumes either that option exercises are "cashless" or that any shares acquired from the exercise are immediately sold. This assumption is common in the empirical incentives literature (see, for example, Armstrong, Jagolinzer, and Larcker (2006)) and is consistent with empirical evidence on employee exercises of stock options.

[17] One way to derive a mean-variance representation of a certainty equivalent is to assume a power utility function with a lognormally distributed payoff. Power utility is consistent with constant relative risk aversion (CRRA) and a lognormal payoff is consistent with a long-horizon distribution of stock prices. Alternatively, negative exponential (i.e., CARA) utility coupled with normally distributed payoffs results in a mean-variance representation for the certainty equivalent.

price of the underlying stock (and thus the impending decline in value of the options). The disutility parameter captures any residual uncertainty that is not explained by these factors and is best thought of as "information risk" related to any uncertainty of the executive about his subjective estimate of the option's valuation.

The executive's subjective value of his option holdings is specified as a linear function of factors specific to the company, executive, and option grant as well as other factors (which collectively constitute the systematic component of utility) and a random error term (which is the stochastic component of utility).

$$SV_{i,k,t} = X'_{i,k,t}\beta + \varepsilon_{i,k,t}$$
$$= \theta'_1 Company_{i,t} + \theta'_2 Executive_{i,t} + \theta'_3 Grant_{i,k,t} + \theta'_4 Other_{i,t} + \varepsilon_{i,k,t} \qquad (2)$$

where $X_{i,k,t}$ is a vector of observable company-specific, executive-specific, grant-specific, and other covariates that affect executive i's subjective value of the options in grant k in period t and $\varepsilon_{i,k,t}$ is an iid error term that reflects unobserved factors that affect executive i's subjective value of the options in grant k in period t.[18] Note that the subjective value can be increasing in certain factors but decreasing in others. The latter are analogous to disutility terms and their location in the subjective value rather than with the disutility parameter is somewhat arbitrary. The term $\beta = [\theta_1\ \theta_2\ \theta_3\ \theta_4]'$ is a vector of coefficients for the company-specific, executive-specific, grant-specific, and other covariates, respectively.

Substituting equation (2) into equation (1) yields the following econometric model:

$$U_{i,k,t} = IV_{i,k,t}E_{i,k,t} + (X'_{i,k,t}\beta + \varepsilon_{i,k,t})H_{i,k,t} - \tfrac{1}{2}D_iH_{i,k,t}^2 \qquad (3)$$
$$= IV_{i,k,t}E_{i,k,t} + H_{i,k,t}X'_{i,k,t}\cdot\beta + \varepsilon_{i,k,t}H_{i,k,t} - \tfrac{1}{2}D_iH_{i,k,t}^2$$

The fraction of the available (i.e., vested and unexercised) option grant exercised in a period is the choice variable of the executive, which is modeled as a continuous outcome variable. Since the utility function in equation (3) is concave in the fraction of the grant exercised, the executive's utility from the option grant is maximized when the following the first-order condition (FOC) is satisfied.

$$U_{i,k,t} = IV_{i,k,t}E_{i,k,t} + SV_{i,k,t}(1 - C_{i,k,t} - E_{i,k,t}) - \tfrac{1}{2}D_i(1 - C_{i,k,t} - E_{i,k,t})^2$$
$$FOC_E:\ IV_{i,k,t} - SV_{i,k,t} + D_i(1 - C_{i,k,t} - E_{i,k,t}) = 0$$
$$\Rightarrow \quad IV_{i,k,t} - SV_{i,k,t} + D_i - D_iC_{i,k,t} - D_iE_{i,k,t} = 0$$
$$\Rightarrow \quad D_iE_{i,k,t} = IV_{i,k,t} - SV_{i,k,t} + D_i - D_iC_{i,k,t}$$

[18] The distributional assumptions placed on this error term are discussed in the next section and these dictate the structure of the resulting model.

=> $$E_{i,k,t} = (1 - C_{i,k,t}) + \frac{IV_{i,k,t} - SV_{i,k,t}}{D_i}$$

=> $$E_{i,k,t} = E^{\max}_{i,k,t} + \frac{IV_{i,k,t} - X'_{i,k,t}\beta + \varepsilon_{i,k,t}}{D_i} \qquad (4)$$

where $C_{i,k,t}$ is the cumulative fraction of the grant exercised prior to period t and $E^{\max}_{i,k,t}$ is the maximum fraction of the grant that can be exercised during the period (i.e., the vested and unexercised portion). In this setup, $E_{i,k,t}$ is a latent variable that represents the optimal fraction of the grant that executive would exercise at time t. However, the fraction of the grant available for the executive to exercise will often constrain his exercise behavior. Specifically, the fraction that can be exercised is bounded below by zero (i.e., the executive cannot exercise a negative fraction of the grant) and bounded above by $E^{\max}_{i,k,t}$, which is the fraction of the grant available for exercise.[19] Thus, the <u>observed</u> outcome, $E^{*}_{i,k,t}$, is as follows:

$$E^{*}_{i,k,t} = \begin{cases} 0 & if \quad E_{i,k,t} \le 0 \\ E_{i,k,t} & if \quad 0 < E_{i,k,t} < E^{\max}_{i,k,t} \\ E^{\max}_{i,k,t} & if \quad E_{i,k,t} \ge E^{\max}_{i,k,t} \end{cases} \qquad (5)$$

I assume that the error term $\varepsilon_{i,k,t}$ is normally distributed, which yields a "doubly-censored Tobit" (or "two-limit Tobit") since censoring can occur at both the upper and lower thresholds. In this case, the density of $E^{*}_{i,k,t}$ is given by:

$$f(E^{*}_{i,k,t}) = \Phi\left(\frac{-\mu_{i,k,t}}{\sigma}\right)^{I\left[E^{*}_{i,k,t}=0\right]} \Phi\left(\frac{\mu_{i,k,t} - E^{\max}_{i,k,t}}{\sigma}\right)^{I\left[E^{*}_{i,k,t}=E^{\max}_{i,k,t}\right]} \left[\frac{1}{\sigma}\phi\left(\frac{E^{*}_{i,k,t} - \mu_{i,k,t}}{\sigma}\right)\right]^{I\left[0<E^{*}_{i,k,t}<E^{\max}_{i,k,t}\right]} \qquad (6)$$

where

$$\mu_{i,k,t} = 1 - C_{i,k,t} + \frac{IV_{i,k,t} - X'_{i,k,t}\beta}{D_i} = E^{\max}_{i,k,t} + \frac{IV_{i,k,t} - X'_{i,k,t}\beta}{D_i}$$

and I[·] is an indicator function equal to one if the observed fraction exercised is zero, the upper limit $E^{\max}_{i,k,t}$, or some fractional amount in between, respectively, and zero otherwise. Thus, the density consists of three pieces that represent (1) outcomes observed at the lower limit (i.e., no exercise), (2) outcomes observed at the upper limit (i.e., exercising all of the available options),

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[19] Although the executive cannot exercise a negative amount of stock options, it is possible to purchase exchange traded options. Also, a negative sale of shares can be interpreted as the purchase of additional shares of stock. Since executives are, on average, net sellers of equity, I do not allow for option or stock purchases in the current analysis. I hope to better accommodate this behavior in a future version of this study.

and (3) outcomes that fall somewhere in between (i.e., exercise of a fraction of the options available).

There are a number of noteworthy features of this model. First, the disutility of holding the options is what gives rise to fractional exercises by the executive. If the executive is "risk-neutral" such that the disutility parameter D_i is equal to zero, then this model is similar to Hallock and Olsen's (2006) model which has a dichotomous outcome where either all or none of the options are exercised and there is zero probability of a fractional exercise.[20] Hallock and Olsen's (2006) model also considers only the first incidence of option exercise, regardless of its magnitude, and discards the subsequent sequence related to that option grant from their analysis. In contrast, the model herein preserves this information by allowing for fractional exercises and thus uses the information conveyed by subsequent (hold and exercise) decisions related to the remaining options in the grant. Related to this point is that the disutility and concomitant fractional exercises are what allow for econometric identification of the model. Specifically, variation in the fraction of the grant exercised and the fraction of the grant the executive continues to hold is what allows for identification of the model parameters.[21]

Another crucial feature of the model is that it is possible to recover estimates of the unstandardized coefficients in the subjective value representation. In a typical latent index model where the outcome is observed only if the latent index exceeds some threshold, only the standardized coefficients (i.e., β/σ) are identified because the threshold in the model is arbitrary (and is typically normalized to zero). However, as Hallock and Olson (2006) point out, in the case of stock option exercise, the threshold is not arbitrary since the executive will exercise options when their intrinsic value exceeds their subjective value. In the econometric model described above, the estimated coefficient on $E^{\max}_{i,k,t}$ is the reciprocal of the standard deviation of the error term (i.e., $1/\sigma$) and the estimated coefficient on the intrinsic value, $IV_{i,k,t}$, is the reciprocal of the disutility term (i.e., $1/D_i$). These parameter estimates can be used to recover the unstandardized coefficients, β, from the estimated standardized coefficients (i.e., $\beta^* = \beta/(D_i\sigma)$). The unstandardized coefficients can then be used to calculate the subjective dollar value of the executives' equity holdings conditional on a set of covariates for the determinants of value.

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[20] Recall that the parameter D_i is not a risk aversion parameter in the formal sense, but instead serves to capture the disutility associated with holding a given fraction of an option grant rather than exercising the options. Therefore, $D_i = 0$ does not correspond to risk-neutrality, per se.

[21] In contrast, Hallock and Olsen's (2006) model requires data on multiple outstanding option grants (with different strike prices and intrinsic values) at the same time for the same employee to identify the model's parameters. This is because their model precludes fractional exercises of a grant and thus loses the information conveyed by this exercise pattern.

3.2. Fixed and Mixed Doubly-Censored Tobit Specifications

There are a number of reasons to suspect that there are differences in how executives subjectively value their equity holdings as a result of differences in wealth, risk-aversion, degree of undiversification, experience, firm specific production functions and other factors that describe the contracting environment. Therefore, in addition to estimating the revealed preferences model of subjective value with fixed coefficients (so that the effect of a given covariate is identical across executives), I also allow certain coefficients to vary across executives in the sample to capture differences in contracting environments and heterogeneity in executive preferences.

The mechanics of the mixture model in this context are similar to those of mixed logit models of discrete choice which have gained widespread application in marketing, transportation, and related disciplines. The defining feature of any mixture model is the specified distributional form of the coefficients. Thus, for each coefficient that is allowed to vary across executives, a mixing distribution, $f(\beta|\theta)$ is assumed to describe how the executive-specific coefficients are distributed in the population. The parameters of the population distribution of coefficients, (i.e., θ) are then estimated rather than point estimates of the coefficients (i.e., β), as is the case with fixed models. In the case of a normally distributed coefficient (i.e., where $f(\cdot) \sim$ Normal), the mean and variance of the population distribution are estimated so that $\theta = [\mu, \sigma^2]$.[22] Under a random coefficients interpretation of the model, the executive-specific parameter estimates are consistent with variation in contracting environments (which include executive's preferences).[23]

3.3. Executive-Specific Coefficient Estimates

Since I have multiple observations for the same executive over time, I can use the estimated parameters of the unconditional population distribution along with an executive's observed sequence of covariates and the associated exercise behavior to infer a more precise conditional distribution of an executive's coefficient values. In particular, this sequence allows me to estimate a conditional distribution for each executive given the sequence of observations and the

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[22] One interesting feature of mixture models is that the significance of the estimated variance (i.e., the scale parameter) can be used to test the suitability of the fixed coefficient assumption. If the estimated variance is significantly different from zero, this suggests that the assumption of fixed coefficients is violated.

[23] Mixture models can be motivated in ways other than a random parameters interpretation. For example, since the primary goal of Brownstone and Train (1999) is prediction, they adopt a mixed logit specification with an error components interpretation. Although equivalent to a random coefficients interpretation, this places more emphasis on modeling correlations over time among alternatives of the choice set. Under both interpretations, the main feature of the mixing distribution is that it captures both variation and covariation in unobserved factors.

population distribution from which this sequence was drawn. Formally, letting $y_{i,t} = \{E^*_{i,1},\ldots,E^*_{i,T}\}$, denote the sequence of (option exercise) choices made by executive i with the sequence of covariate values $x_{i,t} = \{x_{i,1}, \ldots, x_{i,T}\}$, a conditional posterior distribution of the executive's coefficients can be recovered from the unconditional population distribution to which the executive belongs. The main distinction between the two distributions is that the distribution of preferences in the population (i.e., $f(\beta|\theta)$) is an unconditional distribution, while the posterior distribution (i.e. $g(\beta|y,x,\theta)$) is the conditional distribution of preferences in the subpopulation of executives who make a particular set of decisions (i.e., $y_{i,t}$) when facing a certain set of covariates (i.e., $x_{i,t}$). Thus, $g(\cdot)$ conditions on the observed sequence of exercise decisions, $y_{i,t}$, and the covariate values associated with this choice sequence, $x_{i,t}$, while $f(\cdot)$ does not. Figure 1 illustrates the distinction between these two distributions.

Given the distribution of a coefficient in the population (i.e., $\beta_n \sim f(\beta|\theta)$), if β_n were known, the probability of observing this sequence of choices for a particular executive would be

$$P(y_{i,t} \mid x_{i,t}, \beta_n) = \prod_{t=1}^{T} L_{i,t}(y_{i,t} \mid \beta_n) \tag{7}$$

where $L_{i,t}$ is the probability of observing each outcome given by equation (6). However, β is unknown so the probability of observing the sequence of choices given by $y_{i,t,}$ is the integral of $P(y_{i,t}|x_{i,t},\beta_n)$ over the distribution of β, or

$$P(y_{i,t} \mid x_{i,t}, \theta) = \int P(y_{i,t} \mid x_{i,t}, \beta) g(\beta \mid \theta) d\beta \tag{8}$$

which is the mixed probability previously discussed. Now, by Bayes' rule,

$$g(\beta \mid y_{i,t}, x_{i,t}, \theta) \cdot P(y_{i,t} \mid x_{i,t}, \theta) = P(y_{i,t} \mid x_{i,t}, \beta) \cdot f(\beta \mid \theta)$$

The left-hand side of this equation states that the joint density of β and $y_{i,t}$ can be written as the probability of observing $y_{i,t}$ times the probability of β, conditional on observing y_n, while the right-hand side gives the probability of β times the probability of observing the sequence y_n, conditional on observing β. Rearranging the above expression we get

$$g(\beta \mid y_{i,t}, x_{i,t}, \theta) = \frac{P(y_{i,t} \mid x_{i,t}, \beta) f(\beta \mid \theta)}{P(y_{i,t} \mid x_{i,t}, \theta)} \tag{9}$$

This equation shows that the density of β in the subpopulation of executives with covariates $x_{i,t}$ who would choose sequence $y_{i,t}$ (i.e., $g(\beta \mid y_{i,t}, x_{i,t,} \theta)$) is proportional to the density of β times the probability that the sequence of exercise decisions $y_{i,t}$ would be chosen by an executive with covariates $x_{i,t}$. The essence of this estimation approach is that when there is not information about an executive's sequence of choices, we mix over the density of β in the entire population of executives. If, however, there is information about an executive's sequence of previous choices, we can recover a "tighter" distribution of β in the subpopulation of individuals who would have made the same sequence of choices (see Figure 1). Therefore, if there were no prior choices (i.e., exercise decisions) for an executive on which to condition, the conditional distribution for the executive would be identical to the unconditional population distribution of executives and the executive would have a conditional coefficient value of β_n, which is equal to the population mean of β. At the other extreme, if there are infinitely many exercise choices for the executive, then the conditional estimate would be the executive's own β_n. The methodology to recover individual-specific coefficient estimates from the population distribution has been shown to be very robust. In a Monte Carlo experiment, Train (Chapter 11, 2003) shows that conditioning on only one choice captures over 40% of the variation in β_n and conditioning on ten choices captures over 80% of the variation in β_n.

3.4. Simulated Maximum Likelihood Estimation of Mixed Revealed preference Model

Since the unconditional probability f(β|θ) does not have a closed form solution, it is estimated with simulated maximum likelihood estimation (SMLE) as follows. First a draw of β is taken from its distribution (e.g., normal) and the product of the doubly-censored Tobit given by equation (6) is calculated using this value of β_n. This process is repeated many times and the average value is taken. Thus, the simulated probability is given by:

$$\breve{P}_n = \frac{1}{R}\sum_{r=1}^{R} L_n(\beta^r) \tag{10}$$

where R is the number of draws of β from the conditional distribution f(β|θ). The sum of the natural logarithm of the product of the simulated probabilities for each of the N executives are then added together to form the simulated loglikelihood

$$SLL(\theta) = \sum_{n=1}^{N} \ln \breve{P}_n(\theta) \tag{11}$$

The simulated maximum likelihood estimator (SMLE) is the set of parameter values of θ that maximizes the simulated loglikelihood function. The optimization is done using a sequential quadratic programming approach with the BFGS procedure to update the Hessian at each iteration.[24] Since the subjective value is specified as linear in its covariates, the objective function is strictly concave and the optimization results in a globally optimal solution (Train (2003)). Finally, the standard errors are calculated using the robust covariance matrix $H^{-1}GH^{-1}$, where H is the Hessian (and H^{-1} is an estimate of the information matrix) and G is the outer product of the gradient. McFadden and Train (2000) show that this covariance matrix incorporates noise from the simulation.

3.5. Revealed preference Delta and Vega

As discussed in the previous section, the equity incentives construct is typically measured as the change in the executive's subjective value of his or her equity holdings for a given change in the price of the underlying stock. A similar measure (i.e., a revealed preference delta) can be extracted from the revealed preferences model by differentiating the subjective value given by equation (2) with respect to price in order to describe how the executive's subjective value changes as price changes. As discussed further in the following section, the covariates in the subjective value model enter as interactions with the Black-Scholes value of the option.[25] Since the Black-Scholes value of the option is a function of price, this implies that all of the covariates have an effect on the revealed preference delta. However, some of the initial (i.e., non-interacted) covariates are themselves a function of price (e.g., prior returns) and these have two effects on the revealed preference delta. To illustrate, suppose there are two covariates in the model, x_1 and x_2, and both are interacted with the Black-Scholes value of the option. The subjective value is then as follows:

$$SV_{i,k,t} = \beta_1^* BSV_{i,k,t} + \beta_2^* BSV_{i,k,t} x_{1i,k,t} + \beta_3^* BSV_{i,k,t} x_{2i,k,t} + \varepsilon_{i,k,t} \tag{12}$$

where $BSV_{i,k,t}$ is the Black-Scholes value of grant k of executive i during period t and the star on each coefficient indicates that it is unstandardized. Now suppose the first covariate is a function of price (i.e., $x_1 = f(P_{i,t})$) but that x_2 is constant with respect to price. The derivative of the subjective value with respect to price is then given by

$$\left.\frac{\partial SV_{i,k,t}}{\partial P_{i,t}}\right|_{P*} = \beta_1^* \delta_{i,k,t} + \beta_2^* \left(\frac{\partial x_{1i,k,t}}{\partial P_{i,t}} BSV_{i,k,t} + x_{1i,k,tt} \delta_{i,k,t} \right) + \beta_3^* x_{2i,k,t} \delta_{i,k,t} \tag{13}$$

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[24] The BFGS (Broyden-Fletcher-Goldfarb-Shanno) algorithm is a quasi-Newton method for updating the Hessian. The BFGS algorithm and is discussed more thoroughly in Train (Chapter 8, 2003) and Judd (Chapter 4, 1998).

[25] More specifically, the covariates in the model are interacted with a measure of "fundamental value," which is either the Black-Scholes value or the option of the intrinsic value of the options using target price forecasts as a proxy for the executives' beliefs about the future value of their options.

where $\delta_{i,k,t}$ is the Black-Scholes delta of the option. Similarly, the revealed preference vega is calculated as the change in the subjective value for a change in the volatility of the price of the underlying stock. Again, certain covariates in the model are a function of price volatility, and these factors will have two effects on the revealed preference vega while the other covariates will have only one effect (i.e., through the Black-Scholes vega).

3.6. Limitations of Revealed Preferences Approach

There are at least four limitations of the revealed preferences approach. First, similar to most models, this approach assumes that past exercise behavior is representative of future exercise decisions.[26] Second, this approach cannot distinguish between exercise driven by a desire for diversification and exercise due to liquidity shocks.[27] However, if these events are purely random this should not bias the coefficient estimates in the model. In addition, certain covariates are included in the model to proxy for the executives' level of wealth and potential liquidity needs. Third, the revealed preference approach imperfectly incorporates the incentive effects of the employee stock options because it does not formally model how an executive's actions translate into firm value. However, to the extent the incentive effects are captured by certain covariates in the model, this approach constitutes a substantial improvement over the utility-based models used in prior studies which assume that price is strictly exogenous. Similarly, because the revealed preferences model is not derived from a structural model of utility maximization, there is not necessarily time-consistency in the executives' exercise behavior. Fourth, if there are implicit contracts in place that prevent an executive from selling shares or exercising options, this results in unobserved censoring of the data and the wrong threshold will be used in the estimation.[28] As is the case with any censoring, if not accounted for in the estimation, this will result in biased coefficient estimates.

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[26] Train (Chapter 6, 2003) discusses a framework for modeling a decision maker whose tastes are not stable over time. Although this is beyond the scope of the current study, I plan to allow for executives' subjective valuation of their equity holdings to evolve over time in a future version of this study. This seems particularly appropriate in this setting because executives' exercise behavior might exhibit "learning" over time. For example, the option exercise behavior of executives might become less susceptible to behavioral biases as they gain more experience exercising stock options.

[27] A related difficulty is pre-planned trades executed under Section 10b5-1. Option exercises under these plans are based on a stale information set at the time the trade is executed, so the option exercise might not be optimal given the current information set at the time of exercise.

[28] To illustrate, suppose an executive wants to exercise 70% of the vested shares from an option grant but he is implicitly constrained from selling more than 50%. If the executive exercises 50%, that will appear as an uncensored observation to the researcher, but it is in fact a right censored observation because the executive exercised the maximum allowed by the implicit contract and would have liked to have exercise even more.

4. Sample Selection and Subjective Value Model Specification

4.1. Sample Selection and Portfolio Holdings

I focus on the equity incentives of chief executive officers for three main reasons. First, because CEOs are the primary decision makers within their organization, they are in a position to substantially influence the value of the firm, so the incentive effects of equity-based compensation are expected to be most pronounced for these individuals. As discussed earlier, the theoretical and empirical evidence is mixed on whether the subjective value of equity holdings for CEOs should be above or below its risk-neutral value because the magnitude of the incentive effects is ambiguous. The subjective value of equity-based compensation and holdings to these individuals is therefore an important but unresolved question. Second, the revealed preferences measure of subjective value requires information about an executive's stock sale and option exercise activity which is generally available from regulatory filings for CEOs and other senior-level executives. Third, much of the prior equity incentives literature (e.g., Core and Guay (1999) and Aggarwal and Samwick (1999)) focuses on the CEO, so this facilitates the comparability of my results with those presented in prior studies.

The revealed preferences model of subjective value uses the executives' stock sales and option exercises and therefore requires information about how their equity portfolios evolve over time, including restricted stock and option grants, stock sales, and option exercises, cancellations, and expirations. In order to construct a database of CEO equity holdings over time, I exploit the fact that as "insiders" under Section 16 of the Securities Exchange Act of 1934 (and Rule 16a-3(g)), CEOs are required to file Forms 3, 4, and 5 with the SEC for transactions related to their derivative and non-derivative securities (on Table 2 and Table 1, respectively). The Thompson Insider Filing Database contains Form 3, 4, and 5 data related to Table 2 transactions beginning in 1996 and Table 1 transactions beginning in the late-1980s. This is the primary data source used to construct the sample. Since the revealed preference measure requires information about both executives' stock and option holdings over time, I use 1996 to 2005 as my sample period because information from both Table 1 and Table 2 is available from the Thompson Insider Filing Database during this entire period.

Although the Thompson Insider Filing Database records the insider's job title, the description is often unclear. Therefore, I rely on the Execucomp database for identifying CEOs and the year(s) of their tenure. I first collect information from Execucomp for all executives who held the chief executive officer title at some point during the 1996 to 2005 period. I then match these executives with the Thompson Insider Filing Database based on CUSIP, company name and employee name. Next I use the information reported in Execucomp about each executive's stock, restricted stock, and stock option holdings and grants during the year to reconstruct the number and value of each class of security at an annual frequency. Using this annual information about holdings, grants, and divestitures, I then use the Form 3, 4, and 5 filings to reconstruct the executives' portfolio holdings at a monthly frequency.[29]

When reconstructing the executives' monthly holdings, I use the grant date, expiration date, exercise price triplet to identify the option grants to match grant, vesting, and exercise transactions within the Thompson database. I account for stock splits using the split-adjustment factors and stock split dates from CRSP and adjust the exercise price and number of options on the appropriate days. I also use the stock split information from CRSP to verify the amounts reported in the Thompson Insider Filing Database and in almost every case the two are in agreement.[30]

For some option grants either the expiration date or the vesting schedule not available. For these grants, I first look to the proxy statements to see whether the missing information for the grant is available based on the grant date and the exercise price of the options. In most cases the information is available from the proxy statement, but if it is not, I use the average maturity or vesting period for the company as an estimate of the expiration date and vesting schedule, respectively. If the grant date is not available, I attempt to infer it using the expiration date and the average option life for the company.

For certain executive-years, it is not possible to accurately reconstruct their portfolio holdings, so these executives are removed from the sample.[31] In order to validate the reconstructed holdings for the remaining executives, I correlate the fiscal year-end intrinsic value of the equity holdings reconstructed using primarily the Thompson Insider Filing Database with the intrinsic values reported in the annual proxy statements from Execucomp. The correlation between the two sets of values is over 0.92, which is similar to Core and Guay (2002), Hall and Liebman

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[29] The term "divestitures" includes option exercises, cancellations, and expirations. Using any two successive annual proxy statements, it is possible to reconstruct the number and intrinsic value of the executive's beginning holdings, ending holdings, and grants during the year. It is also possible to calculate the aggregate number and intrinsic value of the options that are exercised, cancelled, and expired during the year, but not the separate components.

[30] Although the Thompson Insider Filing Database contains fields for the original number of options and their exercise price and the respective split-adjusted amounts, it is not possible to infer the exact date(s) of a stock split using just this information. However, using the split-adjustment factors and dates from CRSP, the implied split-adjustments in the Thompson Insider Filing Database can be validated.

[31] I have not formally examined the subsample of executives for which it is not possible to accurately reconstruct their portfolio holdings using just the Execucomp and Thompson Insider Filing Database for selection bias. I plan to conduct this analysis for a future revision of this study.

(1998), and Jin and Kothari (2005) who report correlations of 0.99, 0.79 and .95, respectively, for similar procedures to reconstruct executives' portfolio holdings. The final sample consists of 1,651 distinct CEOs and a total of 9,507 executive-year observations.[32]

4.2. Specification of the Revealed preference Model of Subjective Value

The revealed preferences model is based on the idea of a latent (linear) utility index that captures the underlying determinants of executives' subjective valuation of their equity holdings and the associated disutility. I model the subjective value of the stock options as a function of a salient benchmark that aggregates many of the determinants of the option's value into a single quantity. This has the advantage of capturing many of the observable determinants of the option's value. I use two alternative benchmarks throughout the remainder of the analysis.

The first benchmark is the Black-Scholes value of the options and the second is the intrinsic value calculated using the target price forecast. I use the Black-Scholes value because this amount is typically used by compensation consultants for benchmarking and designing CEO compensation packages and is frequently reported by the financial press. Thus, it is likely that CEOs use the Black-Scholes value as a benchmark for evaluating the subjective valuation of their option holdings. The second benchmark is the target intrinsic value of the options calculated using the target price forecast to proxy for the executive's expectations about future stock price. I use target prices from the First Call database which contains forecasts spanning the 1996 to 2004 period.[33] Since more than 90% of the forecasts are for a one-year horizon, I use only one-year-ahead forecasts to calculate the target intrinsic value. Although the target prices are used as a proxy for the executives' expectations of the future stock price, it is necessary to match the horizon at which the executives' plan to exercise their options (based on their current information set). I assume that executives expect to exercise their options after half of their remaining life has expired. If this is beyond one year (which is almost always the case), I calculate the future value of the target price using the long-term risk-free interest rate for the horizon. If the remaining life of the option grant is less than one year I assume that the executive will hold the options to maturity and discount the target price to match this horizon using the (continuously compounded)

[32] As discussed in the next subsection, CEOs that are promoted from within are often subject to Section 16 filing requirements in their previous position. I use this data if available to estimate the revealed preferences model of subjective value, so the total number of executive-grant-months used to estimate this model is larger than the number of CEO-grant-month observations.

[33] Brav and Lehavy (2003) and Bradshaw and Brown (2005) are two recent studies that use the First Call target price database. Both studies provide a detailed description of this database.

growth rate implied by the forecast.[34] For the executives' stock holdings, I assume the appropriate horizon is five years. Finally, I use the median target price forecast and I retain all firm-months with at least one target price forecast.

The advantage of using the Black-Scholes value as the benchmark is that it can be calculated for every option grant in my sample. In contrast, target price data is available for fewer than half of the firms in general and for none of the firms after 2004. The target price benchmark, however, has the advantage that it can be used to estimate a revealed preferences model of stock holdings. Since the Black-Scholes model values stock equal to its market price, it would be impossible to estimate a model of only stock sales using their Black-Scholes value because of this equivalence. Therefore, I estimate separate revealed preference models for the subjective value of both stock and options. For the Black-Scholes benchmark, however, I estimate a single model using only stock option exercises but I calculate subjective values using the estimated coefficients applied to both the executives' stock and option holdings.[35] Since the Black-Scholes model results in the largest sample, I use this model throughout the remainder of this section, but the discussion is equally applicable to the target price model.

I first model the executives' subjective value as a simple function of the Black-Scholes value of the options. Both the simple model and the full model (discussed below) assume that executives value their equity holdings by applying either a discount or premium to their risk-neutral (i.e., Black-Scholes) value. The subjective value in this case is as follows:

$$SV_{i,k,t} = \beta_1 BSV_{i,k,t} + \varepsilon_{i,k,t} \qquad (14)$$

Note that there is no intercept in this model because an option should not have any value if its Black-Scholes value is zero. I also use the tax-effected intrinsic value as the observable benchmark in the estimations. Jin and Kothari (2005) in discussing the literature on the tax implications for exercise and sale decisions conclude that "overall, the evidence shows that CEOs are tax-sensitive in the timing of their option exercise." Therefore, I assume that options are

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[34] To illustrate, if the remaining life of the option is six years, I assume the executive will exercise the option after three years and that the executive's expectation of the stock price in three years is equal to the future value of the one-year-ahead target price forecast compounded for two years using the risk-free rate for two year U.S. Treasury Bills. If, instead, the remaining life of the option is 11 months, I assume that the executive will exercise the options on the date of expiry and that the executive's expectation of the stock price on that date is the one-year-ahead target price forecast discounted back one month using the (continuously compounded) growth rate implied by the forecast.

[35] Panels B and C of Table 5 present the results for the Target Intrinsic Price model of subjective option and stock value, respectively. The results show that all but two of the main covariates have identical signs across the fixed models and the magnitudes are often similar. This suggests that similar (subjective) valuation models underlie the two types of equity holdings and that using the coefficient estimates from the Black-Scholes model to calculate the subjective value of stock holdings is reasonable.

nonqualified (i.e., taxed under Internal Revenue Code Section 83) with the realized intrinsic value taxed as ordinary income (at a 40% rate) upon exercise. I also assume that the executive has a tax basis in their restricted stock holdings equal to half the market value and I apply a capital gains tax rate of 20% to this amount.

The subjective value in equation (14) is a useful starting point, but it does not incorporate other known determinants of subjective value. Since executives' stock sale and option exercise decisions are a manifestation of their subjective value, I draw on prior research on the determinants of stock sales and option exercise (e.g., Huddart and Lang (1996), Heath, Huddart, and Lang (1999), Jin and Kothari (2005), and Armstrong, Jagolinzer, and Larcker (2006)) when specifying additional covariates to include in equation (14), which I now discuss.

Company-specific Covariates

I include both prior and future returns on the underlying stock (i.e., Prior $Return_{i,t}$ and Future $Return_{i,t}$) over the last or the next 250 trading days as the case may be. Prior returns are included in the subjective value primarily to capture the result of the incentive effects of the executive's equity holdings. One of the main reasons for granting equity-based compensation is to provide executives with incentives to increase stock price. If executives take actions that result in stock price appreciation, then it is expected that they will sell some of their equity to realize this increase in value. Further, if executive understand the mapping between their actions and firm value (i.e., the company's production function), then they will have a noisy signal of the impact of their actions and can sell off portions of their equity holdings once the outcome of their actions is reflected in stock price. Prior returns are also included because executives have a substantial portion of their capital (both financial and human) tied to the value of their company, so they become relatively more (less) undiversified as stock price increases (decreases). For both of these reasons, I expect the subjective value to be decreasing in the prior returns.[36] Future returns are included to capture the effects of any inside information on which the executive trades. To the extent an executive has favorable information about future stock price that is not reflected in current stock price, this should increase his subjective value. Therefore, I expect a positive relation between future returns on the underlying stock and subjective value.

The volatility of returns on the underlying stock over the previous 250 trading days (i.e., Prior $Volatility_{i,t}$) is included because the risk-neutral value of a stock option is increasing in the

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[36] A plausible alternative hypothesis is that executive's exhibit a contrarian behavioral bias and thus value their equity holdings more, *ceteris paribus*, following negative prior returns.

volatility of the returns of the underlying stock. However, Lambert, Larcker, and Verrecchia (1991) show that for a risk-averse, undiversified executive with trading restrictions on his equity, the value of the options can actually have an inverse relation with volatility. Thus the relationship between volatility and subjective value depends on an executive's degree of risk-aversion. Prior research (e.g., Armstrong, Jagolinzer, and Larcker (2006)) finds that the rate stock option exercise is increasing in volatility, which is consistent with risk-aversion. I therefore expect to find a negative relation between prior volatility and subjective value.

The final company-specific covariate is an indicator to denote whether the high price of the underlying stock during the month is at or above 90% of its highest price over the prior 250 trading days (i.e., 90% Prior High $\text{Indicator}_{i,t}$). Heath, Huddart, and Lang (1999) demonstrate that stock option exercise is positively associated with exceeding certain thresholds established by the historical price series. Armstrong, Jagolinzer, and Larcker (2006) find confirming evidence that stock option exercise is significantly associated with these simple heuristic benchmarks, which they posit is in part explained by the prominence of the 52-week high price in the financial press. Since the rate of option is expected to be increasing once this threshold is achieved, I conversely expect the subjective value to decline once it is attained.

Executive-specific Covariates

I include three covariates that indicate the employment history of the executive with the company. The first is an indicator for whether the month of the observation is prior to the executive's promotion to the CEO position (i.e., Pre-CEO $\text{Indicator}_{i,t}$) . For executives who become the chief executive through internal promotion, there is typically information about their stock and option holdings related to their previous position in the Form 3, 4, and 5 filings and in the annual proxy statement. In order to preserve this information about the executive's exercise behavior but acknowledge that it might not be representative of their exercise patterns as CEO, I include an indicator to allow for differential valuations across positions.[37]

I also include a covariate equal to the natural logarithm of one plus the number of years the executive has served as the CEO of the company (i.e, $\log(1 + \text{Tenure}_{i,t})$). This covariate is included for three reasons. First, CEOs with a longer tenure are more likely to understand how their actions influence their company's stock price and can therefore better time their exercise

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[37] Ignoring exercise information for executives promoted to the CEO position from within would also induce left-censoring in the data. This would require introducing assumptions about the "initial conditions" of the left-censored employee grants, which is another reason to include these observations in the estimation.

activity to capture the outcome of their value-enhancing actions. Second, CEO tenure is negatively related to the CEO's employment horizon. Therefore, longer serving CEOs are more likely to be closer to retirement which would reduce their subjective valuation of their equity holdings. Other authors (e.g., Dechow and Sloan (1991)) argue that as a manager approaches retirement, his horizon is shorter and he might not be inclined to pursue the best long-term wealth-maximizing strategies. Third, tenure is included to control for the accumulation of equity-holdings as a function of the length of employment with the firm. In this capacity, tenure serves as a proxy for CEO wealth (Guay (1999)). In general, I expect tenure to have a positive relation with the subjective value.

The third covariate in this set is an indicator for whether the executive leaves the CEO position within the next six months. Since these departures are typically a termination of the executive's employment with the company, I refer to these events as "terminations" (i.e., Termination $\text{Indicator}_{i,t}$). Since stock options are typically cancelled within 90 days following the termination of employment, the value of any equity to the CEO is likely to be diminished because of the reduction in time value and the (much) shorter horizon over which the CEO can take actions that affect stock price.

I also include an indicator equal to one if the executive received a grant of either restricted stock or stock options during either of the previous two months (i.e., Recent Grant $\text{Incicator}_{i,t,}$). Prior research (e.g., Ofek and Yermack (2000)) shows that executives tend to rebalance their equity portfolios following a new equity grant. Because this rebalancing typically entails the early exercise of stock options, this extinguishes their remaining time value and would therefore decrease their subjective value to the executive. In addition, the marginal value (i.e., certainty equivalent) of an executive's existing equity holdings is expected to decline following the receipt of a new grant of equity. For both reasons, I expect the subjective value of an executive's existing holdings to decrease following the receipt of a new equity grant.

Finally, I include a set of covariates to capture the related constructs of the executive's wealth and degree of risk aversion and undiversification. First among these is the natural logarithm of one plus the executive's salary during the current year (i.e., log(1+ $\text{Salary}_{i,t}$)). This is included as a proxy for the fixed wealth of the CEO since executive's with higher salaries are more likely to have accumulated a larger amount of fixed wealth over the course of their employment. Related to this point, CEOs with higher salaries are less likely to exercise options to satisfy their consumption needs. Guay (1999) also argues that CEOs with high total cash compensation are more likely to have additional outside investments which would make them more diversified and thus less risk-averse. I therefore expect a positive relation between salary and the subjective value of an executive's equity holdings.

The second covariate is the natural logarithm of one plus age of the executive (in years) at the end of the month of the observation (i.e., $\log(1+Age_{i,t})$). This covariate is included because prior research has shown that risk-aversion is increasing in age. In addition, older executives are closer to retirement so this also captures any "horizon effects" that influence the executive's exercise behavior and corresponding valuation. The third covariate in this set is the natural log of one plus the market value of the executive's portfolio of stock and restricted stock holdings (i.e., $\log(1+\text{Stock Portfolio Value}_{i,t})$). This is included to capture both the level of the agent's total wealth as well as the amount of wealth the executive has tied to his company. If executives' utility functions exhibit wealth effects, the subjective value of their equity is expected to be decreasing in the value of their firm-specific holdings (Lambert, Larcker, and Verrecchia (1991)). I also include the natural logarithm of one plus the intrinsic value of the executive's vested options (i.e., $\log(1+\text{Vested IV}_{i,t})$) and unvested options (i.e., $\log(1+\text{Unvested IV}_{i,t})$). These two covariates are also included to capture both the executives' level of wealth along with their degree of undiversification. The intrinsic value of the options is included rather than their Black-Scholes value because when an executive is deciding whether to exercise options, the intrinsic value is more relevant since this represents the amount currently realizable to the executive. Finally, I include the natural logarithm of one plus the cumulative proceeds realized from stock sales and option exercises prior to the month of the observation (i.e., $\log(1+\text{Cumulative Proceeds}_{i,t})$). This serves as a proxy for the executive's level of wealth. In addition, if the executive learns over time, this covariate could capture the propensity for more rational exercise activity. For both of these reasons, I expect a positive relation between the cumulative proceeds realized and subjective value.

Grant-specific Covariates

The first grant-specific covariate is the natural log of one plus the number of months until the option expires (i.e., $\log(1 + \text{Time Until Expiry}_{i,k,t})$). This is included to capture the time value of the options, which is increasing in the time until the option expires. Although the time until expiry is one of the inputs of the Black-Scholes model (and is therefore already included in the subjective value), this term is included to allow for a different weighting on the time until expiry in the subjective value. I also include a related covariate equal to the reciprocal of the rank in which the option grant expires among all of the executive's outstanding option grants during that month, which I call the Fractional Expiry Rank (i.e., Fractional Expiry $Rank_{i,k,t}$).[38] This covariate is included to capture the empirical regularity that executives in possession of multiple option grants tend to exercise them in order of expiry. Although the time until expiry is included as a covariate, the fractional expiry rank is expected to control for differences in exercise behavior (and thus subjective valuation) related to the number of grants possessed by the executive.

Finally, I include the price-to-strike ratio of the option (i.e., $\text{Price-to-Strike}_{i,k,t}$) because utility-based models such as Carpenter (1998) and Hall and Murphy (2002) suggest that optimal exercise behavior can be described in terms of an exercise threshold expressed as the price-to-strike ratio at a given point along the options duration. In addition, the price-to-strike ratio can also serve as a heuristic reference point by allowing the employee to easily measure stock price appreciation since the grant date (assuming the options are granted at the money, which is almost always the case). For these reasons, I expect a positive relation between the price-to-strike ratio and the subjective value.

Other Covariates

Finally, I include two sets of covariates that are not easily classified into the three categories above. The first consists of the short-term (i.e., Short-term Risk-free Interest $Rate_t$) and long-term (i.e., Long-term Risk-free Interest $Rate_t$) risk-free interest rates, measured as the prevailing interest rate on the six-month Treasury Bill and the ten-year Treasury Note during the month. These are included to proxy for the executive's alternative investment opportunities. Specifically, the interest rate controls for the executive's opportunity cost of keeping his capital tied up in the stock and options of his company rather then liquidating the holdings and investing the proceeds in an alternative investment, such as Treasury Securities.

The second set of covariates consists of three indicators for whether the observation is during the second (i.e., $2^{nd}Quarter_t$), third (i.e., $3^{rd}Quarter_t$), or fourth (i.e., $4^{th}Quarter_t$) quarter of the calendar year. These are included to control for both seasonal liquidity needs and for any increase in the rate of option exercise that accompanies systematic option grants that occur regularly throughout the calendar year. If the consumption or diversification demands are higher in the first quarter, the subjective value of the options will he higher in the second through the fourth quarters of the calendar year.

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[38] To illustrate, if the executive has five option grants outstanding during the month, the first to expire has a value of 1 for that covariate, the second grant to expire has a value of ½ for the covariate, etc… Because this covariate lies in the interval (0,1], I also estimated the fixed revealed preference models using a logit transformation of this covariate and obtained similar results.

The linear representation of the subjective value in this version of the model is thus given by:

$$SV_{i,k,t} = X'_{i,k,t}\beta + \varepsilon_{i,k,t}$$

$$= \theta'_1 Company_{i,t} + \theta'_2 Executive_{i,t} + \theta'_3 Grant_{i,k,t} + \theta'_4 Other_{i,t} + \varepsilon_{i,k,t}$$

$$SV_{i,k,t} = \beta_1 BSV_{i,k,t} + \beta_2 PriorRet_{i,t} \text{ x } BSV_{i,k,t} + \beta_3 FutureRet_{i,t} \text{ x } BSV_{i,k,t} + \beta_4 PriorVol_{i,t} \text{ x } BSV_{i,k,t} + \beta_5 90\% \text{ High Ind}_{i,t} \text{ x } BSV_{i,k,t} + \beta_6 \log(1+Age_{i,t}) \text{ x } BSV_{i,k,t} + \beta_7 \text{Termination Ind}_{i,t} \text{ x } BSV_{i,k,t} + \beta_8 \text{Recent Grant Ind}_{i,t} \text{ x } BSV_{i,k,t} + \beta_9 \log(1+Salary_{i,t}) \text{ x } BSV_{i,k,t} + \beta_{10} \text{Pre-CEO Ind}_{i,t} \text{ x } BSV_{i,k,t} + \beta_{11} \log(1+Tenure_{i,t}) \text{ x } BSV_{i,k,t} + \beta_{12} \log(1+StockPortValue_{i,t}) \text{ x } BSV_{i,k,t} + \beta_{13} \log(1+UnvestedIV_{i,t}) \text{ x } BSV_{i,k,t} + \beta_{14} \log(1+VestedIV_{i,t}) \text{ x } BSV_{i,k,t} + \beta_{15} \log(1+CumulativeProceeds_{i,t}) \text{ x } BSV_{i,k,t} + \beta_{16} \log(1+Duration_{i,k,t}) \text{ x } BSV_{i,k,t} + \beta_{17} (FractionalExpiryRank_{i,k,t}) \text{ x } BSV_{i,k,t} + \beta_{18} \text{Price-to-Strike}_{i,k,t} \text{ x } BSV_{i,k,t} + \beta_{19} \text{IntRate-ST}_t \text{ x } BSV_{i,k,t} + \beta_{20} \text{IntRate-LT}_t \text{ x } BSV_{i,k,t} + \beta_{21} 2^{nd}Quarter_t \text{ x } BSV_{i,k,t} + \beta_{22} 3^{rd}Quarter_t \text{ x } BSV_{i,k,t} + \beta_{23} 4^{th}Quarter_t \text{ x } BSV_{i,k,t} + \varepsilon_{i,k,t} \quad (15)$$

Similar to the simple model of subjective value, there is no intercept in this model. In addition all of the covariates enter nonlinearly through their interaction with the Black-Scholes value of the option. Also similar to the simple model in equation (14), the interactive model assumes that executives base their subjective valuation on a relatively salient benchmark (i.e., the option's Black-Scholes value or intrinsic value using target price forecasts) which is then adjusted either upwards or downwards (in percentage terms) as a function of the factors discussed above. As a simple example, an executive might value a particular option grant at, say, 85% of its Black-Scholes value, but apply another 5% discount to the Black-Scholes value if the underlying stock price is above 90% of its previous year's high perhaps because the executive will exercise some of the options in the grant soon or because a further price increase is less likely. Finally, all of the covariates (other than the Black-Scholes value and the indicator covariates) enter the model as deviations from their mean. This allows for two different values of the same covariate (i.e., one above the mean and one below the mean) to have a different (signed) effect on their adjustment to the Black-Scholes value. Without centering the covariates, all values for a given covariate would adjust the Black-Scholes value in the same direction.

Table 2 presents descriptive statics for the covariates used to estimate the full revealed preference model of subjective value. In addition, the sample of firms have a mean (median) market capitalization of $4,700 million ($1,160 million), annual revenue of $3,700 million ($1,025 million), net income of $198 million ($50 million), assets of $6,800 ($1,250), and market-to-book ratio of 3 (2). These values are similar to the population of companies on Execucomp over the sample period.

4.3. Unit of Analysis and Risk Set

The unit of analysis for estimating the revealed preferences model is the employee-grant-month. This frequency assumes that CEOs make their exercise decision monthly given their information set (as reflected, in part, by the covariates in the subjective value specification). When selecting the frequency (e.g., daily, monthly, and quarterly) there is a tradeoff between efficiency and feasibility. In particular, a more frequent unit of analysis preserves information in the covariates that is lost by aggregating to a more coarse frequency. However a more frequent unit of analysis is more computationally intensive to estimate. The monthly frequency preserves much of this information and is also computationally tractable.

Since the revealed preferences model is fundamentally a hazard model of option exercise, it is important to precisely define what constitutes the "risk set." Specifically, since stock options that are out-of-the-money (i.e., where the underlying stock price is less than the exercise price) will never be exercised, I estimate equations (14) and (15) using only executive-grant-months where the stock option grant is in-the-money. In addition, only vested options are included in the estimation because these are the only options that can be exercised. Although only vested, in-the-money options are used to estimate the model of subjective value, the coefficient estimates can be applied to both unvested and out-of-the-money options to extrapolate their subjective value because these options still have time (and incentive) value to an executive.

Another feature of the revealed preferences model that derives from its formulation as a hazard model is that it accounts for right censoring in the estimation. Since the data used to estimate the revealed preferences model consist of stock options (which typically have a 10-year life) and shares of stock (which have an indefinite life), the problem of right censoring is particularly acute because there are many executive-grants for which the ultimate outcome is never observed. In this case, the censoring is accounted for in the doubly-censored Tobit representation of the probability of the observed event for each executive-grant.

5. Estimates from the Revealed preference Model of Subjective Value

5.1. Hazard Model of Stock Sales and Option Exercise

Prior to estimating the revealed preferences models, it is instructive to estimate a separate hazard model for both the stock sales and option exercises in order to illustrate the role of the covariates in the models of subjective value.[39] Specifically, I estimate a Weibull model, which is a continuous, parametric hazard model where the hazard rate is as follows:

[39] An additional reason for estimating the hazard models is that they allow for the calculation of a pseudo-R^2 statistic (see Royston (2006)) to measure the explained variation in stock sales and option exercises.

$$h(t) = pt^{p-1}\exp\{\beta_0 + \beta_1 x_1 + ... + \beta_n x_n\} \quad (16)$$

where p is the shape parameter and t is time.[40] This model is multiplicatively separable into the baseline hazard (i.e., the hazard when all of the covariates have a value of zero), $pt^{p-1}\exp\{\beta_0\}$, and the relative hazard, $\exp\{\beta_1 x_1 + \ldots + \beta_n x_n\}$. The baseline hazard is solely a function of time and it is separated from the other covariates in the model, which shift the baseline hazard to account for their effect on the rate of option exercise or stock sale. Since hazard models require a dichotomous outcome variable, I consider an exercise of at least 10% of the options in the grant to be an exercise event and any sale of stock to be a sale event.

The estimates of these two models are presented in Table 3 and the signs of the coefficient estimates are generally consistent with both my predictions and prior research (e.g., Armstrong, Jagolinzer, and Larcker (2006) and Heath, Huddart, and Lang (1999)). The estimated coefficients have a direct relation with the overall hazard by shifting the relative hazard. For example, the coefficient of 0.479 on the 90% Prior High Indicator implies that the rate of exercise activity is about 61.5% higher when the underlying stock price is at or above 90% of its prior year's high holding the values of the other covariates constant. The coefficient of -0.137 on future returns in the stock sale model implies that a decline in future returns from 15% to 5% is associated with a 1.4% increase in the rate of stock sales.[41] These magnitudes demonstrate that the included covariates have an economically meaningful effect on the rate of option exercise and stock sales. In addition, the relatively high pseudo-R^2 statistics for both models indicates that overall, the covariates have a high degree of explanatory power for stock sales and option exercises and are therefore expected to be important determinants of the subjective value.[42]

5.2. Simple Model of the Subjective Value of Equity Holdings

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[40] In a Weibull model, the shape parameter describes whether the baseline hazard is monotonically increasing ($p > 1$), monotonically decreasing ($p < 1$), or constant ($p = 1$) over time. The special case of $p = 1$ corresponds to an exponential hazard rate.

[41] The effect of a covariate on the hazard rate, holding everything else constant, is calculated as the ratio of the two hazards. Since the other terms cancel in this ratio (because they are, by assumption, held constant) it is sufficient to compare the exponentiated coefficients. For example, the 61.5% increase in the rate of option exercise when the underlying stock price is at or above 90% of its prior year's high in the example from the text is calculated as exp(0.479*1) – exp(0.479*0) = .6144.

[42] It is important to emphasize that the hazard model explains the rate of option exercise, while the revealed preference model relates to the subjective value of the options and that there is an inverse relation between the two. Therefore, anything that results in an increase in the subjective value will, *ceteris paribus*, diminish the rate of option exercise. Therefore, I expect the coefficients to have opposite signs across the two sets of models.

The coefficient estimates for the simple revealed preferences models of stock and option values (i.e., Equation (14)) are presented in Table 4. These models specify that the executive's subjective value of his equity holdings is a simple multiple of either the Black-Scholes value or the intrinsic value using the one-year-ahead target price forecast. Each panel presents the estimated coefficients for both the fixed and the mixed models and the distributional assumptions for the mixed model.

The estimated coefficients for the fixed model in Panel A suggest that the executives in the sample, on average, value their option holdings at only 70.9% of their Black-Scholes value. The right half of the panel shows that if the coefficient on the Black-Scholes value is normally distributed across executives it has a mean of 0.789 and standard deviation of 0.191.[43] This suggests that executives place a substantially higher average value on their options relative to the fixed specification, but also that there is significant (z-stat = 18.92) variation in this coefficient across the sample. To illustrate the economic magnitude of this variation, suppose two executives each receive a grant of 100,000 at-the-money stock options with an exercise price of $50 on a non-dividend paying stock that have a 10-year life and where volatility of the underlying stock price is .30 and the prevailing risk-free rate is 5%. Further suppose the first executive values these options at one standard deviation above the mean while the other executive values these options at one standard deviation below the mean. Their respective subjective values would be roughly $2,576,000 and $1,572,000 while the options would have a risk-neutral value of $2,628,300. Thus, there is considerable heterogeneity in the subjective valuations that is captured by the mixed model.

If the target price of the underlying stock represents the executives' expectations and if this is the relevant benchmark in their exercise decisions, then Panel B of Table 4 shows that the sample of executives value their option holdings at an average of 61.4% of the target intrinsic value. Similarly, if this coefficient is normally distributed across the sample then the mean value is substantially higher and there is also significant variation in this coefficient.

Finally, Panel C of Table 4 suggests that executives value their stock holdings at 81.5% of their target price using the coefficient estimates from the fixed model. The average valuation is substantially higher (92.5%) in the mixed model, but still below the risk-neutral value. Overall, the results for the simple models suggest that executives, on average, value their stock and option

[43] The (unconditional) probability that an executive will value an option grant at more than the Black-Scholes value is 13.46% = $1 - \Phi((1 - 0.789)/0.191) = 1 - \Phi(0.211/0.191) = .1346$, where Φ is the cumulative distribution function for the standard normal distribution.

holdings below their risk-neutral (i.e., Black-Scholes) values and that there is (both economically and statistically) significant variation in this discount (or premium) across executives.[44]

5.3. Full Model of the Subjective Value of Equity Holdings

Table 5 presents the results for both the fixed and mixed versions of the more comprehensive model of subjective value. The Black-Scholes model of option value presented in Panel A suggests that the executives in the sample value their option holdings at an average of 93.6% of their Black-Scholes value.[45] This value is considerably different from the value obtained from the simple model in Panel A of Table 4, which suggests that the additional covariates are important for explaining the subjective value of option holdings. Most of the covariates have the predicted sign and are economically significant. For example, the estimated coefficient on the indicator that denotes whether the underlying stock price is at or above 90% of its prior year's high indicates that achieving this threshold is associated with roughly a 9% decline in the value of the option relative to its Black-Scholes value. The estimated coefficients on prior and future returns are nearly identical in magnitude and both have the predicted sign and are highly significant, which is a very consistent finding in the literature (e.g., Huddart and Lang (1996), Core and Guay (2001), and Jin and Kothari (2005)).

One notable result is that the estimated coefficient on prior volatility in the fixed model and its mean in the mixed model are both positive (and significant). This is contrary to both my predictions and the results of the hazard model of option exercise in Table 3 and this suggests that executives' subjective valuation of their options is, on average, increasing in volatility. However, the magnitude of the estimated standard deviation of the coefficient's distribution in the population in the mixed model indicates that there is substantial variability across the sample and that 42% (i.e., $\Phi(0.055/0.28)$) of the executives place a negative weight on stock price volatility in their subjective valuation. The estimated coefficient on CEO age is positive, which is also opposite of my prediction. However this is consistent with many prior studies (e.g., Jin and

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[44] The simple models in Table 4 estimate a fixed error term, which is equivalent to assuming homoskedasticity in the stochastic component of utility. I estimated three models that parallel those in Table 4 that allow for heteroskedasticity in the error term by assuming that sigma is lognormally distributed. The results suggest that there is (both economically and statistically) significant variation in the error term across executives, which is consistent with heteroskedasticity in the unobserved component of utility. A future version of this study will pursue this further in the context of both the simple and full revealed preferences models of subjective value.

[45] Since the covariates in the subjective value model enter as deviations from the sample mean, the proper interpretation of the coefficient estimate of 0.936 on the Black-Scholes value is that an executive with average values for every covariate in the model would value the options at 93.6% of their Black-Scholes value.

Kothari (2005)) that also find ambiguous results for the effect of age on executives' sale and exercise behavior.

The estimated means of the coefficients in the mixed specification generally have the same sign as their fixed counterparts, although the magnitudes differ across approaches. In particular, the estimated mean for every covariate in the mixed model is significantly different from its fixed counterpart at the 1% level except for the recent grant indicator and CEO Tenure (which are not statistically different at the 10% level). This observation coupled with the general economic and statistical significance of the estimated standard deviation parameters suggests that there is substantial heterogeneity across the sample of executives that is, in part, captured by the mixed model.

The results for the target price model of subjective option value are presented in Panel B of Table 5. At the sample average of the other covariates, the executives value their option holdings at slightly more (107.5%) than the target intrinsic value. The signs of the other coefficient estimates in the fixed model are generally as predicted but the magnitudes are somewhat larger than their counterparts in the Black-Scholes model (Panel A). One important difference between the two models, however, is that the estimated coefficient on prior volatility in the fixed model is negative and significant. The estimated coefficient on prior volatility in the mixed model is positive and of almost identical magnitude to the coefficient estimate from the Black-Scholes model. Also similar to the Black-Scholes model, there is considerable variation in the coefficients in the sample and the model suggests that many executives place a negative weight on prior volatility.

The target price model of subjective stock value is presented in Panel C of Table 5. The estimated coefficient on target price suggests that when evaluated at the sample mean, the executives value their stock holdings almost identical to the target price forecast. CEO age and prior volatility have signs opposite of my prediction, but only the former is statistically significant. Thus, similar to the two previous models of option value, the coefficients generally have the predicted sign and are both economically and statistically significant.

The top panel of Table 6 reports statistics for the distribution of equity portfolio values using a risk-neutral valuation model as well as certain subjective valuation models. The equity portfolio values for the simple model are consistent with the coefficient estimates from Table 4 (i.e., the subjective portfolio value is generally below the risk-neutral value). Unlike with the simple model, it is not possible to determine whether the subjective value of an executive's equity portfolio using the full model is above or below its risk-neutral value from inspection of the coefficients alone. This is because the overall portfolio value depends on the values of the covariates at which the subjective value is evaluated. The distribution of the subjective portfolio values for both the fixed and mixed full models, however, confirms that the subjective value is generally less than its risk-neutral value.

Figure 2 presents histograms of the ratio of the executives' risk-neutral portfolio values to the full fixed and mixed revealed preferences subjective portfolio values in Panels A and B, respectively. These portfolio values are calculated annually using the fiscal year end holdings information from Execucomp. The results confirm that the subjective values are generally below the risk-neutral values regardless of the specification.

5.4. Incentive Value of Equity Holdings

Using the coefficient estimates from the revealed preference models of subjective value, I calculate the revealed preference delta as described in Section 3.6. I focus on the dollar holdings measure of equity incentives (i.e., the dollar change in equity portfolio value for a 1% change in price) because this the most common measure in recent studies (e.g., Core and Guay (1999) and Coles, Daniel, and Naveen (2006)). The second panel of Table 6 presents distributional statistics for the risk-neutral and selected revealed preference measures of delta. The mean and median risk-neutral deltas are similar to values reported in recent studies that use the dollar holdings measure of equity incentives (e.g., Core and Guay (1999) and Coles, Daniel and Naveen (2006)). The revealed preference subjective portfolio deltas are also generally below the risk-neutral portfolio deltas, which is consistent with the relationship between the revealed preference and risk-neutral portfolio values established in the previous subsection.

Panels A and B of Figure 3 present plots of the fixed and mixed revealed preference deltas versus their risk-neutral counterparts. There is a very pronounced linear relationship between the two sets of values in both panels as illustrated by the superimposed regression line. As expected, the correlation between these two sets of values is extremely high, at .96 and .87 for the fixed and mixed revealed preference deltas, respectively. However, this correlation is induced almost entirely by cross-sectional variation in the executives' portfolio holdings (i.e., the number of stock options and shares of stock).[46]

The third panel of Table 6 presents three measures of vega equity incentives. The mean and median risk-neutral values of this measure lie between the fixed and mixed revealed preference

[46] Within an agency framework, the level of executive portfolio holdings are related to differences in the participation constraint across executives (i.e., the certainty equivalent amount required for the executive to work for the company). This, in turn, is associated with factors such as firm size, executive age, and executive wealth as well as unobservable (to the researcher) factors such as the executive's ability and degree of bargaining power when negotiating the compensation package.

measures and this ordering is fairly constant across the distribution. Similar to the delta incentive measures, the revealed preference vegas are highly correlated with their risk-neutral counterparts, but again this high correlation derives largely from cross-sectional variation in the level of equity holdings rather than an equivalence between risk-neutral and subjective valuations.

5.5. Relationship Between Subjective and Risk-Neutral Values

In order to better understand the relationship between the revealed preference delta and the risk-neutral delta, I separate the dollar holdings measures of incentives into a "wealth" component and a "sensitivity" component. This allows me to control for differences in scale that relate to the size of the executives' portfolio holdings. The dollar holdings measure is calculated as the dollar change in the portfolio value for a 1% change in the price of the underlying stock, which is the product of (1) the number of units of equity (i.e., the number of stock options and shares of stock), (2) 1% of stock price, and (3) the average sensitivity of the equity to price (i.e., the average per unit delta). The product of the first two terms is a measure of the level of equity wealth and is purely a function of the magnitude of the executive's holdings. The third term captures the average sensitivity of this wealth to changes in stock price. Labeling these two components the "equity wealth component" and the "sensitivity component," the dollar holdings measure (in its typical natural logarithmic form) can be written as follows:

$$\begin{aligned}
&\log(\text{Dollar Holdings Portfolio Delta}_{i,t}) \\
&\quad = \log(\text{Units of Equity}_{i,t} \text{ x } 1\%\text{Price}_{i,t} \text{ x } \text{Sensitivity}_{i,t}) \\
&\quad = \log(\text{Equity Wealth}_{i,t} \text{ x } \text{Sensitivity}_{i,t}) \\
&\quad = \log(\text{Equity Wealth}_{i,t}) + \log(\text{Sensitivity}_{i,t}) \qquad (17)
\end{aligned}$$

Thus, equation (17) illustrates that the dollar holdings equity portfolio delta is a composite variable composed of two separate terms that capture both the level of the executive's holdings and the average sensitivity of these holdings to changes in stock price. In Figure 3, the equity wealth component is so large relative to both the fixed (Panel A) and mixed (Panel B) revealed preference sensitivity components that it induces a very high correlation in the composite variable (i.e., the dollar holdings equity portfolio delta).

One important feature about the decomposition in equation (17) is that the equity wealth component is constant across the various dollar holdings equity incentives measures because this component relates solely to how many shares and options the executive has accumulated. The difference between the incentives measures relates entirely to the sensitivity component, which indicates how much an executive's subjective value of the equity holdings changes with price.

This observation enables me to fully control for the level of equity wealth and focus on differences in sensitivity across the measures.

The Pearson (Spearman) correlation between the risk-neutral sensitivity component and the fixed and mixed revealed preference sensitivity components is 0.172 and 0.063 (0.1964 and 0.079), respectively. Thus, controlling for the level of the CEOs holdings, the various measures do not exhibit a high degree of correlation.[47] This point is further illustrated in Figure 4 where the fixed (Panel A) and mixed (Panel B) revealed preference sensitivities are plotted against the risk-neutral sensitivity. The correlation among the alternative measures of vega is somewhat higher. Specifically, after controlling for the level of equity wealth, the correlation between the risk-neutral vega and the fixed and mixed revealed preference vegas is 0.785 and 0.666, respectively.

6. Preliminary Application Results

This section presents the results of three applications that use the components of equity incentives (i.e., equity wealth and delta and vega sensitivity) discussed in the previous section. The first application examines the relationship between equity incentives and executives' risk preferences and future research and development expenditures and stock price volatility. The second analyzes the relation between equity incentives and subsequent operating performance. The third examines the relation between equity incentives and future stock price performance.

Since these applications use future realizations of their respective outcome variables, I calculate the various revealed preference measures by dividing the time series sample into an estimation subsample and a holdout subsample. For each executive, I calculate the number of fiscal year ends for which I have holdings data. I then divide this number in half (rounding down) and place all of the executive-grant-months until, but not including, the first fiscal year end in the second half into the estimation subsample. The remaining executive-grant-months are placed in the holdout subsample.[48] This maximizes the number of executive-grant-month observations in the estimation subsample while still leaving a sufficient time series in the holdout

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[47] The Pearson (Spearman) correlation between the fixed revealed preference sensitivity and the mixed revealed preference sensitivity is 0.350 (0.399), which is suggests that there are still considerable differences between these two revealed preference measures as well.

[48] To illustrate, suppose an executive has 42 months of data from 4/99 until 9/02 and the executive's company has a December fiscal year end. There are three fiscal year ends for this executive (i.e., 12/99, 12/00, 12/01), so I include all of the executive-months that precede the second fiscal year end in the estimation subsample. The remaining executive-months are included in the holdout subsample. The estimation subsample, therefore, consists the first 20 months of data and the holdout subsample consists of the remaining 22 months of data.

sample with which to examine the future outcomes. The fixed and mixed versions of equation (15) are then estimated using only the estimation subsample.[49,50]

6.1. Equity Incentives and Operating Performance

I first examine the relationship between equity incentives and future operating performance. If incentives induce executives to undertake actions that increase shareholder value, the results of these actions should be reflected in future accounting performance, which I measure as return on assets (ROA). In order to test for this relation, however, it is necessary to specify the appropriate benchmark model for expected ROA. I adopt two complementary approaches for this benchmark. First, I estimate a linear regression of future ROA over a one-, three-, and five-year horizon on the revealed preference and risk-neutral delta sensitivity measures, equity wealth, and a number of controls suggested by Core, Holthausen, and Larcker (1999), including the current year's ROA, revenue, sales growth, and industry and year controls.[51] This specification is as follows:

$$\begin{aligned} ROA_{i,t+n} = \; & \psi_0 + \psi_1 \log(\text{RP Delta Sensitivity}_{i,t}) + \psi_2 \log(\text{RN Delta Sensitivity}_{i,t}) \\ & + \psi_3 \log(\text{Equity Wealth}_{i,t}) + \psi_4 ROA_{i,t} + \psi_5 \text{Revenue}_{i,t} + \psi_6 \text{Sales growth}_{i,t} + \varepsilon_{i,t} \qquad (18) \end{aligned}$$

Second, because the control variables in equation (19) might not generate the appropriate benchmark, I use a matched-pair research design to control for omitted or unknown determinants of future ROA (e.g., Baber and Lyons (1997) and Holthausen and Larcker (1996)). Specifically, I attempt to match each executive-year observation with one from another firm by first finding all of the same executive-year observations from the same industry during the same year. From this group, I then identify all observations with current year's ROA between 80% and 120% and market capitalization between 50% and 200% of the original firm. If multiple matches are available, I select the observation with the closest current year's ROA. The unit of analysis is the matched pair and the following equation is estimated:

$$\Delta ROA_{i,t+n} = \psi_0 + \psi_1 \Delta\log(\text{RP Delta Sensitivity}_{i,t}) + \psi_2 \Delta\log(\text{RN Delta Sensitivity}_{i,t})$$

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49 When estimating the revealed preferences model with the estimation subsample, I exclude future returns and the termination indicator because both use forward-looking information (i.e., returns over the next year and whether the CEO departs during the next six months).

50 In order to assess the inter-temporal stability of the subjective valuation model, I also estimate equation (15) using the holdout subsample. Although the two sets of coefficients differ somewhat in magnitude and statistical significance, the signs for the comparative coefficients are virtually identical. This suggests that the executives' subjective valuation model is fairly stable over time and the results for the full sample presented in Table 5 are not confounded by over-fitting.

51 The variables used in Section 6 are defined in the description to the respective Table in which the results are presented.

$$+ \psi_3 \Delta \log(\text{RN Delta Sensitivity}_{i,t}) + \psi_4 \Delta \log(\text{Equity Wealth}_{i,t}) + \varepsilon_{i,t} \qquad (19)$$

where Δ refers to the difference between the variable for the executive-year observation and the value for its matched pair.

The results of the first design are presented in Table 8 (Panel A) and they indicate that the equity wealth component of incentives has a positive and significant association with next year's ROA, but no significant association over a longer horizon. In contrast, risk-neutral delta sensitivity does not exhibit a significant association with one-year-ahead ROA, but does display a significant positive association over a three- and five-year horizon. However, the revealed preference sensitivities are not statistically associated with future ROA over any horizon (and, in fact, the mixed revealed preference delta sensitivity has a negative, and marginally significant, association with next year's ROA). One critical assumption for equation (18) is that the control variables (including current ROA) provide the correct benchmark for future ROA in the absence of any equity incentive effects. This is a potentially problematic assumption because current ROA should be a function of past and current equity incentives.

The results of the matched-pair design (i.e., Equation (19)) are presented Table 8 (Panel B). These results reveal that only the difference in risk-neutral delta sensitivity is associated with differences in future ROA. Similar to the results in Panel A, the effect of the risk-neutral delta sensitivity is observed at a three- and five-year horizon. Together, this finding, along with those of Panel A, suggests that there is a modest, positive association between ROA and risk-neutral delta sensitivity at three- and five-year horizons, no association with the revealed preference delta sensitivities, and no association with equity wealth.

6.2. Equity Incentives, Executive Risk Preferences and Financial and Operating Risk

One desirable feature of stock options is that the (risk-neutral) payoff is convex, which may induce risk-averse executives to undertake risky, positive net present value projects. Coles, Daniel, and Naveen (2006) test this hypothesis by conducting a systematic analysis of the relationship between equity incentives for risk-taking (measured using the portfolio vega from a risk-neutral valuation model) and firm risk. They find that portfolio vega is associated with a number of measures of future operating and financial risk, such as future research and development expense and future stock price volatility. Implicit in their research design (i.e., through their use of a risk-neutral valuation framework) is the assumption that executives' subjective value of their option portfolio is increasing in the volatility of returns on the underlying stock. However, as shown by Lambert, Larcker, and Verrecchia (1991) and confirmed by the results presented in Table 5 of this study, many executives' subjective valuation of their equity holdings is actually decreasing in the volatility of returns on the underlying stock.

One way to quantify an executive's taste for risk is from the executive-specific coefficient estimates on prior volatility (i.e., the mean of each executive's conditional posterior distribution, $g(\beta|x,y,\theta)$) from the mixed revealed preference model of subjective value). This coefficient relates to executives' risk preferences by capturing how volatility of the underlying stock returns affects their subjective valuation of their equity holdings. Therefore, in addition to examining the relation between (disaggregated) equity portfolio vega and risk-taking, I also use the executive-specific coefficient on stock price volatility as a more direct measure of an executive's preferences for risk. This quantity is distinct from the dollar holdings equity portfolio vega, which is dominated by how much equity the executive holds (i.e., the equity wealth component). Another advantage of using executives' preferences rather than vega is that it applies equally to the executives' stock and option holdings. In contrast, current research (e.g., Guay (1999) and Coles, Daniel, and Naveen (2006)) typically ignores executives' stockholdings when calculating their equity portfolio vega because it not clear how the value of stock changes with volatility in a risk-neutral framework.

To test for a relationship between equity incentives and risk-taking, I estimate a regression of either future stock price volatility or future research and development expense on either vega sensitivity or the executive-specific coefficient on volatility from the mixed revealed preferences model. Unlike the sensitivity components of portfolio delta presented in Figure 4, the sensitivity components of portfolio vega are highly correlated so I report only the results using the risk-neutral vega sensitivity to facilitate the comparison of my results with those of prior research.[52] Following Coles, Daniel, and Naveen (2006), I include the equity portfolio delta (in its disaggregated form) because this is could also induce risk-taking. Finally, I include a number of control variables suggested by Coles, Daniel, and Naveen (2006), including the CEO's tenure and cash compensation during the year, the firm's (logarithmically transformed) revenue, book-to-market ratio, cash balance, growth in sales over the prior year, and book leverage.[53] The model of future firm risk is thus

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[52] Pearson (Spearman) correlation of 0.786 (0.769) between the fixed revealed preference vega sensitivity and the risk-neutral vega sensitivity and 0.756 (0.723) between the mixed revealed preferences vega sensitivity and the risk-neutral vega sensitivity, respectively.

[53] Note that Coles, Daniel, and Naveen (2006) include the risk-neutral portfolio delta as a control variable in most of their specifications. Given the previous discussion about the advantages of disaggregating the wealth and sensitivity components of incentives measures, it seems redundant to include a measure of delta

$$\text{Firm Risk}_{i,t+n} = \varphi_0 + \varphi_1\log(\text{RN Vega Sensitivity}_{i,t}) + \varphi_2\text{Prior volatility coef}_i + \varphi_3\log(\text{RP Delta Sensitivity}_{i,t}) + \varphi_4\log(\text{RN Delta Sensitivity}_{i,t}) + \varphi_5\log(\text{Equity Wealth}_{i,t}) + \varphi_6\text{Tenure}_{i,t} + \varphi_7\text{Cash compensation}_{i,t} + \varphi_8\log(\text{Revenue}_{i,t}) + \varphi_9\text{Book-to-market}_{i,t} + \varphi_{10}\text{Surplus cash}_{i,t} + \varphi_{11}\text{Sales growth}_{i,t} + \varphi_{12}\text{Stock return}_{i,t} + \varphi_{13}\text{Book leverage}_{i,t} + \varepsilon_{i,t} \quad (20)$$

where firm risk is measured as either future R&D expense or future stock price volatility. The estimates of equation (20) where firm risk is captured using future R&D expense and future stock price volatility are presented in Panels A and B of Table 9, respectively. The results in Panel A indicate that there is a statistically positive relationship between the equity portfolio vega sensitivity and future R&D expense over a one-, three-, and five-year horizon. This is the expected result because the (risk-neutral) expected value of the equity portfolio is increasing in volatility.[54] In contrast, the equity wealth component of the portfolio vega is negative (and generally significant) over all three horizons. This result suggests that executives become risk averse when they hold a large, undiversified portfolio of wealth. Thus, these two different components of equity incentives have an opposite relationship with risk-taking which is masked by focusing on simply the composite variable (i.e., equity portfolio vega). The coefficient on the executives' risk preferences has the expected positive coefficient over all horizons, but is only significant for the one-year-ahead outcome.

The revealed preference delta sensitivity is positive and significant over all horizons in both specifications. In contrast, the risk-neutral delta sensitivity is negative and generally insignificant over the three horizons. The former result is consistent with executives preferring to invest in positive net present value R&D activities holding the associated affect of risk on their subjective portfolio valuations constant. Together this suggests that executives' revealed preference sensitivity of their equity portfolio to price changes is an important component of incentives for risk-taking. In addition, the signs and significance of the control variables in equation (20) are generally consistent with the findings in previous research.

When future stock price volatility is used to measure firm risk (Table 9, Panel B), the risk-neutral vega sensitivity component of incentives has an unexpected negative and statistically significant association over a one- and three-year horizon (and no association over the five-year horizon). This conflicts with the findings of Coles, Daniel, and Naveen (2006) who find a significantly positive association using equity portfolio vega to measure risk-taking incentives. In

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in the regression once the equity wealth component is explicitly controlled for as is the case for the model specified in Table 9.

[54] The fixed and mixed revealed preference vega sensitivities also have a positive and significant association with R&D expense over all three horizons as predicted. These results are untabulated because the findings are generally insensitive to the choice of vega sensitivity.

contrast, the executive-specific risk preferences coefficient is positive and significant over all three horizons. This result suggests that executives' risk preferences capture a different element of overall risk-taking incentives than the vega sensitivity. Together, these findings highlight the importance of accounting for differing degrees of risk-aversion across executives when examining their incentives for risk-taking.

6.3. Equity Incentives and Future Stock Price Performance

The relation between equity incentives and future stock price performance is an important but unresolved question in the executive compensation literature. From an agency perspective, equity-based compensation serves as an instrument for incentive alignment between boards of directors (acting on behalf of the shareholders) and management. A number of authors have attempted to address this question (e.g., Morck, Shleifer, and Vishny (1988), McConnell and Servaes (1990), and Himmelberg, Hubbard, and Palia (2001)), but various methodological issues make it difficult to draw inferences from these studies. In particular, Demsetz and Lehn (1985) argue that if boards make grants to optimize managerial incentives (to increase stock price), then no relation should be discernable if the researcher has properly controlled for the exogenous determinants of equity incentives. This view implies that a statistical relationship between performance and equity incentives is necessarily the result of model misspecification rather than an underlying structural relation.

One unique feature of the equity incentives decomposition developed in the previous section is that it permits an alternative approach to addressing the relation between incentives and performance. If Demsetz and Lehn (1985) are correct and equity held by executives is optimal, on average, then there should be no relationship between equity incentives and subsequent firm performance. However, as illustrated by Figure 4, the revealed preference measures of sensitivity are not highly correlated with their risk-neutral counterparts so boards cannot simultaneously optimize both incentive measures with one single choice of equity holdings. Since boards generally rely on compensation consultant benchmarks developed using a risk-neutral valuation approach (e.g., Black-Scholes) it is conceivable that boards optimize the risk-neutral level (i.e., equity wealth) and sensitivity of equity incentives. However, the actual executive incentives induced by this choice are more appropriately measured using the executives' subjective valuation of their holdings. Under this view, a relationship between equity incentives (measured from the perspective of the executive) and firm performance is the result of a "mistake" by boards of directors. I examine this conjecture using the following specification:

$$\text{Stock return}_{i,t+n} = \gamma_0 + \gamma_1 \log(\text{RP Delta Sensitivity}_{i,t}) + \gamma_2 \log(\text{RN Delta Sensitivity}_{i,t})$$

$$+ \gamma_3 \log(\text{Equity Wealth}_{i,t}) + \gamma_4 \text{ Std dev of stock return}_{i,t} + \gamma_5 \log(\text{Market value equity}_{i,t})$$
$$+ \gamma_6 \text{Book-to-market}_{i,t} + \gamma_7 \text{Book leverage}_{i,t} + \varepsilon_{i,t} \quad (21)$$

where i and t index the executive and time (in years), respectively, RP Sensitivity is either the fixed or mixed revealed preference equity portfolio delta sensitivity, RN Sensitivity is the risk-neutral equity portfolio delta sensitivity, and stock returns are measured beginning in the month following the fiscal year end of the annual observation and ending either 12, 36, or 60 months later. In addition, I include a number of controls including the standard deviation of daily stock returns over the prior 250 trading days, the natural logarithm of the firm's market capitalization at the fiscal year end, the firm's book to market ratio and book leverage (both computed at the fiscal year end), and year and industry controls.

The estimates of equation (21) are presented in Table 10. Focusing on the one-year horizon, both the fixed and mixed revealed preference delta sensitivities exhibit a statistically positive association with future stock price returns. However, neither the risk-neutral delta sensitivity nor the equity wealth component is significant in either specification. The control variables also have the expected signs and are generally significant. The fixed revealed preference delta sensitivity is also positive and significant at both a three- and five-year horizon, while the risk-neutral delta sensitivity remains insignificant at these horizons. The mixed revealed preference delta sensitivity is positive and marginally significant at the three-year horizon and remains positive but insignificant at the five-year horizon. The results for the revealed preference delta sensitivity are consistent with the idea that boards do not incorporate the actual incentives induced by the executives' subjective valuation of their equity holdings in their compensation decisions.

In order to test the robustness of the specification in equation (21), I also estimated a regression of future returns on the two delta sensitivity measures (i.e., revealed preference and risk-neutral) and the three Fama and French (1993) factors over a one-, three-, and five-year horizon. The tenor of the results is unchanged under this alternative specification – both the fixed and mixed delta sensitivities are positive and significant at both one- and three-year horizons (and the five-year horizon for the fixed revealed preference delta sensitivity) and neither the risk-neutral delta sensitivity nor the equity wealth component has a statistically signification relationship with future returns over any horizon. Although this research design does not address the potentially endogenous nature of executive incentives or why boards may not incorporate executives' subjective valuation into their compensation decisions, these preliminary results provide new insight into the appropriate measure of executive incentives and the impact of equity incentives on shareholder value.

7. Conclusion

This study estimates the subjective value of stock and option holdings for a sample of CEOs using a revealed preferences approach within a random utility framework. This method uses the information conveyed by CEOs' stock sales and option exercises to infer their subjective valuation of their equity holdings. The results indicate that executives' subjective value of their equity holdings is associated with executive-, firm-, and grant-specific factors and that there is significant heterogeneity across executives regarding how these factors affect their valuation. The results also provide some of the first empirical evidence that most executives subjectively value their equity holdings below the risk-neutral expected value which is consistent with risk-aversion and lack of diversification affecting their valuations. This suggests that it is necessary to measure executives' equity incentives from their personal perspective.

This study also provides preliminary evidence regarding the relationship between equity incentives and future operating performance, investment and financial risk, and stock price performance. Specifically, I examine the association between these future factors and the change in CEOs' subjective valuation of their equity holdings to changes in stock price (subjective delta) and volatility (subjective vega). The results indicate that future stock returns are positively associated with subjective delta sensitivities. However, there is no statistical association between future stock returns and either the risk-neutral delta sensitivity or the equity wealth measure. The decomposition of CEOs' portfolio holdings into sensitivity and wealth components provides insight about the association between equity incentives and future stock price performance that are not otherwise available from alternative measures.

Regarding the sensitivity of CEOs' equity portfolio values to stock price volatility, the results show that a positive association exists between both risk-neutral and subjective vega sensitivities and future R&D expenditures over one-, three-, and five-year horizons. However, equity wealth exhibits a negative association with future R&D. These results might explain why the traditional measures used in prior research on equity incentives (i.e., sensitivity multiplied by equity wealth) find very mixed results. When future stock price volatility is used as the measure of firm risk, the results indicate a negative association between the risk-neutral and subjective vega sensitivities and future volatility over one- and three-year horizons. These results are inconsistent with previous studies that find a positive association. There is also evidence of a strong positive association between an executive-specific measure of risk preferences and one-, three-, and five-year-ahead stock price volatility. This provides further support for potential benefits from estimating executives' subjective valuation of their equity holdings.

Finally, confirming the findings of some prior research, this study documents a significantly positive relationship between risk-neutral delta sensitivity and future ROA over a three- to five-year horizon. In contrast, results do not show that a significant association exists between subjective delta sensitivity and future ROA. Similarly, results do not show that a significant association exists between the equity wealth component of equity incentives and future ROA.

Overall, the results illustrate that equity incentives is a complex and multifaceted construct that cannot be easily captured by a single variable such as the Black-Scholes equity portfolio delta or vega. The preliminary results provide support for importance of accounting for differences in contracting environments and differences in executives' preferences when estimating measures of the equity incentives construct.

It is important to note the limitations with the methods and inferences discussed herein. First, the random utility model of subjective equity value is derived from a reduced form representation of utility maximization rather than from a power or negative exponential utility function. Second, for tractability, the models of subjective value are estimated assuming linear specifications and specific distributional assumptions.[55] Finally, results regarding the association between equity incentives and future performance (in Section 6) do not account for potential endogeneity in the relationship.

This paper focuses exclusively on CEOs but the methodology is equally applicable to other employees within the organization. Future research will evaluate whether lower-level employees attribute different subjective values and incentives to their equity holdings. Future research will also examine the currently mixed evidence of an association between equity incentives and accounting manipulation (e.g., Johnson, Ryan, and Tian (2006) and Erickson, Hanlon, and Maydew (2006)). Specifically, I plan to examine whether subjective incentive measures are associated with estimates for earnings management and the incidence of accounting restatements.

[55] Future research will examine the degree to which results are sensitive to these specific assumptions.

References

Aggarwal R. and A. Samwick, 1999. "The other side of the tradeoff: the impact of risk on executive compensation," Journal of Political Economy 107, 65-105.

Armstrong, C., A. Jagolinzer, and D. Larcker, 2006. "Timing of employee stock option exercise and stock option expense valuation." Stanford University Working Paper.

Baker G. and B. Hall, 2004. "CEO incentives and firm size," Journal of Labor Economics 22, 767-798.

Barber, B. M. and J. D. Lyon, 1997. "Detecting long-run abnormal stock returns: the empirical power and specification of test statistics," Journal of Financial Economics 43, 341-371.

Bettis, J., J. Bizjak, and M. Lemmon, 2005. "Exercise behavior, valuation, and the incentive effects of employee stock options." Journal of Financial Economics 76, 445-470.

Black, F. and M. Scholes, 1973. "The pricing of options and corporate liabilities" Journal of Political Economy 81, 637-654.

Bradshaw, M. T. and L. D. Brown, 2005. "Do sell-side analysts exhibit differential target price forecasting ability?," Harvard University Working Paper.

Brav, A. and R. Lehavy, 2003. "An empirical analysis of analysts' target prices: short-term Informativeness and long-term dynamics," Journal of Finance 58, 1933-1967.

Brownstone, D. and K. Train, 1999. "Forecasting new product penetration with flexible substitution patterns," Journal of Econometrics 89, 109-129.

Carpenter, J., 1998. "The exercise and valuation of executive stock options," Journal of Financial Economics 48, 127-158.

Cheng, Q. and T. Warfield, 2005. "Equity incentives and earnings management," Accounting Review 80, 441-476.

Coles, J., N. Daniel, and L. Naveen, 2006. "Managerial incentives and risk-taking," Journal of Financial Economics 79, 431-468.

Core, J. E. and W. Guay, 1999. "The use of equity grants to manage optimal equity incentive levels," Journal of Accounting and Economics 28, 151-184.

Core, J. E. and W. Guay, 2001. "Stock option plans for non-executive employees," Journal of Financial 61, 253-287.

Core, J. E. and W. Guay. 2002. "Estimating the value of employee stock option portfolios and their sensitivities to price and volatility," Journal of Accounting Research 40, 613-630.

Core, J. E. and W. Guay. 2003. "When efficient contracts require risk-averse executives to hold equity: implications for option valuation, for relative performance, and for the corporate governance debate," University of Pennsylvania Working Paper.

Core, J. E., W. Guay, and D. Larcker, 2003. "Executive equity compensation and incentives: a survey," FRBNY Economic Policy Review (April), 27-50.

Core, J. E., W. Guay, and R. Verrecchia, 2003. "Price versus non-price performance measures in optimal CEO compensation contracts," Accounting Review 78, 957-981.

Core, J. E., R. W. Holthausen, and D. Larcker, 1999. "Corporate governance, chief executive officer compensation, and firm performance," Journal of Financial Economics 51, 371-406.

Dechow, P., and R. Sloan, 1991. "Executive incentives and the horizon problem," Journal of Accounting and Economics 14, 51-89.

Demsetz, H. and K. Lehn, 1985. "The structure of corporate ownership: causes and consequences,“ Journal of Political Economy 93, 1155-1177.

Erickson, M., M. Hanlon, and E. Maydew, 2006. "Is there a link between executive equity incentives and accounting fraud?," Journal of Accounting Research 44, 113-143.

Fama, E. F. and K. R. French, 1993. "Common risk factors in the returns on stocks and bonds," Journal of Financial Economics 33, 3-56.

Farrell, A. M., S. D. Krische, and K. L. Sedatole, „Employees' perceived value of their stock option holdings: how training affects the cost-value gap," University of Illinois Working Paper.

Frederic W. Cook & Co., Inc., 2006, http://www.fwcook.com/alert_letters/Top_250_06.pdf

Guay, W., 1999. "The sensitivity of CEO wealth to equity risk: an analysis of the magnitude and determinants," Journal of Financial Economics 53, 43-71.

Hall, B. and J. Liebman, 1998. "Are CEOs really paid like bureaucrats?," Quarterly Journal of Economics 113, 653-691.

Hall, B. and K. Murphy. 2002. "Stock options for undiversified executives," Journal of Accounting and Economics 33, 3-42.

Hallock, K. and C. Olson. 2006. "The Value of Stock Options to Non-Executive Employees," NBER Working Paper.

Heath, C., S. Huddart, and M. Lang, 1999. "Psychological factors and stock option exercises," Quarterly Journal of Economics 114, 601-628.

Himmelberg, C., G. Hubbard, and D. Palia, 1999. "Understanding the determinants of managerial ownership and the link between ownership and performance" Journal of Financial Economics 53, 353-384.

Hodder, J. E. and J. C. Jackwerth, 2005. "Employee stock options: much more valuable than you thought," University of Wisconsin Working Paper.

Hodge, F., S. Rajgopal, and T. Shevlin, 2005. "How do managers value stock and restricted stock?," University of Washington Working Paper.

Holthausen, R. W. and D. Larcker, 1996. "The financial performance of reverse leverage buyouts," Journal of Financial Economics 42, 293-332.

Huber, P. J., 1967. "The behavior of maximum likelihood estimates under non-standard conditions," Proceedings of the Fifth Berkeley Symposium on Mathematical Statistics and Probability 1, 221-233.

Huddart, S. and M. Lang, 1996. "Employee stock option exercises: an empirical analysis," Journal of Accounting and Economics 21, 5-43.

Jensen, M. and K. Murphy, 1990. "Performance pay and top management incentives," Journal of Political Economy 98, 225-264.

Jin, L., 2002. "CEO compensation, diversification, and incentives" Journal of Financial Economics 66, 29-63.

Jin, L. and S. P. Kothari, 2005. "Effect of personal taxes on managers' decision to sell unrestricted equity," Harvard University Working Paper.

Johnson, S., H. Ryan, and Y. Tian, 2006, "Managerial incentives and corporate fraud: the source of incentives matters," Texas A&M University Working Paper.

Judd, K. L., 1998. *Numerical Methods in Economics*. MIT Press, Cambridge MA.

Lambert, R. A., D. F. Larcker, and R. E. Verrecchia, 1991. "Portfolio considerations in valuing executive compensation," Journal of Accounting Research 29, 129-149.

Larkcer, D., and R. Lambert, "How employees value (often incorrectly) their stock options," *Knowledge@Wharton*, http://knowledge.wharton.upenn.edu.

McConnell, J. and H. Servaes, 1990. "Additional evidence on equity ownership and corporate value," Journal of Financial Economics 27, 595-612.

McFadden, D., 1999, "Computing willingness-to-pay in random utility models," in J. Moore, R. Riezman, and J. Melvin, eds., Trade Theory and Econometrics: Essays in Honor or John S. Chipman, Routledge, London, pp. 253-274.

McFadden, D. and K. Train, 2000, "Mixed MNL models of discrete response," Journal of Applied Econometrics 15, 447-470.

Morck, R., A. Shleifer, and R. Vishny, 1988. "Management ownership and market valuation: an empirical analysis," Journal of Financial Economics 20, 293-315.

Ofek E. and D. Yermack, 2000. "Taking stock: equity based compensation and the evolution of ownership," Journal of Finance 55, 1367-1384.

Ragjopal, S. and T. Shevlin, 2002. "Empirical evidence on the relation between stock option compensation and risk taking," Journal of Accounting and Economics 33, 145-171.

Royston, P. 2006. "Explained variation for survival models," The Stata Journal 6, 83-96.

Train. K., 2003. *Discrete Choice Methods with Simulation*, Cambridge University Press, New York.

Train. K., and D. Revelt, 1998. "Mixed logit with repeated choices: households' choices of appliance efficiency level," Review of Economics and Statistics, 647-657.

White, H., 1980. "A heteroskedasticity consistent covariance matrix estimator and a direct test for heteroskedasticity," Econometrica 48, 817-830.

Yermack, D., 1995. "Do corporations award CEO stock options efficiently?", Journal of Financial Economics 39, 237-269.

Table 1
Selected Studies from the Equity Incentives Literature

Study	Measurement of Equity Incentives Construct	Unit of Analysis	Sample	Phenomenon Examined	Main Findings
Core and Guay (1999)	Change in Black-Scholes value of equity portfolio of stock and options for a 1% change in stock price.	CEO	6,214 CEO-year observations from Execucomp between 1992 and 1997	Optimal level of equity incentives	Evidence that firms use annual grants of options and restricted stock to correct deviations from the optimal level of incentives.
Aggarwal and Samwick (1999)	Change in Black-Scholes value of equity portfolio of stock (and options in some analyses) for a 1% and a $1,000 change in stock price.	Top five named executives and CEO separately	CEOs in Execucomp database between 1993 and 1996	Relation between risk and incentives	Evidence that CEO pay-performance sensitivity (PPS) is decreasing in the volatility of firm returns and the PPS at firms with the lowest volatility is an order of magnitude lower than at firms with the highest PPS.
Coles, Daniel, and Naveen (2006)	Change in Black-Scholes value of equity portfolio of stock and options for a 1% change in stock price.	Top five named executives and CEO separately	CEOs in Execucomp database between 1998 and 2002	Relation between incentives and risk-taking	Evidence of a positive relation between the sensitivity of CEO wealth to volatility (vega) and riskier firm policies (more R&D, lower PP&E, more focus, and higher leverage) after controlling for CEO pay-performance sensitivity (delta).
Rajgopal and Shevlin (2002)	Change in Black-Scholes value of equity portfolio of stock and options for a 1% change in volatility of stock returns.	CEO	121 CEO-year observations at oil and gas companies between 1992 and 1997	Relation between executive stock options and risk-taking	Evidence of a positive relation between ESO risk incentives and future exploration risk taking. Also evidence of a negative relation between ESO risk incentives and firm-level hedging activities.
Jin (2002)	Change in Black-Scholes value of current period's options for a $1,000 change in stock price.	CEO	CEOs in Execucomp database between 1992 and 1998	Relation between idiosyncratic and systematic risk and incentives	Evidence that nonsystematic, but not systematic, risk is negatively associated with CEO pay-performance sensitivity.
Himmelberd, Hubbard, and Palia (1999)	Total common equity holdings of top management. as a fraction of total common equity outstanding.	Top five named executives	600 randomly sampled Compustat firms between 1982 and 1992	Relation between changes in managerial ownership and firm performance	After controlling for firm characteristics and unobserved firm fixed effects, there is little evidence of a relation between changes in managerial ownership and firm performance.
Bettis, Bizjak, and Lemmon (2005)	Change in Black-Scholes value and change in certainty equivalent of current period's stock options for a 1% change in stock price and a .01 increase in volatility	Section 16 and Rule 16a-3(g) Insiders	141,120 stock option exercises by insiders at 3,966 firms between 1996 and 2002	Effects of exercise behavior on value of stock options	Evidence that estimates of option values and incentives computed from utility-based model calibrations are similar to estimates from models used to value tradable options (i.e., Black-Scholes).
Yermack (1995)	Change in Black-Scholes value of current period's options for a $1,000 change in stock price and compensation mix.	CEO	5,995 CEO-year observations from Forbes 500 list between 1984 and 1991	Agency costs	Little evidence that the incentives provided by the current period's stock option grants are not associated with variables that proxy for agency costs.
Cheng and Warfield (2005)	Option grants in the current period, unexercisable options, exercisable options, restricted stock grants, and stock holdings, all deflated by shares outstanding.	CEO	CEOs in Execucomp database between 1993 and 2000	Earnings management	Evidence that managers with higher incentives are more likely to report earnings that meet or just beat analysts' earnings forecasts and are more likely to sell more shares in the subsequent period.

Table 2
Descriptive Statistics for the Covariates Included in the Revealed Preferences Models of Subjective Value

Covariate	*Mean*	*Median*	*Standard Deviation*	*Number of Observations*
Intrinsic Value	10.62	6.92	14.43	638,457
Black-Scholes Value	20.85	17.78	16.77	638,457
Target Intrinsic Value	21.98	16.21	21.16	239,574
Stock Price	31.24	27.38	21.80	34,780
Company-specific covariates				
Prior Return	0.096	0.094	0.39	673,237
Future Return	0.123	0.122	0.36	673,237
Prior Volatility	0.442	0.403	0.11	673,237
90% Prior High Indicator	0.48	0.00	0.50	673,237
Executive-specific covariates				
Pre-CEO Indicator	0.20	0.00	0.40	673,237
CEO Tenure (in years)	3.86	3.00	6.98	673,237
Termination Indicator	0.03	0.00	0.16	673,237
Recent Grant Indicator	0.05	0.00	0.21	673,237
Salary (in $ thousands)	1225.83	813.93	1719.75	673,237
Age (in years)	53.10	53.00	7.70	673,237
Stock Portfolio Value (in $ millions)	31.00	3.47	227.00	673,237
Unvested Intrinsic Value (in $ millions)	5.51	0.86	15.70	673,237
Vested Intrinsic Value (in $ millions)	1.74	0.08	6.93	673,237
Cumulative Proceeds Realized (in $ millions)	50.88	2.97	325.77	673,237
Grant-specific covariates				
Time until Expiry (in months)	78.62	74.00	672.23	638,457
Fractional Expiry Rank	0.46	0.49	0.30	638,457
Price-to-Strike Ratio	9.58	1.97	189.80	638,457
Other covariates				
Short-term (6 month) Risk-free Interest Rate	0.04	0.05	0.02	673,237
Long-term (10 year) Risk-free Interest Rate	0.05	0.05	0.01	673,237
2nd Quarter Indicator	0.24	0.00	0.43	673,237
3rd Quarter Indicator	0.25	0.00	0.43	673,237
4th Quarter Indicator	0.25	0.00	0.43	673,237

This table presents descriptive statistics for the sample of 638,457 executive-grant-month stock option observations and 34,780 executive-month stock observations used to estimate the revealed preferences models of subjective value. These descriptive statistics are calculated treating the executives' stock portfolio as a special case of a stock option grant so the total number of observations is 673,237 for all covariates except the *Black-Scholes Value*, *Target Intrinsic Value*, and the *Grant-specific Covariates*. *Intrinsic Value* is equally-weighted intrinsic value (in dollars) of the options in the sample calculated as the maximum of zero and the current stock price less the exercise price. *Black-Scholes Value* is the equally-weighted Black-Scholes value (in dollars) of the options in the sample. *Target Intrinsic Value* is the equally-weighted intrinsic value (in dollars) of the options with target price information available from the First Call database. This value is calculated as the future value (using the risk-free interest rate at the appropriate horizon) of the median one-year ahead price forecast at a horizon equal to half of the remaining life of the options in the grant. *Stock Price* is the median closing price of the stock (in dollars) during the month of the observation. *Prior Return* is the cumulative raw return (excluding dividends) during the prior 250 trading days. *Future Return* is the cumulative raw return (excluding dividends) during the subsequent 250 trading days. *Prior Volatility* is the volatility of the underlying price during the prior 250 trading days. *90% Prior High Indicator* is an indicator equal to one if the highest stock price during the month was at or above 90% of the highest stock price during the previous 250 trading days and zero otherwise. *Pre-CEO Indicator* is an indicator equal to one if the executive is does not hold the title of Chief Executive Officer on the last day of the month and zero otherwise. *CEO Tenure* is the number of years the executive has held the title of Chief Executive Officer as of the last day of the month. *Termination Indicator* is an indicator equal to one if the executive does not hold the title of Chief Executive Officer on the last day of the sixth month following the month of the current observation and zero otherwise. *Recent Grant Indicator* is an indicator equal to one if the executive received either a restricted stock or a stock option grant during either the month of the observation or the two preceding months and zero otherwise. *Salary* is the executive's salary and bonus (in thousands of dollars) at the beginning of the fiscal year of the month of the observation. *Age* is the age of the executive (in years) at the end of the month of the observation. *Stock Portfolio Value* is the market value (in millions of dollars) of the executive's stock and restricted stock holdings calculated using the median closing stock price during the month of the observation. *Unvested Intrinsic Value (IV)* is the intrinsic value (in millions of dollars) of the executive's unvested stock options calculated using the median closing stock price during the month of the observation. *Vested Intrinsic Value (IV)* is the intrinsic value (in millions of dollars) of the executive's vested stock options calculated using the median closing stock price during the month of the observation. *Cumulative Proceeds Realized* is the cumulative amount realized (in millions of dollars) by the executive from stock sales and option exercises through the month prior to the month of the observation. *Time Until Expiry* is the remaining life of the option (in months) as of the end of the month of the observation. *Fractional Expiry Rank* is the reciprocal of the rank of the option grant using all of the executive's option grants outstanding during the month ranked in ascending order according to expiration date. The first grant to expire has a value of 1/1, the second grant to expire has a value of ½, etc… *Price-to-Strike Ratio* is the ratio of the price of the underlying stock to the strike price during the month using the median closing stock price during the month of the observation. *Short-term (6 month) Risk-free Interest Rate* and *Long-term (10 year) Risk-free Interest Rate* are the prevailing 6 month and 10 year Treasury Bill and Treasury Note rates, respectively, as quoted by the Federal Reserve Bank of St. Louis for the month of the observation. *2nd Quarter Indicator, 3rd Quarter Indicator, and 4th Quarter Indicator* are indicators equal to one if the observation is during the second, third, or fourth quarter of the calendar year, respectively.

Table 3
Hazard Model of Stock Sale and Option Exercise

Covariate	Predicted Sign	Option Exercises Coefficient	Option Exercises z-stat	Stock Sales Coefficient	Stock Sales z-stat
Intrinsic Value / Price	+	0.003***	3.19	0.003***	3.10
Company-specific covariates					
Prior Return	+	0.103***	5.61	0.137***	7.98
Future Return	-	-0.095**	-2.57	-0.137***	-4.73
Prior Volatility	+	0.310**	2.30	0.123	1.18
90% Prior High Indicator	+	0.479***	11.83	0.472***	16.30
Executive-specific covariates					
Pre-CEO Indicator	+/-	-0.112	-1.31	0.066	0.98
log(1 + CEO Tenure)	+	-0.039	-0.96	0.089***	2.67
Termination Indicator	+	0.545***	7.05	0.426***	8.68
Recent Grant Indicator	+	0.444***	5.30	0.314***	5.16
log(1 + Salary)	-	0.091	1.16	-0.081	-1.32
log(1+Age)	+	-0.295	-1.44	0.129	0.73
log(1 + Stock Portfolio Value)	+ / -	0.031	0.81	-0.002	-0.08
log(1 + Unvested Intrinsic Value)	+ / -	-0.057***	-2.81	-0.009	-0.55
log(1 + Vested Intrinsic Value)	+ / -	-0.047**	-1.98	0.087***	5.10
log(1 + Cumulative Proceeds Realized)	-	0.111***	6.35	0.233***	15.04
Grant-specific covariates					
log(1 + Months Till Expiry)	-	-0.875***	-45.00		
1 / Expiry Rank	+	1.432***	18.38		
Price-to-Strike	+	0.251***	8.50		
Other covariates					
Short-term Risk-free Interest Rate	+	2.516	1.37	1.655	1.33
Long-term Risk-free Interest Rate	+	-4.417	-1.24	-18.036***	-7.84
2^{nd} Quarter Indicator	-	-0.153***	-3.22	-0.193***	-5.79
3^{rd} Quarter Indicator	-	-0.237***	-5.03	-0.357***	-10.20
4^{th} Quarter Indicator	-	-0.084*	-1.82	-0.188***	-5.85
Intercept		-4.256***	-5.08	-5.812***	-8.43
Shape parameter (p)		0.937		0.936	
Log pseudolikelihood		-14,082		-4,230	
Pseudo R^2		58.39%		21.80%	

This table presents estimates from the Weibull hazard model of stock option exercises (left) and stock sales (right) described by equation (16) using a the executive-grant-month as the unit of analysis. Each executive's entire stock portfolio is treated as a single grant for the stock sale model. For the option exercise model, the outcome *Exercise* is a dichotomous variable equal to one if at least 10% of the total option grant was exercised during the month and zero otherwise. For the stock sale model, the outcome *Exercise* is equal to one if any shares of stock were sold during the month and zero otherwise. The covariates of the models are as defined in the description of Table 2. ***, **, and * represent significance for two-tailed tests (z-statistic) at the 1%, 5%, and 10% levels. The pseudo R^2 measure is a measure of the explained variation as described in Royston (2006).

Table 4
Simple Revealed Preferences Models of Subjective Value

Panel A: Black-Scholes Model of Option Value

Covariate	*Predicted Sign*	*Fixed Coefficient (z-stat)*	*Mixed Coefficient Distribution*	*Mean (z-stat)*	*Standard Deviation (z-stat)*
E^{MAX} (Sigma)	+	18.290*** (39.35)	*Fixed*	10.913*** (23.32)	
Intrinsic Value (1/Disutility)	+	0.117*** (38.73)	*Fixed*	0.117*** (17.16)	
Black-Scholes Value (BSV)	+	0.709*** (39.16)	*Normal*	0.789*** (17.81)	0.191*** (18.92)

Panel B: Target Price Model of Option Value

Covariate	*Predicted Sign*	*Fixed Coefficient (z-stat)*	*Mixed Coefficient Distribution*	*Mean (z-stat)*	*Standard Deviation (z-stat)*
E^{MAX} (Sigma)	+	29.569*** (18.42)	*Fixed*	29.522*** (13.26)	
Intrinsic Value (1/Disutility)	+	0.088*** (20.16)	*Fixed*	0.090*** (13.31)	
Target Intrinsic Value (TIV)	+	0.614*** (19.64)	*Normal*	0.616*** (13.39)	0.005*** (16.42)

Panel C: Target Price Model of Stock Value

Covariate	*Predicted Sign*	*Fixed Coefficient (z-stat)*	*Mixed Coefficient Distribution*	*Mean (z-stat)*	*Standard Deviation (z-stat)*
E^{MAX} (Sigma)	+	2.989*** (57.15)	*Fixed*	2.891*** (341.97)	
Intrinsic Value (1/Disutility)	+	21.618*** (10.08)	*Fixed*	26.88*** (4.41)	
Target Price (TP)	+	0.815*** (28.79)	*Normal*	0.925*** (5.75)	0.005** (2.23)

This table presets coefficient estimates for the simple revealed preferences model of subjective value in equation (14) estimated as a doubly-censored Tobit using Simulated Maximum Likelihood Estimation. The Black-Scholes Model of Option Value (Panel A) is estimated with a sample of 638,457 executive-grant-months. The Target Price Model of Option Value (Panel B) is estimated with a sample of 239,574 executive-grant-months. The Target Price Model of Stock Value is estimated with a sample of 34,780 executive-months. The column of Fixed Coefficients presents the unstandardized coefficient values for the Black-Scholes Model of Option Value (Panel A), Target Price Model of Option Value (Panel B), and the Target Price Model of Stock Value (Panel C). The last three columns relate to the mixed model. The Mixed Coefficient Distribution describes the distributional assumption (if any) for the coefficient. Mean is the estimated mean of the population distribution if the coefficient is mixed and the coefficient estimate if the coefficient is fixed. Standard Deviation is the estimated standard deviation of the coefficient in the population if the coefficient is mixed. z-statistics are presented below the estimated coefficients and are calculated using the robust formula $H^{-1}GH^{-1}$ as discussed in McFadden and Train (2000). ***, **, and * represent significance for two-tailed tests (z-statistic) at the 1%, 5%, and 10% levels.

Table 5
Full Revealed Preferences Models of Subjective Value

Panel A: Black-Scholes Model of Option Value

Covariate	*Predicted Sign*	*Fixed Coefficient (z-stat)*	*Coefficient Distribution*	*Mean (z-stat)*	*Standard Deviation (z-stat)*
E^{MAX} (Sigma)	+	20.866*** (57.58)	*Fixed*	20.083*** (237.08)	
Intrinsic Value (1/Disutility)	+	0.180*** (55.66)	*Fixed*	0.149*** (522.83)	
Black-Scholes Value (BSV)	+	0.936*** (57.18)	*Normal*	1.053*** (49.93)	0.117*** (18.60)
Company-specific covariates					
Prior Ret x BSV	-	-0.025*** (-42.75)	*Normal*	-0.071*** (-31.96)	0.062*** (54.12)
Future Ret x BSV	+	0.025*** (20.87)	*Normal*	0.085*** (51.87)	0.040*** (16.19)
Prior Volatility x BSV	-	0.078*** (30.06)	*Normal*	0.055*** (10.79)	0.280*** (32.72)
90% Prior High Ind x BSV	-	-0.091*** (-47.66)	*Normal*	-0.046*** (29.67)	0.137*** (125.92)
Executive-specific covariates					
pre-CEO Indicator x BSV	+ / -	-0.005*** (-2.70)	*Normal*	0.010*** (4.99)	0.151*** (12.54)
log(1 + CEO Tenure) x BSV	+	0.015*** (16.54)	*Normal*	0.011** (2.10)	0.088*** (21.42)
Termination Indicator x BSV	-	-0.036*** (-13.23)	*Normal*	-0.036*** (-20.67)	0.025* (1.67)
Recent Grant Indicator x BSV	-	-0.062*** (-30.74)	*Normal*	-0.002 (-0.26)	0.047*** (6.57)
log(1 + Salary) x BSV	+	-0.032*** (-54.03)	*Normal*	-0.081*** (-85.64)	0.091*** (12.39)
log(1+Age) x BSV	-	0.068*** (15.91)	*Normal*	0.024*** (18.88)	0.031*** (10.39)
log(1 + Stock Port Value) x BSV	+ / -	-0.002*** (-5.95)	*Normal*	-0.025*** (-11.65)	0.076*** (48.67)
log(1 + Unvested IV) x BSV	+ / -	-0.002*** (-11.87)	*Normal*	-0.021*** (-22.42)	0.008*** (3.97)
log(1 + Vested IV) x BSV	+ / -	-0.006*** (-18.56)	*Normal*	-0.057*** (-14.23)	0.067*** (25.38)
log(1 + Cum. Proceeds) x BSV	+	-0.019*** (-45.70)	*Normal*	0.019*** (8.30)	0.048*** (45.38)
Grant-specific covariates					
log(1 + Mths Till Exp) x BSV	+	0.016*** (22.98)	*Normal*	0.116*** (16.96)	0.061*** (15.85)
(1/Expiry Rank) x BSV	-	-0.087*** (-34.36)	*Normal*	-0.184*** (-7.79)	0.066*** (11.42)
Price-to-Strike x BSV	+	0.000*** (3.55)	*Normal*	0.001*** (14.63)	0.002*** (26.22)
Other covariates					
ST (6 mth.) Risk-Free Rate x BSV	-	-1.910*** (-33.64)	*Normal*	-1.600*** (-1928.58)	0.486*** (555.22)
LT (10 yr.) Risk-Free Rate x BSV	-	-0.856*** (-8.05)	*Normal*	-0.706*** (-859.28)	0.297*** (337.17)
2nd Quarter Indicator x BSV	+	-0.006*** (-4.34)	*Normal*	0.019*** (5.31)	0.009*** (5.55)
3rd Quarter Indicator x BSV	+	0.001 (0.45)	*Normal*	0.031*** (5.73)	0.049*** (30.32)
4th Quarter Indicator x BSV	+	-0.013*** (-9.66)	*Normal*	0.012* (1.88)	0.030*** (2.88)

Table 5 (cont'd)

Panel B: Target Price Model of Option Value

Covariate	*Predicted Sign*	*Fixed Coefficient (z-stat)*	*Coefficient Distribution*	*Mean (z-stat)*	*Standard Deviation (z-stat)*
E^{MAX} (Sigma)	+	21.494*** (165.46)	*Fixed*	21.244*** (984.49)	
Intrinsic Value (1/Disutility)	+	0.521*** (43.38)	*Fixed*	0.400*** (55.58)	
Target Intrinsic Value (TIV)	+	1.075*** (109.61)	*Normal*	1.391*** (116.27)	0.023*** (6.11)
Company-specific covariates					
Prior Ret x TIV	-	-0.043*** (-34.78)	*Normal*	-0.133*** (-45.62)	0.041*** (19.41)
Future Ret x TIV	+	0.057*** (17.17)	*Normal*	0.187*** (31.15)	0.297*** (43.72)
Prior Volatility x TIV	-	-0.149*** (-15.01)	*Normal*	0.054*** (3.74)	0.244*** (40.66)
90% Prior High Ind x TIV	-	-0.057*** (-14.61)	*Normal*	0.081*** (11.49)	0.228*** (36.90)
Executive-specific covariates					
pre-CEO Indicator x TIV	+ / -	0.055*** (8.76)	*Normal*	-0.029*** (-3.50)	0.111*** (23.02)
log(1 + CEO Tenure) x TIV	+	0.038*** (13.76)	*Normal*	0.033*** (8.14)	0.096*** (20.95)
Termination Indicator x TIV	-	-0.132*** (-18.13)	*Normal*	-0.070*** (-6.50)	0.256*** (24.07)
Recent Grant Indicator x TIV	-	-0.082*** (-9.11)	*Normal*	-0.057*** (-7.75)	0.177*** (27.81)
log(1 + Salary) x TIV	+	-0.031*** (-14.76)	*Normal*	-0.211*** (-52.04)	0.206*** (55.02)
log(1+Age) x TIV	-	0.034** (2.45)	*Normal*	0.317*** (19.02)	0.234*** (47.71)
log(1 + Stock Port Value) x TIV	+ / -	-0.010*** (-9.32)	*Normal*	-0.012*** (-4.78)	0.091*** (31.68)
log(1 + Unvested IV) x TIV	+ / -	-0.017*** (-16.12)	*Normal*	-0.043*** (-18.95)	0.131*** (51.98)
log(1 + Vested IV) x TIV	+ / -	-0.014*** (-9.84)	*Normal*	(-0.091*** (-28.06)	0.163*** (58.46)
log(1 + Cum. Proceeds) x TIV	+	-0.047*** (-42.74)	*Normal*	0.026*** (11.75)	0.087*** (36.24)
Grant-specific covariates					
log(1 + Mths Till Exp) x TIV	+	0.055*** (22.15)	*Normal*	0.297*** (74.30)	0.122*** (27.21)
(1/Expiry Rank) x TIV	-	-0.287*** (-36.43)	*Normal*	-0.444*** (-66.64)	0.347*** (35.71)
Price-to-Strike x TIV	+	0.000*** (4.79)	*Normal*	0.004*** (27.87)	0.015*** (34.65)
Other covariates					
ST (6 mth.) Risk-Free Rate x TIV	-	-6.934*** (-70.00)	*Normal*	-5.274*** (-955.92)	0.202*** (61.47)
LT (10 yr.) Risk-Free Rate x TIV	-	-3.074*** (-74.47)	*Normal*	-2.340*** (-672.97)	0.186*** (54.09)
2nd Quarter Indicator x TIV	+	0.033*** (7.14)	*Normal*	0.119*** (16.60)	0.318*** (45.66)
3rd Quarter Indicator x TIV	+	-0.017*** (-3.82)	*Normal*	0.131*** (24.83)	0.203*** (34.86)
4th Quarter Indicator x TIV	+	0.069*** (13.47)	*Normal*	0.074*** (13.55)	0.011* (1.68)

Table 5 (cont'd)

Panel C: Target Price Model of Stock Value

Covariate	*Predicted Sign*	*Fixed Coefficient (z-stat)*	*Coefficient Distribution*	*Mean (z-stat)*	*Standard Deviation (z-stat)*
E^{MAX} (Sigma)	+	2.096*** (58.70)	*Fixed*	2.410*** (305.21)	
Intrinsic Value (1/Disutility)	+	45.104*** (5.74)	*Fixed*	1.911*** (77.77)	
Target Price (TP)	+	1.006*** (23.26)	*Normal*	1.034*** (74.67)	0.529 (24.80)
Company-specific covariates					
Prior Ret x TP	-	-0.125*** (-24.75)	*Normal*	-0.012 (-1.18)	0.593*** (64.65)
Future Ret x TP	+	0.078*** (7.25)	*Normal*	0.056*** (4.68)	0.157*** (20.05)
Prior Volatility x TP	-	0.033* (0.99)	*Normal*	0.002 (0.18)	0.061*** (7.73)
90% Prior High Ind x TP	-	-0.277*** (19.45)	*Normal*	-0.128*** (7.86)	0.396*** (41.86)
Executive-specific covariates					
pre-CEO Indicator x TP	+ / -	-0.075*** (-3.46)	*Normal*	-0.052*** (-4.03)	0.410*** (58.61)
log(1 + CEO Tenure) x TP	+	0.011* (1.11)	*Normal*	0.502*** 30.98	0.307*** (43.47)
Termination Indicator x TP	-	-0.202*** (-7.45)	*Normal*	-0.168*** (-13.49)	0.028*** (3.52)
Recent Grant Indicator x TP	-	-0.147*** (-4.99)	*Normal*	-0.058*** (-4.55)	0.215*** (26.83)
log(1 + Salary) x TP	+	-0.052*** (-6.87)	*Normal*	0.358*** (20.86)	0.207*** (22.53)
log(1+Age) x TP	-	0.369*** (8.18)	*Normal*	-0.078*** (-5.77)	0.151*** (18.62)
log(1 + Stock Port Value) x TP	+ / -	-0.001 (-0.25)	*Normal*	-0.143*** (-13.91)	-0.156*** (22.27)
log(1 + Unvested IV) x TP	+ / -	-0.009*** (-2.98)	*Normal*	-0.212*** (-39.17)	0.665*** (50.39)
log(1 + Vested IV) x TP	+ / -	-0.051*** (-13.88)	*Normal*	-0.317*** (-41.82)	0.041*** (8.06)
log(1 + Cum. Proceeds) x TP	+	-0.128*** (-36.30)	*Normal*	-0.655*** (-51.57)	0.869*** (86.86)
Other covariates					
ST (6 mth.) Risk-Free Rate x TP	-	-2.396*** (-3.66)	*Normal*	-0.819*** (-6.40)	1.151*** (14.50)
LT (10 yr.) Risk-Free Rate x TP	-	-3.556*** (-2.51)	*Normal*	-1.363*** (-10.65)	1.187*** (14.95)
2nd Quarter Indicator x TP	+	0.050*** (3.29)	*Normal*	0.019 (1.48)	0.019* (1.86)
3rd Quarter Indicator x TP	+	0.134*** (8.42)	*Normal*	0.080*** (6.15)	0.058*** (6.02)
4th Quarter Indicator x TP	+	0.068*** (4.13)	*Normal*	0.017 (1.21)	0.031*** (3.83)

This table presets coefficient estimates for the fixed and mixed full revealed preferences model of subjective value in equation (15) estimated as a doubly-censored Tobit using Simulated Maximum Likelihood Estimation. The sample sizes for the three models are as describes in the description of Table 4. The covariates are as described in the description of Table 2. The column of Fixed Coefficients presents the unstandardized coefficient values. The last three columns relate to the mixed model. The Mixed Coefficient Distribution describes the distributional assumption (if any) for the coefficient. Mean is the estimated mean of the population distribution if the coefficient is mixed and the coefficient estimate if the coefficient is fixed. Standard Deviation is the estimated standard deviation of the coefficient in the population if the coefficient is mixed. z-statistics are presented below the estimated coefficients and are calculated using the robust formula $H^{-1}GH^{-1}$ as discussed in McFadden and Train (2000). ***, **, and * represent significance for two-tailed tests (z-statistic) at the 1%, 5%, and 10% levels.

Table 6
Equity Holding and Incentive Values

	Mean	*Median*	*Standard Deviation*	*1st Pctle*	*99th Pctle*
Equity Portfolio Values ($ millions)					
Risk-Neutral Value	52.6	15.6	273.0	0.8	528.0
Simple Mixed RP Black-Scholes Value	34.9	10.3	186.0	0.4	379.0
Full Fixed RP Black-Scholes Value	37.7	10.5	218.0	0.5	374.0
Full Fixed RP Target Intrinsic Value	21.5	8.5	46.5	0.2	203.0
Full Mixed RP Black-Scholes Value	44.6	14.2	206.0	0.9	463.0
Equity Incentives - Delta ($ thousands)					
Risk-Neutral Delta	606.0	200.7	2,757.7	8.6	5,652.9
Simple Mixed RP Black-Scholes Delta	397.7	128.0	1,877.9	4.4	3,989.5
Full Fixed RP Black-Scholes Delta	425.8	130.6	2,198.4	5.2	3,910.6
Full Fixed RP Target Intrinsic Delta	226.5	31.5	456.7	0.4	1,887.2
Full Mixed RP Black-Scholes Delta	504.0	173.6	2,077.9	10.7	4,858.4
Equity Incentives - Vega ($ thousands)					
Risk-Neutral Vega	136.3	56.9	273.4	1.9	1089.4
Full Fixed RP Black-Scholes Vega	124.9	48.7	247.0	0.8	1049.4
Full Mixed RP Black-Scholes Vega	150.0	62.4	291.7	1.0	1346.7

This table presents statistics for the distribution of equity portfolio values (top panel), delta measures of equity incentives (middle panel) and vega measures of equity incentives (bottom panel). The values are calculated annually at the fiscal year-end of each executive's company. The risk-neutral measure of equity portfolio value and delta are calculated using the Black-Scholes value for stock options and the market value for stock and restricted stock holdings. The Simple Mixed Revealed Preferences Black-Scholes measure of equity portfolio value and delta are calculated using the mixed coefficient estimates of equation (14) presented in Panel A of Table 4. The Full Fixed Revealed Preferences Black-Scholes measure of equity portfolio value and delta are calculated using the fixed coefficient estimates of equation (15) presented in Panel A of Table 5. The Full Fixed Revealed Preferences Target Intrinsic Value measure of equity portfolio value and delta are calculated using the fixed coefficient estimates of equation (15) presented in Panel B and Panel C of Table 5. The Full Mixed Revealed Preferences Black-Scholes measure of equity portfolio value and delta are calculated using the mixed coefficient estimates of equation (15) presented in Panel A of Table 5. The Risk-Neutral vega is calculated using the Black-Scholes model for the portfolio option holdings. The Full Fixed Revealed Preferences Black-Scholes vega is calculated using the portfolio option holdings and the fixed coefficient estimates of equation (15) presented in Panel A of Table 5. The Full Mixed Revealed Preferences Black-Scholes vega is calculated using the portfolio option holdings and the mixed coefficient estimates of equation (15) presented in Panel A of Table 5.

Table 7
Aggregate and Portfolio Value and Delta Correlations

	Smallest Risk-Neutral Portfolio Value (millions)	Largest Risk-Neutral Portfolio Value (millions)	Portfolio Value Pearson Correlation	Portfolio Value Spearman Correlation	Delta Pearson Correlation	Delta Spearman Correlation
Aggregate	$0.17	$766.00	0.936	0.945	0.584	0.654
Portfolio						
1	$0.17	$1.54	0.478	0.478	0.599	0.227
2	3.02	6.14	0.209	0.209	0.328	0.046
3	2.72	9.14	0.207	0.207	0.288	0.072
4	5.69	13.80	0.249	0.249	0.360	0.130
5	16.70	12.30	0.077	0.077	0.170	0.233
6	12.50	13.90	0.174	0.174	0.211	0.158
7	14.00	25.80	0.217	0.217	0.207	0.211
8	37.40	47.30	0.257	0.257	0.343	0.279
9	50.50	86.80	0.453	0.453	0.537	0.311
10	88.80	766.00	0.855	0.855	0.819	0.289

This table presents the Pearson and Spearman correlations between the risk-neutral equity portfolio values and the Mixed Revealed Preferences equity portfolio values and the correlations between the risk-neutral equity portfolio delta and the Mixed Revealed Preferences equity portfolio delta. The correlations are calculated using equity portfolio values and deltas computed annually for the sample of 9,507 executive-year observations. The ten portfolios are formed based on the year-end risk-neutral value of the executives' equity portfolio holdings and the correlations are calculated within these portfolios.

Table 8
Regressions of Future Operating Performance Measures on Equity Incentives Measures

Panel A: Linear Regression

	Predicted Sign	Return on Assets Horizon					
		One-year		*Three-years*		*Five-years*	
log(Fixed RP Delta Sensitivity)	+	-0.002 (-0.46)		0.003 (0.14)		-0.020 (-0.42)	
log(Mixed RP Delta Sensitivity)	+		-0.005* (-1.81)		-0.009 (-0.67)		-0.005 (-0.14)
log(Risk-Neutral Delta Sensitivity)	+	0.014 (1.30)	0.015 (1.43)	0.155** (2.31)	0.162** (2.41)	0.316** (2.31)	0.310** (2.28)
log(Equity Wealth)	+	0.002** (2.57)	0.002** (2.23)	0.000 (0.08)	0.000 (-0.08)	0.006 (0.45)	0.005 (0.39)
Return on Assets	+	0.832*** (21.42)	0.830*** (21.04)	2.780*** (12.93)	2.775*** (12.79)	4.496*** (30.79)	4.497*** (30.74)
Revenue	+	0.000 (-0.44)	0.000 (-0.41)	0.000 (-1.42)	0.000 (-1.49)	0.000 (-1.05)	0.000 (-1.02)
Sales Growth	-	-0.022** (-2.07)	-0.022** (-2.10)	-0.047 (-1.48)	-0.047 (-1.49)	-0.309*** (-5.11)	-0.310*** (-5.12)
Year & Industry Controls		YES	YES	YES	YES	YES	YES
Adjusted R^2		67.94%	67.97%	54.37%	54.37%	48.93%	48.92%
F-statistic		143.83	150.93	40.97	41.4	38.75	38.74
Number of Observations		4,685	4,685	2,868	2,868	1,380	1,380

Panel B: Matched Pair

	Predicted Sign	*Δ Return on Assets Horizon*					
		One-year		*Three-years*		*Five-years*	
Δ log(Fixed RP Delta Sensitivity)	+	.004 (0.87)		0.017 (0.67)		0.049 (0.64)	
Δ log(Mixed RP Delta Sensitivity)	+		-0.002 (-0.68)		0.001 (0.08)		0.035 (0.069)
Δ log(Risk-Neutral Delta Sensitivity)	+	0.009 (0.69)	0.11 (0.93)	0.162** (2.35)	0.167** (2.43)	0.356** (2.10)	0.357** (2.11)
Δ log(Equity Wealth)	+	-0.002 (-1.46)	-0.002 (-1.43)	-0.008 (-0.98)	-0.007 (-0.85)	-0.012 (-0.49)	-0.007 (-0.29)
Adjusted R^2		0.00%	-0.02%	0.40%	0.35%	0.56%	0.55%
F-statistic		0.98	0.89	2.19	2.04	1.71	1.73
Number of Observations		1,633	1,633	893	893	380	380

This table presents OLS estimates of equation (18) (Panel A) and equation (19) (Panel B). Fixed RP Delta Sensitivity is the average equity portfolio delta calculated using the fixed coefficient estimates of equation (15) presented in Panel A of Table 5. Mixed RP Delta Sensitivity is the average equity portfolio delta calculated using the mixed coefficient estimates of equation (15) presented in Panel A of Table 5. Risk-neutral delta sensitivity is the average risk-neutral equity portfolio delta. Equity wealth is the product of 1% of current stock price and the number of shares of stock and stock options. Return on assets is annual net income before interest and taxes scaled by average total assets. Revenue is annual (in millions of dollars). Sales growth is the natural logarithm of the ratio of the current year's revenue to the prior year's revenue. Δ in Panel B denotes the difference in the variable values between the matched pair. t-statistics are presented below the estimated coefficients and are calculated using Huber-White estimators adjusted for executive level clustering. ***, **, and * represent significance for two-tailed tests (t-statistic) at the 1%, 5%, and 10% levels.

Table 9
Regressions of Research & Development Expense and Future Stock Price Volatility on Equity Incentives Measures

Panel A: Future Research & Development Expense

	Predicted Sign	*R&D Expense Horizon*					
		One-year		*Three-years*		*Five-years*	
log(Risk-neutral Vega Sensitivity)	+	0.009*** (5.09)		0.031*** (3.10)		0.102*** (3.76)	
Prior Volatility Coefficient	+		0.022** (2.37)		0.029 (0.55)		0.065 (0.38)
log(Fixed RP Delta Sensitivity)	+/-	0.010** (2.32)	0.008* (1.85)	0.057** (2.22)	0.047* (1.83)	0.173** (2.49)	0.140** (2.00)
log(Risk-Neutral Delta Sensitivity)	+/-	-0.008 (-0.66)	-0.022* (-1.81)	-0.028 (-0.40)	-0.071 (-1.04)	-0.080 (-0.56)	-0.103 (-0.71)
log(Equity Wealth)	-	-0.003 (-1.38)	-0.005*** (-2.89)	-0.022** (-2.12)	-0.031*** (-3.22)	-0.030 (-1.03)	-0.068** (-2.45)
Tenure	+/-	0.000 (0.61)	0.000 (0.03)	0.001 (0.76)	0.000 (0.25)	0.005 (1.09)	0.001 (0.26)
Cash Compensation	+/-	0.000*** (3.13)	0.000*** (3.54)	0.000 (1.45)	0.000* (1.90)	0.000 (1.23)	0.000* (1.76)
log(Revenue)	-	-0.017*** (-12.17)	-0.015*** (-11.18)	-0.050*** (-6.79)	-0.044*** (-6.20)	-0.097*** (-4.66)	-0.074*** (-3.69)
Book-to-Market	-	-0.062*** (-8.57)	-0.062*** (-8.52)	-0.340*** (-8.68)	-0.346*** (-8.79)	-0.782*** (-6.63)	-0.800*** (-6.70)
Surplus Cash	+	0.041*** (3.02)	0.046*** (3.35)	0.057 (-0.75)	0.074 (0.98)	-0.345* (-1.77)	-0.259 (-1.32)
Sales Growth	-	-0.008* (-1.79)	-0.010** (-2.11)	-0.101*** (-4.17)	-0.106*** (-4.37)	-0.163* (-1.92)	-0.172** (-1.99)
Stock Return	-	-0.004** (-1.98)	-0.005*** (-2.83)	-0.004 (-0.41)	-0.011 (-1.04)	-0.014 (-0.48)	-0.039 (-1.32)
Book Leverage	-	-0.001 (-0.12)	0.001 (0.13)	-0.157*** (-3.44)	-0.148*** (-3.24)	-0.504*** (-3.60)	-0.457*** (-3.24)
Year & Industry Controls		YES	YES	YES	YES	YES	YES
Pseudo R^2		72.31%	71.71%	81.50%	80.95%	40.56%	39.67%
Likelihood Ratio		2446.44	2426.32	1,351.33	1,342.08	630.5	616.67
Number of Observations		2,683	2,683	1,626	1,626	759	759

Panel A of this table presents Tobit estimates of equation (20) where the cumulative future research and development expense scaled by total assets over a one-, three-, or five-year horizon is the dependent variable. *Risk-neutral Vega Sensitivity* is the average risk-neutral equity portfolio vega. *Prior Volatility Coefficient* is the executive-specific coefficient estimate (i.e., the mean of the executive-specific posterior distribution, $g(\beta|y,x,\theta)$) of prior volatility in equation (15). *Fixed RP Delta Sensitivity* is the average equity portfolio delta calculated using the fixed coefficient estimates of equation (15) presented in Panel A of Table 5. *Risk-Neutral Delta Sensitivity* is the average risk-neutral equity portfolio delta. *Equity Wealth* is the product of 1% of current stock price and the number of shares of stock and stock options. *Tenure* is the number of years the CEO has held the title of Chief Executive Officer as of the last day of the month of the observation. *Cash Compensation* is the annual salary and bonus received by the executive during the fiscal year. *Revenue* is annual revenue (in millions of dollars). *Book-to-Market* is the book-to-market ratio. *Surplus Cash* is the ratio of cash from assets-in-place (i.e., cash flow from operations less depreciation plus research and development expense) to average total assets. *Sales Growth* is the natural logarithm of the ratio of the current year's revenue to the prior year's revenue. *Stock return* is the continuously compounded stock price return over the previous 250 trading days. *Book Leverage* is ratio of long-term debt to total assets. t-statistics are presented below the estimated coefficients and are calculated using Huber-White estimators adjusted for executive level clustering. ***, **, and * represent significance for two-tailed tests (t-statistic) at the 1%, 5%, and 10% levels.

Table 9 (cont'd)

Panel B: Future Stock Price Volatility

	Predicted Sign	*Future Volatility Horizon*					
		One-year		*Three-years*		*Five-years*	
log(Risk-neutral Vega Sensitivity)	+	-0.029*** (-5.36)		-0.024*** (-2.92)		0.016 (1.14)	
Prior Volatility Coefficient	+		0.127*** (4.56)		0.231*** (4.38)		0.417*** (4.02)
log(RP Delta Sensitivity)	+/-	0.017 (1.35)	0.020 (1.56)	0.091*** (3.47)	0.059*** (2.44)	0.026 (0.62)	0.037 (0.94)
log(Risk-Neutral Delta Sensitivity)	+/-	0.067* (1.77)	0.112*** (3.04)	0.101 (1.44)	0.166** (2.48)	0.013 (0.14)	0.015 (0.17)
log(Equity Wealth)	-	-0.029*** (-5.33)	-0.019*** (-3.63)	-0.037*** (-3.73)	-0.027*** (-2.80)	-0.034** (-1.97)	-0.032* (-1.94)
Tenure	+/-	0.001 (1.28)	0.002** (2.07)	0.002 (1.40)	0.003** (2.06)	0.007** (2.51)	0.006** (2.43)
Cash Compensation	+/-	0.000* (1.86)	0.000 (1.09)	0.000 (1.42)	0.000 (0.87)	0.000 (0.08)	0.000 (0.85)
log(Revenue)	-	-0.032*** (-7.77)	-0.036*** (-9.20)	-0.064*** (-8.80)	-0.069*** (-9.75)	-0.090*** (-7.09)	-0.087*** (-7.15)
Book-to-Market	-	-0.024 (-1.10)	-0.016 (-0.76)	-0.044 (-1.14)	-0.026 (-0.69)	-0.078 (-1.08)	-0.068 (-0.96)
Surplus Cash	-	-0.359*** (-8.44)	-0.365*** (-8.58)	-0.582*** (-7.48)	-0.582*** (-7.51)	-0.514*** (-4.11)	-0.480*** (-3.87)
Sales Growth	+	-0.018 (-1.22)	-0.011 (-0.71)	0.049* (1.91)	0.054** (2.11)	0.197*** (3.68)	0.205*** (3.85)
Stock Return	+	0.011* (1.84)	0.014** (2.48)	0.011 (0.98)	0.013 (1.17)	0.034* (1.89)	0.028 (1.58)
Book Leverage	-	-0.028 (-1.13)	-0.034 (-1.40)	-0.059 (-1.29)	-0.066 (-1.46)	-0.151* (-1.79)	-0.152* (-1.83)
Year & Industry Controls		YES	YES	YES	YES	YES	YES
Adjusted R^2		43.44%	43.28%	50.71%	51.05%	52.56%	53.48%
F-statistic		49.04	48.72	42.25	42.77	22.94	23.76
Number of Observations		2,753	2,753	1,685	1,685	793	793

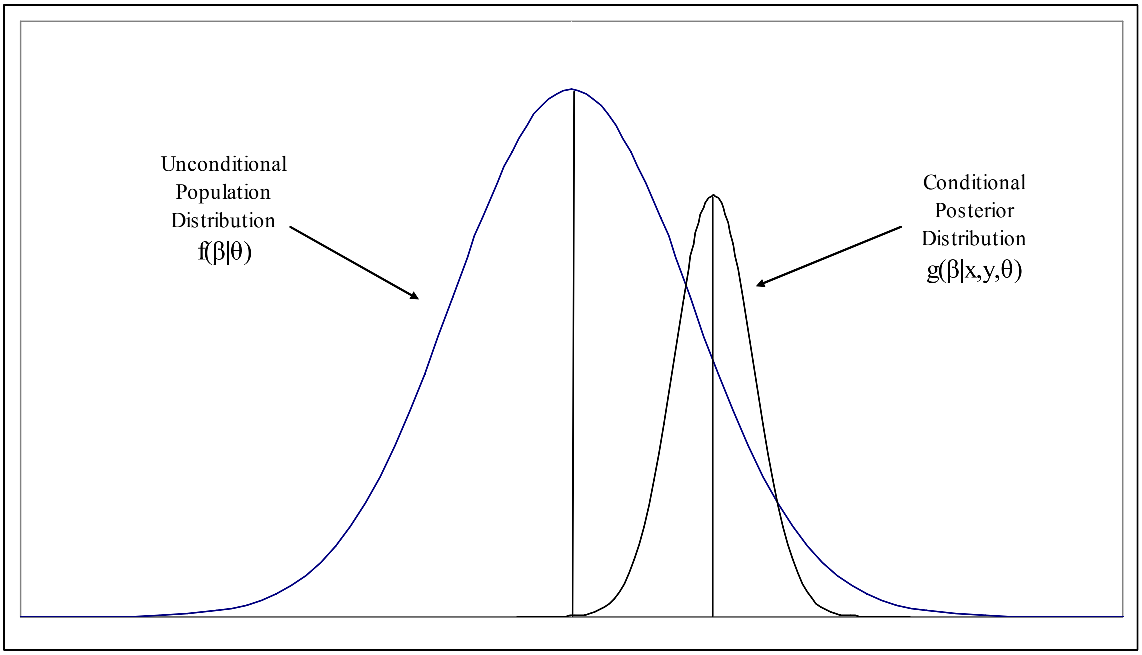
Panel B of this table presents OLS estimates of equation (20) where annualized future stock price volatility over a one-, three-, or five-year horizon is the dependent variable. *Risk-neutral Vega Sensitivity* is the average risk-neutral equity portfolio vega. *Prior Volatility Coefficient* is the executive-specific coefficient estimate (i.e., the mean of the executive-specific posterior distribution, $g(\beta|y,x,\theta)$) of prior volatility in equation (15). *Fixed RP Delta Sensitivity* is the average equity portfolio delta calculated using the fixed coefficient estimates of equation (15) presented in Panel A of Table 5. *Risk-Neutral Delta Sensitivity* is the average risk-neutral equity portfolio delta. *Equity Wealth* is the product of 1% of current stock price and the number of shares of stock and stock options. *Tenure* is the number of years the CEO has held the title of Chief Executive Officer as of the last day of the month of the observation. *Cash Compensation* is the annual salary and bonus received by the executive during the fiscal year. *Revenue* is annual (in millions of dollars). *Book-to-Market* is the book-to-market ratio. *Surplus Cash* is the ratio of cash from assets-in-place (i.e., cash flow from operations less depreciation plus research and development expenditures) to average total assets. *Sales Growth* is the natural logarithm of the ratio of the current year's revenue to the prior year's revenue. *Stock return* is the continuously compounded stock price return over the previous 250 trading days. *Book Leverage* is ratio of long-term debt to total assets. t-statistics are presented below the estimated coefficients and are calculated using Huber-White estimators adjusted for executive level clustering. ***, **, and * represent significance for two-tailed tests (t-statistic) at the 1%, 5%, and 10% levels.

Table 10
Regressions of Future Stock Returns on Incentive Measures

	Predicted Sign	Cumulative Return Horizon					
		One-year		*Three-years*		*Five-years*	
log(Fixed RP Delta Sensitivity)	+	0.122*** (4.75)		0.229*** (3.22)		0.317*** (2.84)	
log(Mixed RP Delta Sensitivity)	+		0.077*** (4.44)		0.090* (1.72)		0.094 (1.34)
log(RN Delta Sensitivity)	+/-	-0.024 (-0.22)	0.017 (0.16)	0.230 (1.19)	0.317 (1.58)	0.216 (1.06)	0.299 (1.34)
log(Equity Wealth)	+/-	-0.002 (-0.20)	0.010 (1.11)	-0.013 (-0.33)	0.006 (0.15)	-0.047 (-1.01)	-0.023 (-0.50)
Std. Deviation of Returns	+	0.184*** (2.63)	0.180*** (2.58)	0.083 (0.42)	0.091 (0.46)	-0.112 (-0.36)	-0.099 (-0.31)
log(Market Value Equity)	-	-0.036*** (-4.04)	-0.040*** (-4.56)	-0.148*** (-3.09)	-0.157*** (-3.28)	-0.130*** (-3.20)	-0.142*** (-3.49)
Book-to-Market	+	0.144*** (3.10)	0.129*** (2.77)	0.309** (2.53)	0.301** (2.43)	0.803*** (3.55)	0.822*** (3.63)
Book Leverage	+	0.089* (1.69)	0.072 (1.40)	0.533*** (2.86)	0.507*** (2.74)	0.631 (1.56)	0.604 (1.50)
Year & Industry Controls		YES	YES	YES	YES	YES	YES
Adjusted R^2		7.17%	7.09%	13.71%	13.53%	19.87%	19.46%
F-statistic		10.10	10.16	9.24	9.22	8.59	8.32
Number of Observations		4,905	4,905	3,044	3,044	1,486	1,486

This table presents OLS estimates of equation (21) where future cumulative stock price return over a one-, three-, or five-year horizon is the dependent variable. *Fixed RP Delta Sensitivity* is the average equity portfolio delta calculated using the fixed coefficient estimates of equation (15) presented in Panel A of Table 5. *Risk-Neutral Delta Sensitivity* is the average risk-neutral equity portfolio delta. *Equity Wealth* is the product of 1% of current stock price and the number of shares of stock and stock options. *Std Deviation of Returns* is the standard deviation of daily stock price returns over the previous 250 trading days. *Market Value of Equity* is the market capitalization of the company at the fiscal year end. *Book-to-Market* is the book-to-market ratio. *Book Leverage* is ratio of long-term debt to total assets. t-statistics are presented below the estimated coefficients and are calculated using Huber-White estimators adjusted for executive level clustering. ***, **, and * represent significance for two-tailed tests (t-statistic) at the 1%, 5%, and 10% levels.

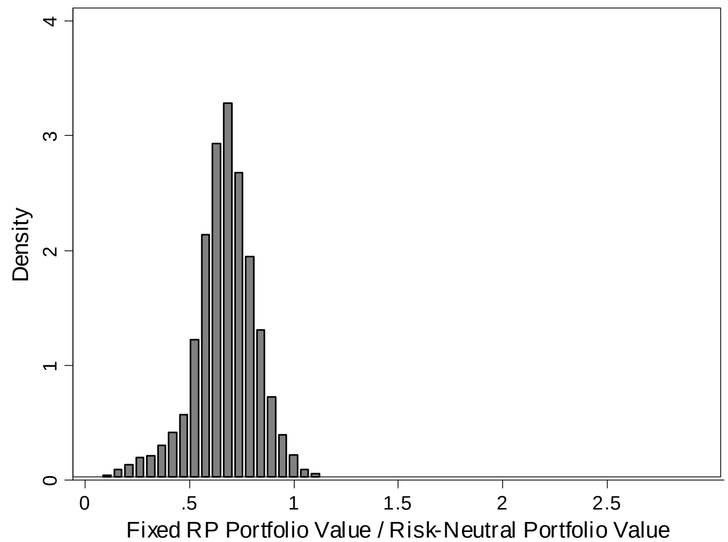
Figure 1
Relationship Between Unconditional Population Distribution and Executive-Specific Conditional Posterior Distribution



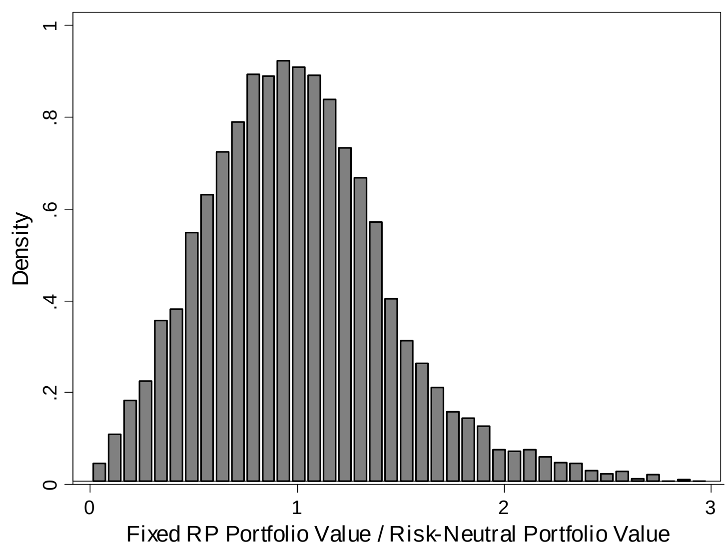
This figure illustrates the distinction between the unconditional population distribution for a mixed coefficient and the conditional posterior distribution of the executive-specific coefficient in the Mixed Revealed Preferences model of subjective value. The unconditional population distribution, $f(\beta|\theta)$, describes the distribution of coefficients in the population and the conditional posterior distribution, $g(\beta|x,y,\theta)$ describes the distribution conditional on the parameters of the unconditional population distribution (i.e., θ), the observed sequence of outcomes (i.e., y) and the accompanying covariates (i.e., x). The vertical lines represent the means of the respective distributions.

Figure 2
Ratio of Fixed and Mixed Revealed Preferences Subjective Portfolio Values to Risk-Neutral Portfolio Values

Panel A: Histogram of Ratio of Fixed Revealed Preferences Port. Value to Risk-Neutral Port. Value



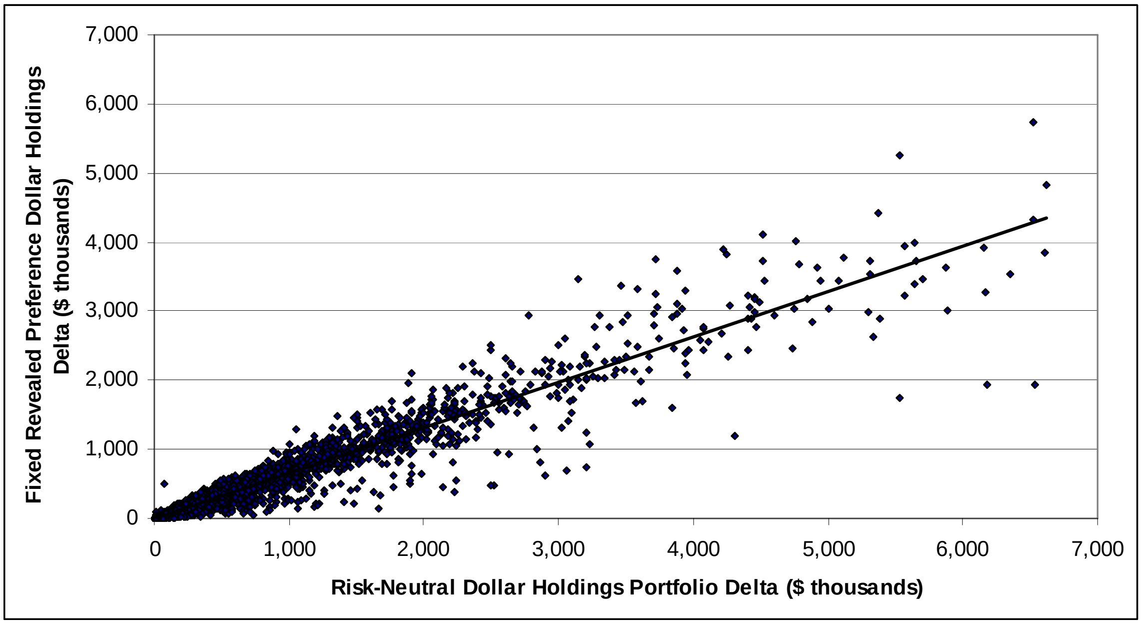
Panel B: Histogram of Ratio of Mixed Revealed Preferences Port. Value to Risk-Neutral Port. Value



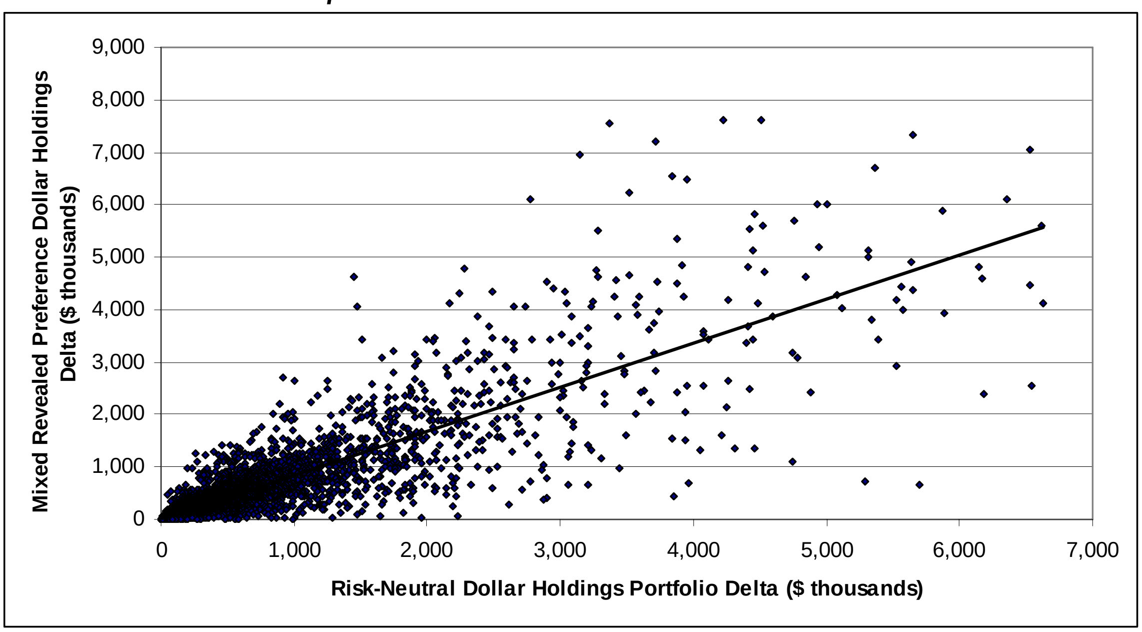
This figure presents histograms of the ratio of the Fixed Revealed Preference Subjective Portfolio Value to the Risk-neutral Portfolio Value (Panel A) and the ratio of the Mixed Revealed Preferences Subjective Portfolio Value to the Risk-Neutral Portfolio Value (Panel B) calculated using the full Black-Scholes model coefficients presented in Panel A of Table 5. The unit of analysis is the executive-year and the portfolio values are computed annually at each the appropriate fiscal year end.

Figure 3
Plots of Revealed Preference Equity Portfolio Deltas versus Risk-Neutral Equity Portfolio Deltas

Panel A: Fixed Revealed Preferences Delta vs. Risk-Neutral Delta



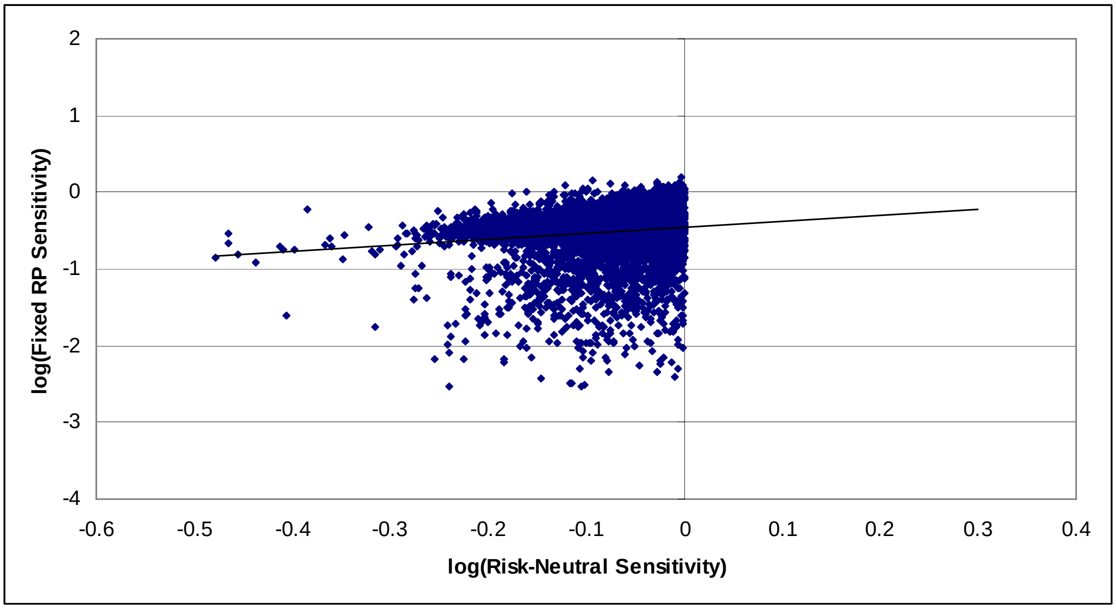
Panel B: Mixed Revealed Preferences Delta vs. Risk-Neutral Delta



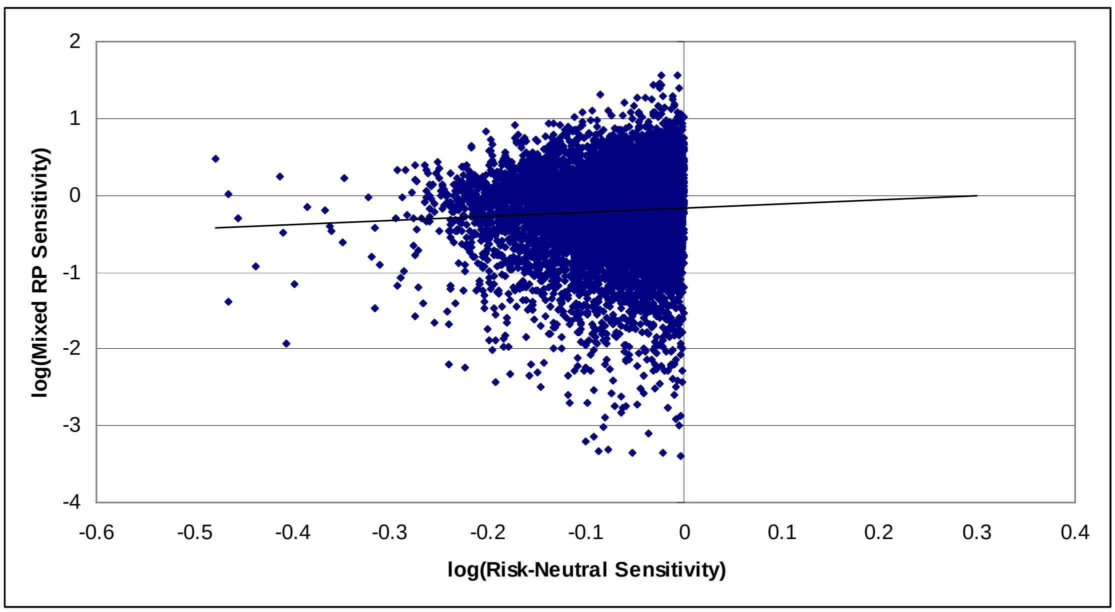
This figure plots the Fixed Revealed Preferences equity portfolio delta (Panel A) and the Mixed Revealed Preferences equity portfolio delta (Panel B) versus the Risk-Neutral equity portfolio delta. The Fixed Revealed Preferences equity portfolio delta is calculated using the fixed coefficient estimates of equation (15) presented in Panel A of Table 5. The Mixed Revealed Preferences equity portfolio delta is calculated using the mixed coefficient estimates of equation (15) presented in Panel A of Table 5.

Figure 4
Plots of Revealed Preference Delta Sensitivities
versus Risk-Neutral Delta Sensitivities

Panel A: Fixed Revealed Preference Delta Sensitivity vs. Risk-Neutral Delta Sensitivity



Panel B: Mixed Revealed Preference Delta Sensitivity vs. Risk-Neutral Delta Sensitivity



This figure plots the Fixed Revealed Preferences delta sensitivity (Panel A) and the Mixed Revealed Preferences delta sensitivity (Panel B) versus the Risk-Neutral delta sensitivity. The Fixed Revealed Preferences delta sensitivity is calculated using the fixed coefficient estimates of equation (15) presented in Panel A of Table 5. The Mixed Revealed Preferences delta sensitivity is calculated using the mixed coefficient estimates of equation (15) presented in Panel A of Table 5. All sensitivity measures are calculated using equation (17).