

PSYCHOLOGICAL FACTORS AND STOCK OPTION EXERCISE*

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We investigate stock option exercise decisions by over 50,000 employees at seven corporations. Controlling for economic factors, psychological factors influence exercise. Consistent with psychological models of beliefs, employees exercise in response to stock price trends—exercise is positively related to stock returns during the preceding month and negatively related to returns over longer horizons. Consistent with psychological models of values that include reference points, employee exercise activity roughly doubles when the stock price exceeds the maximum price attained during the previous year.

I. INTRODUCTION

In this paper we seek to understand what leads employees to exercise the stock options given to them by their firm. In particular, we examine whether psychological factors influence exercise decisions above and beyond the rational factors considered in standard models of exercise. Our data span ten years and contain detailed records for 50,000 employees at seven publicly traded corporations; they indicate when stock options were granted and when they were exercised, so they allow us to track how employees respond to the series of stock price movements as it unfolds over time.

Stock options provide employees with the opportunity to purchase stock in the future at a strike price equal to the stock price at the date of issuance. When employees exercise, they typically do so for cash.¹ As a consequence, stock options effectively provide employees with a choice between a sure amount of cash today and an uncertain amount of cash in the future, much like the decision between continuing to hold a stock and cashing

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1. Although the company issues stock when employees exercise, the majority of employees have access to a mechanism known as “cashless exercise” through which a broker immediately sells the stock and issues a check to the employee for the proceeds. The companies that provided our data indicated that cashless exercise constitutes more than 90 percent of all exercise activity.

out. Unlike stock, however, an employee typically sacrifices much of the expected value of the option by exercising before expiration.

Why do employees exercise? We test several different predictions about why exercise occurs. We derive the predictions from rational economic considerations and two psychological models: one that focuses on beliefs and the other that focuses on values and reference points.

Controlling for economic determinants of exercise, we find that employee exercise decisions depend on recent price movements and whether the current price is above or below a psychological reference point. Thus, for the economics literature the results shed light on the importance of psychological factors in a significant important economic domain. For the psychology literature the paper suggests how reference points are set in a dynamic environment. For the management literature we provide evidence on employee decisions with respect to an increasingly common compensation vehicle.

The impact of psychological factors on exercise behavior is particularly interesting because of three features of employee stock options. First, the individuals in our data set do not select to participate in the market as overtly as the subjects of previous behavioral studies of individual investors (e.g., Shefrin and Statman [1985] and Odean [1998a]). Our employees are granted options by their firm; they do not purchase them directly. Indeed, if self-selection plays a role in our sample, it should work against premature exercise: rational employees who select a job because they value the company's option program either believe that the company's long-term prospects are highly favorable or they are significantly risk seeking. Second, our option-holders have high human capital represented by high salaries, and their employers award them options with substantial monetary value in a format designed to reduce the likelihood that they will quit [Coopers and Lybrand 1993]. Thus, our data capture the behavior of individuals who may be more sophisticated than the median market participant in a context where thousands of dollars of personal wealth are at stake. Third, to the extent that they exist, reference points for stock options are likely set dynamically based on the past stock price series. Because options are not purchased, no purchase price can serve as a reference point. Stock price at issuance is not a reasonable reference point, since the option is worthless if exer-

cised at that price. Therefore, employee stock options provide a natural setting in which to examine dynamically set reference points, an issue that has received little attention in the behavioral literature.

The paper proceeds as follows. Section II describes option exercise from a rational perspective. Section III describes exercise from a behavioral perspective. Section IV presents our empirical findings. Section V concludes the paper.

II. RATIONAL FACTORS AFFECTING EXERCISE

Generally, in rational models of exercise, people should not exercise tradable call options on stocks before they expire because the market value of a “live” option exceeds the proceeds from exercise.² Using the same data as in this study, Huddart and Lang [1996] document that employees frequently exercise their options years before they expire. This premature exercise sacrifices substantial value—on the order of 25 percent of the option’s expected value.

Although this sacrifice of expected value is substantial, this premature exercise may be rational because (in contrast with tradable stock options) the options we study are nontransferable. Employees cannot sell their options, and it is costly to lay off the risk associated with stock options (e.g., by shorting the employer’s stock). If employees need liquidity, they may exercise options because it is difficult to pledge options as security for a loan.³ If employees are risk averse, they may exercise to diversify into other assets [Huddart 1994].

If employees exercise rationally in response to liquidity needs or risk aversion, then they should do so only when the costs associated with exercise are less than the benefits of liquidity or diversification. Rational employees who exercise because of liquidity needs do so when the value they sacrifice by exercising is less than the cost of a loan. Rational employees who exercise for diversification do so only when the value they lose by exercising is

2. There are two exceptions to this general principle: exercise may be optimal immediately before either a dividend payment or a decrease in the tax rate. Neither factor is a major determinant of exercise for our sample. There are few instances in which dividend payments or tax rate changes are likely to be factors. Excluding those observations does not affect results.

3. Michael S. Malone [February 18, 1996, “Nerds’ Revenge: A How-To Manual,” *The New York Times*] describes the difficulty of borrowing against employee stock options.

small relative to the reduction in risk they bear.⁴ In the analyses below, we control for the costs of exercise by including in our analyses the ratio of the value of the option if exercised immediately (which we call its intrinsic value) to the present value of the expected payoff to the employee from continuing to hold the option (which we estimate using a formula for the market value of tradable options, and call the expected value). Whether employees are exercising to meet liquidity needs or to diversify their risks, rational economic considerations suggest that employees will be more likely to exercise when exercise captures more of the option's expected value, i.e., when this ratio is large.

III. BEHAVIORAL FACTORS AFFECTING EXERCISE

In this section we consider the predictions of two behavioral theories about exercise. One theory focuses on expectations or beliefs; the other focuses on utility or values.

1. *Beliefs*

One class of behavioral theories would predict that option-holders will exercise in response to recent stock returns. Belief-based models of investor behavior have received increasing attention in the finance literature over the last few years. Research in psychology has indicated that individuals sometimes expect trends to continue and sometimes expect mean-reversion [Kahneman and Tversky 1973; Tversky and Kahneman 1971]. Recently, researchers have proposed models of individual investors who switch back and forth between separate regimes that involve trending or reversion (cf. Barberis, Shleifer, and Vishny [1998]).

In a series of experiments Andreassen [1987, 1988] demonstrated that when individuals were exposed to price paths from stock market data, they typically expected mean-reversion in prices unless they had a causal belief about why a trend might continue. If our option-holders share the beliefs of Andreassen's subjects, then they may typically expect short-term trends to reverse. However, they may expect long-term trends to continue because they may regard long-term trends as diagnostic of underlying value. This pattern of beliefs would lead exercise to be positively related to short-term trends and negatively related to

4. Also, if the employee can take a short position in similar stocks, exercise to diversify should only occur when the cost of taking such a position is large relative to the value sacrificed in exercise.

long-term trends. Note that both reactions to trends are difficult to explain within the standard rational model. In efficient markets, past trends cannot predict future performance, and rational investors should not react to them.

2. Values

Reference Points. A second class of behavioral models emphasizes, not beliefs, but values. These models emphasize that the values of option-holders may change (and therefore their risk attitude may change) depending on whether they are above or below a reference point.

The notion of a reference point is most commonly associated with Kahneman and Tversky's [1979] value function. The value function has successfully organized a number of phenomena in the behavioral literature in psychology and economics (see Camerer [1995] for a review and Bowman, Minehart, and Rabin [1997] for a recent application). The value function has three properties that give it its characteristic S-shape (see Figure I). (1) Instead of being defined over levels of wealth, it is defined over gains and losses relative to a reference point. (2) Both gains and losses from the reference point exhibit diminishing sensitivity. For both gains

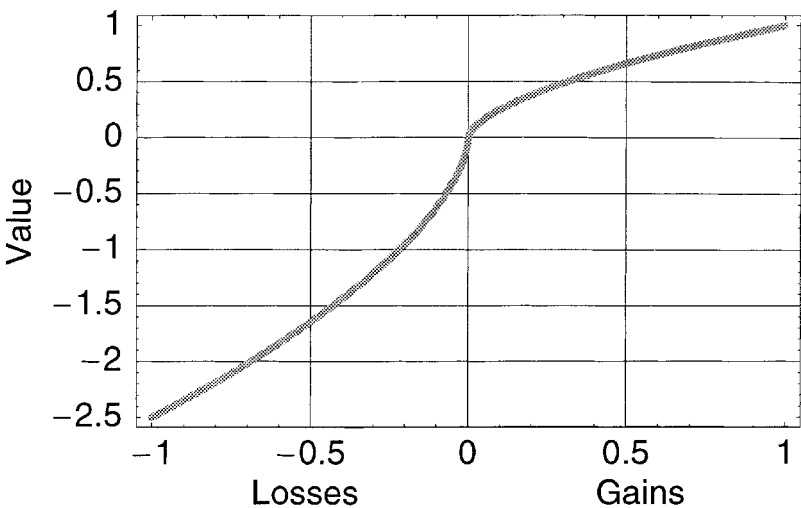


FIGURE I
A Typical Value Function [Kahneman and Tversky 1979]

and losses, a move from 100 to 110 is less noticeable than a move from 0 to 10. This property implies that the function is concave over gains and convex over losses, which leads to the prediction of risk seeking in the region of losses and risk aversion in the region of gains. (3) Losses from the reference point are more painful than gains are satisfying.

Our argument relies on two key features of Prospect Theory: the reference point and diminishing sensitivity (which produces the convex shape to left of the reference point and the concave shape to the right). Since the great majority of option-holders immediately sell the stock acquired on exercise of the options, option-holders face risks when they hold their options, but they acquire a sure payment when they exercise. An option-holder who exercises early is trading a risky option for a sure thing with a lower expected value. This is more likely to occur when the option-holder is above her reference point in the concave region of the value function. Note that option-holders will not exercise automatically when they cross the reference point into the concave region of the value function because their level of risk aversion may not fully offset the loss of expected value being sacrificed by exercise. However, exercise should increase after the reference point because the threshold for exercise should be substantially lower in the concave, risk-averse region than in the convex, risk-seeking region.

Nonstatus Quo Reference Points. Although Prospect Theory specifies the shape of the utility function around the reference point, it does not specify where people set their reference point. Laboratory studies in the psychological literature have most often assumed that the reference point is the status quo.⁵

Outside the psychological literature, nonstatus quo reference points have been studied more frequently, most notably in research on the disposition effect, which treats the original purchase price of an item as the reference point. Shefrin and Statman [1985] coined the term, "disposition effect," to refer to the tendency of individual investors to hold losers and sell winners defined

5. However, this literature has been aware that nonstatus quo reference points are important. In their original paper on Prospect Theory, Kahneman and Tversky [1979] said "there are situations in which gains and losses are coded relative to an expectation or aspiration level that differs from the status quo." See also Kahneman [1992].

relative to a purchase price reference point. They provided evidence for the disposition effect in a sample of individual trades by investors at a retail brokerage. Ferris, Haugen, and Makhija [1988] found volume effects consistent with the disposition effect in the market trading of small firm stocks. Heisler [1994, 1998] found evidence of the disposition effect among futures traders, and Odean [1998a] provided especially compelling evidence for it in a large database of trades by investors at a discount brokerage. In an elegant experiment, Weber and Camerer [1998] showed that the disposition effect was reduced when the securities in an experimental market were automatically sold at the end of every period. This suggests that reference points play a major role in the disposition effect; the automatic sale should have affected only reference points and not other factors such as beliefs about trends.

While our approach is similar to studies of the disposition effect, reference points for options are likely to be set in a more dynamic fashion than reference points for stock purchases. Options have no purchase price to serve as a reference point. Employees do not purchase options, they receive them at a strike price that is equal to the stock price on the date of the grant. Because employees can only exercise their options when the stock price exceeds the strike price, reference points, if they exist, will be dynamically determined by stock price movement after the grant.

In predicting what will serve as a nonstatus quo reference point, research on human learning and memory suggests that employees may set their reference point based on two features of the underlying stock price: central tendency and extremes. In a number of domains (e.g., text, language, pictures, hedonic experience), people are much more likely to remember the general meaning of information than specific details [Anderson 1974; Mandler and Ritchey 1977] (see Anderson [1995, pp. 136–168] for an overview). However, when people do remember specific details, they remember details that are especially novel or unusual [Fredrickson and Kahneman 1993; Fiske and Taylor 1991, pp. 247–254]. Combined, these observations suggest that people do not store a continuous record of events; instead they store central tendencies and salient, extreme values. In our context, these findings imply that option-holders are likely to set reference points in response to the typical stock price (e.g., average or

median) or extremes (e.g., minimum or maximum).⁶ Interestingly, in an experimental study of the disposition effect, Gneezy [1998] found strong evidence that purchase price was a less effective predictor of reference points than were maxima.

The Prospect Theory value function predicts that behavior will shift from risk-seeking to risk-averse after option-holders pass their reference point. Thus, in our analyses below, we look for reference points by exploring how price movements affect exercise. We investigate whether exercise behavior changes when the stock price moves past the prices that represent various percentiles of the historical price (e.g., the 25th, 50th, 75th, and maximum). If employees set reference points at the typical stock price or an extreme, then exercise should increase when stock prices surpass the 50th percentile or the maximum.⁷

Over what period are reference points set? This is another question where the psychological literature is silent. In finance, recent research by Benartzi and Thaler [1995] has argued that people myopically monitor the performance of their investment portfolio over a period of about eleven months. In our study below, we include this interval by examining candidate reference points defined over various periods of time from three months to two years.

3. Comparing the Rational and Behavioral Predictions

Each model we have considered is likely to capture at least some of the variance in how employees exercise their options. The rational theory can predict why individual option-holders will respond to the ratio of intrinsic to expected value, but it has difficulty explaining why option-holders would react to trends or a stock price that moves past a particular percentile of the historical distribution. On the behavioral side, both beliefs and values are likely to affect exercise (see, e.g., Weber and Camerer [1998]), and therefore both trends and percentiles are likely to matter. Table I

6. Minimum stock price is unlikely to have a strong effect in these data because options on stocks that are below historical minima are often out-of-the-money.

7. Note that to show this convincingly, we need to show that option-holders exercise more when the stock price passes a reference point, even after controlling for how they respond to general stock price trends. If we find such changes in exercise behavior, they will be easier to interpret as an effect of reference points rather than beliefs. Belief models typically invoke a smooth updating process, so it would be difficult for them to explain why, after controlling for trends, exercise behavior increases when the price crosses a particular point.

TABLE I
 PREDICTED RELATIONSHIPS BETWEEN STOCK OPTION EXERCISE AND STOCK PRICE
 PATH FOR VARIOUS MODELS OF OPTION-HOLDER BEHAVIOR

Variable	Rational model	Psychological models	
		Belief	Reference point
Fraction of expected value captured at exercise	+	?	?
Short-term price run-ups	0	+	?
Long-term price run-ups	0	-	?
Current price exceeds historical median or maximum	0	0	+

+ Model predicts increases in exercise with increases in the variable.

- Model predicts increases in exercise with decreases in the variable.

0 Model predicts the variable will not affect exercise.

? Model makes no prediction.

summarizes the predictions from the rational, belief, and reference point models.

IV. EMPIRICAL ANALYSIS

1. Data

Our data are employee-by-employee option grant and exercise records for seven companies spanning a period of approximately ten years. The companies supplied these data on condition that they and their employees remain anonymous. Four companies are listed on the NYSE (a manufacturer, two financial institutions, and a high-technology company) and three are recently public NASDAQ high-technology companies.⁸ Several times a year, each company awards varying numbers of options to varying individuals. All options a company awards on a given date have identical terms (e.g., time to expiration, strike price, and vesting schedule), but awards made on different dates may have different terms and typically have different strike prices. We refer to all the options awarded by a company on a single date as a grant. Across the seven companies over the time period covered by our data, there are 160 distinct grants with 10 or more recipients.

8. Results that follow are consistent for both the NYSE-listed companies and the NASDAQ companies, although they are somewhat stronger for the NYSE companies.

Our empirical analysis is limited to exercise from these grants. For each option-holder represented in every one of these grants, our data record the number of options exercised on each day of the sample period. The sample period varies by company. The earliest and latest dates in the sample are August 2, 1985, and December 23, 1994.

Table II describes the economic importance of the options we explore. The average employee in our sample holds exercisable, in-the-money options from between two and three option grants on a typical date in the period we examine, in this case January 1, 1993. Both the intrinsic and expected values of options in dollar terms are highly skewed with respective means of \$113,341 and

TABLE II
DESCRIPTIVE STATISTICS ON IN-THE-MONEY OPTION POSITIONS OF INDIVIDUAL
EMPLOYEES ON JANUARY 1, 1993

Variable	Mean	Standard deviation	25th Percentile	Median	75th Percentile
Panel A—all employees					
Number of grants	2.348	1.959	1	2	3
Intrinsic value (\$)	113,341	895,929	2,278	9,070	39,728
Expected value (\$)	174,958	1,270,383	5,250	15,415	72,806
Panel B—employees with available salary data					
Number of grants	2.705	2.108	1	2	3
Intrinsic value (\$)	163,556	1,136,137	3,545	16,474	68,586
Expected value (\$)	294,752	1,611,744	5,619	25,049	133,259
Salary (\$)	88,692	58,635	63,343	75,600	94,800
Expected value as a fraction of salary	1.595	3.869	0.084	0.353	1.427

On January 1, 1993, 38,456 employees in the sample held exercisable, in-the-money options. In Panels A and B the number of grants is the number of different grants from which the employee holds exercisable options. Intrinsic value is the before-tax proceeds from a hypothetical cashless exercise on January 1, 1993. Expected value is the Barone-Adesi and Whaley [1987] value of a tradable option with similar characteristics as at January 1, 1993. For 23,167 employees, 1993 salary data are also available. Panel B reports the same statistics as in Panel A only for those employees with available salary data. In addition, Panel B reports the expected value of options expressed as a fraction of salary.

\$174,958, and medians of \$9,070 and \$15,415. To put these in perspective, Panel B of the table presents the expected value of the options held by employees for whom we have 1993 salary data. The median employee in our sample earned about \$75,000, and most earned between \$50,000 and \$100,000. For these employees the median expected value of options constitutes 35.3 percent of base yearly salary, and the mean is 159.5 percent.⁹

One general issue is how to aggregate the raw data on exercise since each employee can decide daily whether to exercise.¹⁰ For tractability we aggregate all exercise from a given grant exercised within a given week. So, for example, if options on 10,000 shares were exercised in a given week from an original grant of 1,000,000 options, we would record the amount exercised in the week as 0.01. One advantage of considering the options exercised in a week from a given grant as the unit of analysis is that this controls for multicollinearity across individuals who witness the same stock price path:

$$\text{EXER}_{gt} = \text{options exercised in week } t \text{ from grant } g \\ \text{as a fraction of options granted.}$$

A grant of options that expires in ten years potentially contributes 520 weekly observations of exercise to our regression analysis. However, we exclude weeks when no options could be exercised because none were vested, and weeks when no options could be exercised because the options were underwater. Options from some grants expire in five years. The exercise records do not span the life of every option. For instance, the data record exercise activity only for the first three years of options granted in 1991, but substantially all of the exercise activity for options granted in 1985. Over the observed lives of the 160 grants, there are 12,145 weekly observations of exercise activity when options were available for exercise and in-the-money.

We consider two general sets of explanatory variables. First we include control variables to capture potential economic motives for exercise. Results are not sensitive to the inclusion of any of the control variables. The first potential motive for exercise is to receive value before an employee leaves the company. Typically,

9. The wide range of values reflects in part the fact that the value of the option is determined primarily by stock price performance over its life. A modest option grant can have a very large value if the stock price performance has been strong over its life, particularly since these are long-lived options.

10. When he exercises, a typical employee exercises all available (i.e., vested, unexercised options) from a single grant together on one day.

employees must exercise their options within six months of leaving; afterward, they are canceled. Therefore, one would expect increased exercise of options that are to be canceled:

$CANCEL_{gt}$ = options to be canceled in the six months following week t from grant g as a fraction of options granted.

We also include a variable to measure the percentage of the grant that vested in the prior six months. Prior to vesting, employees are precluded from exercising their options, and therefore when options vest, one might expect some pent-up exercise activity:

$VEST_{gt}$ = options that vested in the six months prior to week t from grant g as a fraction of options granted.

Because we express exercise activity as a fraction of the options originally granted, we include a control for a number of options that remain vested and unexercised:¹¹

$AVAIL_{gt}$ = options available for exercise in week t from grant g as a fraction of options granted.

As argued earlier, exercise due to liquidity needs or risk aversion should be more likely when option-holders lose relatively little of the option's value at exercise. Whether employees exercise their options prematurely for rational reasons of risk aversion (to invest the proceeds in other assets) or liquidity needs (to spend the proceeds), they forgo the payoff from holding the option until later. The discounted value of this uncertain future payoff is the corresponding expected value. To control for the effects of risk aversion and liquidity needs, our regressors include the ratio of the intrinsic value of the option (i.e., the market price of the stock less its strike) to the expected value of the option, which we estimate using the formula of Barone-Adesi and Whaley (BAW) [1987].¹²

In our calculation of the ratio, we use the contractual terms of

11. We could have expressed the exercise variable as a percentage of options available for exercise, but this would treat in the same way an observation in which one employee exercised the last remaining option and an observation in which multiple individuals each exercised their entire grant. As a practical matter, inference is consistent across the two specifications.

12. The BAW value is an extension to American options on dividend-paying stocks of the Black-Scholes formula, which only applies to European options on stocks that do not pay dividends. As a practical matter, our regression results are qualitatively similar when we use the Black-Scholes value.

the option, and interest and stock parameters¹³ appropriate to the observation week:

$$\text{RATIO}_{gt} = \frac{\text{Market price}_{gt} - \text{Strike price}_g}{\text{Barone-Adesi and Whaley option value}_{gt}}.$$

This ratio is the amount the employee would receive, per dollar of the options' expected value, on exercise in the observation week. Thus, RATIO is an index of the opportunity cost of exercising the option. If exercise would capture all the option's expected value, then RATIO is unity. Since we exclude observations when the option is at- or out-of-the-money, the ratio is always greater than zero. RATIO controls across time and grants for variations in the economic consequences of exercise. If employees are more likely to exercise when they sacrifice less value, the rational model predicts a positive coefficient on RATIO in our regressions.

We are primarily concerned with variables that capture potential psychological reasons for exercise. First, we consider the association between exercise and recent returns. Belief models predict that exercise is likely to be positively related to short-term returns and negatively related to long-term returns. We consider several nonoverlapping continuously compounded returns windows, aggregating returns for parsimony. (Below, we define a "month" as a period of four weeks. Also, we define a "year" as a period of twelve "months.") In particular, we focus on

RETWK_{igt} = Stock return of the company issuing grant g
in week $t - i$ for $i = 1, 2, 3,$ and $4;$

RET6MO_{1gt} = Stock return of the company issuing grant g
over the six months -7 to -2 relative to week $t;$ and

13. Interest rates used to compute BAW values are yields on treasury securities with maturities appropriate to the remaining life of the option and drawn from the relevant time period. Dividend yields are annualizations of the most recent quarterly dividend scaled by the stock price for the observation week. It is not practical to use implied volatility estimates because some companies represented in the data do not have exchange-traded options. Moreover, the accuracy of implied volatility estimates over future periods amounting to several years is unknown. Following Alford and Boatsman [1995], we estimate volatility using a year-long series of daily closing stock prices ending on the Friday prior to the observation week. The regression results we report later are not sensitive to the volatility estimate used. The regression coefficients on the other variables reported below and the overall explanatory power of the model are qualitatively similar when RATIO is replaced by the inputs needed to calculate RATIO, namely, the market price expressed as a multiple of the strike, the time remaining until the option expires, the stock's volatility, dividend yield, and interest rate.

$RET6MO_{2gt}$ = Stock return of the company issuing grant g
over the six months -13 to -8 relative to week t .

Selection of returns windows is arbitrary. However, results are not sensitive to the returns window chosen.¹⁴

Second, we consider potential reference points. Based on the literature above, we assume that reference points may be set based on typical or extreme values of the historical price distribution. Below, in our general analysis we divide the distribution of historical prices into percentiles, and consider how exercise shifts as the stock price passes a historical 25th, 50th, 75th, or 100th percentile. We also consider various time periods over which these percentiles may be defined:

$$PCT_{gt}(i, T) = \begin{cases} 1, & \text{if the stock price in week } t \text{ for the company} \\ & \text{issuing grant } g \text{ is above the } i\text{th percentile} \\ & \text{of stock prices in the period from time} \\ & -T \text{ to one month prior to exercise; and} \\ 0, & \text{otherwise.} \end{cases}$$

In calculating these indicator variables, we exclude the month immediately prior to the exercise week to ensure a gap between the observation and when the reference point is set. For example, the indicator for the 75th percentile and the two-year time period takes on a value of one if the current stock price is above the 75th percentile of stock prices over the previous two years, zero otherwise. In much of our analysis we use PCT(100th percentile, one year) as our benchmark case and refer to it as MAX for simplicity.

2. Regression

The analyses in Tables IV and V are based on the following weighted least squares specification:¹⁵

14. We also explored daily returns for 60 trading days preceding exercise and monthly returns for 25 months prior to exercise. Coefficients on the other regressors are qualitatively unchanged when alternative returns variables are used. The general effect of past stock price movement on exercise activity is similar across these other definitions of the returns variables.

15. Since the dependent variable, options exercised as a fraction of options granted, is an average over the number of employees included in the grant, we expect the variance of the disturbance term to decrease as the number of employees included in a grant increases. To account for this heteroskedasticity, we estimate weighted least squares regressions. The weight is the same for each week of a given grant and is proportional to the square root of the number of employees included in the grant. Regression results using weighted Tobit regressions are qualitatively similar.

TABLE III
DESCRIPTIVE STATISTICS ON REGRESSION VARIABLES

Variable	Mean	Standard deviation	25th Percentile	Median	75th Percentile
EXER	0.0020	0.0081	0.0000	0.0000	0.0010
AVAIL	0.3695	0.2224	0.2065	0.3676	0.5430
CANCEL	0.0101	0.0367	0.0000	0.0000	0.0086
VEST	0.0785	0.1130	0.0000	0.0000	0.1266
RATIO	0.7673	0.1834	0.6286	0.7942	0.9319
RETWK ₁	0.0081	0.0573	-0.0216	0.0066	0.0351
RET6MO ₁	0.1466	0.2619	-0.0151	0.1271	0.3011
RET6MO ₂	0.0954	0.2823	-0.0612	0.0986	0.2680
MAX	0.2632	0.4404	0.0000	0.0000	1.0000

There are 12,145 weekly observations of options exercised expressed as a fraction of options granted. EXER, AVAIL, CANCEL, and VEST are the fraction of the total number of options awarded from a single grant that, relative to observation week, are as follows: exercised, available for exercise, and to be canceled within six months; and, that have vested in the prior six months, respectively. RATIO is the difference between the market price of the stock on the Monday of the observation week and the strike price, divided by the option's Barone-Adesi and Whaley [1987] value as of the same date. RETWK₁ is the return on the stock in the week prior to exercise. RET6MO₁ is the return on the stock over months -7 to -2, inclusive relative to the observation week. RET6MO₂ is the return on the stock over months -13 to -8, inclusive. Returns are the logarithm of the ratio of closing stock prices on the days bracketing the relevant period. MAX is a dummy variable that takes the value one if the stock price in the observation week exceeds the maximum of the daily closing stock prices computed over trading days -21 to -260, i.e., the maximum over the prior year excluding the month prior to the observation week.

$$\begin{aligned}
 (1) \quad \text{EXER}_{gt} = & \beta_1 + \beta_2 \text{AVAIL}_{gt} + \beta_3 \text{CANCEL}_{gt} + \beta_4 \text{VEST}_{gt} \\
 & + \beta_5 \text{RATIO}_{gt} + \beta_6 \text{RETWK}_{1gt} + \beta_7 \text{RETWK}_{2gt} \\
 & + \beta_8 \text{RETWK}_{3gt} + \beta_9 \text{RETWK}_{4gt} + \beta_{10} \text{RET6MO}_{1gt} \\
 & + \beta_{11} \text{RET6MO}_{2gt} + \beta_{12} \text{MAX}_{gt} + \varepsilon_{gt}.
 \end{aligned}$$

Table III reports descriptive statistics for variables from this regression.¹⁶ On average, 0.20 percent of an option grant is exercised in a sample week, consistent with the fact that most of the options have a 10-year (roughly 500-week) life. On average, 36.95 percent of a grant is available for exercise, 7.85 percent vested in the prior six months, and 1.01 percent will be canceled in the next six months. In the average sample week, option-holders could capture 76.73 percent of the BAW value by exercising. The average continuously compounded return for the week prior to the observation week is 0.81 percent,¹⁷ and the average return for the

16. We suppress subscripts where there can be no confusion.

17. Because the return one week prior to a given observation week is also the return two weeks prior to the succeeding observation week, the set of values for RETWK₁, RETWK₂, RETWK₃, and RETWK₄ in the data are nearly the same.

two preceding six-month periods range from 10 to 15 percent. In 26.32 percent of cases, the stock price was above the maximum stock price observed during the prior year (i.e., trading days -21 to -260).

Given the structure of the data (pooled time-series and cross-section), a potential concern is correlation of residuals over time or across grants in a given time period. Given the strength of the results that follow, such correlations would have to be quite pronounced to affect inference. Empirically, first-order autocorrelation of residuals is moderate at 9.5 percent on average. Adjusting the regression for autocorrelation using the Cochrane-Orcutt approach has minimal effect on coefficient estimates and t -statistics. Cross-correlation within a given time period is 2.6 percent, suggesting that it is unlikely to be an issue. Our conclusions are the same when we reestimate the regression using one observation per firm/week by averaging independent and dependent variables for each firm/week. We are not aware of other sources of correlation that are likely to affect inference. However, we cannot entirely dismiss correlation of some other form, so conclusions about significance levels should be drawn with caution.

In our analysis we focus on psychological variables based on the past stock price path. One potential concern is that employee exercise is correlated with these variables because they capture profitable trading strategies. While we know of no reason to expect that to be true, we ran several tests to ensure that it was not. First, we examined whether the psychological variables we consider, namely, $RETWK_1$ - $RETWK_4$, $RET6MO_1$, $RET6MO_2$, and MAX , predict future returns over windows ranging from one week to three months after the observation week for the companies in our sample. They do not. Thus, a trading strategy based on current price relative to a previous high or recent returns does not appear profitable in our sample and cannot rationalize employees' exercise decisions. Furthermore, exercise activity ($EXER$) does not explain future returns over these same windows. Finally, we included as additional explanatory variables the returns in the three months following the observation week to the benchmark regression (1). These returns do not load in the regression. Including them does not alter the sign, magnitude, or significance

Hence, descriptive statistics for returns in weeks -2 , -3 , and -4 are virtually identical to those reported for week -1 .

TABLE IV
BENCHMARK-WEIGHTED LEAST SQUARES REGRESSION OF FRACTION OF GRANT
EXERCISED ON EXPLANATORY VARIABLES

$$EX = \beta_1 + \beta_2 AVAIL + \beta_3 CANCEL + \beta_4 VEST \\ + \beta_5 RATIO + \beta_6 RETWK_1 + \beta_7 RETWK_2 + \beta_8 RETWK_3 \\ + \beta_9 RETWK_4 + \beta_{10} RET6MO_1 + \beta_{11} RET6MO_2 + \beta_{12} MAX + \varepsilon$$

Variable	Predicted sign	Coefficient	<i>t</i> -statistic
Intercept	?	-0.00219	-13.0
AVAIL	+	0.00264	14.6
CANCEL	+	0.05466	33.3
VEST	+	0.00108	3.9
RATIO	+	0.00251	12.9
RETWK ₁	+	0.01055	14.3
RETWK ₂	+	0.01232	17.1
RETWK ₃	+	0.00491	6.9
RETWK ₄	+	0.00032	0.5
RET6MO ₁	?	0.00008	0.4
RET6MO ₂	-	-0.00075	-4.8
MAX	+	0.00194	20.6
Adjusted <i>R</i> ²	0.2849		
Number of observations	12,145		

Variables are defined in Table III. The weight on each observation is proportional to the square root of the number of employees included in the grant.

of any of the other regressors. Hence, future returns do not appear to be an omitted correlated variable that could confound our inferences.

As mentioned above, we have conducted analyses with reference points defined across different time periods and percentiles. We will consider these analyses more systematically below. However, for purposes of exposition, Table IV presents the coefficients from a benchmark regression for these analyses based on the maximum over the preceding year.¹⁸ Several facts are clear from this regression. First, as one would expect, exercise is positively associated with the fraction available, fraction to be canceled, fraction recently vested, and the ratio of intrinsic value to BAW value.

18. While this choice of benchmark is somewhat arbitrary, it is consistent with the Benartzi and Thaler [1995] finding that investors monitor their investment over a period of about one year and with the common practice of reporting 52-week high stock prices in the popular press. Results are not sensitive to this choice as indicated in the more detailed analysis that follows.

Controlling for those variables, exercise is sensitive to recent stock price performance. The coefficients on weekly returns for the four weeks prior to the exercise event are all positive, but fade in significance across the four weeks. Similarly, the coefficient on returns for the preceding six months is insignificant, while the six months prior to that is negative. Combining the coefficient on week 1, for example, with mean exercise of 0.20 percent from Table II suggests that a 10 percent weekly stock price run-up results in a 22 percent increase in exercise activity. This suggests that exercise is quite sensitive to short-term stock returns. Odean [1998b] found that individual investors at a discount brokerage also responded to short-term run-ups. The trend coefficients are consistent with psychological models of beliefs that assume investors believe in mean-reversion in the short run and trending in the long run.

Consistent with reference point models, the indicator variable for the maximum stock price is reliably positive, with exercise increasing by 0.00194. To put this in perspective, this result suggests that when the stock price is above a one-year maximum, exercise increases by 97 percent of the average value. The significant coefficient on the maximum is consistent with option-holders relying on reference points in making exercise decisions. Beliefs models, because they typically focus on past returns, do not explain why, conditional on past returns, exercise increases when the price crosses a historical maximum.

3. General Results for Various Percentiles and Time Periods

As we mentioned in the theoretical discussion, the previous literature says little about how reference points are set in dynamic environments. The analysis in Table IV is somewhat arbitrary in that we assumed reference points were set based on the maximum achieved over the prior year. We now reestimate equation (1) replacing MAX with other percentiles computed over various time periods to determine the best candidate for a psychological reference point in our data set. Coefficients on all other variables in these regressions are similar in magnitude and significance to those in Table III and are not reported.

Figure II suggests that exercise is significantly more sensitive to historical maxima than to medians and other percentiles. The figure shows the coefficient estimates associated with the indicator variable in twenty separate regressions: five percentiles (25th, median, 75th, maximum, and "125th"), each defined over four

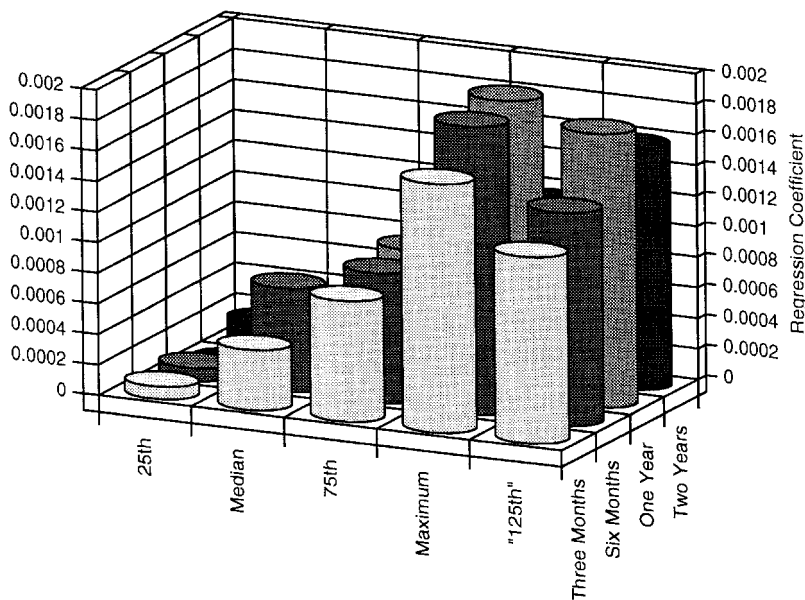


FIGURE II

Coefficients of the Price Dummy for Various Percentiles and Time Periods

The figure plots on the vertical axis the coefficient on variable $PCT(i,T)$ in the regression, $EXER = \beta_1 + \beta_2 AVAIL + \beta_3 CANCEL + \beta_4 VEST + \beta_5 RATIO + \beta_6 RETWK_1 + \beta_7 RETWK_2 + \beta_8 RETWK_3 + \beta_9 RETWK_4 + \beta_{10} RET6MO_1 + \beta_{11} RET6MO_2 + \beta_{12} PCT(i,T) + \varepsilon$, where $PCT(i,T)$ takes the value 1 if the stock price in the observation week exceeds the i th percentile of the stock price computed over a prior period T of length three months, six months, one year, and two years, and ending one month prior to the observation week. The "125th" percentile is defined as the maximum plus the difference between the maximum and the 75th percentile.

different time periods (two years, one year, six months, and three months). We added the "125th" percentile indicator variable to show that exercise does not increase monotonically with price. This variable is coded as a one when the current stock price exceeds the maximum by the same amount that the 75th percentile is below the maximum.¹⁹

One can interpret the coefficients on the dummy variables as the difference between the average value of $EXER$ when the stock price is above the cutoff percentile and the average value of $EXER$ when the stock price is below the cutoff percentile, after controlling for the factors represented by the other regressors. Two facts

19. We added this variable because it is consistent with the other quartile-based cut-points that we test.

are apparent from Figure II. First, in terms of percentiles, exercise increases more sharply when the stock price rises above a prior maximum than when it rises above any quartile or the "125th" percentile. As noted earlier, previous psychological work suggested that reference points might be set based on typical past values or extremes. Figure II suggests that exercise is more sensitive to historical maxima than to medians. Second, exercise appears most sensitive to prices over the previous year. That is consistent with the Benartzi and Thaler [1995] finding that investors monitor portfolio performance over a period of about eleven months.

Table V presents the information in Figure II in tabular form. It reports the numerical coefficient that was plotted in Figure II, along with the t -statistic for the individual regression. The table also indicates the results of a Vuong likelihood ratio test [Vuong 1989]. This test examines which of model (1) and an overlapping competing model in which MAX is replaced by $PCT(i, T)$ is "best" in the sense of being closest to the true distribution of residuals conditional on the explanatory variables.

TABLE V
COEFFICIENTS AND t -STATISTICS ON $PCT(i, T)$ FROM WEIGHTED LEAST SQUARES
REGRESSIONS OF FRACTION OF GRANT EXERCISED ON EXPLANATORY VARIABLES

$$EX = \beta_1 + \beta_2 AVAIL + \beta_3 CANCEL + \beta_4 VEST + \beta_5 RATIO \\ + \beta_6 RETWK_1 + \beta_7 RETWK_2 + \beta_8 RETWK_3 + \beta_9 RETWK_4 \\ + \beta_{10} RET6MO_1 + \beta_{11} RET6MO_2 + \beta_{12} PCT(i, T) + \varepsilon$$

Time period T	Percentile				
	25th	Median	75th	Maximum	125th
Two years	0.00014* (0.8)	0.00018* (1.6)	0.00065* (7.6)	0.00115* (11.4)	0.00158* (2.4)
One year	-0.00027* (-2.0)	0.00036* (3.7)	0.00088* (10.5)	0.00194 ^a (20.5)	0.00179* (11.7)
Six months	0.00009* (0.9)	0.00068* (8.0)	0.00085* (10.6)	0.00188 (20.8)	0.00139* (10.8)
Three months	0.00008* (0.9)	0.00039* (4.7)	0.00079* (10.2)	0.00163 (19.0)	0.00122* (12.0)
Number of observations	12,145				

Regression coefficients and t -statistics (in parentheses) are reported for $PCT(i, T)$, a dummy variable that takes the value 1 if the price in the observation week exceeds the i th percentile of prices over the preceding period, T , and 0 otherwise. Other regression variables are defined in Table III. The weight on each observation is inversely proportional to the square root of the number of employees included in the grant.

a. Coefficient on MAX is from the benchmark model reported in Table IV.

* The Vuong test rejects the hypothesis that the regression model is as close (or closer) to the true data-generating process as the benchmark model at the 0.01 level.

Holding prior period T constant, the coefficients on $PCT(i,T)$ exhibit an inverted-U shape for every period other than two years. The Vuong test rejects at the 1 percent level or better the null against the alternative that model (1) is closer to the true data-generating process for all choices of $PCT(I,T)$ except $PCT(100, 3 \text{ months})$ and $PCT(100, 6 \text{ months})$ where the closeness of the models cannot be distinguished.

The analyses above suggest that maxima set within the previous year discriminate best between exercise and nonexercise behavior. The next two figures provide additional detail on this point: first by refining the partition of percentiles around the maximum, and second by refining the partition of time periods.

Figure III refines the partition of percentiles for the one-year period by adding the 95th and 105th percentiles. Supporting the earlier conclusions, the coefficient and t -statistics are largest for MAX. Vuong tests indicate that the maximum is closest to the true

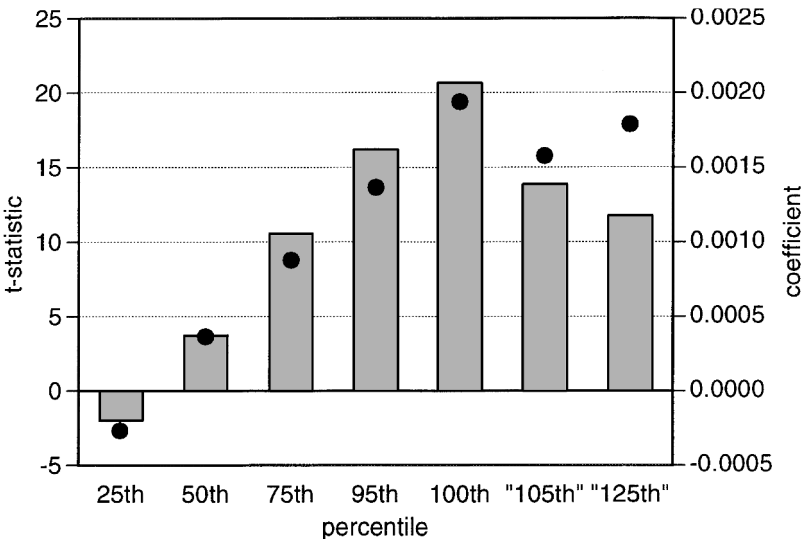


FIGURE III
Indicator Variable for Various Percentiles

Circles plot the coefficient estimate, and the vertical bars are the t -statistic on variable $PCT(i, \text{one year})$ in the regression, $EXER = \beta_1 + \beta_2AVAIL + \beta_3CANCEL + \beta_4VEST + \beta_5RATIO + \beta_6RETWK_1 + \beta_7RETWK_2 + \beta_8RETWK_3 + \beta_9RETWK_4 + \beta_{10}RET6MO_1 + \beta_{10}RET6MO_2 + \beta_{12}PCT(100,T)$, where $PCT(i, \text{one year})$ takes the value 1 if the observation week stock price of the company issuing the grant exceeds the i th percentile of prices over a prior period of twelve months ending one month prior to the observation week. Other variables are defined in Table III.

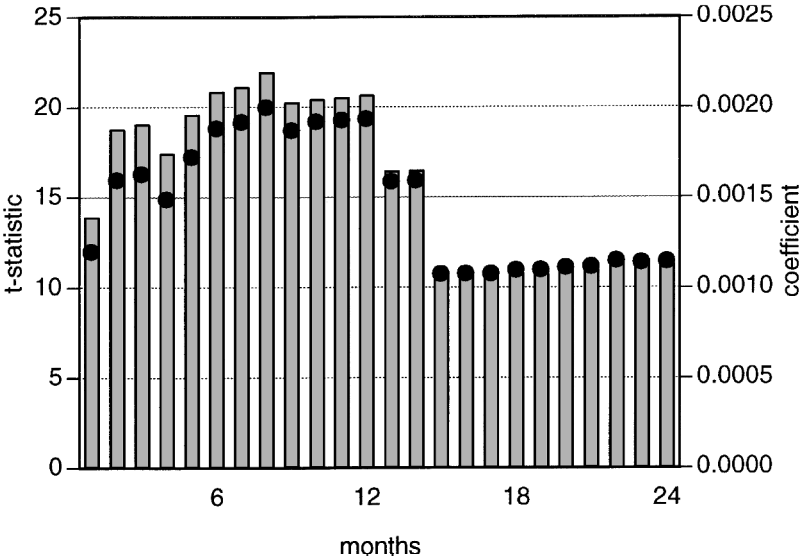


FIGURE IV
Indicator Variable for Various Periods

Circles plot the coefficient estimate, and the vertical bars are the t -statistic on variable $PCT(100, T)$ in the regression, $EXER = \beta_1 + \beta_2 AVAIL + \beta_3 CANCEL + \beta_4 VEST + \beta_5 RATIO + \beta_6 RETWK_1 + \beta_7 RETWK_2 + \beta_8 RETWK_3 + \beta_9 RETWK_4 + \beta_{10} RET6MO_1 + \beta_{10} RET6MO_2 + \beta_{12} PCT(100, T)$, where $PCT(100, T)$ takes the value 1 if the observation week stock price of the company issuing the grant exceeds the maximum stock price computed over a prior period of T months ending one month prior to the observation week. Other variables are defined in Table III.

data-generating process (significant at the 2 percent level). Furthermore, an F -test indicates that the coefficient on MAX is significantly different from the regression coefficients corresponding to the other percentiles (significant at the 2 percent level) except $PCT(125, \text{one year})$. In part, the insignificant difference with respect to this last specification reflects the fact that the standard error on the coefficient for $PCT(125, \text{one year})$ is large because there are few observations where the stock price in the observation week has risen so far above the prior maximum.²⁰

Figure IV plots the coefficient estimates and t -statistics for $PCT(100, T)$ from a series of regressions that consider maxima set over periods ranging from 1 to 24 months. The general pattern

20. $PCT(125, \text{one year}) = 1$ for just 3.6 percent of the observations. The standard error on this coefficient is 50 percent larger than the coefficient on MAX .

suggests that the explanatory power of the maximum variable generally increases over months 1 to 6, is roughly constant over months 6 to 12, and decreases markedly beyond twelve months.

Consistent with this impression, an F -test of the hypothesis that the coefficient on $PCT(100, T)$ is the same as the coefficient on MAX in the benchmark regression is rejected for horizons of one, two, and four months as well as all horizons longer than a year. The Vuong test yields similar results except that the difference for month 4 is not significant.

V. CONCLUSION

Our results suggest that psychological factors affect exercise behavior. In general, employees respond to stock price trends in a way that is consistent with belief models and not with purely rational considerations. Furthermore, our results suggest that values and reference points also matter. Employees are much more likely to exercise their options when stock prices exceed a maximum price that was set sometime during the previous year. We interpret this as evidence that individual option-holders set a reference point based on the maximum stock price that was achieved within the previous year, and that they are more likely to exercise when subsequent price movements move them past their reference point.

These results contribute to the behavioral literature in two ways. First, they reaffirm the importance of reference points other than the status quo. Although the literature on decision making has admitted that nonstatus quo reference points are possible [Kahneman and Tversky 1979], it has focused primarily on the status quo. Our evidence suggests that for option-holders, the maximum of a historical distribution acts as an important reference point. Second, these results suggest that reference points change over time. Option-holders responded most strongly to maxima that were set within the previous year.

Our study indicates that earlier results on reference points [Shefrin and Statman 1985; Odean 1998a] hold for a population with high general human capital and that does not self-select to trade securities. As in previous studies [Odean 1998a], our options-holders sacrifice a substantial portion of their expected value when they exercise their options, and the exercise behavior that can be predicted by our reference point argument is not easy to explain by rational concerns (i.e., it seems unlikely that risk

aversion or liquidity needs change when stock prices cross a maximum set in the previous year).

Second, separate from the reference point effects we document, individuals clearly respond to stock price trends. These effects are consistent with observations about beliefs in psychology [Andreassen 1987, 1988; Kahneman and Tversky 1973; Tversky and Kahneman 1971] and behavioral finance (e.g., Barberis, Shleifer, and Vishny [1998]).

Although the effects of trends are consistent with belief models, they may also be consistent with a reference point model where reference points adapt over time (see, e.g., Odean [1998b]). While the original formulation of Prospect Theory [1979] does not specify how reference points adapt, adaptation is one of the most fundamental biological and psychological processes (cf. Lowenstein and Frederick [1997] for a review). If option-holders adapt to the wealth represented by their options, then as prices change over time, reference points may also change. If reference points adapt (but only over time), then in the short run they should be relatively immobile, and exercise behavior should be positively related to short-term trends. For example, when prices move sharply upward, they may push option-holders past their reference point and cause them to exercise. Models with adaptive reference points have not been considered in the psychological literature, but future research could productively examine how much responses to trends result from adaptive reference points rather than changes in beliefs.

Third, our results support previous results indicating that investors monitor their investments over a time period of approximately one year. In our data the past year's stock price history has a strong effect on exercise behavior. This is consistent with Benartzi and Thaler [1995]. In part, it may not be surprising that individuals seem to attend to the one-year horizon, because this information is quite salient in the institutional environment—the financial press commonly reports one-year maxima. Individual investors, who may already be psychologically predisposed to attend to maxima, may find their predispositions enhanced because information about maxima is so readily available.

Finally, our results suggest some interesting patterns that might be observed in aggregate market data if the typical investor reacts as our option-holders react. For example, option-holders in our sample exercise more often when stocks trended downward

over months -13 to -8 and when stocks trended upward over the last month. Researchers have documented that stock prices show positive autocorrelations on the order of six to twelve months [Jegadeesh and Titman 1993; Daniel 1996] and negative autocorrelations on the order of one month [Jegadeesh 1990; Lehman 1990]. The analysis of reference-point effects suggests an interesting pattern that has not yet (to our knowledge) been tested in aggregate market data. If individual investors bail out of their investments when prices pass historical maxima, then markets may experience increased volume at such points as some individuals exit and other investors take over. Because all investors experience the same stock price path, the maximum stock price may provide a simpler method of testing for reference-point effects than the traditional disposition effect that requires researchers to know when investments were purchased (e.g., Ferris, Haugen, and Makhija [1998]).

Our results also have practical implications for firms, compensation planners, and employees. Over the last few years, stock options have become a pervasive form of compensation: a majority of U. S. companies issue stock options to employees, and many grant options to more than half of all employees. From the firm's perspective, exercise behavior affects the cost and benefits of this form of compensation, because it affects how long options are held. In particular, options only have an incentive effect as long as they are outstanding. If employees systematically exercise options before expiration, then incentives endure for a shorter period of time than might be suggested by the life of the option. Similarly, if employees exercise options in response to particular price paths, then firms will find that options-based incentives are reduced at times when the market has rewarded the firm's performance. For compensation planners, our results show that exercise is not a simple function of either the variables used (i) in standard finance models, or (ii) in formulas prescribed in disclosure standards promulgated by the Securities and Exchange Commission and the Financial Accounting Standards Board. Thus, cost estimation for practical decisions may need to consider how exercise decisions depend on psychological factors. Employees sacrifice significant economic value when they exercise in response to economically irrelevant factors. In the extreme, the results suggest that firms may want to educate employees about the economic underpinnings of option valuation so that they do not sacrifice a substantial

portion of the value of their options in response to short-term stock price movements.

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