Stocking up: Executive optimism, option exercise, and share retention

Rik Sen *
Hong Kong University
of Science and Technology

Robert Tumarkin †
University of New South Wales

April 29, 2015

Abstract

We show that an executive is optimistic about her company's prospects if and only if she retains some of the shares received whenever she exercises company stock options. Empirically, an indicator of optimism based on this idea matches the expected relations between optimism and corporate decision-making better than commonly used indicators based on the timing of option exercise. This makes sense, as our model of an executive's optimal option exercise and portfolio choice demonstrates that the timing of option exercise depends just as much on stock and other executive characteristics as it does on optimism.

Keywords: Optimism, Executive stock option, Exercise Policy, Optimism measures, Corporate financial policies
JEL codes: G11, G30, G32, G34

We thank Jennifer Carpenter, Henry Cao, Alya Al Foori (discussant at Finance Down Under), Xavier Gabaix, Dirk Jenter (discussant at FIRS), Da Ke, Ulrike Malmendier (discussant at AFA), Nishanth Rajan, Robert Whitelaw, Jeffrey Wurgler, Dong Yan, David Yermack, Jin Yu, and Xianming Zhou for helpful discussion on this project. We also thank seminar participants at the American Finance Association Conference, the Financial Intermediation Research Society Conference, Finance Down Under Conference, Hong Kong Joint Finance Workshop, London Business School Trans-Atlantic Doctoral Conference, University of Adelaide, and Macquarie University for many useful suggestions. Rik Sen would like to acknowledge support by the DAG09/10.BM15 grant of the Research Grants Council of Hong Kong for this research.
∗ riksen@ust.hk, Hong Kong University of Science and Technology, Department of Finance, Clear Water Bay, Kowloon, Hong Kong
† Corresponding Author: r.tumarkin@unsw.edu.au, School of Banking and Finance, University of New South Wales Business School, Sydney NSW 2052, Australia

1. Introduction

Optimism shows up as a pervasive and powerful psychological bias in experimental and business settings, and it has been shown to influence key corporate policies, such as financing, investment, and acquisition decisions.[1] As evidence suggests that executives make private and professional decisions similarly (Cronqvist, Makhija, and Yonker, 2012), measures derived from an executive's personal security holdings have been used to analyze the effect of optimism on corporate outcomes. While the important corporate policy implications of executive optimism have received a great deal of theoretical attention, how an executive's optimism affects her management of her personal portfolio of company stock and options has not.[2] Yet, a theoretical foundation that explicitly incorporates optimism is needed to help researchers assess the quality of existing optimism measures and for the development of robust new measures.

We model an optimistic executive's option exercise and portfolio choice problem under a general concave utility function. Given an initial endowment of outside wealth and a non-transferable call option on company stock, the risk-averse executive in our model maximizes her expected utility from terminal wealth. She chooses when to exercise the option and is allowed to take unrestricted long positions in company stock, but is not permitted to short it. We model optimism as a subjective personal belief that the company stock will have positive abnormal returns, even though the true stock-return process has a zero abnormal return.[3]

In our model, executives exercise options for two distinct reasons: to rebalance their portfolios and to capture dividends. When rebalancing to optimize risk and return, optimistic executives tend to exercise their options in a way that limits the time value lost on early exercise, resulting in exercises closer to expiration and at higher underlying stock prices than exercises by their less optimistic peers. This portfolio-rebalancing exercise motive exists for options on both dividend-paying and non-dividend-paying stocks. Moreover, the

[1] Ben-David, Graham, and Harvey (2013), Larwood and Whittaker (1977), March and Shapira (1987), Scheier, Carver, and Bridges (1994), Svenson (1981), and Weinstein (1980) explore the psychological foundations of optimism. Ben-David, Graham, and Harvey (2013), Graham, Harvey, and Puri (2013), Hirshleifer, Low, and Teoh (2012), Kolasinski and Li (2013), Malmendier and Tate (2005a,b, 2008), and Malmendier, Tate, and Yan (2011), among others, show that optimism affects corporate policies.

[2] Theoretical models examining the role of optimism on corporate financial policies include Bergman and Jenter (2007), Campbell et al. (2011), Goel and Thakor (2008), Hackbarth (2009), Heaton (2002), and Malmendier and Tate (2005a).

[3] Like Baker, Ruback, and Wurgler (2007), Baker and Wurgler (2013), and Ben-David, Graham, and Harvey (2013), we use the term "optimism" specifically to mean that the executive has higher return expectations for her company's stock than those held by the market. Optimism in this paper is a belief. It is not necessarily a personality trait, an overestimation of ability, or a general market outlook. By contrast, Malmendier and Tate (2005a,b, 2008) consider an overconfident executive to be one who overestimates her skill, believing her firm will outperform market expectations. Such overconfident executives are a subset of our optimistic ones, which, for example, also includes executives who overestimate returns but accurately evaluate their own skill.

model demonstrates that the dividend-capture motivation is universal, affecting even the most optimistic executives. In standard option pricing theory, the ability to dynamically replicate an option's payoff makes an agent's outlook on a stock irrelevant; an agent who is allowed to short stock will hedge the option in the market and may exercise before expiration to capture dividends. We show that an optimistic executive who is unable to hedge an option should nonetheless exercise it whenever an unconstrained agent would. An executive will not delay option exercise beyond a reasonable price boundary because she can always buy shares in the open market to satisfy her desire for equity exposure to the firm.

A significant value of our model is the theoretical sandbox it provides for analyzing option exercise policy and evaluating indicators of executive optimism. The model demonstrates an interplay among optimism, option exercise policy, observable stock parameters, like dividend yield, volatility, and beta, and unobservable characteristics of the executive, such as outside wealth and risk aversion. It therefore provides a deeper understanding of how optimism will affect exercise decisions for executives. For example, an option on a high beta stock should be exercised at higher prices and closer to expiration than an option on a stock with a low beta and equivalent total volatility. It may also be optimal for an optimistic executive to exercise options well before expiration or at seemingly low stock prices if the executive has low outside wealth or is very risk averse. A key prediction of the model is that the retention of shares received from option exercise is positively related to the option's intrinsic value and negatively related to its remaining time until expiration. We confirm these predictions empirically.

Our theoretical analysis shows that an executive will retain shares received from exercising company stock options if and only if she is optimistic. Whereas a characterization of the timing of option exercise as a function of optimism is complicated by the intricate way stock and executive characteristics determine the exercise policy, share retention has a simple interpretation. Whether rebalancing to achieve a more optimal risk-return balance or to capture dividends, non-optimistic executives sell all shares realized from option exercise, while optimistic executives retain a fraction of the shares.

We turn this theoretical result into a novel empirical technique to determine if an executive is, in fact, optimistic. Influential papers by Malmendier and Tate build off the behavioral consistency of executives to infer professional managerial biases from personal investment portfolio decisions. Similarly, our indicator of optimism, *Share Retainer*, is based on observing an executive's stock transactions that coincide with option exercise. We show that executives who hold shares after exercising behave in ways that optimistic executives would be expected to behave in terms of leverage, financing, and acquisitions.[4]

In fact, *Share Retainer* establishes support for key predictions of the theoretical behavioral corporate finance literature for a wider cross-section of firms and a more recent sample period than analyzed in previous studies. Option-portfolio-based indicators of optimism commonly used in the literature have been tested on a sample of large firms, frequently covering the period from 1980 through 1994. We find that these indicators do not provide statistically significant results for our sample of firms, which covers a greater variety of firm sizes from 1996 through 2012. *Share Retainer*, on the other hand, is strongly related to leverage, financing, and acquisitions for this sample.

It is straightforward to compute *Share Retainer*. Regardless of her risk aversion, wealth, or the company's stock characteristics, one need only examine whether an executive sells or retains shares received on option exercise to determine if an executive is optimistic. On the other hand, optimal option exercise time and price thresholds are greatly affected by factors other than the executive's behavioral bias.[5] While it may be possible to calibrate a complicated model that makes predictions about the exercise boundary given observable parameters, such a calibration would be difficult and still omit unobservable parameters. By contrast, *Share Retainer* requires no calibration and is immune to reasonable variation in unobservable traits of the executive. Moreover, indicators that classify executives using delayed option exercise can only do so if a stock reaches a defined price threshold at a specific time before option expiration. For this reason, these indicators may omit optimistic executives whose company's stock experienced a significant price increase, necessitating optimal exercise shortly after an option was granted. Or, they may exclude optimistic executives whose stock did not sufficiently appreciate, leaving out periods of moderate stock market returns. *Share Retainer*, on the other hand, is not only robust to variations in model parameters, it is also relatively insensitive to variation in the stock price history. Yet, even with its benefits, *Share Retainer* still fits into the established context of behavioral consistency (Epstein, 1979), building off the same underlying intuition that inspired the workhorse

[4]The tendency of an executive to purchase shares for her personal portfolio could also indicate optimism. However, as discussed later, *Share Retainer* has several desirable empirical qualities that would not be present in an optimism indicator based on share purchases.

[5]For example, our base case numerical results show that the expected time at which an option is exercised changes by approximately 1.2 years as an executive's coefficient of relative risk aversion increases from 1.10 to 5.00.

indicators in the behavioral finance literature.

Moreover, *Share Retainer* has several desirable empirical characteristics not present in other indicators of executive optimism. First, *Share Retainer* can be computed for a greater variety of firms and with fewer approximation assumptions than indicators based on delayed option exercise. Option exercise delay indicators require information on an executive's full portfolio of options. S&P Capital IQ Executive Compensation (ExecuComp) contains these data only for firms in the S&P 1500 after 2006. For 1992 to 2006, it only has summary statistics, which forces researchers to make assumptions when approximating the underlying option portfolio composition. *Share Retainer* only requires information on trading activity. It can be calculated without any additional assumptions using data provided by Thomson Reuters Insider Filings (Thomson), which covers all publicly traded firms beginning in 1996. Consequently, *Share Retainer* allows researchers to study the effects of executive optimism in small firms. Second, *Share Retainer* exhibits a unique characteristic among optimism indicators: it can identify optimism in transactions in which an executive reduces her dollar exposure to the firm. An executive's outlook, for example, can transition from highly to mildly optimistic due to stock price appreciation. Such a change may cause the executive to sell shares or exercise options, impairing the ability of other optimism indicators to correctly identify that the executive remains optimistic. However, as the executive's option exercise policy still results in retained shares, *Share Retainer* will recognize the executive's residual optimism.

The remainder of this paper is organized as follows. In Section 2, we present a two-period model in which an optimistic executive optimally exercises her options to maximize a general concave utility function. Section 3 extends the model into a continuous time framework. Numerical results from solving the continuous time model are explored in Section 4. Section 5 establishes a taxonomy of optimism indicators, contrasting the empirical accuracy of indicators based on portfolio holdings with those based on portfolio rebalancing transactions. Section 6 discusses the data and the construction of the optimism indicators, including *Share Retainer*. In Section 7, we provide our empirical results. We first test the implications of the model in the data. Then, we examine the relations between *Share Retainer* and corporate decision-making, benchmarking *Share Retainer* against other option-exercise-based indicators of optimism commonly used in the literature. Section 8 concludes.

2. Two-Period Discrete Time Model

We begin by modeling the portfolio choice and optimal exercise problem of a risk-averse executive. There are three dates, $t \in \{0, 1, 2\}$. The executive maximizes expected terminal utility from wealth under an increasing, concave, and twice differentiable utility function $U(\cdot)$ that exhibits decreasing absolute risk aversion. She is endowed with outside wealth W_0, which she can invest in company stock, subject to a short-sale constraint, and in a riskless asset, whose gross return is assumed, without loss of generality, to be 1.[6] The executive is free to sell any initial endowment of company stock. Hence, endowed stock is considered part of her outside wealth. The executive also has a non-transferable and non-divisible pseudo-American option on the company stock with strike price K, which can be exercised at either $t = 1$ or $t = 2$.[7]

The stock earns a gross return of either u or d from $t = 0$ to $t = 1$ and from $t = 1$ to $t = 2$. The stock does not earn an excess return over the risk-free rate. Consequently, the probability of the high state return occurs with probability $q_0 = (1 - d)/(u - d)$. The executive, however, believes that the high state return occurs with probability q, $1 > q > 0$. An executive is optimistic if she believes the stock earns a positive expected excess return, $q > q_0$. This belief is assumed to be constant over time.

Let S_t and W_t denote the time-t stock price and executive wealth, respectively. Assume that the stock pays a dividend $S_1 \cdot \delta \geq 0$ at $t = 1$, such that its post-dividend price is S_1. If the option is exercised at $t = 1$, the executive pays the strike price, obtains the stock instantaneously, receives the dividend, and can then trade the stock in the market. Consequently, the cash flow received from early exercise of the option is equal to $S_1 + S_1\delta - K$.

Define the executive's expected utility from exercising the option at $t = 1$ and investing I in the stock as $U_{1,E}(q, W_1, S_1, I)$, for optimism level q, wealth W_1, and stock price S_1. Similarly, call the expected utility

[6] We consider a continuous time model with an investment opportunity set that includes a market security in the next section.

[7] Executives are not allowed to sell the options they are granted by the company. Section 16(c) of the Securities Exchange Act of 1934 forbids executives from short selling company stock.

from holding the stock option until expiration and investing I in the stock $U_{1,N}(q, W_1, S_1, I)$. Therefore,

$$U_{1,E}(q, W_1, S_1, I) = q \cdot U\left(W_1 + (S_1 + S_1\delta - K) + I(u-1)\right)$$
$$+ (1-q) \cdot U\left(W_1 + (S_1 + S_1\delta - K) + I(d-1)\right), \text{ and}$$

$$U_{1,N}(q, W_1, S_1, I) = q \cdot U\left(W_1 + I(u-1) + [uS_1 - K]^+\right) + (1-q) \cdot U\left(W_1 + I(d-1) + [dS_1 - K]^+\right). \quad (1)$$

Define the optimal investment strategies as

$$I^*_{1,E}(q, W_1, S_1) = \underset{I \geq 0}{\operatorname{argmax}}\, U_{1,E}(q, W_1, S_1, I), \text{ and}$$

$$I^*_{1,N}(q, W_1, S_1) = \underset{I \geq 0}{\operatorname{argmax}}\, U_{1,N}(q, W_1, S_1, I). \quad (2)$$

The corresponding optimal utility functions are

$$U^*_{1,E}(q, W_1, S_1) = U_{1,E}(q, W_1, S_1, I^*_{1,E}(q, W_1, S_1)), \text{ and}$$

$$U^*_{1,N}(q, W_1, S_1) = U_{1,N}(q, W_1, S_1, I^*_{1,N}(q, W_1, S_1)). \quad (3)$$

Therefore, the executive's problem at $t = 1$ is to choose an exercise policy $X \in \{0, 1\}$ that maximizes her expected utility:

$$U^*_1(q, W_1, S_1) = \max_{X \in \{0,1\}} \left\{ X U^*_{1,E}(q, W_1, S_1) + (1-X) U^*_{1,N}(q, W_1, S_1) \right\}. \quad (4)$$

At $t = 0$, the executive must choose how much to invest in company stock. For a given initial stock price S_0 that has a gross return of x from $t = 0$ to $t = 1$, the post-dividend stock price at $t = 1$ is $S_0 x(1-\delta)$. Therefore, the executive's problem at $t = 0$ is to choose an investment $I_0 \geq 0$ that solves:

$$I^*_0(q, W_0, S_0) = \underset{I \geq 0}{\operatorname{argmax}} \Big\{ q \cdot U^*_1\left(q, W_0 + I(u-1), S_0 u(1-\delta)\right)$$
$$+ (1-q) \cdot U^*_1\left(q, W_0 + I(d-1), S_0 d(1-\delta)\right) \Big\}. \quad (5)$$

2.1. The Executive's Option Exercise Decision

In traditional option pricing models, option values are derived from dynamic replication of the option payoffs. An unconstrained agent who owns a non-transferable option on a stock can hedge all unwanted risk created from holding the option by trading in the underlying stock and the risk-free asset. Even though the agent can hedge the option, early exercise may be necessary to maximize total value by capturing dividends paid to shareholders. A short-sale constrained executive is unable to synthetically sell a non-transferable call option. Despite this limitation, the dividend capture motive is universal. The short-sale constrained executive, regardless of her level of optimism or outside wealth, will exercise the option early whenever it is optimal for an unconstrained agent to do so.

Proposition 1. *Define $\bar{S_1}$ as the minimum post-dividend stock price at which an unconstrained agent would prefer early exercise of the option at $t = 1$. For all post-dividend stock prices S_1 greater than or equal to $\bar{S_1}$, it is optimal for a risk-averse executive who is subject to a short-sale constraint to exercise the option early, regardless of the executive's subjective probability, q, of the high stock price state occurring and her wealth:*

$$U^*_{1,E}(q, W_1, S_1) \geq U^*_{1,N}(q, W_1, S_1) \text{ for all } q \in (0, 1) \text{ and } S_1 \geq \bar{S_1} \ .$$

Proof. Appendix A.1. □

The executive may also exercise the option before expiration to achieve a portfolio with a more optimal balance of risk and return. The executive cannot short stock to hedge unwanted risk in the option. By exercising early, the executive indicates that the risk from holding the option outweighs any improvement in expected returns at the given stock price. An executive with lower optimism will perceive a smaller benefit from holding the stock. She will, therefore, have a more unfavorable risk-return trade-off at that stock price and also exercise the option early.

Proposition 2. *For two executives with equal outside wealth and the same utility function, if early exercise of an option is optimal at post-dividend stock price S_1 for an executive with optimism q_h, early exercise would be optimal for an executive with a lower optimism level q_l :*

$$\text{If } U^*_{1,E}(q_h, W_1, S_1) > U^*_{1,N}(q_h, W_1, S_1), \text{ then } U^*_{1,E}(q_l, W_1, S_1) > U^*_{1,N}(q_l, W_1, S_1) \text{ for all } q_l < q_h.$$

Proof. Appendix A.1. □

While Propositions 1 and 2 characterize an executive's exercise decision, they do not easily permit a comparison across executives. In other words, it is not generally true that an optimistic executive holds an option longer or exercises at higher stock prices than a less optimistic executive. Such a comparison is only appropriate when the two executives have the exact same utility functions and outside wealth, and when the underlying stocks are essentially identical. Moreover, optimism is only associated with a tendency to hold the option when an unconstrained agent would not exercise it for dividend capture. Once the stock price is sufficiently high, all executives exercise to capture dividends.

Whether rebalancing to achieve a more optimal risk-return balance or to capture dividends, the executive's decision to hold stock obtained from early exercise of the option is affected by her outlook. An executive who retains some shares received from exercising options must be optimistic. Furthermore, an optimistic executive will retain shares provided her wealth does not suffer a significant negative shock just before the option exercise date.

Proposition 3. *An executive that retains some of the shares received from options exercise is optimistic. Furthermore, an optimistic executive who exercises her options at $t = 1$ will retain some of the shares she receives if her wealth does not suffer a significant shock prior to the exercise decision.*

If $I^*_{1,E}(q, W_1, S_1) > I^*_0(q, W_0, S_0)$ *then* $q > q_0$;

if $q > q_0$ *and* $U^*_{1,E}(q, W_1, S_1) \geq U^*_{1,N}(q, W_1, S_1)$, *there exists a* $\bar{W}_1 < W_0$ *such that for all* $W_1 \geq \bar{W}_1$,

$$I^*_{1,E}(q, W_1, S_1) > I^*_0(q, W_0, S_0).$$

Proof. Appendix A.1. □

In the following section, we analyze a dynamic continuous time model to provide further insight into the executive's option exercise decision and how she structures her portfolio after exercising options. While this section's model provides an accessible framework to develop intuition, it restricts the executive's trading to discrete points in time. By allowing the executive to trade whenever she chooses in a more general, continuous-time model, we establish a tighter link between optimism and the retention of shares: an executive retains shares from option exercise if and only if she is optimistic.

3. Continuous Time Model

We now consider a continuous time, partial-equilibrium version of the model that also includes a market security. This allows us to consider the executive's investment and option exercise decisions in a dynamic setting that includes unhedgeable idiosyncratic and hedgeable systematic risks.

As before, a risk-averse executive is choosing the optimal investment and option exercise policy to maximize utility of terminal wealth under an increasing and concave utility function $U(\cdot)$.[8] At $t = 0$, the executive has outside wealth W_0 and receives n non-transferable options with strike price K. Time evolves continuously from this starting point until the options expire at $t = T$. The options can be exercised only after vesting at $t = t_v$.

The executive's investment opportunity set consists of three securities: a risk-free asset B, a market security M, and the firm's stock S. While she can take unrestricted long positions in all three securities, the executive can only have short positions in the risk-free and market securities. Once again, we impose a restriction that the executive cannot short the firm's stock, ensuring that the executive cannot hedge firm specific risk while holding the option.[9] However, the stock and market may be correlated, allowing the executive to reduce exposure to systematic risk in the non-transferable option. We assume the executive's trading in the stock does not affect prices.

The risk-free asset grows exponentially at the constant instantaneous rate r. The market and stock securities follow geometric Brownian motions, which satisfy the following stochastic differential equations under the physical measure:

$$dM_t/M_t = \mu dt + \sigma_m dB_{1,t}, \text{ and}$$

$$dS_t^P/S_t = (\lambda - \delta)dt + \sigma_s dB_{2,t}, \tag{6}$$

where μ and λ are the instantaneous expected returns on the market and stock, respectively, δ is the stock's

[8]The terminal utility function need not exhibit decreasing absolute risk aversion, which is assumed in the discrete-time model.

[9]Section 16(c) of the Securities Exchange Act of 1934 forbids executives from short selling company stock. In practice, Section 16(b) insiders are subject to short swing profit rules that prevent them from trading in opposite directions within a six month period and making a net profit. However, the omission of this rule from the model should not have a significant impact on the main theoretical results.

instantaneous dividend yield, σ_m and σ_s are the instantaneous volatilities of the market and stock, respectively, and $B_{1,t}$ and $B_{2,t}$ are standard Brownian motions with instantaneous correlation ρ. Without loss of generality, we assume that the market does not pay dividends. Dividends paid by the market do not enter into the executive's portfolio choice or option exercise decisions. We impose the CAPM and assume

$$\lambda = \beta(\mu - r) + r, \tag{7}$$

where $\beta = \rho\sigma_s/\sigma_m$.

The executive is optimistic about the expected return of the company's stock. She believes that the stock has an excess instantaneous drift of ηdt, which it earns in addition to the appropriate market compensation for systematic risk. The executive's optimism is constant ex ante: past returns do not affect her outlook on the stock. Therefore, she makes decisions assuming the stock obeys the following stochastic differential equation under her optimistic probability measure

$$dS_t^E/S_t = (\lambda - \delta + \eta)dt + \sigma_s dB_{2,t}. \tag{8}$$

The executive solves the problem of maximizing terminal utility by choosing a time τ to exercise the options and an investment policy ω_t. We assume that the n options must be simultaneously exercised.[10] Therefore, at time t and stock price S_t, an executive with outside wealth W_t solves the problem

$$f(W_t, S_t, t) = \max_{t_v \leq \tau \leq T, \omega_t^M, \omega_t^S \geq 0} \mathbb{E}\left[V(W_\tau^\omega + n(S_\tau - K)^+, \tau)\right]. \tag{9}$$

By following the investment strategy in the market and stock $\omega_t = (\omega_t^M, \omega_t^S)$, the executive believes her outside wealth W_τ^ω obeys the stochastic differential equation

$$dW_t^\omega/W_t = \left[r + \omega_t^M(\mu - r) + \omega_t^S(\lambda + \eta - r)\right]dt + \omega_t^M\sigma_m dB_{1,t} + \omega_t^S\sigma_S dB_{2,t}. \tag{10}$$

$V(\cdot,\cdot)$ is the indirect utility function representing the solution to the executive's portfolio choice problem

[10] Grasselli and Henderson (2009) provide a theoretical foundation in which a block option exercise policy arises endogenously for a risk-averse agent due to market frictions, such as transaction costs. To achieve tractability, Grasselli and Henderson assume executive options have an infinite life. Hence, while we maintain block exercise of options, we choose not to impose market frictions in our model. This allows us to analyze how the executive's option exercise policy is related to the time remaining until option expiration.

after option exercise:

$$V(W,\tau) = \max_{\theta_t^M,\theta_t^S \geq 0} \mathbb{E}\left[U\left(W_T^\theta\right)\right] \tag{11}$$

$$\text{s.t. } dW_t^\theta/W_t = \left[r + \theta_t^M(\mu - r) + \theta_t^S(\lambda + \eta - r)\right] dt + \theta_t^M \sigma_m dB_{1,t} + \theta_t^S \sigma_S dB_{2,t}, \tag{12}$$

where $\theta = (\theta^M, \theta^S)$ is the investment strategy in the market and stock securities after exercise. Investment strategies ω_t and θ_t are assumed to satisfy standard regularity conditions.

A number of existing papers model the optimal exercise policy of executives (Carpenter, 1998; Carpenter, Stanton, and Wallace, 2010; Grasselli and Henderson, 2009; Hall and Murphy, 2002; Ingersoll Jr, 2006). While the model in this section extends that by Carpenter, Stanton, and Wallace (2010), we make two contributions to the broad literature. First, existing models only consider rational executives. By allowing for a behavioral bias, we are able to analyze executive beliefs that are thought to also influence corporate decision-making. Second, other models exogenously specify the executive's holdings of company stock. With an optimistic executive, fixing the executive's portfolio can lead to incorrect implications. For example, such a model could predict that an optimistic executive holds on to the option for too long as a means of maintaining exposure to company equity, when in fact she would exercise the option and simply purchase an optimal amount of company stock if she were allowed to do so. Allowing for non-trivial endogenous portfolio choice also creates a more realistic setting in which the executive must trade-off the market security and company stock in her portfolio.

3.1. The Executive's Option Exercise Decision

Section 2 demonstrates that dividend capture is optimal for an executive who, due to a short-sale constraint, is unable to synthetically sell a non-transferable call option in discrete time. Dividend capture is also optimal for the executive in continuous time. Define the continuation region D as the set of values (W, S, t) for which the executive does not exercise the options as

$$D = \left\{(W,S,t) : t < t_v \text{ or } f(W,S,t) > V(W + n(S-K)^+, t)\right\}. \tag{13}$$

Consider the parallel investment and option exercise problem for an unconstrained, non-optimistic agent who is able to short company stock. The agent has a non-divisible, non-transferable option on the company stock. Let f^u and V^u be the unrestricted forms of problems (9) and (11), respectively; precise definitions are provided in the proof in Appendix A.2. Define the continuation region D^u, in which the unconstrained agent does not exercise the options as

$$D^u = \left\{(W, S, t) : t < t_v \text{ or } f^u(W, S, t) > V^u(W + (S - K)^+, t)\right\}. \tag{14}$$

The continuation region for a constrained executive lies within the continuation region for an unconstrained agent. In other words, whenever it would be optimal for an unconstrained agent to exercise the option before expiration, it is also optimal for a constrained executive to do so.

Proposition 4. *The continuation region D of the constrained, optimistic executive is a subset the continuation region D^U of an unconstrained, non-optimistic agent:*

$$D \subseteq D^u.$$

Proof. Appendix A.2. □

Proposition 4 shows that dividends can significantly alter the timing of option exercise, affecting both optimistic and non-optimistic executives. When a stock pays a dividend, D^u is bounded and early exercise may be optimal even if the executive is very optimistic. On the other hand, D^u is unbounded if the stock does not pay a dividend. A non-optimistic executive may, therefore, optimally hold options until expiration. For example, this can occur when an executive with decreasing absolute risk aversion has large outside wealth.

Critically, the executive's decision to retain shares received from option exercise is determined exclusively by her outlook on the stock. At exercise, an optimistic executive will exchange exposure to the company stock embedded in the option with explicit exposure through shares. Non-optimistic executives, on the other hand, will exercise the option and move to an optimal portfolio that does not include company stock. These decisions hold whether the option exercise decision is driven by the executive's desire to adjust her risk-return profile or to capture dividends.

Proposition 5. *The executive retains shares received from option exercise if and only if she is optimistic.*

Proof. Appendix A.2. □

This theoretical result establishes a direct link between the retention of shares received from option exercise and executive optimism, which holds no matter when the options are exercised. On the other hand, the links between optimism and the executive's timing of option exercise and investment policies are not as definite. Optimistic executives may want to delay option exercise, but may need to exercise the option to offset lost wealth or to capture dividends. Similarly, an optimistic executive will want to purchase shares in the company, but may sell shares if her outside wealth decreases.

In fact, the executive's decision to retain shares on option exercise will hold even if she changes her beliefs about the stock's excess return based on the realized stock price path, learning from market information, or for other reasons. The proof of Proposition 5 uses properties of the indirect utility function instantaneously after exercise that flow through to the indirect utility function instantaneously before exercise. Hence, even if the executive's optimism varies over time, her decision to retain shares only depends on whether she is optimistic at the time of option exercise.

The presence of this outside portfolio choice problem within an optimal option exercise problem makes an analytical characterization of the option continuation region difficult. Highly non-intuitive results have been found in similar problems, such as positive investment in assets with negative expected abnormal returns (Henderson and Hobson, 2008) and split continuation regions (Carpenter, Stanton, and Wallace, 2010). Other researchers generally achieve analytical tractability by assuming the executive invests all her wealth in the risk-free asset (or a fixed portfolio) when deriving theoretical statements. However, the interdependence of the executive's endogenous portfolio decision and the option exercise policy is at the heart of our economic problem. Therefore, similar to Carpenter, Stanton, and Wallace (ibid.), we use numerical analysis to characterize how the option's continuation region changes with executive and market characteristics.

4. Numerical Results

Option exercises occur in the continuous time model for two reasons: portfolio rebalancing and dividend capture. As demonstrated in the previous section, the optimal dividend capture policy is shared by all executives. However, the option exercise policy that achieves the best balance of risk and return will vary across executives.

We explore how the executive's optimal option exercise policy is affected by observable parameters of the stock-price process, like dividend yield, beta, and volatility, and unobservable characteristics of the executive, such as wealth and risk aversion. Assuming that the indirect utility function $f(W_t, S_t, t)$ is sufficiently smooth, in the continuation region it satisfies

$$\max_{t_v \le \tau \le T, \omega_t^M, \omega_t^S \ge 0} \mathcal{L}^\eta f(W_t, S_t, t) = 0, \tag{15}$$

where the operator $\mathcal{L}^\eta$ is defined as

$$\begin{aligned} \mathcal{L}^\eta = {} & f_t + f_S S\left(\lambda + \eta - \delta\right) + f_W W\left(r + \omega_t^M(\mu - r) + \omega_t^S(\lambda + \eta - r)\right) \\ & + \frac{1}{2} f_{SS} S^2 \left(\omega_t^S \sigma_S\right)^2 + \frac{1}{2} f_{WW} W^2 \left((\omega_t^M \sigma_M)^2 + 2\rho\omega_t^M \omega_t^S \sigma_M \sigma_S + (\omega_t^S \sigma_S)^2\right) \\ & + f_{SW} W S\left(\omega_t^M \rho \sigma_M \sigma_S + \omega_t^S \sigma_S^2\right). \end{aligned} \tag{16}$$

$\mathcal{L}^\eta$, therefore, describes the evolution of the indirect utility function under the optimistic probability measure that is used by the executive for decision-making.

We solve the Partial Differential Equation (PDE) in Eq. (15) numerically, using a Du Fort-Frankel (1953) explicit, leapfrog finite difference scheme.[11] We specify that the executive's preference over terminal payouts exhibit constant relative risk aversion $U(W) = \frac{1}{1-\gamma} W^{1-\gamma}$, where γ is the coefficient of relative risk aversion. The first-order conditions for the PDE and the executive's short-sale constraints imply the optimal holdings in the stock and market securities. To find the optimal exercise policy, we compare the continuation indirect utility to that achieved by exercising the options. Option exercise is optimal when the indirect utility from exercise exceeds that from continuation. See the online appendix for details on our numerical approach.

4.1. The Executive's Option Exercise Policy

An executive's optimal option exercise policy depends on three state parameters: the executive's outside wealth, the stock price, and the time remaining to option expiration. However, detailing a three-dimensional

[11] As an explicit scheme, the Du Fort-Frankel method is well suited to our model, in which an executive solves a non-trivial portfolio choice problem. It is unconditionally stable (unlike most explicit finite difference methods), but requires using a sufficiently small time step for consistency (Gustafsson, Kreiss, and Oliger, 1995). We verify the accuracy of our numerical method by closely replicating the results of Carpenter, Stanton, and Wallace (2010).

policy function provides little insight into the executive's option exercise decision. Instead, we analyze how conditional expectations of measures that encapsulate key properties of the exercise policy vary with optimism and other model parameters.

Optimistic executives exercise options closer to expiration and at higher underlying stock prices than non-optimistic executives. To evaluate how this tendency changes with characteristics of the executive and stock price parameters, we consider two separate statistics. The first is the remaining time to expiration when the option is exercised. At exercise time τ, the remaining time to expiration is defined as $T - \tau$. The tendency of an optimistic executive to delay exercise is captured by a decrease in the remaining time to expiration on exercise. The second statistic is the ratio of the intrinsic value of the option at exercise to the value of a similar freely-traded American option (similar to Bettis, Bizjak, and Lemmon (2005)). At exercise time τ, the value ratio is defined as $(S_\tau - K)^+/P_\tau$, where S_τ is the stock price, K is the option's strike price, and P_τ is the market price of an American option with the same characteristics as the executive's option. This ratio assesses the way optimism simultaneously affects the timing of and the required stock price for option exercise. Optimistic executives will receive a higher fraction of option value at exercise.[12]

While non-optimistic agents will choose to sell all shares obtained on exercise, optimistic executives will want to retain some (Proposition 5). We examine the effect of optimism on the expected proportion of shares retained by the executive on exercise of the option, defined as $(\theta^S_{\$,\tau} - \omega^S_{\$,\tau})/(n \cdot S_\tau)$, where n is the number of options exercised and $\theta^S_{\$,\tau}$ and $\omega^S_{\$,\tau}$ are the dollar amounts held by the executive immediately after and immediately before option exercise, respectively.

We compute the expected value of the measures described above, conditional on exercise, using the Du Fort-Frankel finite difference method. Define the time-t operator $\mathbb{E}^P_t$ as the expectation under the physical probability measure and ∂D as the boundary of the continuation region. The expected value of a measure X conditional on option exercise is given by

$$\mathbb{E}^P_t \left[X | (W_\tau, S_\tau, \tau) \in \partial D \right] = \frac{\mathbb{E}^P_t \left[X \cdot 1_{(W_\tau, S_\tau, \tau) \in \partial D} \right]}{\mathbb{E}^P_t \left[1_{(W_\tau, S_\tau, \tau) \in \partial D} \right]}, \tag{17}$$

where $1_{(W_\tau, S_\tau, \tau) \in \partial D}$ is the indicator function that takes the value of 1 if (W_τ, S_τ, τ) is on the boundary of

[12] We also considered the ratio of the exercise price of the option to the option's strike price as an alternate statistic that identifies the effect of optimism on exercise prices separately from timing of exercise. Untabulated results show that the effect is nearly identical to that from the value ratio.

the continuation region, and 0 otherwise. Once the executive's strategy is known by numerically solving Eq. (15), it is possible to solve for the conditional expected values: remaining time until expiration, value ratio, and proportion of stocks retained on exercise. The numerator and denominator of Eq. (17) both satisfy the partial differential equation

$$\mathcal{L}^0 \mathbb{E}_t^P \left[X \cdot 1_{(W_\tau, S_\tau, \tau) \in d} \right] = 0, \tag{18}$$

where $\mathcal{L}^\eta$ is the operator introduced in Eq. (16). $\mathcal{L}^0$ describes the evolution of an expectation under the physical probability measure.[13] All partial differential equations are solved using the optimal portfolio investment policy ω^* and optimal option exercise policy τ^* implied from solving Eq. (15).

4.2. The Impact of Optimism on Exercise Behavior

We use univariate modifications of a base case to study how the executive's optimal option exercise policy varies with executive and stock characteristics. In our baseline case, the executive has a relative risk aversion coefficient of 3. At inception, the executive has outside wealth of 1 and receives 1 non-transferable option. The stock price is initially 1 and the option is granted at-the-money. The stock has a instantaneous standard deviation of 40%, a beta of 1.2, and pays a dividend yield of 3%. The risk-free rate is 5%. The market security has a risk premium is 8% and a 20% instantaneous standard deviation.

Fig. 1 plots the early exercise boundary for different levels of optimism and outside wealth. For each wealth level, as optimism increases, the exercise boundary moves outward to higher stock prices. This supports the intuition used in Malmendier and Tate (2005a,b) that optimism is associated with an executive's tendency to exercise options at high stock prices and close to expiration. However, as can be seen, unobservable parameters, such as the executive's outside wealth, greatly affect the optimal exercise boundary and its relation with optimism.

Table 1 shows how the remaining time until expiration at option exercise is affected by various model parameters. Optimistic executives perceive a benefit from being exposed to the risk in the option, resulting in exercises closer to expiration. Univariately, remaining time until expiration decreases as the stock's beta and

[13] The value of the freely traded American option value, which appears in the denominator of the value ratio, does not depend on the exercise and portfolio choice policies of the executive. Instead, in its continuation region, the market value is governed by the standard Black-Scholes option pricing PDE.

executive outside wealth increase. But it increases with stock dividend yield, stock volatility, and executive risk aversion. The cost from bearing risk plays a critical role in these relations. Risk-tolerant and wealthy executives hold the option longer than others because bearing risk is less costly to them. Since executives can choose to hedge systematic risk, these costs arise from idiosyncratic risk. When the stock's idiosyncratic risk is low, such as when it has high beta or low volatility, the option is held longer.

The degree to which the remaining time until expiration at option exercise changes with optimism depends on model parameters. In the range of parameters tabulated, remaining time until expiration at option exercise shows greater sensitivity to optimism for stocks with higher beta and for executives with greater outside wealth, for example. Interestingly, parameters may not affect this sensitivity monotonically. Consider the effect of executive wealth. The exercise policy for an executive with very high wealth would be close to that of an unconstrained risk-neutral agent, regardless of her optimism. Therefore, remaining time until expiration at option exercise would demonstrate low sensitivity to optimism for both high and low executive wealth levels, but show high sensitivity to optimism for moderate executive wealth. Notably, the non-optimistic executive's remaining time until expiration at option exercise does not have a stable baseline, independent of model parameters. The results, therefore, suggests that an indicator of optimism based on timing of stock option exercise will be noisy.

The cost and benefits from bearing risk also drive how the expected value ratio at exercise relates to model parameters, as seen in Table 2. When the cost of bearing risk is low, executives are willing to hold on to the options longer and at higher stock price levels. Consequently, the expected value ratio at exercise increases as the stock's beta and the outside wealth of the executive increase. Executive risk aversion and stock volatility are negatively associated with the expected value ratio at exercise. As discussed earlier, optimistic executives perceive a benefit from being exposed to the risk in the option. As a result, the expected value ratio at exercise increases with optimism.[14]

Table 3 shows how the expected proportion of shares retained on option exercise relates to executive optimism. Optimistic executives desire exposure to company stock. Hence, the expected proportion of shares

[14] The percentage of a call option's value represented by its intrinsic value increases with the stock's dividend yield. As such, the value ratio is a mechanical function of the dividend. While options on dividend paying stocks are exercised at lower prices than options on similar non-dividend stocks, the executive receives a higher percent value of the option's total value conditional on exercise. This explains why the expected time to exercise decreases with dividends, while the expected value ratio at exercise increases as the dividend yield increases.

retained on exercise increases with optimism. For optimistic executive, share retention increases with the stock dividend yield, the stock beta, and the executive's outside wealth, but decreases with stock volatility and executive risk aversion.

Critically, non-optimistic executives sell all the shares received from exercise. Stock parameters and characteristics of the executive affect how many shares are retained by optimistic executives. But, if an executive retains any shares acquired from exercising the options, she must be optimistic. Therefore, the proportion of shares retained on exercise allows for clear empirical inferences of executive optimism from option exercise activity, as it has a natural baseline of zero.

5. Portfolio-Based Empirical Optimism Indicators

In the bulk of current empirical work, an executive is deemed optimistic based entirely on her portfolio holdings of her company's securities: an approach consistent with the implications of theoretical models of the behavior of rational executives. Malmendier and Tate, for example, use the Hall and Murphy (2002) option exercise model to determine a rational executive's optimal option exercise policy. They consider an executive to be optimistic if she chooses not to exercise an option when the Hall and Murphy model says she should. However, indicators developed within this framework can capture factors other than the executive's optimism. For example, as we have already seen, the thresholds that Malmendier and Tate use actually increase with executive wealth and risk tolerance. As a result, those thresholds cannot be properly applied without first taking those factors into account.

This paper suggests an alternative. Instead of looking at an executive's portfolio holdings, one can instead analyze the transactions an executive makes when rebalancing her portfolio. Indicators of executive optimism derived within this framework can distinguish optimistic from non-optimistic executives, irrespective of model parameters. *Share Retainer*, for example, considers an executive that retains any shares from option exercise to be optimistic.[15]

In the remainder of this section, we analyze how successful these frameworks are in identifying executive

[15] While we emphasize *Share Retainer* in our empirical tests, other optimism indicators can be derived from rebalancing activity. For example, it may be possible for future researchers to examine the way an executive rebalances her portfolio when restricted stock vests. This would require information on the exact dates on which restricted stocks vest, which is currently not available in any of the standard executive compensation databases like ExecuComp and Thomson Financial.

optimism in a variety of empirical scenarios. To simplify terminology, we call the first approach the portfolio "holdings" framework and the second the "rebalancing" transactions framework. The numerical results of Section 4 are used to characterize the frameworks' performance under various model parameters and stock price histories. We also consider the role of relevant institutional details that are not part of the model. As empirical indicators of executive optimism will surely evolve, we contrast the frameworks to ensure the analysis has relevance to future researchers. While no framework can correctly classify executives in all possible scenarios, the discussion demonstrates that optimism indicators derived from executive rebalancing activities have advantages over those derived from executive portfolio holdings.

5.1. Model parameters

The holdings framework for optimism indicators requires a precise parameterization of an underlying portfolio choice model. Fig. 1 illustrates several issues with this approach. Consider, for example, an option-based continuation-region rule with the calibrated model parameters used to create panel (c). A possible classification rule implied by this calibration is to consider as optimistic any executive who holds an option that is more than 100% in the money with six years remaining until expiration. However, if the executive's outside wealth is not properly calibrated, the model may misclassify the executive. An executive with 66% lower wealth who believed the stock would outperform by 6% annually would exercise the option before it reached this threshold, as seen in panel (a). Consequently, she would not be classified correctly by the rule despite being significantly optimistic. While the plots do not display executive pessimism, panel (d) implies that this optimism classification rule might even classify an executive who expected company stock to underperform the market to be optimistic provided she was sufficiently wealthy. Therefore, high executive wealth is associated with type I errors (a non-optimistic executive is categorized as optimistic) and low executive wealth is associated with type II errors (an optimistic executive is not identified as such).

In general, any categorization rule based on portfolio holdings may correlate with model parameters other than optimism, leading to both type I and type II errors. Table 1 summarizes the sensitivity of the continuation-region to model parameters. In particular, we see that risk-tolerant and wealthy executives delay option exercise and, therefore, tend to get classified as optimistic. Table 1 also indicates that an executive whose company stock pays low (or no) dividends, has a high beta, or has low idiosyncratic volatility will also delay option exercise and tend to be classified as optimistic. Critically, the classification errors are not random, but instead are correlated with underlying model parameters. As these relations are non-linear and some parameters are unobservable, it is difficult to properly control for underlying distortions in the holdings framework. Hence, holdings framework indicators may lead to incorrect empirical attribution in some settings.

Optimism indicators from the rebalancing perspective, on the other hand, can be robust to model parameters. For example, share retention is positive for optimistic executives regardless of parameter values, as shown in Proposition 5 and demonstrated numerically in Table 3. Non-optimistic executives never retain shares. Consequently, while model parameter heterogeneity can lead to type I and type II errors in the holdings framework, it does not necessarily do so in the rebalancing framework.

The parameter robustness of the rebalancing framework provides empirical benefits in addition to the reduction of type I and type II errors. In some empirical settings, for instance, it may be desirable to update executive optimism classifications dynamically. While optimism about one's abilities may be an personality trait (Scheier, Carver, and Bridges, 1994; Svenson, 1981; Weinstein, 1980), optimism for a corporate executive is measured relative to firm performance. Thus, while an executive's underlying nature may not change, the context in which the executive operates will change. An executive who is optimistic when her company stock is trading at $5 per share may no longer be optimistic if the stock price were to quickly jump to $100 per share. Graham and Harvey (2001) show that CFOs consider stock undervaluation and overvaluation when deciding to issue equity, while Baker and Wurgler (2002) provide evidence that firms know when their stock is overvalued and adjust financing policy according. Optimism indicators that do not update with changing environments assume, in essence, that executive optimism is pathological, since it does not change with the situation. It is very difficult to recognize changes in executive optimism with holdings-based optimism indicators because the underlying calibration is so sensitive to model parameters. On the other hand, an executive can transition between optimistic and non-optimistic classifications quite easily within the rebalancing framework.

5.2. *Stock price path*

Since both frameworks consider executive security portfolios, they may misclassify executives, or be unable to classify them, depending on the particular stock price path. For example, consider option-based optimism indicators. It may be that a particular stock only reaches an option exercise boundary for the first time as it is approaching expiration. Unfortunately, as seen in Fig. 1, the exercise boundaries for different optimism levels are very close to one another near expiration. In fact, in these situations, even exercise boundaries for pessimistic executives are close to those of optimistic executives. Therefore, any executive who does not exercise the option with perfect timing, perhaps due to inattention, will be classified as optimistic, leading to type I errors. A rebalancing framework indicator will not make these classification errors. Provided the option is exercised, the rebalancing framework will permit correct classification of executive optimism. On the other hand, a stock may breach a rational executive's option exercise threshold and then decline in value, resulting in an option expiring out of the money. Since an optimistic executive will not exercise an option on a stock following this price path, a holding framework optimism indicator will correctly recognize the executive as optimistic, while the rebalancing framework will be unable to classify her. As a final example, consider a stock whose price decreases after an executive receives an option grant and remains below the strike price throughout the life of the option. In this case, neither of the frameworks would be able to classify the executive as optimistic.[16]

5.3. *Institutional details*

An executive's desire to minimize taxes, cash needs, and restricted stock holdings can drive portfolio and rebalancing decisions away from optimality and, therefore, create classification errors for optimism indicators. We discuss the extent to which each of these factors induce errors for holdings and rebalancing framework indicators below.

Taxes create an incentive for an executive to opportunistically match profits from transactions in company stock and options to their other income. For example, an executive may time option exercise so that the

[16] While this price-path discussion emphasizes option-based optimism indicators, similar arguments hold for indicators based on characterizing the executive's stock holdings. The only scenario in which a stock rebalancing indicator provides a benefit is when the stock price repeatedly declines. An executive that chooses to purchase stock to retain desired exposure to company returns may be classified as optimistic about future returns.

realized income occurs in a year in which her other income is low. Thus, optimization of tax treatment can distort the timing of portfolio transactions, which can cause the holdings approach to make both type I and type II errors. However, taxes should have no impact on an executive's rebalancing policy. Companies generally grant executives non-qualified options. When exercised, the difference between the stock price and the strike price of the option is treated as taxable income in that year. From a tax perspective, retained shares are equivalent to simply buying the stock in the market on the exercise date. Given this, the executive does not have any additional tax incentive to hold onto the stock obtained from exercise, even if the tax system treats long- and short-term capital gains differently.

An executive with an immediate need for cash has an incentive to sell stock or exercise options. Therefore, holdings-based optimism indicators may misclassify an optimistic, cash-needy executive as non-optimistic (a type II error). Rebalancing framework indicators may also misclassify these executives because the liquidation of portfolio assets will appear similar to portfolio rebalancing. However, both types of indicators should function correctly for executives who do not need cash immediately, even if they are cash constrained. For example, an executive's lack of sufficient liquid assets to pay the strike price and taxes prior to option exercise would not affect an indicator derived under the rebalancing framework. *Share Retainer*, for instance, only requires that an executive retain some shares from option exercise to be considered optimistic. Thus, an executive who sells a portion of her shares to fund the payment of the strike price and taxes will still be classified as optimistic.

Restricted stock will also distort the portfolio and rebalancing strategies of executives. An executive with more restricted stock than that parameterized in a calibrated model may sell more stock and exercise options sooner than predicted, leading to possible type II errors. Opposite distortions will hold for an executive with less restricted stock than calibrated, leading to type I errors. Hence, holdings-based indicators may misclassify executives if restricted stock deviates from the model calibration. Rebalancing indicators, while not completely immune to these distortions, are relatively robust. For example, a non-optimistic executive sells all shares received from option exercise, regardless of the presence of restricted stock in her portfolio. An optimistic executive with restricted stock may retain fewer shares from option exercise than she would have without the restricted stock. At the extreme, an optimistic executive with a large amount of restricted stock may sell all the stock acquired on option exercise. Therefore, while type I errors should not occur for a rebalancing framework optimism indicator, type II errors can occur, but should be less frequent than under the holdings framework.

Finally, executive stock and options are generally granted subject to a vesting period, prior to which the securities cannot be traded or exercised. This vesting schedule necessitates a "burn-in" period for all types of optimism indicators, during which an executive cannot be classified. This issue is not particularly material for rebalancing framework optimism indicators, which have the potential to categorize an executive as soon as a security vests. Options, for example, generally vest three years after the grant date, but often vest sooner if the firm grants options with a staggered vesting schedule. However, holdings indicators can have significant burn-in periods. Option-based holdings indicators have, to date, been implemented such that a single vesting horizon is chosen to reasonably ensure that all options have vested. Malmendier and Tate's option-based optimism indicators can only begin to classify an executive when an option has five years until expiration, which is typically five years after the first option grant.[17]

6. Data

We evaluate the theoretical implications of the model and the empirical performance of optimism indicators using a sample of firms in the S&P 1500 stock market index and their CEOs. The tests of the model's predictions require information on CEO option exercises and equity trades, CEO compensation, and stock characteristics. Our tests of optimism indicators examine canonical results in the behavioral corporate finance literature examining how CEO biases affect firm leverage, financing, and acquisitions. Therefore, for the firms in our sample, we require information about financial performance, debt issuance, secondary equity offerings, acquisition activity, and corporate governance. The sample begins in 1996, the earliest year for which we observe CEO option exercise activity, and ends in 2012.

Our sample construction begins with the annual firm-CEO observations present in two S&P Capital IQ databases, Compustat North America (Compustat) and Executive Compensation (ExecuComp). We take firm financial information from the Compustat's annual fundamentals table. CEO overall compensation data

[17]While the holdings approach can be generalized with specific exercise price thresholds for all possible vesting periods, this had not been done to date. Any such implementation may not be possible due to data availability, and the calibrated price thresholds would still suffer the parameterization and stock history issues discussed previously.

and employment history is provided by ExecuComp. We use Thomson Reuters SDC Platinum to determine if a firm engaged in an acquisition or held a seasoned equity offering in a fiscal year. ISS Governance Services RiskMetrics is our source for corporate governance data covering corporate constitutional and anti-takeover provisions. Stock return, volatility, and dividend characteristics are derived from The Center for Research in Security Prices (CRSP) daily data.

6.1. Empirical Indicators of Optimism

Our primary indicator of CEO optimism in the empirical tests is *Share Retainer*. This indicator derives from Proposition 5, which implies that an executive who retains some of the shares received on option exercise must be optimistic.[18] *Share Retainer* is implemented on an annual basis. A CEO who retains some shares acquired from option exercise during a year is given a *Share Retainer* value of 1. All other CEOs are given a *Share Retainer* value of 0. We emphasize *Share Retainer* in the theoretical tests, as the model makes clear predictions relating the retention of shares to the value ratio realized at, and the timing of, option exercise.

The model suggests that *Share Retainer* will be less noisy than other indicators of optimism. We assess this by benchmarking its empirical performance to indicators of CEO optimism in the established behavioral corporate finance literature. Malmendier and Tate (2005a,b) introduce two indicators of CEO optimism, *Holder 67* and *Longholder*.[19] *Longholder* is a time-constant CEO characteristic; the indicator uses information from a CEO's full tenure and, therefore, includes forward-looking information. *Post-Longholder*, first used in Malmendier and Tate (2008), refines the *Longholder* indicator, allowing for time variation for a CEO and deriving from backward-looking information only. We, therefore, use *Holder 67* and *Post-Longholder* as benchmark empirical indicators of optimism.

Details on the construction of all three optimism indicators follow.

[18] Within the rebalancing framework, an option-based optimism indicator has advantages over a stock transaction-based indicator. For example, while stock purchases may be consistent with optimism, it is impossible to differentiate stock sales that arise when an executive is not optimistic from those that arise when an executive transitions from highly to mildly optimistic. As a result, a stock transaction-based indicator may be unable to recognize optimism for an executive whose company stock significantly appreciates. An option-based indicator, such as *Share Retainer*, can correctly identify optimism in these cases. On the other hand, a stock purchase indicator may have advantages when an executive buys stock in a company that continuously loses value because option exercise cannot occur below the strike price. Continuous value loss is rare in the sample, as it generally results in CEO turnover. In untabulated results, we find that incorporating information about stock purchases into *Share Retainer* adds no predictive value.

[19] The overconfident CEOs of Malmendier and Tate are a subset of our optimistic ones. To Malmendier and Tate, an overconfident overestimates her skill, believing her firm will outperform market expectations.

6.1.1. Share Retainer

The Thomson Reuters Insider Filings (Thomson) Insider Filings database provides the option exercise and stock trading data used to compute *Share Retainer*. Thomson compiles these data from SEC filings made by firm insiders. Thomson evaluates the figures by referencing external sources, assigning "cleanse indicators," which rate the reported data's accuracy and reasonableness. We keep only those records that Thomson either (i) believes are accurate with a high degree of confidence (indicators R, H, and C) or (ii) cleaned or improved, but could not verify from secondary sources (indicators L and I). We drop all records that are an amendment to a previous report.

We link the CEOs in our sample to Thomson via a computer-assisted, manual name matching process. Because Thomson identifiers are not always unique and CEOs may trade through multiple legal entities, we find all the Thomson identifiers associated with each CEO to ensure we get an comprehensive picture of his or her trading activity. A detailed description of the matching process is provided in the online appendix.

To compute *Share Retainer*, we first analyze days on which the CEO exercises an option.[20] On these days, we compute the number of shares retained as the difference between the number of shares obtained from exercise and the number of shares sold. This value is set to zero if the CEO sold more shares than were obtained from exercise. Then, we aggregate the number of shares retained and the number of shares obtained from exercise over each CEO-fiscal year observation. The fraction of shares retained from option exercise is defined as the total number of shares retained divided by the total number of shares received on option exercise. *Share Retainer* is defined to be 1 if the fraction of shares retained from option exercise during a fiscal year exceeds 1% and 0 otherwise. The 1% threshold ensures that the indicator only captures those cases when a CEO holds a non-trivial portion of shares received from option exercise. *Share Retainer* is set to its most recent computed value for years in which a CEO did not exercise an option.

6.1.2. Holder 67 and Post-Longholder

Malmendier and Tate rely on the Hall and Murphy (2002) option exercise model to derive the *Holder 67* and *Post-Longholder* indicators. For a specific parameter set, the Hall and Murphy model predicts that the

[20] In Thomson, an option is marked with a derivative identifier equal to one of the following: 'OPTNS', 'EMPO', 'NONQ', 'ISO', 'CALL', 'DIRO', 'WT', or 'DIREO.'

CEO should exercise options with five years remaining to expiration that are more than 67% in the money.[21] Therefore, *Holder 67* classifies any CEO who delays exercising such an option as optimistic, taking a value of 1. The parameterized model also predicts that CEOs should also exercise options with one year remaining to expiration that are more than 40% in the money. The *Post-Longholder* indicator takes a value of 1 at the start of the first fiscal year in which the CEO's portfolio includes such an option. Per Malmendier and Tate, both indicators retain the value of 1 for all subsequent fiscal years once a CEO has delayed exercise on a corresponding option.[22]

We compute *Holder 67* and *Post-Longholder* using CEO option portfolio holdings derived from ExecuComp data, tracking the strike price, expiration date, and number of underlying shares for all outstanding options held by a CEO as of each fiscal year. These data are directly observable starting in 2006, when Financial Accounting Standards Board (FASB) standard FAS 123R required companies to report details on all outstanding equity awards held by key executives. For the sample period before FAS 123R took effect, companies provided detailed information on new option grants, but only summary statistics on outstanding option portfolios each fiscal year. To determine the outstanding option portfolios, we follow a dynamic portfolio simulation algorithm similar to that developed by Hall and Liebman (1998). For each CEO in our sample, we work through the history of option grants and exercises chronologically. For each fiscal year, we take the CEO's prior outstanding option portfolio and add any new option grants. We then exercise options until we reach the reported total number of unexercised options held by the CEO at year end. We prioritize the options using a closest-to-expiration, lowest strike price decision rule, which is designed to approximate a rule whereby the CEO minimizes the loss of the time value of the option at exercise. We adjust the number of shares underlying options and strike prices for stock splits at all times during the process. Appendix B provides full details on the portfolio determination algorithm.

[21] The CEO is parameterized with constant relative risk aversion utility and a risk aversion coefficient of 3. At the model's inception, the CEO is granted 5,000 call options, which are issued at par with a strike price of $30. Initial CEO outside wealth is $5 million, with 67% invested in company stock and 33% in a risk-free asset. The CEO shareholdings are assumed to be time-constant. That is, the CEO share ownership is exogenously fixed at approximately 111.7 thousand shares, regardless of any changes to her outside wealth over time.

[22] Hall and Murphy (2002) model a rational executive who has an exogenously fixed share ownership in company stock. The model, therefore, determines the optimal exercise policy for an agent with rational expectations, but subject to exercise timing distortions created by exogenous stock holdings. Optimistic executives should exercise options closer to expiration and at higher stock prices than rational executives. Yet, a rational agent who could endogenously choose her stock portfolio would also exercise options closer to the expiration date and at higher stock prices than an executive in their model. Therefore, it is not clear whether delaying option exercise beyond the Hall and Murphy thresholds indicates executive optimism or simply an ability to endogenously invest outside wealth.

6.2. Sample Description

We obtain an initial sample of 28,671 firm-year observations from Compustat, covering the period between 1996 and 2012. ExecuComp data indicates that 5,884 executives served as a CEO of a company in that sample. We are able to find a corresponding identifier in Thomson for 5,662 (96.2%) of these CEOs. Nearly half of the unmatched CEOs appear to have held the position on an interim basis, serving less than a year as CEO.

A CEO enters the sample once one of the three optimism indicators, *Share Retainer*, *Holder 67*, or *Post-Longholder*, can discriminate between optimistic and non-optimistic CEOs. 54.9% of the CEOs enter the sample during a year in which both *Share Retainer* and *Holder 67* are first available. When this occurs, *Post-Longholder* is assigned a value of 0. 31.5% of the CEOs enter in a year in which they exercised an option, but did not have an option in their portfolio meeting the classification criteria of either *Holder 67* or *Post-Longholder*. For CEOs who have not yet been classified for *Holder 67* or *Post-Longholder*, exercising an option indicates that the CEO will not use the option to meet the *Holder 67* and *Post-Longholder* requirements. Therefore, the CEO is given a value of 0 for both indicators. The majority of the remaining CEOs, 13.6% of the sample, enter as soon as they have an option meeting the *Holder 67* classification criteria. For these cases, both *Share Retainer* and *Post-Longholder* are set to 0. Only 15 CEOs are first classifiable by *Post-Longholder*. In these cases, *Share Retainer* and *Holder 67* are set to 0.

The selection approach ensures the optimism indicators are compared in identical empirical contexts. *Holder 67* and *Post-Longholder* are traditionally implemented without consideration of the CEO's option exercise history. As a CEO cannot use an exercised option to meet the classification criteria used by these indicators, inclusion of option exercise data should provide meaningful information and improve the robustness of these indicators. In untabulated results, we find supporting evidence that this is the case: *Holder 67* and *Post-Longholder* perform better using the implementation described above than when implemented solely with option holdings data. On the other hand, *Share Retainer* is only defined when options are exercised. A portfolio meeting the *Holder 67* or *Post-Longholder* does not provide information to assign a CEO a *Share Retainer* classification. Our procedure of setting *Share Retainer* to 0 in such cases may result in optimistic CEOs being categorized as non-optimistic. In untabulated results, we find that the empirical results with

Share Retainer are economically and statistically unchanged when these observations are omitted.

The three optimism measures exhibit modest correlation in classifying CEOs. For each optimism indicator, we define a new CEO-level variable that takes a value of 1 if the CEO is ever classified as optimistic and 0 otherwise. *Share Retainer* classifications have a correlation coefficient of 0.18 with those by both *Holder 67* and *Post-Longholder*. The correlation between the classification of *Holder 67* and *Post-Longholder* is 0.37.

7. Empirical Results

In this section, we test the model's theoretical implications in the data. We also evaluate *Share Retainer* as a tool for understanding leverage, financing, and acquisitions, benchmarking its performance to option-portfolio-based indicators of CEO optimism from the established behavioral corporate finance literature.

7.1. Implications of the Model

The model predicts that the option exercise policy of an executive who retains some shares received on option exercise will differ from that of an executive who sells all shares. The share-retaining executive's policy should yield option exercises for which the intrinsic value represents a large portion of the option's market value. Similarly, an executive who retains shares should exercise options closer to expiration than a peer who does not.

We test these theoretical predictions using the *Share Retainer* indicator. For each option exercise in the sample, we compute the value ratio and the remaining time until the option would have expired.[23] These data are aggregated for each CEO on an annual basis, using a simple average over the number of options exercised. This approach ensures that our summary statistics that describe CEO option exercise policy match the frequency of *Share Retainer*, which is implemented annually.[24] We are careful when computing these averages to exclude "reload options," a type of CEO option not analyzed in our model.[25] Reload options

[23] The value ratio is discussed in Section 4. It is defined as the ratio of the intrinsic value of the option at exercise to the market value of a similar freely traded American option.

[24] The weighted average value ratio and remaining time until option expiration are only available in years during which a CEO exercised an option. Therefore, in these tests, *Share Retainer* is always computed concurrently with the option exercise policy statistics. When testing the effects of CEO optimism on firm leverage, financing, and acquisitions, *Share Retainer* is set to its most recent computed value in years in which a CEO did not exercise an option. This is similar to the approach used by Malmendier and Tate to describe a CEO's underlying bias.

[25] When a CEO exercises a reload option and pays the exercise price with shares, she receives one new share for each option exercised. In addition, she receives new options, which are generally issued with a strike price equal to the current market price of the stock. The number of new options issued by the firm will be equal to or less than the number of options exercised.

have a dramatically different risk-return profile and optimal exercise policy from traditional options; they provide a mechanism by which a CEO can greatly reduce risk while simultaneously locking in capital gains. We filter out reload option exercises by eliminating any option exercise day on which a CEO both exercised existing options and was granted new options. Options were granted on approximately 3.3% of the observed option exercise days.

Table 4 presents descriptive statistics both for our entire sample and for two subsamples based on *Share Retainer*. We use the methodology from Section 6, assigning a CEO who retained shares received on option exercise to the *Share Retainer*, *SR=1*, subsample. All other CEOs are placed in the *SR=0* subsample. Univariate tests of the model's implications are in Panel A of the table. The difference in means tests provides statistically and economically significant univariate support for the model. Share retention is positively associated with the value received on option exercise. The economic significance of this result can be understood by considering the problem from the CEO's point of view. When exercising early, a CEO forgoes some time value in the option. This "lost" value corresponds to one minus the value ratio. The *Share Retainer* sample of CEOs sacrificed 7.9% less of the option's market value when compared to other CEOs.[26] Additionally, the univariate results demonstrate that the retention of shares is positively associated with exercises closer to expiration. On average, the *Share Retainer* subsample exercised options with 2.5 years until expiration, representing exercises with 24.1% less time remaining until option expiration than exercises in the $SR = 0$ sample.

We explore these relations in greater detail through regression analysis in Table 5. For CEO i during fiscal year t, we analyze a dependent variable y using the empirical specification

$$y_{i,t} = \beta_1 Optimism\ Indicator_{i,t} + \beta_2 X_{i,t} + Year\ FE_t + Industry\ FE_i + \epsilon_{i,t}, \tag{19}$$

where X is a vector of control variables and *Year FE* and *Industry FE* are year and industry fixed effects, respectively. Our choice of control variables emphasizes factors that arise from our theoretical model. These variables either influence option valuation, affect the CEO's optimal option exercise policy, or both. All regression specifications include security characteristics (such as the stock's volatility, dividend yield, and returns over the previous four years), an indicator variable for dividend paying stocks, and the risk-free rate.

[26]The *SR=1* sample of CEOs gave upon 5.8% of option value at exercise. The *SR=0* sample sacrificed 6.3% of option value.

We also include specifications containing additional controls for observable CEO characteristics that should be correlated with wealth, as represented by the CEO's stock and option holdings. All reported standard errors are clustered by CEO.

Columns (1) and (2) of Table 5 support the first implication of the model, demonstrating a statistically significant, positive relation between *Share Retainer* and the value ratio. The average CEO in our sample cedes approximately 6% of an equivalent American option's value through early exercise. Therefore, our results indicate that the sample of *Share Retainer* CEOs captures approximately 10.0% more value than other CEOs, based on the more conservative estimate from the two specifications. Columns (3) and (4) support the model's second implication: share-retaining CEOs exercise options closer to expiration. The more conservative coefficient demonstrates that *Share Retainer* is associated with exercises approximately 0.8 years closer to expiration. The inclusion of CEO control variables in columns (2) and (4) provide strong support for the *Share Retainer* indicator. By construction, the CEO vested option ownership percentage indicates any general tendency of a CEO not to exercise options. Hence, it is associated with exercises at a higher value ratio and closer to expiration. Variation in vested option ownership can arise, for example, from unobserved heterogeneity of risk aversion in the cross-section of CEOs. The continued statistical significance of *Share Retainer* in columns (2) and (4), therefore, indicates that the retention of shares is correlated with the value ratio and timing of exercise even after controlling for the tendency of any specific CEO to delay exercise, as captured by vested option ownership.

7.2. Leverage, Financing, and Acquisitions

Optimistic CEOs are expected to favor debt over equity, both in equilibrium and when raising capital. Hackbarth (2009) provides a theoretical argument that CEO optimism is associated with higher firm leverage in equilibrium. Heaton (2002) and Malmendier, Tate, and Yan (2011) predict that an optimistic CEO whose firm has unmet financing needs will use a higher percentage of debt when raising capital than a rational CEO would.

Roll (1986) argues that managerial optimism is a driver of acquisition activity: optimistic CEOs should overestimate the returns from acquisitions and, therefore, be more likely to undertake an acquisition than their non-optimistic peers. As financially unconstrained firms can more easily pursue acquisitions, we expect optimistic CEOs of financially unconstrained firms to complete acquisitions more frequently than optimistic CEOs of financially constrained firms. Malmendier and Tate (2008) make a similar argument when analyzing overconfident managers, which are a subset of our optimistic managers. Provided they have access to the necessary financing, an overconfident manager will undertake acquisitions more frequently than a manager who is not overconfident, because she overestimates her ability to improve the performance of an acquired firm.

We test these predictions, examining firm leverage, financing decisions, and acquisition activity. The analysis of leverage allows us to evaluate the performance of the indicators in an equilibrium setting, whereas the analysis of financing and acquisition help us evaluate the indicators' performance on dynamic decisions.

7.2.1. Leverage

We analyze the association of CEO optimism with *Firm Leverage*, defined as the ratio of the book value of debt to the market value of assets. The fixed effects panel specification is

$$\begin{aligned} Leverage_{i,t} =& \beta_1 Optimism\ Indicator_{i,t} + \beta_2 X_{i,t} + \beta_3 FD_{i,t} + Firm\ FE_i + \\ & Year\ FE_t + \epsilon_{i,t}. \end{aligned} \tag{20}$$

where i indexes firms, t indexes fiscal years, X is a vector of firm- and CEO-level controls, and *Firm FE* and *Year FE* are firm and fiscal year fixed effects, respectively.[27] Our firm-level controls are the logarithm of total assets, Q, return on assets (profitability), and property, plant, and equipment (asset tangibility). We also include *Financing Deficit (FD)*, as defined by Frank and Goyal, which measures a firm's investment and net working capital needs that are not met by cash flow. Firm-level controls also include annual stock returns over the past four years to control for any potential correlation between the stock price path and the observability of optimism indicators. As firms may endogenously choose optimistic managers (Gervais, Heaton, and Odean, 2011), we include firm fixed effects and the Bebchuk, Cohen, and Ferrell (2009) Entrenchment Index (E Index) in the specification. Finally, to benchmark *Share Retainer* as an indicator of CEO optimism, we also include

[27] In all of our empirical specifications, we stipulate an exhaustive set of year fixed effects, which subsumes the constant terms in all regressions.

CEO-level controls (the CEO's stock and vested option ownership of the firm) found in Malmendier, Tate, and Yan (2011).

Table 6 presents the results from estimating Eq. (20). Each optimism indicator is initially estimated separately from the other. Columns (1), (2), and (3) report results using *Share Retainer*, *Holder 67* and *Post-Longholder* as the optimism indicator, respectively. Column (4) shows estimates from a specification that includes all three optimism indicators simultaneously. Optimistic CEOs, as indicated by *Share Retainer*, are associated with firms that have higher leverage than their peers. *Holder 67* and *Post-Longholder*, however, do not show a statistically significant relation with leverage (columns (2) and (3)). *Share Retainer* retains a statistically significant association with leverage in the specification that also includes the other two optimism indicators.

7.2.2. Financing Decisions

We use two variables to describe financing decisions. *Debt Issuance* is the net debt issuance over a fiscal year, normalized by the book value of assets at the start of the fiscal year. Because employee option grants dominate accounting measures of equity issuance (McKeon, 2013), we do not look at changes in the book value of equity. Instead, we identify market equity offerings. *Equity Issuance* is the total amount of equity issued over a fiscal year (excluding IPOs) normalized by the book value of assets at the start of the fiscal year.

We perform our tests of financing decisions using a financing deficit framework (Frank and Goyal, 2003, 2009; Shyam-Sunder and Myers, 1999). For a financing decision variable y, the empirical specification is

$$\begin{aligned} y_{i,t} =& \beta_1 Optimism\ Indicator_{i,t} \times FD_{i,t} + \beta_2 Optimism\ Indicator_{i,t} + \beta_3 X_{i,t} \times FD_{i,t} + \beta_4 X_{i,t} + \\ & \beta_5 FD_{i,t} + Firm\ FE_i + Year\ FE_t \times FD_{i,t} + Year\ FE_t + Industry\ FE_i \times FD_{i,t} + \epsilon_{i,t}, \end{aligned} \tag{21}$$

where i indexes firms, t indexes fiscal years, *FD* is the financing deficit (defined earlier), X is a vector of firm- and CEO-level controls, and *Firm FE*, *Year FE*, and *Industry FE* are firm, fiscal year, and industry fixed effects, respectively. Firm-level controls are annual changes in the logarithm of total assets, in Q, in return on assets (profitability), and in property, plant, and equipment (asset tangibility). As before, annual stock returns over the past four years are included to control for any potential correlation between the stock price path and the observability of optimism indicators. CEO-level controls are the CEO's stock and vested option ownership of the firm. Finally, we interact industry fixed effects with the financing deficit term. This allows us to control for differences across industries when raising capital and when using debt or equity financing to respond to unmet financial needs.

In Table 7, we report estimates of Eq. (21) using fixed effect panel models. Specifications analyzing *Debt Issuance* are in columns (1) through (4). If optimistic CEOs are more likely to issue debt when faced with a financing deficit than non-optimistic CEOs then the coefficient on the interaction between an optimism indicator and *Financing Deficit* should be positive. Column (1) shows that optimistic CEOs, as categorized by *Share Retainer*, issue more debt in response to a financing deficit. *Post-Longholder* also exhibits a statistically significant relation with debt issuance in accordance with this theoretical prediction (column (3)). While *Holder 67* suggests that optimistic CEOs issue debt when their firm has a financing deficit, the coefficient is not statistically significant. When all indicators are used in the specification in column (4), the coefficient on *Post-Longholder* decreases in magnitude relative to that from estimation without the other optimism indicators (column (3)) and is not statistically significant. On the other hand, *Share Retainer*, is statistically significant, even after accounting for the effect of *Post-Longholder* and *Holder 67* on debt issuance.

Columns (5) through (8) of Table 7 present results analyzing *Equity Issuance*. A negative coefficient on the interaction between an optimism indicator and financing deficit supports the theoretical predication: optimistic CEOs are less likely to issue equity in response to a financing deficit than their peers who are not optimistic. Of the three optimism indicators, only CEOs classified as *Share Retainer* are less likely to issue equity in response to a financing deficit. The effect is statistically significant when *Share Retainer* is the only optimism indicator (column (5)) and when the other optimism indicators are included in the specification (column (8)). While *Holder 67* and *Post-Longholder* CEOs are associated with a tendency to issue equity, the relation is never statistically significant.[28]

[28]Table VIII of Malmendier, Tate, and Yan (2011) shows that financing decisions are related to CEO overconfidence for the time period between 1992 and 2007. However, the indicator is a time-constant CEO characteristic, and the specification does not include firm fixed effects.

7.2.3. Acquisitions

We examine the relations between optimism indicators and acquisition activity using conditional logit models. The indicator variable *Acquisition* is defined as 1 in any fiscal year in which a firm completes an acquisition and 0 otherwise. We use the requirements provided by Masulis, Wang, and Xie (2007) to filter out insignificant acquisitions. Specifically, the acquiring firm must not have had a controlling interest in the target before completing the acquisition. The acquisition must exceed one million dollars in value and the market capitalization of the target before the acquisition announcement must exceed one percent of the acquiring firm's market capitalization.

Evaluation of the prediction that financial constraints affect the ability of optimistic CEOs to undertake acquisitions requires a relative ranking of financial constraints. We use the Kaplan and Zingales (1997) (KZ) Index as implemented by Lamont, Polk, and Saá-Requejo (2001), assigning any firm with a KZ Index below the median value of its peers in a given fiscal year to the financially unconstrained group.

For firm i in year t, the linear prediction functions for our conditional logit specifications are

$$\begin{aligned} Acquisition_{i,t+1} =& \beta_1 Optimism\ Indicator_{i,t} + \beta_2 X_{i,t} + \beta_3 FUNC_{i,t} + \\ & Firm\ FE_i + Year\ FE_t + \epsilon_{i,t}, \text{ and} \end{aligned} \tag{22}$$

$$\begin{aligned} Acquisition_{i,t+1} =& \beta_1 Optimism\ Indicator_{i,t} \times FUNC_{i,t} + \beta_2 Optimism\ Indicator_{i,t} + \\ & \beta_3 X_{i,t} \times FUNC_{i,t} + \beta_4 X_{i,t} + \beta_5 FUNC_{i,t} + Firm\ FE_i + \\ & Year\ FE_t \times FUNC_{i,t} + Year\ FE_t + \epsilon_{i,t}, \end{aligned} \tag{23}$$

where X is a vector of firm- and CEO-level controls, *FUNC* is an indicator with a value of 1 if the firm is unconstrained financially, and *Firm FE* and *Year FE* are firm and year fixed effects, respectively. To control for size, investment opportunities and cash available to conduct acquisitions, we use the logarithm of total assets, Q, and cash flows as firm-level variables in X. We also include the E Index and the four-year annual return history as firm-level controls. As before, the CEO-level controls are the CEO's stock and vested option ownership of the firm. Standard errors are clustered by firm.

Table 8 shows the results of estimating Eqs. (22) and (23) using conditional logit regressions.[29] Columns (1) show that *Share Retainer* is positively and statistically significantly related to the firm undertaking an acquisition in the next year. *Holder 67* has a nearly identical effect, both economically and statistically, as seen in column (2). Both variables retain their economic and statistical significance when used simultaneously in the specification in column (4). *Post-Longholder*, however, does not show a statistically significant relation with acquisition activity.

We expect that the effects of optimism on acquisition activity should be more pronounced for CEOs of financially unconstrained firms, who can more easily undertake acquisitions. Column (5) demonstrates that, when optimism is defined using *Share Retainer*, optimistic CEOs of financially unconstrained firms are likely to complete an acquisition. Consistent with this prediction, optimistic CEOs of financially constrained firm exhibit no statistically different relation with acquisition likelihood than non-optimistic CEOs. *Holder 67*, while related to acquisition activity in general, does not have a stronger relation for the CEOs of financially unconstrained firms as seen in column (6). The effect is negative and not statistically significant. These relations among *Share Retainer*, *Holder 67*, and financial constraints are unchanged when all three optimism indicators are used in the specification found in column (8).

8. Conclusion

We study the optimal option exercise and portfolio choice problem of an optimistic executive who faces a short-sale constraint on company stock. By allowing the executive to purchase stock in the market, our model expands on ones that pre-specify the share ownership of a rational executive (Carpenter, 1998; Carpenter, Stanton, and Wallace, 2010; Grasselli and Henderson, 2009; Hall and Murphy, 2002; Ingersoll Jr, 2006). Endogenous stock holdings are particularly important in this context because an optimistic executive wants to own company equity. If the executive's stock holdings were exogenously fixed, the optimistic executive would not be able to achieve her desired level of stock ownership. As a result, the exercise policy derived from such a model would be incorrect.

[29] Conditional logic estimation requires dropping all firms that did not complete an acquisition during the sample period. We do not model industry-specific relations between financially unconstrained firms and acquisition activity due to convergence problems when the conditional logit model includes a large number of independent variables. In untabulated results, we find virtually identical results in fixed effect, linear probability models that include interaction terms between industry dummies and the financially unconstrained indicator.

The model demonstrates that the executive's exercise policy is determined by a complex interplay among optimism, stock parameters, and executive characteristics. An optimistic executive will exercise an option closer to expiration than a similar non-optimistic executive. However, any executive, regardless of her level of optimism, should exercise an option whenever a rational unconstrained agent, who is able to short the stock, does so. Therefore, it is not optimal for an executive to hold a deep-in-the-money option on a dividend paying stock until maturity. Stock and executive characteristics, some of which may be unobservable, can have a substantial impact on the optimal exercise policy, dampening or magnifying the effects of optimism in a non-linear fashion. For example, remaining time until expiration at option exercise would demonstrate low sensitivity to optimism for both high and low executive wealth levels, but demonstrate high sensitivity to optimism for moderate executive wealth.

Optimistic executives retain some shares received from exercising options, while non-optimistic executives sell all shares. We prove this for an executive with general concave utility. In stark contrast to the way exercise timing is affected by all model parameters, whether an executive retains shares is uniquely determined by optimism.

We turn this theoretical result into a novel empirical technique to determine if an executive is, in fact, optimistic. Our indicator of optimism, *Share Retainer*, is based on observing an executive's stock transactions that coincide with option exercise. Empirically, *Share Retainer* is more related to investment leverage, financing, and acquisition decisions associated with optimistic CEOs than other option-exercise-based indicators of optimism used in the literature. These other option-exercise-based indicators of optimism, which work well for a sample of large firms covering the 1980s and early 1990s, do not provide robust results in our sample, which covers a wider cross-section of firms between 1996 and 2012.

The approach used in this paper can enable further research into developing ways to measure other behavioral biases. Our option exercise and portfolio choice model examines an executive subject to a specific behavioral bias. The framework can be adapted to allow researchers to consider the effects of other behavioral biases. Exercise policies are multidimensional; models of executives with different behavioral biases may suggest new techniques to infer more than one unobservable executive characteristic from option exercise data. Executives, for example, are thought to both overestimate returns and underestimate risk. Gervais, Heaton, and Odean (2011) argue that managers who do not assess risk correctly are more likely to invest in projects than rational managers. While the empirical literature examining managerial miscalibration of risk has used survey data (Ben-David, Graham, and Harvey, 2013), studies of firms beyond those surveyed could be undertaken with the introduction of an option-exercise-based proxy of managerial miscalibration.

Finally, we hope *Share Retainer* makes new research opportunities in behavioral corporate finance possible. As most studies, including this one, have analyzed large-capitalization companies, our understanding of the effects of executive optimism in small companies is quite limited. Yet, due to their focused business models, these firms may be highly affected by executive biases. *Share Retainer* can be easily computed for a large variety of firms (including all publicly traded US firms), with few approximation assumptions and with standard data sets. As *Share Retainer* can even recognize optimism within transactions in which an executive reduces her dollar exposure to the firm's securities, it provides information in a large variety of business environments. Therefore, *Share Retainer*, by allowing researchers to explore areas that are empirically intractable with existing indicators of optimism, can help shed further light on the causes and consequences of executive optimism

Appendix A. Proofs

A.1. Discrete Time Proofs

Let p be the risk-neutral probability of the stock returning u and Δ be the option's delta equivalent dollar value of shares in a replicating portfolio at $t = 1$. Define $\bar{S}_1$ as the post-exercise stock price at which a risk-neutral agent would exercise the option for dividend capture.[30] An unconstrained agent, who can short-sell the stock, would also exercise the option for all stock prices greater than or equal to $\bar{S}_1$ regardless of her subjective probability q of the high state occurring and her risk aversion. Standard binomial option pricing theory gives these values for our model as

$$p = \frac{1-d}{u-d},$$

$$\Delta = \frac{[uS_1 - K]^+ - [dS_1 - K]^+}{u-d}, \text{ and}$$

$$\bar{S}_1 = \frac{(1-p)K}{1+\delta - up}. \tag{24}$$

Define OV as the risk-neutral value of the option to a unconstrained agent. In the following proofs, we use the following identities to simplify notation and emphasize equivalence between terminal option payouts and hedging activity:

$$OV = p\,[uS_1 - K]^+ + (1-p)\,[dS_1 - K]^+,$$

$$[uS_1 - K]^+ = OV + \Delta(u-1), \text{ and}$$

$$[dS_1 - K]^+ = OV + \Delta(d-1). \tag{25}$$

Given this notation, the executive's expected utility from holding the stock option at $t = 1$ and investing

[30]This critical price can be found by considering the state when $u \cdot S_1 \geq K \geq d \cdot S_1$ and equating the immediate exercise value of the option, $S_1 + S_1\delta - K$, with the risk neutral valuation of the terminal payoff at expiration, $p \cdot (uS_1 - K)$. When $u \cdot S_1 > d \cdot S_1 \geq K$, the payoffs are weakly higher from exercising the option than holding it until expiration (this relation is strict if the stock pays dividends). When $K \geq u \cdot S_1 > d \cdot S_1$, the option is worthless.

I in the stock can be written as

$$U_{1,N}(q, W_1, S_1, I) = q \times U\left(W_1 + OV + \Delta(u-1) + I(u-1)\right)$$
$$+ (1-q) \times U\left(W_1 + OV + \Delta\left(d-1\right) + I\left(d-1\right)\right). \tag{26}$$

A.1.1. Discrete Time Lemmas

The proofs require three Lemmas. The first examines state-specific terminal payoffs when the post-dividend stock price is greater than $\bar{S}_1$. The remaining two Lemmas provide relations between the executive's investment in stock conditional on the exercise decision for post-dividend stock prices less than $\bar{S}_1$.

Lemma 1. *For all stock prices, S_1, above the critical price threshold at which a risk-neutral agent would exercise the option, $\bar{S}_1$, the state-specific terminal payoffs at time t=2 realized by exercising the option at $t = 1$ and purchasing a delta equivalent value of company stock exceed those realized by holding the option until expiration.*

$$\textit{For all } S_1 \geq \bar{S}_1,\ S_1 + S_1\delta - K + \Delta(u-1) \geq [uS_1 - K]^+\,,\ \textit{and}$$
$$S_1 + S_1\delta - K + \Delta(d-1) \geq [dS_1 - K]^+\,.$$

Proof: Given that $S_1 \geq \bar{S}_1$, the time $t = 1$ payoff from exercising the option early exceeds the risk-neutral value of the options, $S_1 + S_1\delta - K \geq OV$. Assume at $t = 1$ that the agent exercises the option and purchases a delta dollar value of stock by borrowing at the risk-free rate. If the terminal stock price is $u \cdot S_1$, the payoff from this strategy exceeds the payoff from holding the option to expiration,

$$S_1 + S_1\delta - K + \Delta(u-1) \geq OV + \Delta(u-1)$$
$$= [uS_1 - K]^+\,. \tag{27}$$

Similarly, if the terminal stock price is $d \cdot S_1$, the payoff from exercising the option and buying delta dollar value of shares exceeds the payoff from holding the option to expiration,

$$
\begin{aligned}
S_1 + S_1\delta - K + \Delta(d-1) &\geq OV + \Delta(d-1) \\
&= [dS_1 - K]^+ . \qquad \square
\end{aligned}
\tag{28}
$$

Lemma 2. *For all stock prices, S_1, below the critical price threshold at which a risk-neutral agent would exercise the option, $\bar{S}_1$, if it is optimal for the executive to exercise the option at $t = 1$ then the executive will hold less than the option's delta equivalent value of company stock.*

$$\text{For all } S_1 < \bar{S}_1, \text{ if } U^*_{1,E}(q, W_1, S_1) > U^*_{1,N}(q, W_1, S_1), \text{ then } I^*_{1,E}(q, W_1, S_1) < \Delta.$$

Proof. Proceed by contradiction and assume that $I^*_{1,E}(q, W_1, S_1) \geq \Delta$. Consider the strategy of holding the option until expiration and purchasing the post-exercise optimal investment value of company stock less Δ, $I'_{1,N}(q, W_1, S_1) = I^*_{1,E}(q, W_1, S_1) - \Delta$. By the assumption, $I'_{1,N}(q, W_1, S_1) \geq 0$ and is a feasible investment for the short-sale constrained agent. The utility from this strategy is $U_{1,N}\left(q, W_1, S_1, I'_{1,N}(q, W_1, S_1)\right)$:

$$
\begin{aligned}
U_{1,N}\left(q, W_1, S_1, I'_{1,N}(q, W_1, S_1)\right) &= q \times U\left(W_1 + OV + \Delta(u-1) + I^*_{1,E}(u-1) - \Delta(u-1)\right) \\
&\quad + (1-q) \times U\left(W_1 + OV + \Delta(d-1) + I^*_{1,E}(d-1) - \Delta(d-1)\right) \\
&= q \times U\left(W_1 + OV + I^*_{1,E}(u-1)\right) + (1-q) \times U\left(W_1 + OV + I^*_{1,E}(d-1)\right) \\
&\geq q \times U\left(W_1 + S_1 + S_1\delta - K + I^*_{1,E}(u-1)\right) \\
&\quad + (1-q) \times U\left(W_1 + S_1 + S_1\delta - K + I^*_{1,E}(d-1)\right) \\
&= U^*_{1,E}(q, W_1, S_1),
\end{aligned}
\tag{29}
$$

where the inequality above follows from the assumption that $S_1 < \bar{S}_1$. As $U_{1,N}\left(q, W_1, S_1, I'_{1,N}(q, W_1, S_1)\right) > U^*_{1,E}(q, W_1, S_1)$ contradicts $U^*_{1,E}(q, W_1, S_1) > U^*_{1,N}(q, W_1, S_1)$, it must be that $I^*_{1,E}(q, W_1, S_1) < \Delta$. $\square$

Lemma 3. *For all stock prices, S_1, below the critical price threshold at which a risk-neutral agent would exercise the option, $\bar{S}_1$, if it is optimal for an executive with optimism q_h to exercise the option at $t = 1$, then the executive would not optimally invest in company stock if she were forced to hold the option until expiration. Furthermore, all executives with optimism levels less that q_h would also not invest in company* *stock if she were forced to hold the option until expiration.*

$$\textit{For all } S_1 < \bar{S}_1, \textit{ if } U^*_{1,E}(q_h, W_1, S_1) > U^*_{1,N}(q_h, W_1, S_1) \textit{ then } I^*_{1,N}(q_l, W_1, S_1) = 0 \textit{ for all } q_l \leq q_h.$$

Proof. First, consider the case of optimal investment for optimism q_h. Proceed by contradiction. Assume the executive optimally invests in the stock conditional on exercise, $I^*_{1,N}(q_h, W_1, S_1) > 0$. Therefore, $I^*_{1,N}(q_h, W_1, S_1)$ is not a corner solution to the executive's investment problem and must maximize the unconstrained utility maximization problem:

$$\begin{aligned} I^*_{1,n} = \underset{I}{\operatorname{argmax}} \Big\{ & q_h \times U\left(W_1 + OV + \Delta(u-1) + I(u-1)\right) \\ & + (1-q_h) \times U\left(W_1 + OV + \Delta(d-1) + I(d-1)\right) \Big\}. \end{aligned} \tag{30}$$

This, therefore, implies that $I^*_{1,N} + \Delta$ must maximize a related utility problem:

$$I^*_{1,n} + \Delta = \underset{I}{\operatorname{argmax}} \Big\{ q_h \times U\left(W_1 + OV + I(u-1)\right) + (1-q_h) \times U\left(W_1 + OV + I(d-1)\right) \Big\}. \tag{31}$$

Conditional on exercising the option, the executive's optimal investment is given by $I^*_{1,E}(q_h, W_1, S_1)$. The optimal utility conditional on exercising the option then satisfies

$$\begin{aligned} U^*_{1,E}(q_h, W_1, S_1) &= q_h \times U\big(W_1 + S_1 + S_1\delta - K + I^*_{1,E}(q_h, W_1, S_1)(u-1)\big) \\ &\quad + (1-q_h) \times U\big(W_1 + S_1 + S_1\delta - K + I^*_{1,E}(q_h, W_1, S_1)(d-1)\big) \\ &\leq q_h \times U\big(W_1 + OV + I^*_{1,E}(q_h, W_1, S_1)(u-1)\big) \\ &\quad + (1-q_h) \times U\big(W_1 + OV + I^*_{1,E}(q_h, W_1, S_1)(d-1)\big) \\ &\leq q_h \times U\big(W_1 + OV + \Delta(u-1) + I^*_{1,N}(q_h, W_1, S_1)(u-1)\big) \\ &\quad + (1-q_h) \times U\big(W_1 + OV + \Delta(d-1) + I^*_{1,N}(q_h, W_1, S_1)(d-1)\big) \\ &= U^*_{1,N}(q_h, W_1, S_1), \end{aligned} \tag{32}$$

where the first inequality follows from the assumption that $S_1 < \bar{S}_1$ and the second inequality derives from the preceding observation on the optimality of $I^*_{1,N}(q_h, W_1, S_1) + \Delta$. This contracts $U^*_{1,E}(q_h, W_1, S_1) > U^*_{1,N}(q_h, W_1, S_1)$. Therefore, it must be that $I^*_{1,N}(q_h, W_1, S_1) = 0$.

Now consider the case of $q_l < q_h$. The first-order condition for the executive's optimal investment conditional on not exercising the option at $t = 0$ is $\frac{\partial U_{1,N}}{\partial I}$. The convexity of the utility function means that $\frac{\partial^2 U_{1,N}}{\partial I^2} < 0$ for all I. In other words, the first-order condition is strictly decreasing in I. Therefore, the executive chooses the constrained solution, $I^*_{1,N}(q, W_1, S_1) = 0$, and does not purchase company stock if and only if $\frac{\partial U_{1,N}(q,W_1,S_1,I)}{\partial I}|_{I=0} < 0$. Evaluating the first-order condition at $I = 0$ reveals that

$$\left.\frac{\partial U_{1,N}(q, W_1, S_1, I)}{\partial I}\right|_{I=0} = q \times U'\left(W_1 + OV + \Delta(u-1)\right)(u-1)$$

$$+ (1-q) \times U'\left(W_1 + OV + \Delta(d-1)\right)(d-1) \tag{33}$$

Therefore, $\left.\frac{\partial U_{1,N}(q,W_1,S_1,I)}{\partial I}\right|_{I=0} < 0$ if and only if

$$\frac{q}{1-q} < \frac{U'\left(W_1 + OV + \Delta(d-1)\right)(1-d)}{U'\left(W_1 + OV + \Delta(u-1)\right)(u-1)}. \tag{34}$$

As shown above, if $U^*_{1,E}(q_h, W_1, S_1) > U^*_{1,N}(q_h, W_1, S_1)$ then $I^*_{1,N}(q_h, W_1, S_1) = 0$. Therefore, it must be that q_h satisfies the condition above. The right hand side of the expression relates two marginal utilities and is a constant, unrelated to optimism. The left-side of the expression $\frac{q}{1-q}$ is strictly increasing in q for $q \in (0, 1)$. Therefore, all $q_l < q_h$ will satisfy the condition that $\left.\frac{\partial U_{1,N}(q,W_1,S_1,I)}{\partial I}\right|_{I=0} < 0$. Hence, $I^*_{1,N}(q_l, W_1, S_1) = 0$ for all $q_l < q_h$. □

A.1.2. Proofs of Discrete Time Propositions

Proposition 1. *Define $\bar{S}_1$ as the minimum post-dividend stock price at which an unconstrained agent would prefer early exercise of the option at $t = 1$. For all post-dividend stock prices S_1 greater than or equal to $\bar{S}_1$, it is optimal for a risk-averse executive who is subject to a short-sale constraint to exercise the option early, regardless of the executive's subjective probability, q, of the high stock price state occurring and her wealth:*

$$U^*_{1,E}(q, W_1, S_1) \geq U^*_{1,N}(q, W_1, S_1) \text{ for all } q \in (0, 1) \text{ and } S_1 \geq \bar{S}_1 \ .$$

Proof: Assume the executive exercises the option. However, instead of investing the optimal amount in stock after exercise, $I^*_{1,E}$, the executive's investment in stock is equal to the optimal amount that she would have purchased if she had not exercised the option plus an amount required to replicate the option payoff, $I^*_{1,N} + \Delta$.

Then, since $U(\cdot)$ is increasing and $S_1 \geq \bar{S}_1$, the inequalities in Lemma 1 imply

$$\begin{aligned}
U^*_{1,E}(q, W_1, S_1) &\geq U_{1,E}(q, W_1, S_1, I^*_{1,N} + \Delta) \\
&= q \times U\left(W_1 + S_1 + S_1\delta - K + (I^*_{1,N} + \Delta)(u-1)\right) + \\
&\qquad (1-q) \times U\left(W_1 + S_1 + S_1\delta - K + (I^*_{1,N} + \Delta)(d-1)\right) \\
&\geq qU \times \left(W_1 + [uS_1 - K]^+ + I^*_{1,N}(u-1)\right) + \\
&\qquad (1-q) \times U\left(W_1 + [dS_1 - K]^+ + I^*_{1,N}(d-1)\right) \qquad (35) \\
&= U^*_{1,N}(q, W_1, S_1). \qquad \square
\end{aligned}$$

Proposition 2. *For two executives with equal outside wealth and the same utility function, if early exercise of an option is optimal at post-dividend stock price S_1 for an executive with optimism q_h, early exercise would be optimal for an executive with a lower optimism level q_l :*

$$\textit{If } U^*_{1,E}(q_h, W_1, S_1) > U^*_{1,N}(q_h, W_1, S_1), \textit{ then } U^*_{1,E}(q_l, W_1, S_1) > U^*_{1,N}(q_l, W_1, S_1) \textit{ for all } q_l < q_h.$$

Proof: First, consider the case when $S_1 > \bar{S}_1$. By Proposition 1, early exercise of the option is optimal for all agents. Now, consider the case when $S_1 \leq \bar{S}_1$, which means that $OV \geq S_1 + S_1\delta - K$. By Lemma 2, $\Delta > I^*_{1,E}(q_h, W_1, S_1)$. Therefore,

$$W_1 + OV + \Delta(u-1) \geq W_1 + S_1 + S_1\delta - K + I^*_{1,E}(q_h, W_1, S_1)(u-1). \qquad (36)$$

In other words, if the stock were to have a terminal value of $u \cdot S_1$, then the executive would realize a higher terminal utility from not exercising the option than from exercising the option and investing in the stock:

$$U\left(W_1 + OV + \Delta(u-1)\right) \geq U\left(W_1 + S_1 + S_1\delta - K + I^*_{1,E}(q_h, W_1, S_1)(u-1)\right). \qquad (37)$$

Given that $U^*_{1,E}(q_h, W_1, S_1) > U^*_{1,N}(q_h, W_1, S_1)$, if the terminal utility when the terminal price of the stock is $u \cdot S_1$ is higher from not exercising the option than from exercising, the opposite must hold when the terminal price of the stock is $d \cdot S_1$:

$$U\left(W_1 + OV + \Delta(d-1)\right) \leq U\left(W_1 + S_1 + S_1\delta - K + I^*_{1,E}(q_h, W_1, S_1)(d-1)\right). \qquad (38)$$

By Lemma 3, the executive would not optimally invest in stock if she were forced to hold the option until expiration. Therefore, the difference in utilities realized from not exercising the option at the two optimism levels is given by

$$
\begin{aligned}
U^*_{1,N}(q_h, W_1, S_1) - U^*_{1,N}(q_l, W_1, S_1) &= (q_h - q_l)\left[U\left(W_1 + OV + \Delta\left(u-1\right)\right) - U\left(W_1 + OV + \Delta(d-1)\right)\right] \\
&> (q_h - q_l)\Big[U\Big(W_1 + S_1 + S_1\delta - K + I^*_{1,E}(q_h, W_1, S_1)(u-1)\Big) \\
&\qquad -U\Big(W_1 + S_1 + S_1\delta - K + I^*_{1,E}(q_h, W_1, S_1)(d-1)\Big)\Big] \\
&= q_h U\Big(W_1 + S_1 + S_1\delta - K + I^*_{1,E}(q_h, W_1, S_1)(u-1)\Big) \\
&\qquad - (1-q_h)U\Big(W_1 + S_1 + S_1\delta - K + I^*_{1,E}(q_h, W_1, S_1)(d-1)\Big) \\
&\qquad - q_l U\Big(W_1 + S_1 + S_1\delta - K + I^*_{1,E}(q_h, W_1, S_1)(u-1)\Big) \\
&\qquad + (1-q_h)U\Big(W_1 + S_1 + S_1\delta - K + I^*_{1,E}(q_h, W_1, S_1)(d-1)\Big) \\
&= U^*_{1,E}(q_h, W_1, S_1) - U_{1,E}(q_l, W_1, S_1, I^*_{1,E}(q_h, W_1, S_1)) \\
&> U^*_{1,E}(q_h, W_1, S_1) - U^*_{1,E}(q_l, W_1, S_1). \qquad (39)
\end{aligned}
$$

Therefore, $U^*_{1,E}(q_l, W_1, S_1) - U^*_{1,N}(q_l, W_1, S_1) > U^*_{1,E}(q_h, W_1, S_1) - U^*_{1,N}(q_h, W_1, S_1)$. Given that $U^*_{1,E}(q_h, W_1, S_1) > U^*_{1,N}(q_h, W_1, S_1)$, it must be that $U^*_{1,E}(q_l, W_1, S_1) > U^*_{N}(q_l, W_1, S_1)$. □

Proposition 3. *An executive that retains some of the shares received from options exercise is optimistic. Furthermore, an optimistic executive who exercises her options at $t = 1$ will retain some of the shares she receives if her wealth does not suffer a significant shock prior to the exercise decision.*

If $I^*_{1,E}(q, W_1, S_1) > I^*_0(q, W_0, S_0)$ then $q > q_0$;

if $q > q_0$ and $U^*_{1,E}(q, W_1, S_1) \geq U^*_{1,N}(q, W_1, S_1)$, there exists a $\bar{W}_1 < W_0$ such that for all $W \geq \bar{W}_1$,

$$I^*_{1,E}(q, W_1, S_1) > I^*_0(q, W_0, S_0).$$

Proof: Begin with the first part of the proposition. Given the short-sale constraint on the investment in company stock, share retention implies that the executive owns a positive amount of company stock after option exercise. Analyze the executive's optimal investment after option exercise. The first-order condition for the executive's optimal investment conditional exercising the option at $t = 1$ is

$$\frac{\partial U_{1,E}(q, W_1, S_1, I)}{\partial I} = q \times U'\left(W_1 + S_1 + S_1\delta - K + I(u-1)\right)(u-1) + (1-q) \times U'\left(W_1 + S_1 + S_1\delta - K + I(d-1)\right)(d-1). \tag{40}$$

Investment is subject to a short-sale constraint. Therefore, under the model's assumptions, investment is positive only if $\frac{\partial U_{1,E}(q,W_1,S_1,I)}{\partial I} = 0$. Rearranging the first-order condition above implies that positive investment must satisfy

$$\frac{U'\left(W_1 + S_1 + S_1\delta - K + I(d-1)\right)}{U'\left(W_1 + S_1 + S_1\delta - K + I(u-1)\right)} = \frac{1-q_0}{q_0} \times \frac{q}{1-q} \tag{41}$$

The term on the left-hand side is the ratio of two marginal utilities. Due to the concavity of the utility function, this term is strictly greater than 1 if and only if $I > 0$. The term on the right-hand side is strictly greater than 1 if and only if $q > q_0$. Therefore, the executive optimally invests in company stock after option exercise only if she is optimistic: $I^*_{1,E}(q, W_1, S_1) > 0$ only if $q > q_0$. Hence, if the executive retains shares received from exercising options, she must be optimistic: $I^*_{1,E}(q, W_1, S_1) > I^*_0(q, W_0, S_0)$ implies $q > q_0$.

Consider the second part of the proposition. Let $q > q_0$ and early exercise be optimal at $t = 1$. To simplify notation, let π_{ab} be the payout under the optimal investment and exercise strategy for the stock having return a from $t = 0$ to $t = 1$ and return b from $t = 1$ to $t = 2$. Rewrite the executive's problem at $t = 0$ as

$$I_0 = \operatorname{argmax} q\left(qU(\pi_{uu}) + (1-q)U(\pi_{ud})\right) + (1-q)\left(qU(\pi_{du}) + (1-q)U(\pi_{dd})\right) \tag{42}$$

The first-order conditions for the investment decisions at $t = 0$ and $t = 1$ imply

$$\frac{1-q_0}{q_0} \times \frac{q}{1-q} = \frac{U'(\pi_{ud})}{U'(\pi_{uu})} = \frac{U'(\pi_{dd})}{U'(\pi_{du})} = \frac{qU'(\pi_{du}) + (1-q)U'(\pi_{dd})}{qU'(\pi_{uu}) + (1-q)U'(\pi_{ud})} \tag{43}$$

Let $\kappa = \dfrac{1-q_0}{q_0} \times \dfrac{q}{1-q}$. The above expressions imply: $U'(\pi_{uu}) = \frac{U'(\pi_{ud})}{\kappa}$ and $U'(\pi_{dd}) = \kappa U'(\pi_{du})$.

Substituting these into the rightmost term reveals that

$$\frac{U'(\pi_{du})}{U'(\pi_{ud})} = 1. \tag{44}$$

Hence, the executive structures her investment policy to ensure that payoffs π_{du} and π_{ud} are equal.

Let $I_{1,a}$ be the investment conditional on the stock returning a from $t = 0$ to $t = 1$. Given that $U(\cdot)$ exhibits decreasing absolute risk aversion, $I_0 \geq 0$ from the short-sale constraint on company stock, and the equivalence of marginal utilities implied in equation Eq. (43), it must be that the optimal investment after stock price depreciation is not greater than that after stock price appreciations: $I^*_{1,d} \leq I^*_{1,u}$.

There are two possibilities for the exercise policy when the stock returns d between $t = 0$ and $t = 1$: early exercise or continue holding the option. Assume that early exercise is optimal. Given that payoffs π_{du} and π_{ud} are equal,

$$\begin{aligned}\pi_{ud} &= W_0 + I_0(u-1) + S_0u - K + I_{1,u}(d-1) \\ &= W_0 + I_0(d-1) + S_0d - K + I_{1,d}(d-1) = \pi_{dd}.\end{aligned} \tag{45}$$

Since $I^*_{1,d} \leq I^*_{1,u}$, rearranging the above shows that

$$\begin{aligned}I^*_0\,(u-d) + S_0\,(u-d) &= I^*_{1,d}(u-1) + I^*_{1,u}(1-d) \\ &\leq I^*_{1,u}(u-d).\end{aligned} \tag{46}$$

As $S_0(u-d) > 0$, this implies that an optimistic executive retains shares received from option exercise conditional on her wealth not decreasing: $I^*_0 < I^*_{1,u}$.

The other possibility is that exercise of the option is not optimal at $t = 1$ when the stock returns d. Repeating the above exercise shows that

$$\begin{aligned}\pi_{ud} &= W_0 + I_0(u-1) + S_0u - K + I_{1,u}(d-1) \\ &= W_0 + I_0(d-1) + (S_0d(1-\delta) - K)^+ + I_{1,d}(d-1) = \pi_{dd}\end{aligned} \tag{47}$$

Since $I^*_{1,d} \leq I^*_{1,u}$, rearranging the above shows that

$$I^*_0\,(u-d) + S_0 u - (S_0 d(1-\delta) - K)^+ = I^*_{1,d}(u-1) + I^*_{1,u}(1-d)$$

$$\leq I^*_{1,u}(u-d). \tag{48}$$

As $S_0 u > S_0 d(1-\delta) - K)^+$, an optimistic executive retains shares received from option exercise conditional on her wealth not decreasing: $I^*_0 < I^*_{1,u}$.

Therefore, the executive always invests strictly more in company stock that she had initially provided her wealth increases. That is, $I^*_{1,u}(q, W_1, S_1) > I^*_0 q, W_0, S_0$ for all $W_1 \geq W_0$. Optimal investment is a continuous function of model parameters. Hence, for some $\bar{W}_1 < W_0$, it will be that $I^*_{1,E} > I^*_0$ for all $W_1 > \bar{W}_1$. $\square$

Extension 1 *Allow the executive to exercise a fractional amount ψ of options at time $t = 1$. If she retains some of the shares received from options exercise, then she is optimistic.*

Proof: Assume the executive may endogenously choose a fractional amount ψ of the option to exercise at time $t = 1$, $0 \leq \psi \leq 1$. Define the executive's utility, conditional on exercising this fraction of options, as

$$U_{1,\psi}(q, W_1, S_1, I) = q \times U\left(W_1 + \psi(S_1 + S_1\delta - K) + (1-\psi)[uS_1 - K]^+ + I(u-1)\right)$$

$$+ (1-q) \times U\left(W_1 + \psi(S_1 + S_1\delta - K) + (1-\psi)[dS_1 - K]^+ + I(d-1)\right). \tag{49}$$

The executive's problem at time $t = 1$ is to maximize $U_{1,\psi}(q, W_1, S_1, I)$ over I and ψ. The optimal investment in company stock conditional on exercising a ψ fraction of options is

$$I^*_{1,\psi}\,(q, W_1, S_1) = \operatorname*{argmax}_{I \geq 0} U_{1,\psi}(q, W_1, S_1, I). \tag{50}$$

Investment is subject to a short-sale constraint. If the optimal investment is positive, then the derivative of the indirect utility function with respect to investment is zero. Rearranging the first-order condition for the executive's optimal investment conditional on exercising ψ fraction of options implies

$$\frac{U'\left(W_1 + \psi(S_1 + S_1\delta - K) + (1-\psi)[dS_1 - K]^+ + I^*_{1,\psi}(d-1)\right)}{U'\left(W_1 + \psi(S_1 + S_1\delta - K) + (1-\psi)[uS_1 - K]^+ + I^*_{1,\psi}(u-1)\right)} = \frac{1-q_0}{q_0} \times \frac{q}{1-q}. \tag{51}$$

The marginal utility function is strictly positive and decreasing. Therefore, if $I^*_{1,\psi}(q, W_1, S_1) > 0$ then the left-hand side is strictly greater than 1. The right-hand side being strictly greater than 1 implies $q > q_0$. Therefore, if the executive optimally invests in company stock after option exercise, then she is optimistic: $I^*_{1,\psi}(q, W_1, S_1) > 0$ implies $q > q_0$. Since this holds for all $0 \le \psi \le 1$, it would hold for the optimally chosen value of ψ as well. □

A.2. Continuous Time Proofs

We assume the solutions to the executive's indirect utility problems Eqs. (9) and (11) are smooth with continuous first derivatives in time and continuous second derivatives in the state variables. The executive's indirect utility function after exercising the option $V(W_t, S_t, t)$ is guaranteed to be increasing and strictly concave in outside wealth by Theorem 7.7 of Karatzas and Shreve (1998, p. 115). Similar assumptions are not valid for the executive's indirect utility function before exercise of the option $f(W_t, S_t, t)$. The option's convex payoff, for example, may override the executive's risk aversion, encouraging risk-taking in some states. In the following proofs, all properties of the indirect utility function $f(W_t, S_t, t)$ are derived from its relation with the indirect utility function $V(W_t, S_t, t)$.

The solution to the executive's indirect utility function before exercising the option obeys the PDE

$$\begin{aligned} 0 = f_t + f_S S\left(\lambda + \eta - \delta\right) + \max_{\omega^M \in \mathbb{R}, \omega^S \ge 0} \Bigg\{ & f_W W \left(r + \omega_t^M(\mu - r) + \omega_t^S(\lambda + \eta - r)\right) \\ & + \frac{1}{2} f_{SS} S^2 \left(\omega_t^S \sigma_S\right)^2 + \frac{1}{2} f_{WW} W^2 \left((\omega_t^M \sigma_M)^2 + 2\rho\omega_t^M \omega_t^S \sigma_M \sigma_S + (\omega_t^S \sigma_S)^2\right) \\ & + f_{SW} W S \left(\omega_t^M \rho \sigma_M \sigma_S + \omega_t^S \sigma_S^2\right) \Bigg\}. \end{aligned} \tag{52}$$

Similarly, the solution to the executive's indirect utility function after exercising the option obeys the PDE

$$\begin{aligned} 0 = V_t + \max_{\omega^M \in \mathbb{R}, \omega^S \ge 0} \Bigg\{ & V_W W \left(r + \omega_t^M(\mu - r) + \omega_t^S(\lambda + \eta - r)\right) \\ & + \frac{1}{2} V_{WW} W^2 \left((\omega_t^M \sigma_M)^2 + 2\rho\omega_t^M \omega_t^S \sigma_M \sigma_S + (\omega_t^S \sigma_S)^2\right) \Bigg\}. \end{aligned} \tag{53}$$

We consider option exercise regions that do not contain isolated points in the executive's outside wealth. That is, for all $(W_t, S_t, t) \notin D$, there exists a region $A^-_\epsilon(W_t, S_t, t) \subset D^c$ or a region $A^+_\epsilon(W_t, S_t, t) \subset D^c$, or both, where $A^-_\epsilon(\cdot)$ and $A^+_\epsilon(\cdot)$ are the sets of wealth levels infinitesimally smaller and greater than W_t, respectively, D is the option continuation region, and D^c is the option exercise region.[31] In other words, the executive does not use a "knife-edge" exercise policy in which she exercises the option for a given outside wealth, but does not exercise the option for all infinitesimally different outside wealth levels.

A.2.1. Continuous Time Lemmas

The proofs requires two Lemmas. The first shows that smooth pasting conditions apply to the executive's problem. The executive's marginal indirect utility with respect to wealth does not change as a result the exercise decision. Additionally, a useful outcome of this condition is that the marginal indirect utility with respect to the stock price can be written in terms of the marginal indirect utility with respect to wealth at exercise because the option is being converted into wealth on exercise. The second Lemma demonstrates that the absolute risk aversion of the executive's indirect utility function does not increase on exercise of the option. The executive structures her investment policy in anticipation of the option exercise decision, and, as a result, her risk aversion is continuous.

Lemma 4. *For any (W_t, S_t, t) not in the continuation region, the executive's indirect utility functions before and after option exercise satisfy smooth pasting conditions with respect to wealth and the stock price:*

$$f_W(W_t, S_t, t) = \quad V_W(W_t + n(S_t - K)^+, t) \ \text{, and}$$

$$f_S(W_t, S_t, t) = n \cdot V_W(W_t + n(S_t - K)^+, t) \ \text{for all } (W_t, S_t, t) \notin D.$$

Proof. The executive can always choose to exercise the option early. Thus, her indirect utility from holding the option will always be at least as great as that realized from immediately exercising the option:

$$f(W_t, S_t, t) > V(W_t + n(S_t - K)^+, t) \qquad \text{for all } (W_t, S_t, t) \in D \text{ , and}$$

$$f(W_t, S_t, t) = V(W_t + n(S_t - K)^+, t) \qquad \text{for all } (W_t, S_t, t) \notin D.$$

[31] These sets are $A_\epsilon^-(W_t, S_t, t) = \left\{(\dot{W}, S_t, t) \middle| 0 < W_t - \dot{W} < \epsilon\right\}$ and $A_\epsilon^+(W_t, S_t, t) = \left\{(\dot{W}, S_t, t) \middle| 0 < \dot{W} - W_t < \epsilon\right\}$.

Choose a (W_t, S_t, t) that is not in the continuation region, $(W_t, S_t, t) \notin D$. For any $\epsilon > 0$, it must be that

$$\frac{f(W_t+\epsilon, S_t, t) - f(W_t, S_t, t)}{\epsilon} \geq \frac{V(W_t + n(S_t-K)^+ + \epsilon, t) - V(W_t + n(S_t-K)^+, t)}{\epsilon}, \quad \text{and} \tag{54}$$

$$\frac{f(W_t, S_t, t) - f(W_t-\epsilon, S_t, t)}{\epsilon} \leq \frac{V(W_t + n(S_t-K)^+ + \epsilon, t) - V(W_t + n(S_t-K)^+, t)}{\epsilon}. \tag{55}$$

Taking the limit of Eq. (54) implies that $f_W(W_t, S_t, t) \geq V_W(W_t + n(S_t-K)^+, t)$. Similarly, the limit of Eq. (55) implies that $f_W(W_t, S_t, t) \leq V_W(W_t + n(S_t-K)^+, t)$. Therefore, it must be that

$$f_W(W_t, S_t, t) = V_W(W_t + n(S_t-K)^+, t) \quad \text{for all } (W_t, S_t, t) \notin D. \tag{56}$$

A similar argument proves that the first derivatives of $f(\cdot)$ and $V(\cdot)$ with respect to the stock price are equal for all $(W_t, S_t, t) \notin D$. As the executive will only exercise when $S_t > K$,

$$f_S(W_t, S_t, t) = \frac{\partial}{\partial S} V(W_t + n(S_t-K)^+, t) = n \cdot V_W(W_t + n(S_t-K)^+, t) \quad \text{for all } (W_t, S_t, t) \notin D. \tag{57}$$

□

Lemma 5. *For any (W_t, S_t, t) not in the continuation region, the absolute risk aversion of the executive's indirect utility function immediately before exercise is equal to that of the indirect utility function immediately after exercise:*

$$-\frac{f_{WW}(W_t, S_t, t)}{f_W(W_t, S_t, t)} = -\frac{V_{WW}(W_t + n(S_t-K)^+, t)}{V_W(W_t + n(S_t-K)^+, t)} \quad \textit{for all } (W_t, S_t, t) \notin D. \tag{58}$$

Proof. By construction, for all $f(W_t, S_t, t)$ there exists an wealth $\hat{W}_t$ such that the executive is indifferent between (i) owning the option and (ii) receiving wealth $\Lambda(W_t, S_t, t)$ in exchange for forfeiture of the option. Define this as

$$f(W_t, S_t, t) = V(\hat{W}_t, t), \text{ where } \hat{W}_t = W_t + \Lambda(W_t, S_t, t). \tag{59}$$

$\Lambda(W_t, S_t, t)$ is the executive's subjective value for the options as a function of wealth, the stock price, and time. The subjective value function is bounded below by the intrinsic value of the option $(S_t - K)^+$, because the executive will never have utility lower than that realized by immediately exercising the option.

Since $f(W_t, S_t, t)$ and $V(W_t, S_t, t)$ have continuous second derivatives in the state variables, $\Lambda(W_t, S_t, t)$ also has continuous second derivatives in these variables. The second partial derivative of $f(W_t, S_t, t)$ with respect to wealth can be written as a function of the partial derivatives of $V(\cdot)$ and $\Lambda(\cdot)$:

$$f_{WW}(W_t, S_t, t) = V_{WW}(\hat{W}_t, t)\left[1 + \Lambda_W(W_t, S_t, t)\right]^2 + V_W(\hat{W}_t, t)\Lambda_{WW}(W_t, S_t, t). \tag{60}$$

The executive's subjective value of the options is equal to the option's intrinsic value whenever early exercise is optimal. That is

$$\Lambda(W_t, S_t, t) = n(S_t - K)^+ \text{ for all } (W_t, S_t, t) \notin D. \tag{61}$$

The optimal exercise policy does not contain isolated points in wealth. For any point (W_t, S_t, t) in the exercise region, there exists a wealth interval that includes (W_t, S_t, t) and is in the exercise region. As the subjective value of the options is constant over this interval, the first and second derivatives of $\Lambda(\cdot)$ with respect to wealth are 0 for all points in the interval: $\Lambda_W(W_t, S_t, t) = \Lambda_{WW}(W_t, S_t, t) = 0$ for all $(W_t, S_t, t) \notin D$. Therefore,

$$f_{WW}(W_t, S_t, t) = V_{WW}(W_t + n(S_t - K)^+, t) \text{ for all } (W_t, S_t, t) \notin D. \tag{62}$$

Combining this result with the smooth pasting result of Lemma 4 means that the absolute risk aversion of the executive's indirect utility function does not change on exercise of the option:

$$-\frac{f_{WW}(W_t, S_t, t)}{f_W(W_t, S_t, t)} = -\frac{V_{WW}(W_t + n(S_t - K)^+, t)}{V_W(W_t + n(S_t - K)^+, t)}. \qquad \square$$

A.2.2. Proofs of Continuous Time Propositions

Proposition 4. *The continuation region D of the constrained, optimistic executive is a subset the continuation region D^U of an unconstrained, non-optimistic agent:*

$$D \subseteq D^u.$$

Proof: Define f^u and V^u as the indirect utility functions representing the solution for an unconstrained agent's portfolio choice problem as

$$f^u(W_t, S_t, t) = \max_{t_v \leq \tau \leq T, \omega_t^M, \omega_t^S} V(W_\tau^\omega + n(S_\tau - K)^+, \tau), \text{ and} \tag{63}$$

$$V^u(W_t, \tau) = \max_{\omega_t^M, \omega_t^S} \mathbb{E}\left[U\left(W_T^\omega\right)\right] \text{ s.t. (10)}. \tag{64}$$

The unconstrained agent synthetically sells the option in the market and invests optimally. Hence, the agent's exercise policy will reflect the market valuation maximization exercise policy for the option. Therefore, without loss of generality, assume that the unconstrained agent has an optimism level equal to that of the executive. Choose $(W_t, S_t, t) \notin D^u$. The definition of the continuation region implies that $f^u(W_t, S_t, t) \leq V^u(W_t + (S_t - K)^+, t)$. By definition, $f(W_t, S_t, t) \leq f^u(W_t, S_t, t)$. Therefore, $f(W_t, S_t, t) \leq V^u(W_t + (S_t - K)^+, t)$.

V^u and V are smooth, increasing in outside wealth, and strictly concave in outside wealth. Given that the executive is optimistic about stock returns, the short-sale constraint does not bind after exercise, $V^u(W_t + (S_t - K)^+, t) = V(W_t + (S_t - K)^+, t)$. So, $f(W_t, S_t, t) \leq V(W_t + (S_t - K)^+, t)$. Therefore, $(W_t, S_t, t) \notin D$. $\square$

Proposition 5. *The executive retains shares received from option exercise if and only if she is optimistic.*

Proof: Taking first-order conditions of Eq. (52) with respect to ω^M and ω^S and solving for the optimal portfolio weights yields

$$\omega^M = \frac{-f_W}{f_{WW}W}\frac{(\mu - r)}{\sigma_M^2} - \beta\left(\omega^S + \frac{f_{SW}}{f_{WW}}\frac{S}{W}\right), \text{ and}$$
$$\omega^S = \max\left[\frac{-f_W W(\lambda + \eta - r) - f_{SW}WS\sigma_S^2 - f_{WW}W^2\rho\sigma_M\sigma_S\omega^M}{(f_{SS}S^2 + f_{WW}W^2)\sigma_S^2}, 0\right]. \tag{65}$$

Similarly, the optimal portfolio weights after option exercise are found by taking first-order conditions of Eq. (53) and solving:

$$\theta^M = -\frac{V_W}{V_{WW}W}\frac{(\mu - r)}{\sigma_M^2} - \beta\theta^S, \text{ and}$$
$$\theta_S = \max\left[-\frac{V_W}{V_{WW}W}\frac{\eta}{((1-\rho^2))\sigma_S^2}, 0\right]. \tag{66}$$

Immediately before exercise of the option, the executive's optimal holding in company stock, ω^S, is either positive or zero. First, consider the case when $\omega^S = 0$. Eq. (66) shows that the optimal holdings after option exercise are strictly positive if and only $\eta > 0$ (the inverse coefficient of relative risk aversion term $-\frac{V_W}{V_{WW}W}$ is positive for an executive maximizing a risk-averse terminal utility function by Theorem 7.7 of Karatzas and Shreve (1998, p. 115)). Therefore, if the executive does not own stock immediately before option exercise, she retains shares received from option exercise if and only if she is optimistic.

Consider the case when the executive holds a positive amount of company stock immediately before option exercise, $\omega_S > 0$. Consider the optimal stock holdings in Eq. (65). By the smooth pasting from Lemma 4, $f_S = n \cdot f_W$. Given that the optimal exercise policy does not contain isolated points in wealth, there is an interval in wealth that includes (W_t, S_t, t) for which this analytical form of f_S is appropriate. Differentiation with respect to W implies that $f_{SW} = n \cdot f_{WW}$ for $(W_t, S_t, t) \notin D$. Substitute this into Eq. (65) along with the optimal holdings in the market ω_M and solve to find the optimal stock holdings immediately before option exercise:

$$\omega^S = -\frac{f_W W \cdot \eta}{\sigma_S^2 \left(f_{WW} W^2 (1-\rho^2) + f_{SS} S^2\right)} - \frac{f_{WW} W S \cdot n(1-\rho^2)}{\left(f_{WW} W^2 (1-\rho^2) + f_{SS} S^2\right)}. \tag{67}$$

For all points outside the continuation region, the proof of Lemma 5 shows that $f_{WW} = V_{WW} < 0$. The indirect utility function must also be concave with respect to the stock price outside the continuation region, $f_{SS} < 0$. [32] Therefore, the denominator in Eq. (67) is negative. The second term on the right-hand side of Eq. (67) (with f_{WW} in the numerator), representing hedging demand, is negative. The absolute value of the left-hand term's denominator can be reduced by eliminating the f_{SS} term. Combining these observations implies

$$\omega^S < -\frac{f_W \eta}{f_{WW} \sigma_S^2 \left(W(1-\rho^2)\right)}. \tag{68}$$

Define the dollar holdings in company stock before option exercise as $\omega_\$^S = \omega_S \times W$ and the dollar holdings in company stock after option exercise as $\theta_\$^S = \theta_S \times W$:

$$\omega_\$^S < -\frac{f_W(W_t, S_t, t)}{f_{WW}(W_t, S_t, t)} \frac{\eta}{\left((1-\rho^2)\right) \sigma_S^2}, \text{ and} \tag{69}$$

$$\theta_\$^S = -\frac{V_W(W_t + n(S_t - K)^+, t)}{V_{WW}(W_t + n(S_t - K)^+, t)} \frac{\eta}{\left((1-\rho^2)\right) \sigma_S^2}. \tag{70}$$

[32] A proof of this point proceeds by contradiction. Choose a (W_t, S_t, t) for which exercise of the option is optimal, $(W_t, S_t, t) \in D$. Assume that $f_{SS}(W_t, S_t, t) \geq 0$ at (W_t, S_t, t). Consider a strategy in which the executive invests all her wealth in the risk-free asset and instantaneously delays exercise of the option. This leads to stochastic outcomes in the stock, but a guaranteed increase in wealth. By definition, $f(\cdot) \geq V(\cdot)$. Therefore, due to Jensen's inequality and a positive risk-free rate, this strategy yields a higher utility than immediate exercise, so $(W_t, S_t, t) \notin D$. Therefore, $f_{SS} < 0$. An intuitive proof proceeds by assuming the existence of a set of stock prices bordering S, for which it is optimal for the executive to exercise the option. The subjective value of the option is $(S - K)^+$ for early exercise points. So, $\Lambda_S = 1, \Lambda_{SS} = 0$. Apply the logic used in Lemma 5 to write the derivatives of the indirect utility function $f(\cdot)$ in terms of derivatives of $V(\cdot)$ and $\Lambda(\cdot)$, $f_{SS} = V_{WW}\Lambda_S^2 + V_W \Lambda_{SS}$. Therefore, $f_{SS} = V_{WW} < 0$.

Share retention requires that $\theta^S_\$ > \omega^S_\$$ and $\theta^S_\$ > 0$. The inverse coefficients of absolute risk aversion in the expressions above are equal by Lemma 5. Hence, shares are retained if and only if $\eta > 0$. Therefore, if the executive owns company stock immediately before option exercise, she retains shares received from option exercise if and only if she is optimistic. □

Appendix B. Determination of CEO option holdings

The indicators of Malmendier and Tate require observing the composition of CEO option portfolios for each fiscal year. This information is available for proxy statements filed on or after December 15, 2006, when SEC amendments to executive compensation disclosure took effect, requiring that firms report details on outstanding equity awards in addition to already mandated information on new equity awards. The outstanding award data provide details on outstanding options, including the number of underlying securities, strike price, and expiration date. However, prior to December 15, 2006, the SEC did not require firms to report details on executives' outstanding equity options.

Therefore, we need to determine the option portfolios for each CEO for the sample prior to and including 2006. These option portfolios are calculated following a dynamic portfolio simulation algorithm similar to that developed by Hall and Liebman (1998). Our algorithm is adjusted to use SEC standardized disclosure requirements for the compensation of CEOs and senior executives that were in place for our sample period, but not for most of the period from 1980 through 1994 examined by Hall and Liebman. Beginning with all proxy statements issued after January 1, 1993, companies were required to report details of new option grants, summary statistics on the total number of options granted in a fiscal year, and the total number of options held by an executive at the end of the fiscal year. Prior to this, companies reported heterogeneous compensation information, which required Hall and Liebman to infer some option exercise and grant data when determining executive option portfolios. These inferences are not necessary for our sample period. A description of our algorithm follows and a detailed comparison to Hall and Liebman concludes this section.

B.1. Algorithm

The algorithm tracks the dynamic portfolio of executive incentive options. For each CEO in our sample, it works through the history of option grants and exercises chronologically to determine the annual composition of the incentive option portfolio. The algorithm starts each fiscal year with the portfolio from the prior fiscal year-end (for tenured executives) or with a newly created portfolio (for new executives). Starting allocations for new option portfolios are described below in the *Initial conditions.* The algorithm then adds any new option grants reported in the Execucomp stock option grants table. The total number of options granted from the stock options grant table is compared to that reported in the Execucomp annual compensation table and any missing options are added as described under *Grant data reconciliation process.* The algorithm then removes options exercised by the executive during the fiscal year from the portfolio until it reaches the reported total number of unexercised options held by the executive at year-end. To determine the options to exercise, the algorithm first sorts options by expiration and exercises those closest to expiration. When multiple options share an expiration date, the algorithm exercises options in order of increasing strike price. This composite exercise rule is designed to approximate a policy of minimizing the loss of the time-value of the option forgone on exercise. At the end of the each fiscal year, any options that remain in the algorithmic portfolio that would have expired during the fiscal year are removed. Finally, the algorithm reconciles the total number of options remaining in the algorithmic portfolio with the total number of options reported as held by the CEO in Execucomp, adding or removing options as described under the *Year-end reconciliation process.* The algorithm adjusts the number of shares underlying and strike prices for stock splits at all times during the process.

B.2. Initial conditions

We begin tracking option grant and holdings data when a CEO enters the Execucomp database. In many cases, a CEO will be a senior executive before being named CEO. As SEC rules during our sample period required that firms report compensation information on the four highest compensated employees, in addition to the CEO, we can often observe option grants for several years before a senior executive was named CEO. By incorporating information from this period, we are able to build a more accurate initial portfolio at the start of an executive's tenure as CEO.

In some cases, a CEO will enter the sample with an existing option portfolio reported in the Execucomp annual compensation table, but without any corresponding history of option grants. For these cases, we assume a representative option was granted three years prior with a strike price equal to the median stock price in that fiscal year. As executive options are typically granted with an expiration time of ten years, we assume this representative option has seven years remaining. If the firm does not have a stock price history covering those prior three years, we cannot compute a strike price for the representative option. For these cases, we sequentially look at the two-year prior, one-year prior, and current fiscal year to determine a period for which data is available. The strike price is set to the median price over the oldest fiscal year for which price data is available. The grant date and the expiration date of the representative option are adjusted according.

B.3. Grant data reconciliation process

For each fiscal year, we reconcile grant information contained in the Execucomp stock options grant table to that in the annual compensation table. The stock options grant table contains detailed information on each incentive option granted to an executive. These data include the number of underlying shares, grant date, strike price, and expiration date for each grant. The annual compensation table only contains an aggregate total of the number of options granted. Our objective in reconciling the data sources is to use the detailed information from the option grant table, while ensuring that we capture the total number of options granted to the CEO.

There are two possible types of reconciliation issues. The total number of options awarded reported on the stock options grant table may be less than the total reported on the annual compensation table. Alternatively, the grants table may report that the CEO received more options in aggregate than reported in the annual compensation table. We address each of these reconciliation problems separately.

The most common reconciliation issue occurs when the total number of options awarded from the stock option grant table is less than that reported on the annual compensation table. In such cases, the option grant table may either present incomplete information on grants or no data at all. When the option grant table has incomplete information, we add options to each individual grant so that the total number of options equals that from the annual compensation table. Our process adds options proportionally so that each individual grant retains its weight relative to the overall option package, where weights are based on the number of options. When the annual compensation table indicates that an executive received incentive option grants in a fiscal year, but the stock option grants table does not have any detailed information, we follow the approach of Hall and Liebman. We assume the executive received an option with a strike price equal to the median stock price over the fiscal year and an expiration period of 10 years.

In a very small number of cases, the total number of options granted on the stock option grants table exceeds that from the annual compensation table. For these cases, we make no specific adjustment to reconcile the data in the two tables. Instead, we allow the option exercise and end-of-year reconciliation components of the algorithm to address such problems.

B.4. Year-end reconciliation process

At the end of each fiscal year, we ensure that the total number of options in the algorithmic portfolio matches the total number of unexercised option reported in Execucomp. When the algorithmic portfolio contains too many options, we remove the excess options following the closest-to-expiration, lowest strike price decision rule described earlier. When the algorithmic portfolio contains too few options, we follow Hall and Liebman and scale up the number of underlying shares in the algorithmic portfolio to match the reported year-end amount.

In a very small number of cases, the algorithm will determine that all of an executive's options had expired at year-end, but the annual compensation table will report the executive had options remaining. These cases occur most frequently in the period before an executive had been named CEO. As the SEC required companies to report the compensation of the four highest non-CEO executives, there may be gaps in executive pre-CEO compensation history, which limits information in the algorithm and results in all options in the algorithmic portfolio expiring. For these cases, we simply reseed the algorithm using the representative-option approach described earlier.

B.5. Comparison to Hall and Liebman (1998)

Hall and Liebman examine CEO compensation from 1980 through 1994. Hall and Liebman develop their algorithm to make the best use of data available during their sample period, when compensation reporting requirements for firms were not standardized. Hall and Liebman focus on commonly reported elements, option grant data, and the dollar value of gains from option exercise to determine CEO option portfolios over time.

The Hall and Liebman algorithm proceeds by determining an initial option portfolio, incorporating any known information from the period before a senior executive was named CEO. Then, for each year, newly granted options are added to the portfolio. Next, an estimate of the number of options exercised in each year is computed by dividing the total dollar gains from option exercise by the median stock price. Options are then removed from the portfolio assuming the CEO follows a policy of exercising her oldest options first. Finally, the remaining number of options in the portfolio is adjusted to reconcile with the proxy statement's record of the total number of options held by the CEO. In many cases, the total number of options is not available from the proxy statement. In these cases, Hall and Liebman do not make any adjustments to the CEO's year-end option portfolio.

Our algorithm differs from that of Hall and Liebman in several ways. First, we use a slightly different rule when determining which option an executive exercised during a fiscal year. Our rule prioritizes option expiration date, followed by option strike price, whereas Hall and Liebman emphasize option age. As firms do not generally vary the expiration period of incentive option grants over time, both decision rules tend to choose the same option from the portfolio. Both decision rules are designed to simplify the underlying economic decision of an executive. When an option is exercised, the time value of the option is lost. Therefore, executives should choose options to minimize this loss. Time value of an option is a function of time remaining to expiration and strike price. We believe our approach approximates the portfolio choice problem for the executive. We first screen on option expiration to minimize the possibility that the algorithm implicitly assumes that an executive chooses to let options expire in the money. The second screen, based on option strike price, ensures that we are selecting options with relatively little time value remaining.

The second important difference is in determining the number of options exercised and reconciling the algorithmic portfolio holdings to the summary data from proxy statements. Hall and Liebman need to infer the number of options exercised, as companies frequently reported the value, but not the number, of options exercised during their sample period. Hall and Liebman estimate a number of options assuming that CEOs exercised options at a median stock price. When the number of options is available at fiscal year-end, Hall and Liebman first rectify any shortfall in the algorithmic portfolio by adding back exercised options. We are able to simplify this approach, since SEC rules required firms to report year-end option holdings for our sample. The exercise and add-back procedure under Hall and Liebman is equivalent to our approach in which we simply exercise options to reach the end-of-year level.

The third difference arises from the availability of two sources of option grant data during our sample period. Our data allows us to add integrity checks during the option grant procedure. Specifically, we are able to compare data from the stock option grant table to that from the annual compensation table. This allows us to identify any option grants missing from the grants table and either add a representative option or scale up the number of options granted.

Our algorithm, therefore, captures the core methodology employed by Hall and Liebman. The small differences in approaches derive from adapting the algorithm to take advantage of the types of data available after 1993.

Appendix C. Variable definitions

C.1. Optimism indicators

Share Retainer is an optimism indicator defined as 1 if the cumulative shares retained by a CEO on days with option exercise during a fiscal year exceeds 1% and 0 otherwise. On each day during which the CEO exercises an option, we compute the number of shares retained as the difference between the number of shares obtained from exercise and the number of shares sold. This value is set to 0 if the CEO sold more shares than were obtained from exercise. The percent shares retained from option exercise is equal to the total number of shares retained divided by the total number of shares exercised over the fiscal year. When *Share Retainer* is not available for a CEO during a fiscal year, we use the most recent computed value.

Holder 67 is the indicator introduced by Malmendier and Tate. At the start of each fiscal year, we examine the CEO's portfolio to see if it includes an option that is both (i) at least 67% in the money and (ii) has five years remaining until expiration. If the CEO delays exercising this option, the indicator is set to 1. It retains this value for all subsequent fiscal years.

Post-Longholder is the indicator introduced in Malmendier and Tate (2008). It is similar to the *Longholder* indicator first used in Malmendier and Tate (2005a,b), but refined to allow for time variation for a manager and derive from backward-looking information only. *Post-Longholder* indicator begins with a value of 0 for each CEO. It takes a value of 1 at the start of the first fiscal year in which the CEO's portfolio includes an option that is both (i) at least 40% in the money and (ii) has less than one year to expiration. The indicator then retains the value of 1 for all subsequent fiscal years.

C.2. Dependent and control variables

Acquisition is an indicator variable that takes the value of 1 if a firm completes at least one acquisition in a fiscal year and 0 otherwise. Acquisitions must meet conditions as specified in Masulis, Wang, and Xie (2007). Specifically, the deal value must be at least $1 million and be at least 1% of the firm's market value as of 11 days prior to the announcement date. The firm must control less than 50% of the target's shares prior to announcing the acquisition and hold 100% of the target's shares on completing the transaction.

Assets is the book value of total assets.

Cash Flow is the total of income before extraordinary items, depreciation, and amortization, normalized by the book value of total assets at the start of the fiscal year.

CEO Stock Ownership is the total number of shares owned by the CEO, excluding options, normalized by the firm's number of common shares outstanding.

CEO Vested Option Ownership is the total number of shares underlying the CEO's vested, unexercised options, normalized by the firm's number of common shares outstanding.

Debt Issuance is net total debt issuance over a fiscal year, normalized by the book value of total assets at the start of the fiscal year. Net total debt issuance is equal to long-term debt issuance minus any reduction in long-term debt plus changes in current debt.

Equity Issuance is total equity issuance (excluding IPOs) over a fiscal year, normalized by the book value of total assets at the start of the fiscal year.

E Index is the Bebchuk, Cohen, and Ferrell (2009) Entrenchment Index. The index is an integer value between 0 and 6 that captures whether a board of directors can prevent a majority of shareholders from imposing its preferences on the firm. The index is the count of the number of four possible "constitutional" and two possible "takeover" provisions applicable to a firm.[33]

Financing Deficit is dividends plus net investment plus change in net working capital less cash flow after interest and taxes (a definition used by Frank and Goyal (2003)). It is normalized by the book value of total assets at the start of the fiscal year. We use the constituent variable definitions of Malmendier, Tate, and Yan (2011).[34]

Financially Unconstrained is an indicator variable that takes the value of 1 if a firm's Kaplan and Zingales (1997) index of financial constraint is less than its peers, and 0 otherwise. We use the coefficient estimates and constituent variable definitions from Lamont, Polk, and Saá-Requejo (2001).[35]

Leverage is the book value of debt divided by the market value of assets. The book value of debt is defined as total long-term debt plus debt in current liabilities. The market value of assets is taken as the book value of assets, net of the book value of common/ordinary equity, plus the market value of equity, defined as closing share price at the end of the fiscal year multiplied by the number of common shares outstanding.

PP&E is total net property, plant, and equipment, normalized by the book value of total assets at the start of the fiscal year.

[33] The constitutional provisions are the presence of a classified board, limits on shareholder ability to amend corporate bylaws, limits on shareholder ability to amend the corporate charter, and requirements that a supermajority of shareholders approve an acquisition. The takeover provisions are the presence of a poison pill (shareholder rights plan) and the existence of golden parachutes for executives.

[34] Net investment is defined as capital expenditures + any increase investments + acquisitions + other uses of funds - the sale of property, plant, and equipment - sales of investment. Change in net working capital is the change in operating working capital + the change in cash and cash equivalents + change in current debt. Cash flow after interest and taxes is equal to income before extraordinary items + depreciation amortizations + extraordinary items and discontinued operations + deferred taxes + equity in net loss + other funds from operations + gain (loss) from sale of property, plant, equipment and other investments. Net investment, change in net working capital, and cash flow after interest and taxes are computed based on Compustat format codes.

[35] The KZ Index is given by $-1.001909 \times \textit{cashflow to capital} + 0.2826389 \times \textit{market to book} + 3.139193 \times \textit{debt to total capital} - 39.3678 \times \textit{dividends to capital} - 1.314759 \times \textit{cash holdings to capital}$, where *market to book* is the market to book ratio of assets and the market value of assets is as defined under Q; *debt to total assets* is total long-term debt + debt in current liabilities, normalized by the sum of total stockholder's equity, total long-term debt, and debt in current liabilities; *cash flow to capital* is the total of income before extraordinary items + depreciation and amortization, normalized by capital; *dividends to capital* is cash dividends, normalized by capital; and *cash holdings to capital* is cash and short-term investments, normalized by capital. Capital is defined as total net property, plant, and equipment.

Q is the market value-to-book value ratio of assets. The market value of assets is taken as the book value of assets, net of the book value of common/ordinary equity, plus the market value of equity, defined as closing share price at the end of the fiscal year multiplied by the number of common shares outstanding.

Return on Assets is operating income before depreciation, normalized by the book value of total assets at the start of the fiscal year.

References

Baker, M., Ruback, R., Wurgler, J., 2007. Behavioral corporate finance: a survey. In: Eckbo, E. (Ed.), The Handbook of Corporate Finance: Empirical Corporate Finance. Elsevier, Amsterdam, pp. 145–186.

Baker, M., Wurgler, J., 2002. Market timing and capital structure. The Journal of Finance 57, 1–32.

Baker, M., Wurgler, J., 2013. Behavioral corporate finance: an updated survey. In: Constantinides, G. M., Harris, M., Stulz, R. M. (Ed.), Handbook of the Economics of Finance. Elsevier, Amsterdam, pp. 357–424.

Bebchuk, L., Cohen, A., Ferrell, A., 2009. What matters in corporate governance? Review of Financial Studies 22, 783–827.

Ben-David, I., Graham, J. R., Harvey, C. R., 2013. Managerial miscalibration. Quarterly Journal of Economics 128, 1547–1584.

Bergman, N. K., Jenter, D., 2007. Employee sentiment and stock option compensation. Journal of Financial Economics 84, 667–712.

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

Campbell, T. C., Gallmeyer, M., Johnson, S. A., Rutherford, J., Stanley, B. W., 2011. CEO optimism and forced turnover. Journal of Financial Economics 101, 695–712.

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

Carpenter, J. N., Stanton, R., Wallace, N., 2010. Optimal exercise of executive stock options and implications for firm cost. Journal of Financial Economics 98, 315–337.

Cronqvist, H., Makhija, A. K., Yonker, S. E., 2012. Behavioral consistency in corporate finance: CEO personal and corporate leverage. Journal of Financial Economics 103, 20–40.

Du Fort, E., Frankel, S., 1953. Stability conditions in the numerical treatment of parabolic differential equations. Mathematical Tables and Other Aids to Computation 74, 135–152.

Epstein, S., 1979. The stability of behavior: I. on predicting most of the people much of the time. Journal of Personality and Social Psychology 37, 1097–1126.

Frank, M. Z., Goyal, V. K., 2003. Testing the pecking order theory of capital structure. Journal of Financial Economics 67, 217–248.

— 2009. Capital structure decisions: which factors are reliably important? Financial Management 38, 1–37.

Gervais, S., Heaton, J. B., Odean, T., 2011. Overconfidence, compensation contracts, and capital budgeting. The Journal of Finance 66, 1735–1777.

Goel, A. M., Thakor, A. V., 2008. Overconfidence, CEO selection, and corporate governance. The Journal of Finance 63, 2737–2784.

Graham, J. R., Harvey, C. R., 2001. The theory and practice of corporate finance: evidence from the field. Journal of Financial Economics 60, 187–243.

Graham, J. R., Harvey, C. R., Puri, M., 2013. Managerial attitudes and corporate actions. Journal of Financial Economics 109, 103–121.

Grasselli, M., Henderson, V., 2009. Risk aversion and block exercise of executive stock options. Journal of Economic Dynamics and Control 33, 109–127.

Gustafsson, B., Kreiss, H.-O., Oliger, J., 1995. Time Dependent Problems and Difference Methods. John Wiley & Sons, New York.

Hackbarth, D., 2009. Determinants of corporate borrowing: a behavioral perspective. Journal of Corporate Finance 15, 389–411.

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

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

Heaton, J. B., 2002. Managerial optimism and corporate finance. Financial Management 31, 33–45.

Henderson, V., Hobson, D., 2008. An explicit solution for an optimal stopping/optimal control problem which models an asset sale. Annals of Applied Probability 18, 1681–1705.

Hirshleifer, D., Low, A., Teoh, S. H., 2012. Are overconfident CEOs better innovators? The Journal of Finance 67, 1457–1498.

Ingersoll Jr, J. E., 2006. The subjective and objective evaluation of incentive stock options. The Journal of Business 79, 453–487.

Kaplan, S. N., Zingales, L., 1997. Do investment-cash flow sensitivities provide useful measures of financing constraints? The Quarterly Journal of Economics 112, 169–215.

Karatzas, I., Shreve, S. E., 1998. Methods of Mathematical Finance. Springer, New York.

Kolasinski, A. C., Li, X., 2013. Can strong boards and trading their own firm's stock help CEOs make better decisions? Evidence from acquisitions by overconfident CEOs. Journal of Financial and Quantitative Analysis 48, 1173–1206.

Lamont, O., Polk, C., Saá-Requejo, J., 2001. Financial constraints and stock returns. The Review of Financial Studies 14, 529–554.

Larwood, L., Whittaker, W., 1977. Managerial myopia: self-serving biases in organizational planning. Journal of Applied Psychology 62, 194–198.

Malmendier, U., Tate, G., 2005a. CEO overconfidence and corporate investment. The Journal of Finance 60, 2661–2700.

— 2005, b. Does overconfidence affect corporate investment? CEO overconfidence measures revisited. European Financial Management 11, 649–659.

— 2008. Who makes acquisitions? CEO overconfidence and the market's reaction. Journal of Financial Economics 89, 20–43.

Malmendier, U., Tate, G., Yan, J., 2011. Overconfidence and early-life experiences: the effect of managerial traits on corporate financial policies. The Journal of Finance 66, 1687–1733.

March, J. G., Shapira, Z., 1987. Managerial perspectives on risk and risk taking. Management Science 33, 1404–1418.

Masulis, R. W., Wang, C., Xie, F., 2007. Corporate governance and acquirer returns. The Journal of Finance 62, 1851–1889.

McKeon, S. B., 2013. Firm-initiated versus investor-initiated equity issues. Unpublished working paper, University of Oregon.

Roll, R., 1986. The hubris hypothesis of corporate takeovers. Journal of Business 59, 197–216.

Scheier, M. F., Carver, C. S., Bridges, M. W., 1994. Distinguishing optimism from neuroticism (and trait anxiety, self-mastery, and self-esteem): a reevaluation of the Life Orientation Test. Journal of Personality and Social Psychology 67, 1063–1078.

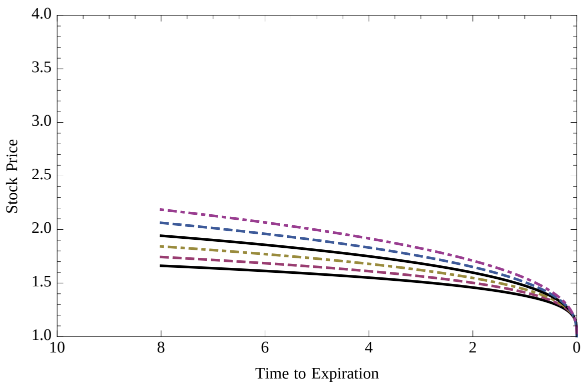
Shyam-Sunder, L., Myers, S. C., 1999. Testing static tradeoff against pecking order models of capital structure. Journal of Financial Economics 51, 219–244.

Svenson, O., 1981. Are we all less risky and more skillful than our fellow drivers? Acta Psychologica 47, 143–148.

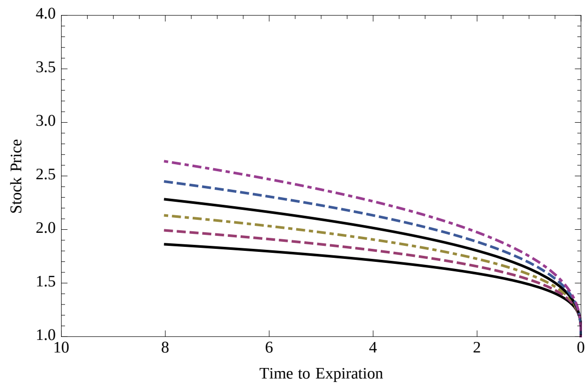
Weinstein, N. D., 1980. Unrealistic optimism about future life events. Journal of Personality and Social Psychology 39, 806–820.

Figure 1: Early Exercise Boundary Evolution with Optimism, Time, and Outside Wealth

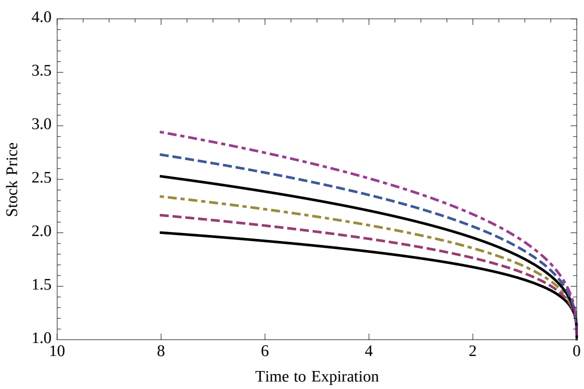
The graphs show the impact of optimism on the executive's early exercise boundary for the option. The optimism level η represents the executive's (instantaneous) expectation of stock returns above the market risk premium. η is 0.0 for the low solid line, 0.02 for the low dashed line, 0.04 for the low dotted-dashed line, 0.06 for the high solid line, 0.08 for the high dashed line, and 0.10 for the high dotted-dashed line. Panels (a), (b), (c), and (d) represent different amounts of outside wealth. The model parameters are $S_0 = 1$, $K = 1$, $\beta = 1.2$, $\delta = 0.03$, $\sigma_m = 0.2$, $\sigma_s = 0.4$, $r_f = 0.05$, $\mu = 0.13$, $t_v = 2$, and $T = 10$.



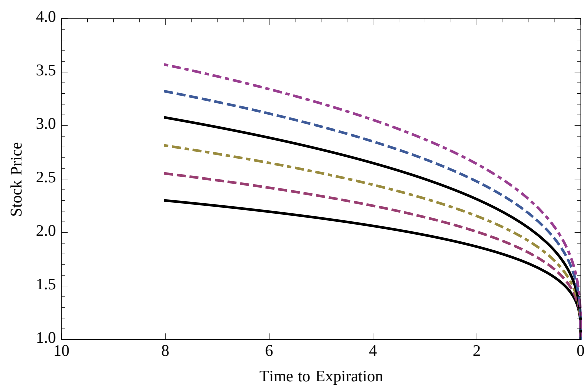
(a) Wealth = 0.51



(b) Wealth = 1.00



(c) Wealth = 1.49



(d) Wealth = 3.06

Table 1: Expected Remaining Time to Expiration at Option Exercise

The table shows the expected remaining time to expiration when an optimistic executive exercises a stock option. This conditional expectation is taken under the physical probability measure. The results are obtained by numerically solving the executive's terminal utility maximization problem. At time 0, the company stock has a price equal to 1 and the executive receives 1 at-the-money option on the stock, which vests in 2 years. The executive optimally exercises the option and optimally invests outside wealth in the company stock (subject to a short sale constraint), the market security, and a risk free asset. The executive has initial wealth 1.0 and constant relative risk aversion of 3. The continuously compounded risk free rate is 5%. The price of the market security follows a geometric Brownian motion with an instantaneous mean of 13% and an instantaneous volatility of 20%. The stock price also follows a geometric Brownian motion. In the base case, the stock pays a dividend of 3%, has a beta of 1.2, and has an instantaneous volatility of 40%. Under the physical probability measure, the stock's mean instantaneous return is equal to beta times the market risk premium plus the risk-free rate (i.e, as given by CAPM). The executive uses an optimistic probability measure when making decisions, believing that the stock return has instantaneous mean with drift given by CAPM plus her optimism level η. All executive portfolio and option exercise decisions are made under the optimistic probability measure.

		Optimism					
		$\eta = 0\%$	2%	4%	6%	8%	10%
Panel A: Dividend Effects							
$\delta =$	0.00	5.154	4.860	4.532	4.178	3.815	3.434
	0.01	5.247	4.975	4.694	4.386	4.063	3.722
	0.02	5.339	5.091	4.834	4.571	4.299	4.008
	0.03	5.418	5.195	4.974	4.731	4.499	4.251
	0.04	5.496	5.293	5.090	4.887	4.684	4.475
Panel B: Beta Effects							
$\beta =$	0.60	5.633	5.457	5.286	5.096	4.900	4.689
	0.80	5.591	5.408	5.224	5.021	4.818	4.602
	1.00	5.520	5.327	5.119	4.906	4.686	4.462
	1.20	5.418	5.195	4.974	4.731	4.499	4.251
	1.40	5.271	5.008	4.752	4.496	4.229	3.999
Panel C: Volatility Effects Holding Correlation Constant							
$\sigma_s =$	0.30	5.139	4.701	4.251	3.809	3.396	3.085
	0.35	5.297	4.994	4.681	4.364	4.036	3.720
	0.40	5.418	5.195	4.974	4.731	4.499	4.251
	0.50	5.586	5.458	5.325	5.200	5.069	4.938
	0.60	5.762	5.680	5.610	5.539	5.465	5.398
Panel D: Risk Aversion Effects							
$\gamma =$	1.10	4.578	4.041	3.585	3.260	3.077	3.001
	2.00	5.034	4.683	4.318	3.960	3.623	3.339
	3.00	5.418	5.195	4.974	4.731	4.499	4.251
	4.00	5.651	5.493	5.325	5.162	5.000	4.825
	5.00	5.801	5.679	5.556	5.434	5.308	5.184
Panel E: Initial Wealth Effects							
$W_0 =$	0.50	5.716	5.583	5.464	5.334	5.202	5.068
	0.75	5.541	5.356	5.166	4.974	4.777	4.588
	1.00	5.418	5.195	4.974	4.731	4.499	4.251
	1.50	5.184	4.897	4.608	4.318	4.027	3.757
	3.00	4.701	4.274	3.877	3.537	3.278	3.114

Table 2: Expected Value Ratio at Option Exercise

The table shows the expected ratio at exercise of an optimistic executive's option's intrinsic value to the value of a freely-traded American option. The executive is initially endowed with outside wealth and an at-the-money stock option. She invests outside wealth optimally in company stock (subject to a short sale constraint), a market security, and a risk-free asset, while simultaneously determining the optimal option exercise policy. This problem is solved numerically under the executive's optimistic probability measure with parameters as described in Table 1. The expected value ratio at exercise is computed under the physical probability measure, conditional on the executive exercising the option. Under the physical probability measure, the stock's instantaneous geometric mean return is equal to that given by CAPM (beta times the market risk premium plus the risk free rate). The executive's optimistic probability measure has an instantaneous geometric mean return equal to that given by CAPM plus her optimism level η.

		Optimism					
		$\eta = 0\%$	2%	4%	6%	8%	10%
Panel A: Dividend Effects							
$\delta =$	0.00	0.805	0.840	0.870	0.896	0.917	0.935
	0.01	0.841	0.873	0.901	0.924	0.943	0.958
	0.02	0.867	0.898	0.923	0.943	0.959	0.972
	0.03	0.887	0.915	0.938	0.956	0.970	0.980
	0.04	0.902	0.928	0.949	0.964	0.976	0.985
Panel B: Beta Effects							
$\beta =$	0.60	0.843	0.872	0.896	0.917	0.935	0.950
	0.80	0.854	0.883	0.907	0.928	0.945	0.959
	1.00	0.869	0.897	0.921	0.940	0.956	0.969
	1.20	0.887	0.915	0.938	0.956	0.970	0.980
	1.40	0.909	0.937	0.958	0.973	0.983	0.989
Panel C: Volatility Effects Holding Correlation Constant							
$\sigma_s =$	0.30	0.921	0.956	0.978	0.991	0.997	1.000
	0.35	0.904	0.936	0.959	0.975	0.987	0.994
	0.40	0.887	0.915	0.938	0.956	0.970	0.980
	0.50	0.852	0.875	0.895	0.912	0.927	0.939
	0.60	0.818	0.836	0.853	0.867	0.880	0.892
Panel D: Risk Aversion Effects							
$\gamma =$	1.10	0.972	0.990	0.997	1.000	1.000	1.000
	2.00	0.935	0.961	0.978	0.989	0.996	0.999
	3.00	0.887	0.915	0.938	0.956	0.970	0.980
	4.00	0.843	0.871	0.895	0.916	0.933	0.948
	5.00	0.806	0.833	0.857	0.878	0.896	0.913
Panel E: Initial Wealth Effects							
$W_0 =$	0.50	0.813	0.841	0.865	0.886	0.904	0.920
	0.75	0.859	0.888	0.913	0.933	0.949	0.962
	1.00	0.887	0.915	0.938	0.956	0.970	0.980
	1.50	0.920	0.946	0.965	0.979	0.988	0.994
	3.00	0.960	0.981	0.992	0.997	0.999	1.000

Table 3: Expected Proportion of Shares Retained on Option Exercise

The table shows the expected proportion of the shares received on option exercise that (instantaneously) continue to be held in the executive's optimal portfolio. The executive is initially endowed with outside wealth and an at-the-money stock option. She invests outside wealth optimally in company stock (subject to a short sale constraint), a market security, and a risk-free asset, while simultaneously determining the optimal option exercise policy. This problem is solved numerically under the executive's optimistic probability measure with parameters as described in Table 1. The expected proportion of shares retained on exercise is computed under the physical probability measure, conditional on the executive exercising the option. Under the physical probability measure, the stock's instantaneous geometric mean return is equal to that given by CAPM (beta times the market risk premium plus the risk free rate). The executive's optimistic probability measure has an instantaneous geometric mean return equal to that given by CAPM plus her optimism level η.

		Optimism					
		$\eta = 0\%$	2%	4%	6%	8%	10%
Panel A: Dividend Effects							
$\delta =$	0.00	0.000	0.082	0.156	0.218	0.267	0.300
	0.01	0.000	0.084	0.162	0.230	0.286	0.330
	0.02	0.000	0.085	0.167	0.242	0.305	0.359
	0.03	0.000	0.086	0.171	0.252	0.325	0.389
	0.04	0.000	0.087	0.174	0.260	0.344	0.422
Panel B: Beta Effects							
$\beta =$	0.60	0.000	0.064	0.128	0.191	0.252	0.308
	0.80	0.000	0.068	0.137	0.204	0.268	0.327
	1.00	0.000	0.075	0.150	0.223	0.291	0.353
	1.20	0.000	0.086	0.171	0.252	0.325	0.389
	1.40	0.000	0.105	0.206	0.296	0.374	0.445
Panel C: Volatility Effects Holding Correlation Constant							
$\sigma_s =$	0.30	0.000	0.158	0.299	0.416	0.523	0.638
	0.35	0.000	0.114	0.225	0.322	0.407	0.484
	0.40	0.000	0.086	0.171	0.252	0.325	0.389
	0.50	0.000	0.053	0.106	0.159	0.211	0.261
	0.60	0.000	0.036	0.072	0.107	0.143	0.178
Panel D: Risk Aversion Effects							
$\gamma =$	1.10	0.000	0.290	0.548	0.730	0.815	0.833
	2.00	0.000	0.144	0.275	0.393	0.505	0.615
	3.00	0.000	0.086	0.171	0.252	0.325	0.389
	4.00	0.000	0.061	0.121	0.181	0.241	0.297
	5.00	0.000	0.047	0.094	0.141	0.187	0.233
Panel E: Initial Wealth Effects							
$W_0 =$	0.50	0.000	0.054	0.109	0.164	0.221	0.277
	0.75	0.000	0.071	0.142	0.212	0.281	0.344
	1.00	0.000	0.086	0.171	0.252	0.325	0.389
	1.50	0.000	0.115	0.221	0.312	0.394	0.473
	3.00	0.000	0.184	0.334	0.474	0.605	0.711

Table 4: Summary Statistics of Sample Exercised Options, Firms, and CEOs

The table reports mean values and standard deviations (SD) of annual characteristics on the sample of options exercised, firms, and CEOs. All statistics are reported for the full sample and for two subsamples determined by the *Share Retainer (SR)* optimism indicator. *Share Retainer* is defined as 1 if the cumulative shares retained by a CEO on option exercise days during a fiscal year exceeds 1% and 0 otherwise. The sample is split into a *Share Retainer* subsample consisting of those observations where *Share Retainer* is 1. All other observations are placed in the non-*Share Retainer* subsample. *Value Ratio* is the ratio of the intrinsic value of the option (stock price less strike price) to the price of a freely-traded American option. The pricing model uses standard risk-neutral pricing and allows for early option exercise. It is calibrated to match the risk-free rate, option strike price, remaining time to expiration, underlying stock price, dividend yield, and stock return volatility at exercise. *Time to Expiration* is the remaining number of years until option expiration at exercise.Reported *Value Ratio* and *Time to Expiration* are aggregated for each CEO on an annual basis, using a simple average over the number of options exercised. All firm and CEO characteristics are defined in appendix C. t-statistics marked with ***, **, and * are significant at the 1%, 5% and 10% level, respectively.

	Full sample		Share Retainer Subsamples		
	Mean	SD	$SR = 1$ Mean	$SR = 0$ Mean	t-stat of difference
Panel A: Option Characteristics at Exercise					
Time to Expiration (years)	2.776	2.603	2.504	3.301	−13.513***
Value Ratio	0.940	0.106	0.942	0.937	2.046**
Panel B: Firm Characteristics					
Assets ($ billions)	13.880	71.768	15.513	10.553	3.084***
Cash Flow (normalized by assets)	0.119	0.101	0.114	0.128	−6.393***
E Index	1.246	1.036	1.315	1.105	9.062***
Financing Deficit (normalized by assets)	0.025	0.167	0.027	0.020	2.000**
Kaplan and Zingales Index	−8.143	18.366	−8.230	−7.969	−0.624
PP & E (normalized by assets)	0.297	0.267	0.299	0.294	0.788
Q	2.216	1.461	2.188	2.274	−2.643***
Return on Assets	0.176	0.119	0.172	0.184	−4.698***
Panel C: CEO Characteristics					
CEO Stock Ownership	0.016	0.040	0.018	0.012	7.412***
CEO Vested Option Ownership	0.009	0.010	0.009	0.009	−0.010

Table 5: Optimism and CEO option exercise behavior

The table reports empirical results from ordinary least squares (OLS) models examining the relation between the CEO optimism indicator, *Share Retainer*, and characteristics of exercised options. The dependent variable in columns (1) and (2) is *Value Ratio*, defined as the ratio of the intrinsic value of the option (stock price less strike price) to the price of a freely-traded American option. The pricing model uses standard risk-neutral pricing and allows for early option exercise. It is calibrated to match the risk-free rate, option strike price, remaining time to expiration, underlying stock price, dividend yield, and stock return volatility at exercise.The dependent variable in columns (3) and (4) is *Time to Expiration*, defined as remaining number of years until option expiration at exercise.Reported *Value Ratio* and *Time to Expiration* are aggregated for each CEO on an annual basis, using a simple average over the number of options exercised. CEO-years without option exercises are omitted from the analysis. *Share Retainer* is an optimism indicator defined as 1 if the cumulative shares retained by a CEO on option exercise days during a fiscal year exceeds 1% and 0 otherwise. *Stock Volatility* is the annualized standard deviation of daily log stock returns over the preceding year, *Dividend Yield* is the annualized dividend yield of the stock (calculated as the split-adjusted dividend payout over the preceding year divided by the year-end stock price), *Dividend Payer* is an indicator that takes the value of 1 if the stock paid a dividend in the preceding year and 0 otherwise, and *Risk-Free Rate* is the annual interest rate on a 10-year U.S. Treasury note. CEO stock ownership percentage and CEO vested option percentage are defined in Appendix C. All standard errors are clustered by CEO. t-statistics are reported in parentheses. Coefficients marked with ***, **, and * are significant at the 1%, 5% and 10% level, respectively.

	Value ratio (OLS)		Time to expiration (OLS)	
	(1)	(2)	(3)	(4)
Share Retainer	0.007**	0.006**	−0.894***	−0.844***
	(2.248)	(2.061)	(−11.767)	(−11.239)
Stock Volatility	−0.717***	−0.772***	26.725***	29.800***
	(−3.824)	(−4.121)	(6.005)	(6.767)
Dividend Yield	0.355***	0.354***	−3.738	−3.923
	(2.776)	(2.769)	(−1.136)	(−1.196)
Dividend Payer	0.020***	0.024***	−0.269**	−0.400***
	(4.341)	(5.078)	(−2.341)	(−3.531)
Risk-Free Rate	−0.250	−0.237	7.865*	7.545
	(−1.198)	(−1.129)	(1.656)	(1.609)
CEO Stock Ownership		−0.001		−4.806***
		(−0.017)		(−4.134)
CEO Vested Option Ownership		0.846***		−28.167***
		(5.392)		(−7.704)
Additional controls:				
Year FE	Yes	Yes	Yes	Yes
Industry FE	Yes	Yes	Yes	Yes
Return History	Yes	Yes	Yes	Yes
Observations	7646	7646	7646	7646
R^2	0.035	0.040	0.137	0.157

Table 6: Optimism and Leverage

The table reports empirical results from fixed effects (FE) models examining the relations between CEO optimism indicators and firm leverage. The dependent variable is *Leverage*, defined as the total book value of long term and current debt normalized by the market value of equity plus the book value of non-equity assets. *Share Retainer* is an optimism indicator defined as 1 if the cumulative shares retained by a CEO on option exercise days during a fiscal year exceeds 1% and 0 otherwise. *Holder 67* is an indicator that takes a value of 1 if a CEO at the start of the current or any prior fiscal year had an exercisable option expiring in five years that was more than 67% in the money. *Post-Longholder* is an indicator that begins with a value of 0 and takes a value of 1 once a CEO has held an option with less than one year to expiration that is also more than 40% in the money at the start of a fiscal year. All variables, including the controls of log assets, Q, return on assets, property, plant, and equipment, Bebchuk, Cohen, and Ferrell Entrenchment index, CEO stock ownership, CEO vested option ownership, and financing deficit, are defined in appendix C. All models include controls for stock returns over the preceding four years; coefficients are suppressed for brevity. Specifications include firm and year fixed effects. Standard errors are clustered by firm. t-statistics are reported in parentheses. Coefficients marked with ***, **, and * are significant at the 1%, 5% and 10% level, respectively.

	Leverage (FE)			
	(1)	(2)	(3)	(4)
Share Retainer	0.005**			0.005**
	(2.062)			(2.102)
Holder 67		−0.003		−0.002
		(−0.995)		(−0.879)
Post-Longholder			−0.002	−0.002
			(−0.654)	(−0.562)
Log Assets	0.024***	0.024***	0.024***	0.024***
	(5.846)	(5.809)	(5.875)	(5.875)
Q	−0.011***	−0.011***	−0.011***	−0.011***
	(−5.125)	(−4.981)	(−5.089)	(−4.996)
Return on Assets	−0.140***	−0.140***	−0.140***	−0.140***
	(−7.271)	(−7.234)	(−7.242)	(−7.284)
PP & E	−0.022*	−0.022*	−0.022*	−0.022*
	(−1.678)	(−1.679)	(−1.688)	(−1.658)
E Index	0.001	0.001	0.001	0.001
	(0.503)	(0.471)	(0.503)	(0.466)
CEO stock ownership	0.189***	0.190***	0.190***	0.191***
	(4.433)	(4.448)	(4.443)	(4.466)
CEO vested option ownership	1.056***	1.071***	1.059***	1.078***
	(6.168)	(6.215)	(6.178)	(6.259)
Financing deficit	0.109***	0.109***	0.109***	0.109***
	(15.561)	(15.529)	(15.540)	(15.539)
Additional controls:				
Firm FE	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes
Return history	Yes	Yes	Yes	Yes
Observations	15502	15502	15502	15502
R^2	0.831	0.831	0.831	0.831

Table 7: Optimism and Financing

The table reports empirical results from fixed effects (FE) models examining the impact of CEO optimism indicators on financing decisions. The dependent variable in columns (1) through (4) is *Debt Issuance*, defined as net debt issuance normalized by the lagged book value of assets. The dependent variable in columns (5) and (8) is *Equity Issuance*, defined as total equity issuance (excluding IPOs) normalized by the lagged book value of assets. *Share Retainer* is an optimism indicator defined as 1 if the cumulative shares retained by a CEO on option exercise days during a fiscal year exceeds 1% and 0 otherwise. *Holder 67* is an indicator that takes a value of 1 if a CEO at the start of the current or any prior fiscal year had an exercisable option expiring in five years that was more than 67% in the money. *Post-Longholder* is an indicator that begins with a value of 0 and takes a value of 1 once a CEO has held an option with less than one year to expiration that is also more than 40% in the money at the start of a fiscal year. *Financing Deficit* is the total dividend, investment, and working capital requirements less firm cash flow after interest and taxes, normalized by lagged assets. All variables, including the controls of log assets, Q, return on assets, property, plant, and equipment, Bebchuk, Cohen, and Ferrell Entrenchment index, CEO stock ownership, and CEO vested option ownership, are defined in appendix C. Models include controls for stock returns over the preceding four years; coefficients are suppressed for brevity. Specifications include firm and year fixed effects as well as interactions of year indicator, industry indicator (defined using Fama-French 12 industry categories), and stock return variables with financing deficit. Standard errors are clustered by firm. t-statistics are reported in parentheses. Coefficients marked with ***, **, and * are significant at the 1%, 5% and 10% level, respectively.

	Debt Issuance (FE)				Equity Issuance (FE)			
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Share Retainer	0.066***			0.062**	−0.020**			−0.022**
× Financing Deficit	(2.656)			(2.452)	(−2.145)			(−2.297)
Share Retainer	0.002			0.002	<0.001			<0.001
	(1.256)			(1.306)	(0.319)			(0.342)
Holder 67		0.018		0.008		0.001		−0.002
× Financing Deficit		(0.716)		(0.327)		(0.119)		(−0.233)
Holder 67		0.003		0.003*		−0.002		−0.002
		(1.625)		(1.692)		(−1.231)		(−1.224)
Post-Longholder			0.057**	0.043			0.009	0.014
× Financing Deficit			(2.125)	(1.531)			(0.675)	(1.039)
Post-Longholder			<0.001	−0.001			−<0.001	<0.001
			(0.016)	(−0.358)			(−0.129)	(0.075)
Δ Log Assets	0.018	0.014	0.017	0.021	−0.181***	−0.180***	−0.179***	−0.180***
× Financing Deficit	(0.447)	(0.346)	(0.424)	(0.526)	(−9.453)	(−9.387)	(−9.334)	(−9.457)
Δ Log Assets	0.031***	0.031***	0.031***	0.031***	−0.007	−0.007	−0.007	−0.007
	(4.332)	(4.352)	(4.332)	(4.331)	(−1.578)	(−1.561)	(−1.585)	(−1.577)
Δ Q	−0.018	−0.020	−0.020*	−0.017	−0.008**	−0.007*	−0.007*	−0.008**
× Financing Deficit	(−1.501)	(−1.596)	(−1.656)	(−1.411)	(−2.112)	(−1.931)	(−1.935)	(−2.098)
Δ Q	−0.009***	−0.009***	−0.009***	−0.009***	0.003***	0.003***	0.003***	0.003***
	(−7.411)	(−7.415)	(−7.432)	(−7.311)	(4.059)	(4.090)	(4.131)	(4.051)

(*Continued*)

Table 7: Continued

	Debt Issuance (FE)				Equity Issuance (FE)			
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Δ Return on Assets × Financing Deficit	−0.192	−0.179	−0.187	−0.199	0.096**	0.092*	0.090*	0.094**
	(−1.275)	(−1.191)	(−1.242)	(−1.320)	(2.048)	(1.942)	(1.904)	(2.011)
Δ Return on Assets	−0.059***	−0.059***	−0.060***	−0.059***	−0.007	−0.007	−0.007	−0.008
	(−5.469)	(−5.479)	(−5.607)	(−5.439)	(−1.033)	(−1.048)	(−1.012)	(−1.096)
Δ PP & E × Financing Deficit	0.076	0.071	0.072	0.075	0.035	0.036	0.036	0.035
	(0.982)	(0.917)	(0.925)	(0.964)	(1.007)	(1.041)	(1.039)	(1.014)
Δ PP & E	0.059***	0.059***	0.060***	0.060***	−0.022***	−0.022***	−0.022***	−0.022***
	(7.237)	(7.214)	(7.238)	(7.253)	(−4.779)	(−4.798)	(−4.788)	(−4.776)
E Index × Financing Deficit	0.010	0.012	0.011	0.010	−0.008	−0.009	−0.009*	−0.008
	(0.741)	(0.861)	(0.803)	(0.741)	(−1.574)	(−1.636)	(−1.662)	(−1.584)
E Index	−0.002*	−0.002	−0.002*	−0.002	<0.001	<0.001	<0.001	<0.001
	(−1.676)	(−1.537)	(−1.653)	(−1.574)	(0.369)	(0.301)	(0.355)	(0.305)
CEO Stock Ownership × Financing Deficit	−0.041	0.034	−0.025	−0.065	−0.201	−0.222*	−0.228*	−0.214*
	(−0.154)	(0.128)	(−0.095)	(−0.244)	(−1.576)	(−1.711)	(−1.783)	(−1.682)
CEO Stock Ownership	−<0.001	−0.001	−<0.001	−<0.001	0.007	0.008	0.008	0.008
	(−0.020)	(−0.028)	(−0.004)	(−0.013)	(0.372)	(0.396)	(0.382)	(0.390)
CEO Vested Option Ownership × Financing Deficit	−1.710	−1.897	−1.954	−1.832	−0.778	−0.754	−0.759	−0.808*
	(−1.478)	(−1.552)	(−1.629)	(−1.579)	(−1.595)	(−1.542)	(−1.548)	(−1.663)
CEO Vested Option Ownership	0.348***	0.327***	0.335***	0.323***	−0.055	−0.046	−0.056	−0.049
	(2.848)	(2.670)	(2.739)	(2.650)	(−0.601)	(−0.502)	(−0.612)	(−0.528)
Financing Deficit	0.582***	0.627***	0.622***	0.570***	0.247***	0.230***	0.228***	0.246***
	(7.917)	(8.784)	(8.846)	(7.670)	(8.629)	(8.092)	(8.111)	(8.417)
Additional controls:								
Firm FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Return History	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year FE × Financing Deficit	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Return History × Financing Deficit	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Industry FE × Financing Deficit	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	14786	14786	14786	14786	14786	14786	14786	14786
R^2	0.664	0.663	0.663	0.665	0.589	0.589	0.589	0.590

Table 8: Optimism and Acquisition Activity

The table reports empirical results from conditional logit (CLOGIT) models examining the impact of CEO optimism indicators on acquisition activity. The dependent variable is *Acquisition*, an indicator defined to be 1 if the firm completed an acquisition worth at least 3% of its market capitalization in the year following the measurement of CEO optimism and control variables. *Share Retainer* is an optimism indicator defined as 1 if the cumulative shares retained by a CEO on option exercise days during a fiscal year exceeds 1% and 0 otherwise. *Holder 67* is an indicator that takes a value of 1 if a CEO at the start of the current or any prior fiscal year had an exercisable option expiring in five years that was more than 67% in the money. *Post-Longholder* is an indicator that begins with a value of 0 and takes a value of 1 once a CEO has held an option with less than one year to expiration that is also more than 40% in the money at the start of a fiscal year. *Financially Unconstrained* is a indicator variable that takes a value of 1 if the firm's Kaplan-Zingales index in a fiscal year is less than the median for that firm's industry peers over the same fiscal year. Peers are determined using Fama-French 12 industry categories. All variables, including the controls of log assets, Q, cash flow, Bebchuk, Cohen, and Ferrell Entrenchment index, CEO stock ownership, and CEO vested option ownership, are defined in appendix C. All models include controls for stock returns over the preceding four years; coefficients are suppressed for brevity. Specifications include firm and year fixed effects. Interacted models in columns (5) through (8) include year indicator and stock return variables interacted with financing deficit. CLOGIT models group observations by firm and report pseudo-R^2. Standard errors are clustered by firm. t-statistics are reported in parentheses. Coefficients marked with ***, **, and * are significant at the 1%, 5% and 10% level, respectively.

	Acquisition (CLOGIT)							
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Share Retainer					0.460***			0.457***
× Financially Unconstrained					(2.733)			(2.682)
Share Retainer	0.191**			0.193**	−0.066			−0.065
	(2.054)			(2.060)	(−0.516)			(−0.500)
Holder 67						−0.231		−0.243
× Financially Unconstrained						(−1.305)		(−1.335)
Holder 67		0.192**		0.197**		0.311**		0.319**
		(1.981)		(1.992)		(2.214)		(2.228)
Post-Longholder							0.011	0.068
× Financially Unconstrained							(0.048)	(0.283)
Post-Longholder			0.024	−0.036			0.017	−0.063
			(0.187)	(−0.271)			(0.094)	(−0.349)
Log Assets					−0.056	−0.054	−0.067	−0.045
× Financially Unconstrained					(−0.711)	(−0.676)	(−0.840)	(−0.556)
Log Assets	−0.422***	−0.449***	−0.421***	−0.450***	−0.395***	−0.427***	−0.391***	−0.431***
	(−4.368)	(−4.571)	(−4.334)	(−4.554)	(−3.962)	(−4.209)	(−3.888)	(−4.203)
Q					0.003	0.011	0.003	0.011
× Financially Unconstrained					(0.038)	(0.138)	(0.043)	(0.133)
Q	−0.005	−0.013	−0.002	−0.017	−0.011	−0.024	−0.008	−0.026
	(−0.098)	(−0.248)	(−0.031)	(−0.319)	(−0.165)	(−0.336)	(−0.115)	(−0.373)

(*Continued*)

Table 8: Continued

	Acquisition (CLOGIT)							
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Cash Flow × Financially Unconstrained					0.395	0.388	0.444	0.329
					(0.406)	(0.396)	(0.456)	(0.337)
Cash flow	3.231***	3.261***	3.235***	3.258***	3.022***	3.091***	3.023***	3.098***
	(6.048)	(6.100)	(6.045)	(6.102)	(3.989)	(4.046)	(3.989)	(4.057)
E Index × Financially Unconstrained					−0.008	−0.006	−0.007	−0.007
					(−0.081)	(−0.063)	(−0.073)	(−0.071)
E Index	−0.022	−0.016	−0.021	−0.017	−0.015	−0.006	−0.012	−0.011
	(−0.333)	(−0.232)	(−0.311)	(−0.251)	(−0.182)	(−0.074)	(−0.137)	(−0.123)
CEO Stock Ownership × Financially Unconstrained					2.276	2.589	2.432	2.380
					(0.889)	(0.980)	(0.925)	(0.911)
CEO Stock Ownership	0.109	0.085	0.084	0.116	−1.208	−1.437	−1.327	−1.288
	(0.073)	(0.056)	(0.056)	(0.076)	(−0.602)	(−0.699)	(−0.658)	(−0.628)
CEO Vested Option Ownership × Financially Unconstrained					3.881	5.040	2.906	5.818
					(0.404)	(0.526)	(0.304)	(0.598)
CEO Vested Option Ownership	5.315	3.998	4.918	4.404	2.162	0.331	2.456	0.175
	(0.778)	(0.578)	(0.721)	(0.633)	(0.265)	(0.040)	(0.301)	(0.021)
Financially Unconstrained	−0.052	−0.048	−0.052	−0.048	−0.323	0.084	0.093	0.487
	(−0.453)	(−0.422)	(−0.457)	(−0.416)	(−0.413)	(0.109)	(0.121)	(0.385)
Additional controls:								
Firm FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Return History	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year FE × Fin. Unc.	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Return History × Fin. Unc.	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	7426	7426	7426	7426	7426	7426	7426	7426
Pseudo-R^2	0.067	0.067	0.066	0.068	0.079	0.078	0.077	0.081