How Do Executives Exercise Their Stock Options?

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Abstract

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Keywords: Stock options, early exercise decisions, executive compensation

JEL Classifications: G30, M52

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1 Introduction

This paper performs a comprehensive analysis of the factors that determine executives' decisions to exercise their stock options. Executives exercise their stock options earlier than diversified investors would, and understanding and modeling the reasons for early exercise is important for the correct valuation of executive stock options. The decline in the use of stock options in compensation contracts appears to be based, among other factors, on the perception that stock options are expensive.[1] Such an assessment requires an accurate valuation of executive stock options, which should be based on those factors of exercise behavior that are empirically of first-order importance. There is a literature on the valuation of executive stock options, which relies heavily on theoretical models, typically utility-based models of risk aversion, to create valuation models for executive stock options.[2] Little is known empirically about the main motivations of top executives to exercise their stock options early, and the papers that address stock option exercise behavior empirically are mostly based on samples of non-executive employees from a small number of firms.[3] Moreover, managers' stock option exercises are also relevant because managers still receive a large portion of their incentive pay in the form of stock options. These incentive schemes work as planned only if compensation committees properly forecast managers' decisions to hold or exercise these options.[4]

[1]The downward trend in the usage of stock options has been widely documented. E.g., Bettis, Bizjak, Coles, and Kalpathy (2018) show that between 1998 and 2012, the number of time-based awards at US firms has about halved (see their Table 1). Many commentators attribute this to the fact that the passage of FAS 123R has increased the perceived costs of awarding stock options (e.g., Hayes, Lemmon, and Qiu (2012)).

[2]The earliest papers in this literature are Jennergren and Näslund (1993), Huddart (1994), and Kulatilaka and Marcus (1994). Detemple and Sundaresan (1999) provide a general valuation framework for non-traded derivatives. A recent contribution to the analytic pricing of executive stock options is Cvitanić, Wiener, and Zapatero (2008). Other models include Carr and Linetzki (2000), Henderson (2005), and Ingersoll (2006).

[3]Huddart and Lang (1996, 2003) and Heath, Huddart, and Lang (1999) use the same sample of almost 60,000 employees for 8 companies. Armstrong, Jagolinzer, and Larcker (2007) have a sample of 10 companies with 800 to 6,700 employees each. Hallock and Olson (2006) have data on 2,180 mid-level managers from one firm. Carpenter, Stanton, and Wallace (2012) have data for about 1.3 million option grants from 103 firms. Only Bettis, Bizjak, and Lemmon (2005) and Carpenter (1998) analyze executives, but ask different questions and use a different methodology, which we discuss below.

[4]There is a large literature on the subjective valuation of options, beginning with Lambert, Larcker, and Verrecchia (1991). Later contributions discuss subjective valuations in conjunction with incentive effects, e.g., Hall and Murphy (2002) and Dittmann and Maug (2007). See also the papers listed in footnote 2.

We take a two-step approach to this question. We begin by evaluating a number of theoretical approaches that have already been used in the empirical literature on stock option exercises. These include models that focus on executives' preferences, in particular models based on risk aversion and reference-dependent preferences, as well as arguments that focus on executives' beliefs, information, and expectation formation. While most of our results are consistent with the prior literature and show effects that support these theories, we find that their overall explanatory power is low or at best moderate.

In the second step, we expand the analysis by introducing two sets of variables that have been absent from the prior empirical literature. The first group comprises option portfolio effects and argues that executives' decisions to exercise a particular stock option does not only depend on their preferences and beliefs, but also on their entire portfolio of stock options.[5] The second group of variables is even more heterogeneous and attempts to capture a range of institutional constraints that executives have to observe when exercising their stock options, e.g., vesting periods and blackout periods. While these variables are usually not incorporated into theoretical models, they are plausibly important and turn out to have much more explanatory power compared to those variables motivated by existing theories. We conjecture that including option portfolio effects and institutional constraints have a first-order impact on the valuation of executive stock options, and suggest that future modeling efforts should incorporate these effects.[6]

We offer a comprehensive analysis that tests and compares these explanations. We also add to the existing approaches and quantify the incremental contribution of each of the variables we consider. We analyze a data set with 211,010 option packages of 14,171 executives at 2,008 firms from the Insider Filing Data Feed (IFDF) of ThomsonReuters. The options vest between 1996 and 2008. We use a flexible, semi-parametric hazard model that allows

[5] Arguably, it depends on their entire portfolio, but we focus on the composition of their option portfolio, on which we have high-quality data.

[6] One effort in this direction is Kadan, Liu, and Yang (2009), who include vesting constraints and conclude that including institutional constraints like these leads to substantially lower values for executive stock options.

us to analyze censored data, as censoring is an important issue in our sample. The model allows for unobserved heterogeneity across individuals, which is significant in our sample and a potential source of bias.

There is little support for the predictions specific to standard models of risk aversion. Managers of firms whose stock is more correlated with the stock market index and who bear less firm-specific risk exercise their options earlier, whereas models based on standard utility theory predict the opposite. Higher volatility induces higher exercise rates, consistent with the diversification motive, but this effect is economically and statistically weak. In the Conclusion we argue that the diversification motive is probably important, but it may not be adequately captured by standard models so that more theoretical work is needed here. Past highs and lows of stock prices, which are suggested by models of preferences based on reference dependence are empirically more successful, but the overall explanatory power of preference-based factors on stock option exercises is only moderate.

We include a range of variables that have been suggested in the literature to capture variation in executives' beliefs. In contrast to Heath, Huddart, and Lang (1999), some of our results are not consistent with the notion that executives extrapolate long-term trends. We suggest that a more parsimonious interpretation of our results on how executives' exercise behavior responds to past returns is that they are not driven by non-standard beliefs but also by reference dependence. We analyze how managers react to fluctuations in investor sentiment. Interestingly, managers seem to see through investor sentiment and exercise options earlier if stock prices appear to be driven up by bullish investors, and they exercise later if prices seem to be depressed by bearish investors. Another strand of the literature shows that executives time their stock option exercises based on inside information.[7] Our findings are consistent with the earlier literature in this respect, but we also show that managers are cautious not to make use of information that is released shortly after they exercise, probably because of insider trading laws. Overall, we find that information-related

[7] Carpenter and Remmers (2001), Huddart and Lang (2003), Bartov and Mohanram (2004).

variables have moderate explanatory power.

Next, we turn to those factors that have not been discussed in the literature yet and begin with a discussion of option portfolio effects. Executives in our sample chose not only whether to exercise an option, but also which option to exercise from a portfolio of options. This analysis is more exploratory and cannot rely as much on models from the literature.[8] We formulate several additional hypotheses based on the notion that managers engage in consumption smoothing and have target ownership levels. Our findings are consistent with these hypotheses. The joint explanatory power of variables that describe the option portfolio is very large.

Finally, we investigate a range of institutional factors that influence exercise behavior. Relevant factors include vesting periods and blackout periods. We find that these factors are of first-order relevance, whereas other factors mentioned in the literature, such as the desire to capture dividends, have only a negligible influence. The joint explanatory power of institutional factors is also very large. At the end of the paper we subject our specifications, variable definitions, and the econometric model to a range of robustness checks.

Our overall conclusion is that the variables that contribute most to explaining the variation in stock option exercise behavior are different from those considered relevant in extant theories. In particular, variables that describe executives' portfolios of stock options as well as institutional parameters are of primary importance and explain a significant portion of the variation in stock option exercise behavior. Other factors, in particular past highs and lows of stock prices and past stock returns are somewhat important. By contrast, variables such as volatility, the correlation with the general stock market, or investor sentiment have a negligible influence. In the Conclusion we suggest that future theoretical developments and models used to value executive stock options should include those variables that best capture managers' exercise decisions.

We contribute to the literature on stock option exercises at the methodological as well as

[8] One model that explicitly incorporates the existence of portfolios of options is Grasselli and Henderson (2009), who consider the special case in which options have an infinite maturity.

the substantive level. Previous research on the diversification motive by Carpenter (1998) and Bettis, Bizjak, and Lemmon (2005) tests utility theory by calibrating a lattice framework to a utility-based model and comparing it to a model based on the assumption that executives receive exogenous liquidity shocks. These papers compare which of these calibrated models performs better in terms of predicting key moments, in particular the ratio of the stock price to the strike price at exercise and the mean or median time to maturity at exercise. This calibration approach is useful for analyzing and understanding option valuation models, but does not permit any inference about their explanatory power and cannot test whether the suggested variables have the influence on stock option exercises predicted by the theories.

Heath, Huddart, and Lang (1999) were the first to identify the importance of past stock price developments for stock option exercises. Our more comprehensive approach leads to different findings on long-term trend extrapolation and we expand the set of behavioral factors to include the minimum of past prices as well as investor sentiment. We also differ from their analysis by distinguishing between exercises associated with sales of stock and exercises for which managers hold on to the stock, which turns out to be important for the results.

In addition, we contribute by explicitly modeling the portfolio of options managers hold and incorporate the arrival of new option grants. Therefore, we go beyond existing theories, which mostly focus on the exercise of one representative option and abstract from the features of option portfolios.

At the methodological level, we innovate by using hazard analysis, which allows us to properly incorporate censoring and to avoid biases from the fact that, of the 211,010 option packages in our data set, only 12.9% are not censored.[9] Hazard analysis naturally integrates time-varying covariates, which allows us to model the influence of factors such as blackout periods around earnings announcements, the expiry of vesting restrictions, or the dynamic

[9]Armstrong, Jagolinzer, and Larcker (2007) and Klein (2018) are the only other paper we are aware of that also uses hazard analysis, but they do not compare different explanatory approaches for early exercises and focus on the application of their results to the valuation of stock options instead.

evolution of the option portfolio. We show that all these aspects are of first-order importance, even though the literature on stock option exercises commonly abstracts from them.

2 Data

Our main data source is the Insider Filing Data Feed (IFDF) provided by Thomson Reuters, which collects data from forms insiders have to file with the SEC: Form 3 ("Initial Statement of Beneficial Ownership of Securities"), Form 4 ("Statement of Changes of Beneficial Ownership of Securities"), and Form 5 ("Annual Statement of Beneficial Ownership of Securities"). Under Section 16 of the Securities Exchange Act of 1934 insiders in this sense are mainly direct and indirect beneficial owners of more than ten percent of any class of equity securities and any director and any officer of the issuer of such securities (Rule 16a-2).[10] Insiders have to file transactions in derivative securities as well as in non-derivative securities, such as stock. These filings contain the numbers of securities transacted or held, transaction dates, expiration dates, strike prices, and vesting dates. The filings contain a verbal description of the respective vesting scheme instead of a date if vesting depends on aspects other than the date, which is the case for performance-based vesting schemes. However, IFDF does not contain these verbal descriptions of vesting schemes. The vesting date is missing in this case and the option package is then not included in our data set.

IFDF contains filings of insiders' transactions in their companies' securities as well as holding records for stock and for derivative securities. Transactions included are, among others, purchases and grants of stock and options, sales, exercises, deliveries of withholding securities in order to pay an option's exercise price or the associated tax liability, expirations or cancellations of derivatives, gifts of securities, dispositions to the issuer (e.g., forfeiture due to failure to meet performance targets, reloads), and transactions in equity swaps.[11]

[10]Rule 16a-1(f) defines "officer" to include the president, principal financial officer, principal accounting officer, any vice-president of the issuer in charge of a principal business unit, division, or function (such as sales, administration, or finance), any other officer who performs a policy-making function, or any other person who performs similar policy-making functions for the company.

[11]"Withholding securities" is IFDF's terminology for a transaction where insiders can pay an option's

For derivative securities, IFDF has different transaction codes for executive stock options (ESOs) and for market traded options.

We obtain the database for 2008, which covers data going back to 1995. We extract all option packages that have at least one record with an ESO transaction code (grant, ESO exercise, delivery of stock to the issuer to pay for the exercise price) and non-missing entries in the identifying variables person ID, CUSIP of the underlying security, strike price, vesting date, and expiration date. For our analysis, we remove all observations with incomplete or missing information about the vesting scheme. We retain only grants that vest between January 1, 1996 and December 31, 2008. Managers frequently receive time-vested option grants, in which all options have the same strike price but differ in their vesting periods. In our baseline specification, we break up grants with multiple vesting dates and treat them as separate option packages. In order to reduce the dependence among observations we also report results for a specification in which we treat these option grants as one package and use the longest vesting period of the grant.

For our baseline analysis we define exercises by requiring that insiders report the sale of at least some of the stock they obtain upon exercise in the same insider filing in which they report the exercise itself. This condition is relevant because several hypotheses we discuss below rely on the notion that managers exercise options because they do not wish to be exposed to the firm's risk in the form of stock or options.[12] We consider the exercises not associated with stock sales separately as a robustness check. In total, we obtain 2,110,575 option packages associated with 255,072 exercises by 135,348 insiders. Table 1 summarizes the steps of the construction of the sample.

We match the IFDF data to the 2008 version of ExecuComp to obtain additional information about the executives themselves.[13] From ExecuComp we obtain the beginning and

strike price at exercise with stock. IFDF represents these transactions in two parts: In the first transaction insiders receive all underlying shares, in the second transaction they give back some of these shares to pay for the strike price.

[12]For example, Aboody, Hughes, Liu, and Su (2008) obtain different results depending on whether they study exercises after which shares are sold as opposed to exercises where shares are held.

[13]We can match by person names and firms' CUSIPs. We match by first name, middle name, last name,

the end of employment with the company, and the fiscal year end. We lose 1,796,166 option packages because we cannot match them to ExecuComp, mostly because ExecuComp covers larger firms and only the top 5 managers, whereas IFDF also covers smaller firms and insiders other than the top 5 executives. However, using the employment periods from ExecuComp is critical, because they help us distinguish voluntary exercises within the employment period and forced exercises, which happen after the employment period. On the one hand without this distinction, we would underestimate exercise probabilities after the employment period, simply because voluntary exercises are no longer possible and forced exercises are not fully covered by the IFDF data. On the other hand, we could potentially overestimate voluntary exercise probabilities short after the employment period when forced exercises take place. Overall, mixing voluntary exercises with forced exercises could potentially bias our results.[14]

We match these data with stock price data from CRSP. We lose another 15,282 option packages, either because we cannot match observations to CRSP, or because there is no stock price information on CRSP for the relevant period. Finally, we are only interested in options that are potentially exercisable. Therefore, we omit all option packages (88,117 in total) that are out of the money for all data points we have between the vesting date and the maturity date. Our final sample covers 211,010 option packages from 14,171 executives and 2,008 firms. For these options IFDF records 47,478 exercises.

We obtain annual dividend yields and dividend payment dates from CRSP. For firm-years with missing dividend information we set the dividend yield to zero. Additionally, we obtain dates of earnings announcements and accounting data from Compustat. The later hazard analysis will be based on weekly data. We therefore aggregate all exercises within the same week into one single exercise decision.

The unit of our analysis is an option package. Table 2 provides descriptive statistics for option packages at the vesting date for those options that are in the money for at least

and name affix ("Jr.", "Sr.", etc.). Sometimes one database contains the affix, whereas the other database does not. In such cases, we match by first name, middle name, and last name. If the middle name is also not available in one database, then we match by first name and last name only.

[14] Klein (2018) shows that both types of exercises follow different dynamics.

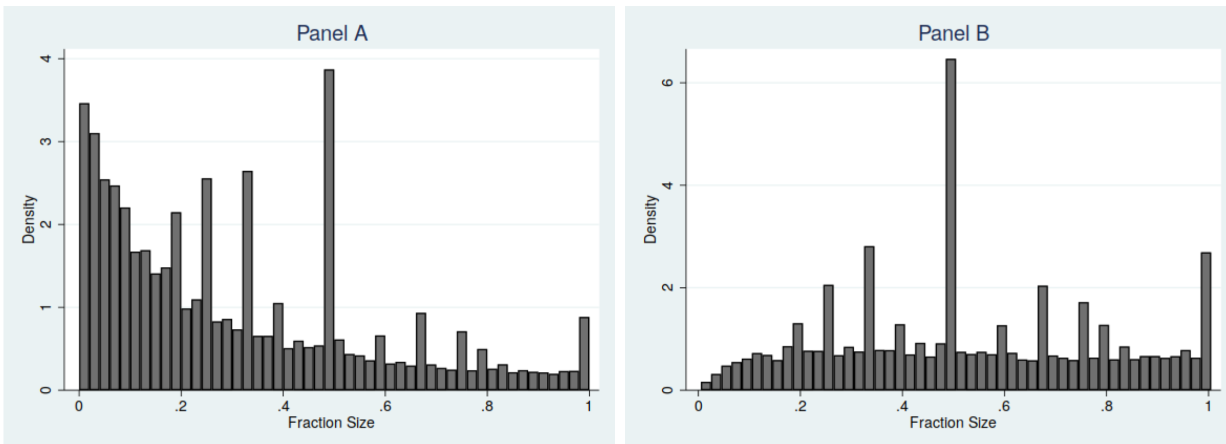
one week during the period between the vesting date and the earlier of the maturity date and the date until which we have data. Executive stock options are American options, hence we follow Heath, Huddart, and Lang (1999) and calculate option values using the model of Barone-Adesi and Whaley (1987), which accounts for the early exercise premium for American options when the underlying stock pays dividends. We refer to these values as BAW values from here on. For non-dividend paying stocks the BAW values coincide with the Black/Scholes values.[15] We further report the time to maturity at the vesting date, the moneyness, the volatility based on returns for the past 52 weeks, the dividend yields at the end of the last calendar year, and the interest rate. For the interest rate we use zero coupon yields of zero-coupon government bonds with maturities of 1, 2, 3, 5, and 10 years and use the bond with a maturity that is closest to the maturity of the respective option. The value of option packages at the vesting date is \$0.70 million on average (median: \$0.07 million). Of the 211,010 option packages in our sample, 161,870, or 77%, are in the money at the vesting date with an average stock-price-to-strike-price ratio of 10.17. (The median is only 1.28, as few firms have very large stock price increases between the grant date and the vesting date). The dividend yield of the firm is 0.95% on average and 0.85% for the median option package.

Executives sometimes exercise only a fraction of the option package. Of the 47,478 exercises in our sample, 59% are for a fraction of less than 100% of the initial grant, 43% are for less than 50%, 29% are for less than 25%, and 16% of all exercises are for less than 10% of the initial grant. In our baseline specification, we count only the 47,478 exercises above 25% as economically meaningful. There are, on average, 1.35 exercises per option package for those packages where some options are exercised early. On average, 60% of an option package is exercised if at least some options are exercised early.

Figure 1 shows two histograms of the fraction sizes for partial exercises. In Panel A

[15] A more appropriate model for risk-averse managers is probably Detemple and Sundaresan (1999). However, their model requires the knowledge not only of managers' wealth, but also of the liquid portion of their wealth as well as assumptions about trading restrictions. We can, therefore, not implement their model with our data.

Figure 1: Partial exercises. The figure displays the frequency of fraction sizes for partial exercises. The fractions are calculated as parts of the total option package that was initially granted. Option grants with multiple vesting dates are broken up so that all options in the same package have the same vesting date. The bars in Panel A are proportional to the frequency of the fraction sizes, whereas the bars in Panel B are weighted with the fraction size itself.



the bars in the histogram are proportional to the frequency of exercises for the particular fraction size, whereas in Panel B frequencies are weighted with the fraction size itself so that two exercises of 10% each have the same weight as one exercise of 20%. The pattern of fractional exercises reveals that executives prefer multiples of one fifth, one fourth, and one third of the initial grant. Note that this cannot be attributed to the structure of the grants themselves, which are sometimes staggered (equal fractions vest after 1, 2, and 3 years or similarly), since we ignore the exercises before the latest vesting date of such grants. (This deletion is inconsequential for our later analysis.) The histogram in Panel A is downward sloping, which implies that managers use smaller partial exercises more frequently than larger exercises. Panel B shows that, apart from the spikes noted above, the frequency of any fraction size is inversely related to the fraction size itself. This observation suggests that managers either exercise small portions of their option packages frequently, or larger portions, but then infrequently.

For the hazard analysis we use weekly data and exclude all weeks for which an option package is out of the money.[16] We only include options for which the vesting date is available, so the standard left censoring problem considered in hazard analysis (options where the beginning of their relevant lifetime cannot be observed) does not exist for our data set.[17] However, for 31% of all option packages in our sample, we do not observe the grant date and there may be option packages that do not enter the database because their grant is not recorded on IFDF and they are not exercised early. We keep options without grant information in the data set and define the number of options granted as the number of options held at the first available transaction record or holdings record. For these options we potentially underestimate the total number of options granted and therefore overestimate the fraction that is exercised.[18] Our later results show that the fraction of option grants that is exercised does not have an impact on the results, so this measurement error seems inconsequential. Grant dates are not important for our analysis because for our purposes we count option lifetime from the vesting date and we retain the exercises of option packages without grant date as long as we know the vesting date. Our study is therefore not affected by the fact that grant dates are sometimes missing, especially for those option packages that were granted earlier, presumably because the coverage of the database was then less complete.

Right censoring is present in our analysis whenever we have no record of the exercise of an option. Since multiple exercises per option package are possible, an option package may be right censored even if a fraction of it was exercised early. The major reason for right censoring (62.0% of the sample) is that the database records only exercises until December 2008. We are interested in early exercises only because they involve an economic decision by the manager. Exercises at maturity are outside the scope of our analysis because they result from the decision not to exercise earlier and are therefore covered indirectly by the

[16]Exercising out-of-the-money call options is possible but irrational. For an analysis of irrational exercise behavior for exchange traded options see Poteshman and Serbin (2003).

[17]For options without vesting period, the vesting date is equal to the grant date.

[18]Sometimes there are inconsistencies in the data and the number of options exercised exceeds the number of options initially granted. In these cases we redefine the number of options granted as the total number of options exercised.

analysis of early exercises. Hence, from the point of view of our analysis, all options that are not exercised until one week before they expire are right censored. This reason for right-censoring applies to 1.2% of our sample. For a further 8.4% of the sample we observe no exercises because the options expire out of the money.

Right censoring occurs also because insiders leave the firm. Usually, insiders have to exercise their ESOs within a certain period of time after they leave the firm, otherwise their ESOs forfeit. However, the exact regulations also depend on the reasons why a manager left the firm. These rules are firm-specific and we do not have data on them.[19] Therefore, we take the date when an executive leaves the firm (which we obtain from ExecuComp) as the censoring date and 11.3% of the option packages are right censored for this reason. All exercises after this date - some but not all of which are recorded on IFDF - are therefore not included in our data set.

A further 4.2% of our sample is right-censored because insiders return options to the issuer, for example in case of option repricings or if they dispose of them for other reasons. In the case of a repricing, the return of options to the issuer (cancellation) and the grant of new options with a lower strike price have to be filed with the SEC as separate transactions. However, repricings do not play a major role in our sample since they usually take place when options are out of the money. Only 12.9% of the option packages in our sample are not censored. Table 4 provides a detailed overview of all variables and their definitions. Table 5 presents descriptive statistics. We discuss these variables and their definitions in Sections 4 and 5.

3 Methodology

We analyze stock option exercise patterns by CEOs and other insiders by using hazard analysis.[20] To fix ideas, denote by $f(t, x_t)$ the probability density function for the event that

[19]Dahiya and Yermack (2008) have a detailed discussion of the rules for option forfeiture in these cases.

[20]The discussion in this section is based on Kiefer (1988), Lancaster (1990), and chapters 17-19 of Cameron and Trivedi (2005).

the insider exercises her option package at time t, where x_t is a vector of variables relevant for the decision, which includes the characteristics of the option package, of the firm, of the market environment, and of the manager. Let $F(t, x_t)$ be the cumulative density function associated with f. Then define the *hazard rate* $h(t, x_t) = f(t, x_t)/(1 - F(t, x_t))$ as the conditional instantaneous probability that the insider exercises her stock options at time t if she has not exercised (all of) them yet.

3.1 Dependent variable: Exercise

The unit of investigation for our study is an option package. All options in one package have the same strike price and the same vesting period. Commonly, option grants include options with different vesting periods. In these cases we break up the grant into multiple option packages, one for each vesting period. Robustness checks below show that this decision is inconsequential for our main results. The dependent variable in all our regressions is the dummy variable $Exercise_t$, which assumes a value of one if any number of options in the package are exercised at time t, and zero otherwise. Later, we report robustness checks for alternative definitions of *Exercise*, which require that an economically meaningful minimum fraction of the option grant have been exercised.

We report relative hazards for individual variables as $hr_i = exp\{\beta_i\} - 1$ to facilitate interpretation.[21] We express all independent variables other than dummy variables as deviations from their means, scaled by their standard deviations. Hence, if $exp\{\beta_i\} - 1$ equals 0.3, then this implies that a one standard deviation increase in x_i increases the probability of exercise in week t by 30%. For the dummy variables $exp\{\beta_i\} - 1$ is simply the change in the hazard rate if the dummy variable changes its value from zero to one.

[21] Conventionally, the relative hazard is defined as $exp\{\beta_i\}$, which then has the interpretation of a factor. Since $\beta_i \approx exp\{\beta_i\} - 1$ for sufficiently small β_i, our convention saves us from reporting separate tables for the coefficients.

3.2 Hazard analysis

The hazard approach offers major advantages.[22] In particular, hazard analysis can easily deal with censored data. Neglecting the right censoring in our data would bias the estimate of the exercise probability downward because some exercise decisions are not observed. Restricting our analysis to uncensored observations would lead us to omit about three-quarters of all option packages in the sample (see Table 3 for a breakdown of the sample into different reasons for right censoring). Alternatively, we could estimate the conditional density f directly, for example by way of a logit or probit model and then infer unconditional probabilities. However, the dynamic logit approach cannot include censored observations.[23]

We proceed by using a proportional hazard model with piecewise constant baseline hazard as our baseline specification. The model is specified as follows:

$$h\left(t, x_t\right) \quad = \quad \lambda_q exp\left\{x_t^{\prime}\beta\right\}\nu, \tag{1}$$

where x_t is the time-varying vector of variables, λ_q are scalars for prespecified time intervals q, β is a vector of coefficients, and ν is a multiplicative random error that varies across individuals. The expression for $h\left(t, x_t\right)$ has three components.

The first component is λ_q and is referred to as the baseline hazard, which gives the

[22]Carpenter, Stanton, and Wallace (2012) identify two limitations of hazard rate analysis. First, since the unit of analysis are option grants, the analysis may miss out on cross-grant correlations. This is correct for the standard hazard rate approach, but does not apply to our analysis. Our model takes care of cross-grant correlations through a range of independent variables that model the option portfolio as well as firm-specific and individual-specific effects that may give rise to correlations. In addition, our model allows for random manager effects. We show below that our results hold up with bootstrapped standard errors, which addresses the concern that unmodeled cross-grant correlations may give rise to overestimating statistical significance. Results are also robust to using clustered robust standard errors, a potential alternative to modeling cross-grant correlations. Second, Carpenter, Stanton, and Wallace (2012) argue that hazard analysis does not take into account fractional exercises. We take this into account by looking at a range of fractions to define the dependent variable in Table 8. Almost all results are robust to changes in the threshold above except for option portfolio effects, which we discuss in Section 5.1.

[23]The hazard function approach does not estimate more or different parameters because parameterizing the problem in terms of conditional or unconditional probabilities is equivalent (see Kiefer, 1988, p. 649). Shumway (2001) shows that the hazard function approach and a dynamic logit approach are identical if all observations for which no failure event (here: option exercise) takes place are included in the analysis. He also shows that standard logit analysis will not provide correct standard errors.

conditional probability of exercise when the other two factors both equal one. We seek the most flexible model for the baseline hazard, which does not impose any restrictions on the shape of the baseline hazard over time. We use a non-parametric approach and use quarterly dummy variables to model the baseline hazard. We use weekly observations and estimate the baseline hazard for intervals of 13 weeks each. This approach only restricts the baseline hazard to be identical across all weeks within the same quarter of the time to maturity.[24]By contrast, the widely used Weibull model assumes a monotonic baseline hazard and violations of this assumption may bias coefficients. The second factor in equation (1), $exp\{x_t'\beta\}$, is the relative hazard, which multiplies the baseline hazard by a factor that depends on the variables x_t. This factor is the core of our analysis.

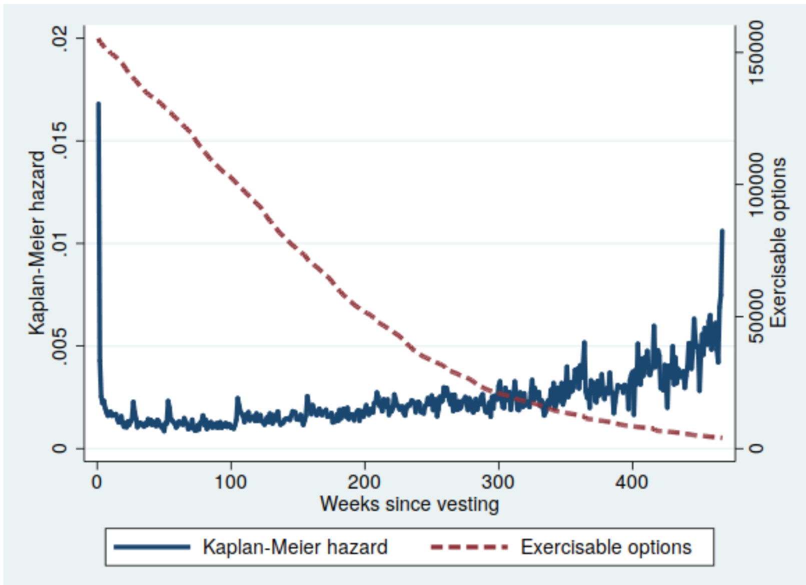
The third component in (1) is the individual error term ν, which models unobserved heterogeneity. Unobserved heterogeneity is an important characteristic of our data, and results from factors such as preferences, managers' risk aversion, or their holdings of non-firm related assets. Ignoring unobserved heterogeneity when it is present can bias the estimates of the parameters of interest β. Therefore, we estimate a mixture model in which heterogeneity is modeled as a multiplicative individual error term ν that is common for all option grants of the same manager and distributed gamma.[25] This specification is comparable to a random effects model for linear panel data and provides our main approach to model the correlation between observations for the same individual. In one robustness check we report bootstrapped standard errors to make sure that our standard errors are not overstated because of other correlations. We have 14,171 individuals in our analysis, which precludes the use of individual fixed effects.

Figure 2 shows the empirical hazard rate (solid line) as a function of time for our sample. For each week, it shows the ratio of the options exercised in that week relative to the

[24]Our approach is very close to the commonly used Cox hazard model, which does not impose any restrictions on the functional form of the baseline hazard. However, it requires less computational resources.

[25]The specification is also known as a shared frailty model or a mixed proportional hazard model. See Cameron and Trivedi (2005), chapter 18, for a discussion of unobserved heterogeneity and also for the discussion of alternative distributions of the error term ν.

Figure 2: Empirical hazard rate. The solid line shows the non-parametric Kaplan-Meier estimate of the empirical hazard rate (left scale). This is the number of option packages with exercises of the original package, expressed as a fraction of all option packages that could have been exercised at that point in time. The dashed line (right scale) shows the number of option packages that could have been exercised.



number of unexercised options available at that point in time. The empirical hazard rate is non-monotonic. Exercise activity is very high immediately after vesting, and 10% of all exercised option packages are exercised, partially or fully, within two weeks of the vesting date. After vesting the empirical hazard rate drops to a lower rate, and finally increases again towards the end of the lifetime of the options. There are peaks in the hazard rate in annual intervals from the vesting date. We expect that this pattern is driven by annual events like grants of new options, vesting dates of existing options, and option expirations. Figure 2 shows the number of options that are still alive at any point in time. It takes 336 weeks, or about 8 years from vesting, for this number to fall below 10%, and 413 weeks from vesting to fall below 5% of the original sample.

4 Evaluating theories of option exercises

In this section we evaluate theories of stock option exercises that have been developed in the literature. We organize this discussion into an analysis of theories that focus on different approaches to modeling executives' preferences (Section 4.1) and an analysis of theories of executives' beliefs and information (Section 4.2). In Section 4.3 we briefly discuss the results for the control variables. Finally, in Section 4.4 we evaluate the overall explanatory power of each of these theoretical approaches.

We estimate a hazard model that includes all variables that are relevant in this section and the next. This approach avoids omitted variable problems that may arise from estimating separate models. Table 6 presents the estimation results for four specifications of this model: Model (1) is the baseline model in which option grants with multiple vesting dates are split into multiple option grants, as described above; model (2) does not split up option grants by vesting date; instead, the vesting date of the option package is that of the option with the last vesting date; if some exercises occur before this date we ignore them; model (3) estimates the baseline model for the period before 2003 and model (4) estimates the baseline model for the period since 2003. In many cases, the difference between specifications are economically or statistically not meaningful and we will comment on these differences only in those cases in which we find meaningful differences.

4.1 Preferences

Diversification. Our starting point for the discussion of preference-based approaches is the notion that risk averse insiders exercise their stock options early because their investment in their own company's securities exposes them to firm-specific risk. We measure the riskiness of the firm by two variables, *Correlation* and *Volatility*. *Correlation* is the coefficient of correlation between the firm's stock return and the return on the CRSP value-weighted index. *Correlation* captures the idea that the managers can reduce their exposure to market risk, e.g. by trading stock index futures or simply by reducing their exposure to the market (Garvey and Milbourn (2003)), whereas it is more costly if not impossible for them to reduce their exposure to the idiosyncratic risk of their own firm.[26] Thus, they can hedge the exposure to market risk through trading in the stock market, whereas they cannot hedge the idiosyncratic risk of the firm. Cai and Vijh (2005) and Carpenter, Stanton, and Wallace (2010) present models in which a risk averse manager can invest in a risk-free asset, the firm's stock, and the market portfolio. They show that managers value options subjectively higher when the correlation between returns of the stock and the returns of the market portfolio is higher. We expect that managers exercise options earlier if they find it more difficult to hedge their exposure, hence, when the correlation with the market is lower and with that their subjective value of the option. Therefore, the coefficient on *Correlation* should be negative. We report robustness checks below for other variables that may capture the same effect, namely a measure of firm-specific risk and the firm's beta (see Section 6.1).

The coefficient on *Correlation* is positive and statistically significant at the 1%-level for all definitions of *Exercise*. The value of the coefficient implies that a one-standard deviation increase in *Correlation* increases the probability of exercise by 3%. We will show later that this result is robust to alternative definitions of idiosyncratic risk. This finding implies that executives behave in a way that is in direct contradiction to standard utility theory.

The effect of the stock's volatility on the decision to exercise early is ambiguous because volatility has two effects. Higher volatility makes the option more risky, so that a risk-averse manager would exercise early. However, volatility also increases the time value of the option. The first effect outweighs the second effect only if the manager is sufficiently risk-averse, so we cannot make an unambiguous prediction here. *Volatility* is defined as the standard deviation of stock returns calculated over the 52 weeks preceding week t. The coefficient on *Volatility* is small and positive, but highly significant. Our interpretation is

[26] Garvey and Milbourn (2003) develop this idea in a formal model in which managers have to hold firms' securities but can trade in the stock market. They show how trading in the stock market can replicate an indexed contract.

that managers do wish to diversify their portfolios, but the diversification motive is almost outweighed by the countervailing effect on option values.

The results on *Correlation* and on *Volatility* contradict each other from the point of view of utility theory, since the positive coefficient on *Volatility* suggests a moderate diversification motive, whereas the positive coefficient on *Correlation* does not. However, these findings are consistent with rank-dependent preference theories, which predict that individuals combine diversified portfolios with undiversified holdings in individual stocks (Polkovnichenko 2005, Barberis and Huang 2008).[27] Interestingly, the effect on *Volatility* changes signs between the pre-2003 period, where it is positive (+0.11) and the later period, where it is negative.

Reference point dependence. The literature documents that individuals pay attention to the recent highs and lows of stock prices, which seem to anchor perceptions. These findings may result because individuals use extreme values of the stock price to form reference points.[28] We follow this literature and include *MaxPrice* and *MinPrice* in our hazard regression. These are dummy variables, which equal one if the stock price in week t is above its maximum, respectively minimum, over the preceding 52 weeks. We expect that individuals exercise their options more frequently if the stock trades above *MaxPrice* and less frequently if it trades below *MinPrice*. Consequently, the predicted coefficient on *MaxPrice* is positive and the predicted coefficient on *MinPrice* is negative.

The dummy variable *MaxPrice* is consistently significant with positive coefficients, whereas the coefficients on *MinPrice* are always negative, as expected. The likelihood that managers exercise their options increases by 56% if their company's stock trades above its 52-week maximum and the probability of exercise decreases by 49% if the stock trades below its 52-week minimum. This finding supports the notion that managers use salient stock prices like

[27]Polkovnichenko (2005) shows that consumers have such portfolios.

[28]Heath, Huddart, and Lang (1999) refer to prospect theory (Kahneman and Tversky, 1979) to motivate the notion that individuals value their options by comparing the current stock price to a reference price. If the stock trades above this reference price, then individuals are risk-averse and exercise early. However, if the stock trades significantly below the reference price, then individuals become risk-seeking and defer exercising their options. Huddart, Lang, and Yetman (2009) argue that investors pay more attention to stocks when they break out of their 52-week trading range and offer evidence consistent with this hypothesis.

minima and maxima to form reference points, and then exercise their options if the stock trades above or below these reference points. Interestingly, reference-point behavior is more pronounced in the second part of the sample since 2003 (model (4)) than in the earlier period (model (3)). Note that we cannot rule out the alternative interpretation that managers are contrarian and pay more attention to their stock when it breaks out of its 52-week trading range (see Huddart, Lang, and Yetman (2009)).

In conclusion to the discussion of preference-based theories of exercise behavior, we observe that the variables suggested by reference dependence are larger in absolute value by about one order of magnitude compared the variables suggested by utility theory. This comparison is valid given our normalization of variables and suggests that the explanatory power of reference-dependent preference models is much higher than that of models based on utility theory.

4.2 Beliefs and information

Trends in stock prices. Individuals seem to form beliefs based on the rule that short-term trends revert back to the mean, whereas long-term trends continue.[29] If managers believe that a recent upward trend in their company's stock reverts to the mean, then they believe that their stock is currently overvalued and it may be optimal for them to exercise the option and sell the stock now. We use four periodicities for past returns to explore the dependence of exercises on past returns, where we calculate returns over the last 13 weeks, 26 weeks, 52 weeks, and 156 weeks.

Our results are partially in line with the findings of Heath, Huddart, and Lang (1999) and support the notion that managers believe in mean reversion. The coefficients on *Return13* and *Return26* are all positive, significant at the 1%-level, and economically large. If the firm's stock price increases by one standard deviation (19% in 13 weeks from Table 5) over

[29]To the best of our knowledge, Heath, Huddart, and Lang (1999) were the first to test this hypothesis for stock option exercises. The findings on trends go back to Kahneman and Tversky (1973) and Tversky and Kahneman (1971).

the past three months, then the likelihood of exercising the option increases on average by 11% in our baseline case. The results are similar but smaller for a 26-week interval. By contrast, the results for long-term trend extrapolation are ambiguous. The coefficients on *Return52* are negative, as expected based on the trend extrapolation hypothesis, whereas the coefficient on *Return156* is positive, which is not in line with the results of Heath, Huddart, and Lang (1999).[30] The size of the coefficients on the return variables are somewhat unstable between the earlier and the later sample period without exhibiting a clear pattern (cf. model (3) and model (4)).

The findings for all return variables except *Return156* are consistent with reference point behavior and the disposition effect, because managers seem to be more inclined to exercise options and sell stock when recent returns are positive and the stock trades above its recent high ("sell winners"), and hold on to options when the stock price has declined (see Odean (1998) for a related interpretation of stock trading behavior). Note that the coefficient on *Return156* is insignificant in the pre-2003 sample period. Reference dependence is therefore a more parsimonious explanation that may be sufficient to explain our findings on the stock-price dependence of managers' exercise decisions.

Investor sentiment. Many authors have documented the impact of investor sentiment on asset prices.[31] We expect that stock option exercise decisions also respond to investor sentiment. If managers behave like small retail investors, then they should invest more in risky stocks if investor sentiment is bullish and less if investor sentiment is bearish. Accordingly, we expect that managers who are subject to investor sentiment exercise their options later if investor sentiment is high. However, if managers are rational, they may recognize if prices are temporarily inflated (depressed) by retail investors subject to investor sentiment and may then exercise their options earlier (later).

[30] We performed an additional robustness check to make sure that these findings are not driven by the definition of returns, because the return variables overlap. If we define returns so that they are non-overlapping, then the results are very similar (see Table 11, column (1)).

[31] See Baker and Wurgler (2006) and the literature they cite. For an early paper see Shiller (1984).

For the purpose of our analysis we adopt the view of Lemmon and Portniaguina (2006) and use the consumer confidence index as an indicator of investor sentiment. The consumer confidence index is based on a monthly survey of 5,000 U.S. households and averages five indices, each of which is based on a questionnaire regarding current or expected economic conditions. We expect the coefficient on *Sentiment* to be negative if managers behave like noise traders who believe that high sentiment indicates higher future stock prices, and we expect it to be positive if managers act like rational investors who believe that high (low) sentiment indicates that stock prices are temporarily inflated (deflated) and likely to revert to their fundamental levels. Our sample covers almost as many bullish option-weeks than bearish ones, with *Sentiment* having a median of 100.54 (mean 103.8), slightly above the neutral value of 100.

The coefficient on *Sentiment* is positive in all specifications and highly significant. A one-standard deviation increase in the consumer confidence index (17 index points) increases the probability of an early stock option exercise by 10% in our baseline case. This effect is, therefore, economically significant and contradicts the notion that managers are influenced by investor sentiment in their exercise decisions. Rather, they seem to see through investor sentiment and anticipate lower future returns when sentiment is high and vice versa.

Asymmetric information Employees of the companies in our sample may have private information and exercise their options more often before negative news is disclosed, and less frequently before positive news is disclosed. Several authors find exercise patterns consistent with this notion.[32] We proxy for inside information by calculating buy-and-hold abnormal returns (BHARs) for, respectively, 2 weeks, 13 weeks, and 26 weeks after week t. Testing for inside information by using realizations of ex post abnormal returns is standard in the insider trading literature (e.g., Lakonishok and Lee, 2001). If managers exercise options later because they expect positive news to materialize, or if they exercise earlier because

[32]See Carpenter and Remmers (2001), Huddart and Lang (2003), Brooks, Chance, and Cline (2012), and Aboody, Hughes, Liu, and Su (2008). Bartov and Mohanram (2004) relate the stock price patterns around exercises to earnings management.

they expect negative news to materialize, then the coefficients on *BHAR2*, *BHAR13*, and *BHAR26* should all be negative.[33]

As predicted, we find that the coefficients on all buy-and-hold abnormal returns are significant and negative for all definitions of the dependent variable. Executives who exercise stock options and sell stock before the disclosure of bad news may violate insider trading rules, whereas those who delay exercises before the disclosure of good news do not. To investigate this further, we split each BHAR-variable into a negative and a positive component (see Table 11, column (2)).[34] We find that the resulting coefficients are very similar for the negative and for the positive component of *BHAR13* and *BHAR26*, but they differ significantly for *BHAR2*, where the negative component of *BHAR2* has a positive sign: Managers avoid exercising their options and selling their stock shortly before negative news is released, probably to conform with insider trading prohibitions.

4.3 Control variables

We include three control variables in the analysis, the time value of the option, a CEO indicator, and the remaining maturity of the option.

Time value. We approximate the market value of the option by the Barone-Adesi and Whaley (1987) (BAW) value and calculate the relative time value of the option as the difference between the BAW value and the intrinsic value of the option and scale this difference by the BAW value. The time value of the option is relevant for all theories discussed above. All theories identify some benefit from exercising stock options early, such as benefits from diversification (utility theory), capturing temporary deviations of the stock price from its

[33]We note that the abnormal returns subsequent to the average option-week are negative, which is puzzling. We investigated this further and found that the average and the median BHAR are indistinguishable from zero for the firms in our sample. Hence, the negative BHARs for option-weeks arise because firm-weeks that are followed by negative BHARs are weighted with a larger number of options than firm-weeks followed by positive BHARs.

[34]More precisely, we define the two components as $PosBHAR\# = Max(0, BHAR\#)$ and $NegBHAR\# = Min(0, BHAR\#)$.

fundamental value (sentiment), or capturing a temporary informational advantage. The time value of the option, which is lost upon exercise, is the opportunity cost that managers trade off against the benefits from exercise.

We define *TimeValue* as the time value of the option, divided by its BAW-value.[35] Hence, *TimeValue* can take values between zero for options that are close to expiration or deep in the money, and one for far out-of-the-money options. The coefficient on *TimeValue* has the expected negative sign and is economically large. A one standard-deviation increase in *TimeValue* reduces the likelihood of exercise by 58% in the baseline case, in line with all theories discussed above.

Heterogeneity across individuals. Exercise behavior may depend on the status of the manager in the hierarchy of the firm. We distinguish between the CEO and the other top executives and include a dummy variable that equals one for CEOs. The coefficient on *CEO* is 0.13, so CEOs exercise options more frequently than other managers, but this result is not stable across the specifications in Table 6. The variance σ_f^2 measures the variation of the random effects ν in equation (1) in the model and it is significant in all specifications. Individual effects are, therefore, important and cannot be related to other observed characteristics.

Maturity. We include the maturity of the option as a separate explanatory variable. The coefficient is small and negative. Interpreting this coefficient is difficult, because parts of the effect of *Maturity* are also captured by TimeValue and the baseline hazard, but including this variable provides additional flexibility to the estimation imposed by our restrictions on the baseline hazard rate.

[35] Some of the models based on utility theory explicitly identify exercise boundaries, where the benefits from diversification exactly balance the time value, for example Huddart (1994) and Kulatilaka and Marcus (1994).

4.4 Contribution of explanatory approaches

In this section, we evaluate the relative explanatory power of all variables in our analysis. In linear models, we could develop a quantitative benchmark by looking at partial R-squared measures, which are not available here. We attempt something similar for our hazard model by using likelihood ratio tests.

In Table 7 we proceed as follows. Our baseline specification is again model (1) in Table 6. From this specification, we remove individual variables or groups of variables and perform a likelihood ratio test. The LR-test statistics in column *LR* in Table 7 test for the joint significance for each group of variables in the table. For example, the test for "Preferences" is for the joint exclusion of all variables suggested by preference-based theory, and the test for *"Correlation, Volatility"* is for the joint exclusion of these two variables from the baseline model. Under the null hypothesis, the likelihood ratios are distributed Chi-square and column *1% Chi-squared* reports the cut-off values for the 1% significance level and the appropriate number of degrees of freedom. All variables pass conventional significance levels. However, these are not our concern here since our interest is in explanatory power. For the purpose of this discussion, and somewhat arbitrarily, we classify variables and groups of variables that have Chi-squared values below 100 as having low explanatory power and those with values above 5,000 has having high explanatory power, and all others as having "moderate" or "intermediate" explanatory power.

The quantitative importance of the variables specific to the diversification motive (*Correlation, Volatility)* is small (LR-statistic of 64). Whereas the findings for *Volatility* provide weak evidence for the diversification motive, the results for *Correlation* contradict the predictions of utility theory. We conclude that the diversification motive is poorly modeled by conventional utility theory. The relevance of variables suggested by reference-dependent preference models is higher (LR-statistic of 1,565). Explanations based on asymmetric information (BHARs) and trend extrapolation (Returns) also have moderate explanatory power, with LR-statistics of 499 and 1,110, respectively, whereas the explanatory power of *Senti-*

ment is also low. The explanatory power of all variables associated with preferences and beliefs is much smaller than that of the control variables, especially $TimeValue$. Therefore, we conclude that explanations based on the theories we rely on in this section can account for only a small part of the cross-sectional variation in stock option exercise behavior.

5 Alternative explanations

The discussion of variables suggested by models of preferences, beliefs, and information in the extant literature in Section 4 shows that these variables have low to moderate explanatory power. In this section we discuss two alternative approaches to predicting stock option exercises, option portfolio effects (Section 5.1) and institutional constraints (Section 5.2).

5.1 Option portfolio effects

Theoretical background. Models of stock option exercises typically focus on optimal exercise decisions with respect to one option and ignore the fact that managers typically own a portfolio of options. As such, a theory of how managers make such decisions is virtually non-existent and it is beyond the scope of this paper to develop a complete model.[36] Instead, we proceed by identifying three motives that should guide managers. First, we hypothesize that managers engage in consumption smoothing and try to generate a steady stream of revenues from their stock option exercises.[37] Second, it seems plausible that managers optimize their holdings of the firm's stock and options. Hence, whenever they are granted new options, their option holdings should exceed the previous optimum. Hence, we expect them to adjust their holdings and exercise some of the existing options after new option grants. This would always happen if managers have some target ownership of stock options, so that a new option

[36] The only papers we are aware of that analyzes option portfolios are Grasselli and Henderson (2009) and Henderson and Hobson (2011). In Grasselli and Henderson (2009), managers exercise options with lower strike prices before they exercise options with higher strike prices. However, in their model options have infinite maturity so that time value and strike price are indistinguishable.

[37] This argument could not matter in a frictionless world in which managers could use the capital market to separate their exercise decisions from their consumption decisions.

grant increases their holdings above their target level.[38] Managers may have such a target ownership because of optimal portfolio considerations or from stock ownership guidelines.[39]

New option grants. We test the third of the three implications above first and include *GrantWeekBefore*, a dummy variable that equals one in the week before the manager receives a new option grant, and *GrantWeekAfter*, a dummy variable that equals one in the week of and in the week after a new option grant. We expect the coefficients on both variables to be positive.

Option portfolio effects affect small and large exercises differently. Hence, we run the regressions in Table 6 again, but now define *Exercise* to be one only if the exercises are economically significant and exceed a certain threshold. Table 8 reports the results for exercise thresholds of 10%, 25%, 50%, and 100% of the original option package. Otherwise, the specifications in Table 8 are the same as those in Table 6, but we only report the results for option packages, since all other results are virtually identical.

The coefficient on *GrantWeekAfter* in Table 6 is large and significant and increases monotonically from 2.96 (no threshold) to 3.96 (100% exercises), whereas the impact of *GrantWeekBefore* is always negative, and declines monotonically from -0.25 (no threshold) to -0.38 (100% exercises). Overall, this evidence is consistent with the notion that managers try to keep their option holdings at some target level and exercise more after and less before the arrival of new option grants. Comparing the results for models (3) and (4) in Table 6 shows that this behavior can be observed in both, the pre-2003 and the post-2003 sample period, but it is much more pronounced in the earlier period.

Small versus large exercises. Next, we include $PackageSize_{jt}$, which is the Barone-Adesi and Whaley (1987) value of all options in grant j that have not been exercised until time

[38]The results from Ofek and Yermack (2000) are consistent with the notion that senior managers have ownership targets with respect to their stock holdings, so that they build up their ownership if it drops below this target.

[39]Core and Larcker (2002) analyze the impact of stock ownership guidelines for managers for a hand-collected sample of 195 firms.

t, scaled by the value of the manager's entire stock-dependent portfolio, and $FractionLeft_{jt}$, defined as the fraction of the initially granted option package that managers still hold. Table 6 shows that the coefficient on $PackageSize$ is positive with a zero-exercise threshold, and always negative and significant for positive thresholds. The coefficient decreases from -0.07 (threshold=10%) to -0.32 (threshold=100%). A one standard deviation increase in *FractionLeft* (0.14 from Table 5) decreases the probability of exercise by 6% in the baseline case.

Hence, executives are more likely to exercise larger grants in smaller fractions, whereas they exercise smaller grants in larger fractions. The simultaneous prevalence of infrequent but large and frequent but small exercises is difficult to reconcile with theories of trading frictions (Grasselli and Henderson (2009)), which predict an exercise strategy that optimally resolves the trade off between incurring the high fixed costs from trading more frequently and a utility loss from infrequent exercises. While this result cannot provide a direct test on the consumption smoothing motive, it is consistent with the notion that managers have a target dollar value for option exercises. It is also consistent with the notion that managers vary in the attention they pay to their stock option portfolios.

Table 7 shows that the option portfolio effects captured by these four variables have a quantitatively large impact of stock option exercise behavior. The LR-statistic of 9,524 for option-portfolio effects suggests that these effects have more explanatory power than all variables suggested by preference-based and belief-based theories combined.

5.2 Institutional constraints and other control variables

Black-out periods. Most firms restrict trading of insiders by imposing black-out periods during which insiders are not allowed to trade. Bettis, Coles, and Lemmon (2000) show that 92% of the firms in their sample impose such trading restrictions and that these trading restrictions lead to a significant decline in trading activity and a narrowing of bid-ask spreads for the firm's stock. They show that a common window imposed for trading is 3 to 12 days after earnings announcements. Since we restrict our sample to option exercises for which managers sell the shares they receive from exercises, we expect that trading restrictions around earnings announcements also affect exercise patterns. We capture this hypothesis with two variables, *BeforeAnnouncement*, a dummy variable that equals one in the week before the earnings announcement, and *AfterAnnouncement*, a dummy variable that equals one in the week of and the week after an earnings announcement. We expect managers to shift exercises from the period before earnings announcements to the period immediately after the announcement, i.e., we expect the coefficient on *BeforeAnnouncement* to be negative and the coefficient on *AfterAnnouncement* to be positive.

Trading restrictions because of blackout periods are important. The coefficients on *BeforeAnnouncement* and *AfterAnnouncement* have the predicted signs, are statistically highly significant, and economically large. In the week before earnings announcements, exercises are on average 63% below their normal rate in the baseline case. In the week after earnings announcements, exercises are 112% above their usual level.

Vesting period. The vesting period prevents managers from exercising their options before the vesting date. All theories we discuss above imply that managers sometimes wish to exercise their options early, so that the vesting constraint becomes binding. Therefore, we expect that managers exercise a significant portion of their options immediately after the options vest, independently of the specific reason for early exercise. We include *VestingWeek*, a dummy variable that equals one in the week of and in the week after the option vests and we expect the coefficient on this variable to be positive. The coefficient on *VestingWeek* implies that in the week of and the week after vesting, exercise rates are higher by 281%, hence vesting constraints are binding.

Dividend capture. Managers may adjust their exercise strategies to their companies' dividend policies if their options are not dividend protected. (Normally they are not.) We define *Dividend* as a dummy variable, which equals one in the week before and the week of a dividend payment and expect the coefficient on *Dividend* to be positive. The coefficients on *Dividend* are economically insignificant and statistically insignificant except for the earlier sample period (model (3) in Table 6), for which it has the opposite of the predicted sign. Hence, our findings lend no support to the hypothesis that early exercises are driven by the desire to capture dividend payments. Dividend yields are typically low and are zero for more than half of our sample (see Table 2) and may simply not play a major role.

Close-to-maturity effects. We define *Maturity8WeeksBefore* as a dummy variable, which equals one in the eight weeks before the maturity of the option and zero otherwise. The coefficients on *Maturity8WeeksBefore* is positive and large, which confirms our expectation that there are more exercises close to maturity.

We conclude that institutional constraints are of first-order importance of stock option exercise behavior. Managers react strongly to blackout periods, vesting constraints, and sometimes exercise options close to maturity. These constraints are of first-order importance and explain a larger fraction of the cross-sectional variation of stock option exercises than any other group of variables. To the best of our knowledge, Kadan, Liu, and Yang (2009) is the only model of executive stock options so far that takes some of these constraints, notably the vesting period, seriously and incorporates them into a valuation model. They show that the value of executive stock options is significantly below the Black-Scholes value if institutional constraints are taken into account.

6 Robustness checks

In this section we perform several robustness checks on our baseline specifications. The first part of this section deals with alternatives to our research design, in particular regarding variable definitions, whereas the second part analyzes specification issues regarding the econometric model. We provide some additional robustness checks in Table 11. For similar reasons we do not report coefficients for our control variables that are still part of all models.

6.1 Research design

Include only first exercises. Managers exercise their stock options in fractions over time. Therefore, it is plausible that the second and subsequent fractional exercises of option packages are dependent on earlier exercises. We address this in our baseline specification by including *FractionLeft* and *ExercisesLastYear*, but these variables may not adequately account for time dependence. In column (1) of Table 9, we estimate a model that includes only the first exercise of each option package to avoid potential distortions from the time dependence of sequential exercises.[40] Coefficient estimates and significance levels for this robustness check are very similar to those for the baseline case, so there is no evidence that modeling sequential exercises for the same option package distorts our results.

No sale of stock upon exercise. In our sample, 13% of the exercises are not associated with the sale of any shares in the same filing, and we exclude these exercises from our baseline sample. In column (2) of Table 9 we rerun our baseline regression on this complementary sample, which includes only observations not associated with stock sales.[41] We refer to this complement sample as the exercise-and-hold sample and contrast it with our baseline exercise-and-sell sample. The results for the exercise-and-hold sample are very different from those for the exercise-and-sell sample. The coefficients on *Return26* and *Return*52 both change signs, although *Return26* is not significant. This finding is consistent with the interpretation given in Section 4.2 above: If executives believe that the stock price will decline, then they will sell rather than hold the stock upon exercise, and the opposite when they believe the stock will go up. Hence, we should expect the opposite signs for the exercise-and-hold sample compared to the exercise-and-sell sample.

The coefficient on *MinPrice* also changes signs and the effect is economically very large:

[40] Including significant exercises only gives qualitatively the same results.

[41] Veenman, Hodgson, van Praag, and Zhang (2008) compare abnormal stock returns following exercises for which stock is sold with exercises for which stock is held. They focus on a different question and find a higher information content for exercises that are followed by stock sales. Aboody, Hughes, Liu, and Su (2008) find that exercises for which shares are sold indicate bad news, whereas exercises for which shares are held indicate good news.

Executives are 86% more likely to exercise an option and hold the stock if the price is below its 52-week minimum. This finding is consistent with those of Cicero (2009), who interprets his results as evidence for exercise date backdating: Executives backdate the exercise date to a day with a low stock price, so that a smaller portion of compensation is subject to the high income tax rate, and a larger portion is subject to the lower capital gains tax rate. The result is a V-shaped price pattern, where the minimum price is reached on the exercise date. *BHAR2* changes signs so that exercises now precede abnormal stock price run-ups, consistent with backdating. The fact that the coefficients of *BHAR13* and *BHAR26* do not change signs suggests that backdating occurs only over short time intervals.

Correlation and idiosyncratic risk. In our baseline specification we test for the opportunity to hedge the market risk of the company by using the coefficient of correlation as an independent variable. Alternatively, we could also approach this hypothesis by looking at idiosyncratic risk, which is the portion of the volatility the manager cannot hedge. We therefore use *ISVolatility* which is the standard deviation of the regression residuals from a market model regression as an independent variable instead of *Correlation* If managers are averse to idiosyncratic risk, then they should exercise their options earlier if idiosyncratic risk is high and the coefficient on *ISVolatility* should be positive. Column (3) in Table 9 shows the results. The coefficient on *ISVolatility* is in fact negative and implies that a one-standard deviation increase in idiosyncratic risk reduces the probability of exercise by 18%. This finding confirms the finding from the baseline case. We also use the firm's beta with respect to the CRSP value weighted index as an alternative measure of correlation and obtain very similar results to those for *Correlation* and for *ISVolatility* (seeTable 11, column (3)). Our results on *Correlation* are therefore robust.

6.2 Specification issues

Clustered robust standard errors. Another important issue for our estimation procedure is cross-grant correlation, which we already discuss above. Cross-grant correlations may arise if executives' exercise decisions may be influenced by a common factor across the grants of the same individual. We incorporate this aspect in our analysis by including option portfolio variables and by explicitly modeling unobserved heterogeneity, which effectively introduces manager-specific random effects. An alternative strategy to unobserved heterogeneity is the estimation of a model with clustered robust standard errors at the manager level or at the firm level. In column (1) of Table 10 we estimate a model with clustered standard errors at the manager level instead of unobserved heterogeneity. We obtain the same results if we cluster standard errors at the firm level rather than at the manager level (see Table 11, column (4)).

The results are similar to those in the baseline case. *Correlation*, *FractionLeft*, and *Return156* become insignificant. *Volatility* retains significance, but changes signs, which suggests that the impact on option value is actually stronger than the diversification effect, giving rise to a negative and significant coefficient. We conclude that our results are robust to alternative ways of modeling cross-grant correlation.

Bootstrapped standard errors. A further check on the correctness of our standard errors is to use bootstrapped standard errors, which we show in column (2). The point estimates then remain unchanged. Standard errors become larger as expected and *Volatility and Return156* drop to the 10% significance level.

Weibull model. A known problem in estimating parametric hazard models is the choice of functional form of the baseline hazard. We want to check if the common Weibull model is also appropriate. This model differs from the piecewise constant model only in the modeling of the baseline hazard rate. Column (3) of Table 10 shows the results, which are again very similar to those for the baseline case. Closer inspection shows that the estimates of the baseline hazard rate are very different for the Weibull model compared to the piecewise constant model, but the restrictive functional form of the Weibull model does not seem to bias the coefficients on the independent variables.

7 Conclusion

This paper provides a comprehensive analysis of the factors that drive executives' decisions to exercise their stock options early. We begin with a discussion of existing theories of stock option exercises based on a range of variables that model executives' preferences, beliefs, and private information. We find support for most of the predictions of these theories, but conclude that their combined explanatory power is only moderate. We then explore two sets of variables that turn out to have much larger explanatory power. The first set of variables captures the variation in executives' stock option portfolios and explicitly models the fact that executives decide not only whether they want to exercise stock options, but also which stock option they want to exercise. The second set of variables captures institutional constraints, such as vesting periods and blackout periods, which imposing binding constraints on executives' exercise decisions.

There is an awkward tension between the variables that extant theory of exercise behavior regard as relevant and those variables associated with most explanatory power in our analysis. Economic theories focus on the diversification motive, which has practically no explanatory power. In addition, executives exercise their options less when they carry more idiosyncratic risk, which is inconsistent with the diversification motive. Variables related to asymmetric information and behavioral explanations have some explanatory power. By contrast, institutional constraints and effects from the composition of option portfolios are of primary importance and overshadow the economic and statistical significance of all other variables. These effects have been neglected by the theoretical literature. We suggest that our results are best explained by managers engaging in consumption smoothing and having target ownership levels. Incorporating these concepts into theoretical models of stock option exercises and valuation models for executive stock options should be on the agenda for future research and lead to an improvement of existing valuation models.

One limitation of our data and our methodology is that we have only limited information about manager characteristics. Hazard rate analysis focuses on the time-series variation and by incorporating unobserved heterogeneity, we lose the ability to test theories of time-invariant characteristics of managers. As such, our approach reveals that individual characteristics are important, but we cannot evaluate theories based on overconfidence or optimism within the confines of our data set and methodology.

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Tables

Table 1: Sample design from raw IFDF data to our final sample. We report the number of option packages, the number of exercises, the number of persons, and the number of firms for derivatives with non-missing entries for the strike price, vesting date, and expiration date in IFDF. We show losses of observations after matching the IFDF data with ExecuComp and CRSP. We drop options that are never in the money or that never become vested. We only consider exercises for at least 25% of the option package.

	Option packages	Exercises	Persons	Firms
IFDF data	2,110,575	255,072	135,348	12,800
Observations lost because of:				
Missing employment periods	1,796,166	187,529	118,661	10,546
No stock price information	15,282	2,034	830	159
Options never exerciseable	88,117	11,184	1,686	87
Exercise restrictions	0	6,847	0	0
Final sample	211,010	47,478	14,171	2,008

Table 2: Option characteristics. Information refers to the vesting date. The BAW value is the Barone-Adesi and Whaley (1987) value for American options. Volatility is the volatility of the return of the underlying stock for weekly data measured over the 52 weeks before vesting. Dividend yield is the sum of all dividends during the previous calendar year divided by the stock price at the end of the previous calendar year. The interest rate is the yield of a zero-coupon government bond closest to the maturity of the respective option, where maturities are 1, 2, 3, 5, or 10 years.

	Option packages	Mean	Std. Dev	First Quartile	Median	Third Quartile
BAW-value ($ million)	208,672	0.70	20.38	0.02	0.07	0.30
Time to maturity (years)	211,010	7.37	2.03	6.31	7.96	8.98
Stock price/Strike price	210,349	10.17	1,648.44	1.01	1.28	1.81
Volatility	208,672	0.40	0.20	0.26	0.36	0.49
Dividend yield (%)	211,010	0.95	1.82	0.00	0.00	1.43
Interest rate (%)	211,010	4.47	0.91	3.92	4.44	4.92

Table 3: Reasons for right censoring. The table reports the total number of option packages and the percentage of the total for each possible reason for right censoring. If multiple reasons for right-censoring apply to the same option package then the table reports the reason that applies to the largest fraction of the package. We define option packages as right censored if the respective option package is not exercised early. We exclude the week where the option expires from the analysis.

Censoring reason	Number	% of total
Exercised at maturity	2,529	1.2
Expired out of the money	17,805	8.4
Holder left firm	23,831	11.3
Alive in Dec. 2008	130,870	62.0
Other Disposal	8,813	4.2
No censoring	27,162	12.9
Total	211,010	100.0

Table 4: Variable definitions and data sources. The Table lists all variables, their definitions, and data sources. Variable groups correspond to the explanatory approaches in the text (see Section 4).

Variable	Description	Source
Preferences		
Correlation	52 weeks correlation of stock returns with returns on the CRSP value weighted index	CRSP
Volatility	Annualized volatility of stock returns (52 weeks)	CRSP
MaxPrice	1 if the stock price is above its 52-week high, zero otherwise	CRSP
MinPrice	1 if the stock price is below its 52-week low, zero otherwise	CRSP
Beliefs and information		
*Return*13	Stock returns over the past 13 weeks	CRSP
*Return*26	Stock returns over the past 26 weeks	CRSP
*Return*52	Stock returns over the past 52 weeks	CRSP
*Return*156	Stock returns over the past 156 weeks	CRSP
Sentiment	Consumer confidence index based on a monthly survey of 5,000 U.S. households conducted for The Conference Board. The index averages five indices, each of which is based on a question regarding current or expected economic conditions.	Datastream
*BHAR*2	Buy and hold abnormal return in the following 2 weeks; Expected returns result from a regression of stock returns on the CRSP value weighted index using a 52 weeks estimation window	CRSP
*BHAR*13	Buy and hold abnormal return in the following 13 weeks; Expected returns result from a regression of stock returns on the CRSP value weighted index using a 52 weeks estimation window	CRSP
*BHAR*26	Buy and hold abnormal return in the following 26 weeks; Expected returns result from a regression of stock returns on the CRSP value weighted index using a 52 weeks estimation window	CRSP

Option portfolio effects		
GrantWeekBefore	1 in the week before a new option grant, zero otherwise	IFDF
GrantWeekAfter	1 in the week of and in the week after a new grant, zero otherwise	IFDF
PackageSize	Value of current option package / portfolio value	IFDF
FractionLeft	Fraction of the option package that is still left	IFDF
Institutional constraints		
BeforeAnnouncement	1 in the week before an earnings announcement date if available, zero otherwise	CompuStat
AfterAnnouncement	1 in the week of until two weeks after an earnings announcement if available, zero otherwise	CompuStat
VestingWeek	1 in the week of and in the week after vesting, zero otherwise	IFDF
Dividend	1 in the week before a dividend payment date if available, zero otherwise	CRSP
Mat8WeeksBefore	1 in the last 8 weeks before maturity	IFDF
Control variables		
TimeValue	Ratio of time value (=BAW value minus intrinsic value) to the BAW values	IFDF
CEO	1 if option holder is chief executive officer of the issuer, zero otherwise	IFDF
Maturity	Time to maturity in years	IFDF

Table 5: Descriptive statistics on option packages. The table contains information on all variables in the baseline specification based on observations for 26,100,542 option package-weeks. See Table 4 for all variable definitions.

	Mean	Std. Dev	Min.	First Quartile	Median	Third Quartile	Max.
Preferences							
Correlation	0.47	0.18	-0.53	0.36	0.48	0.59	0.96
Volatility	0.35	0.16	0.02	0.24	0.32	0.42	3.74
MaxPrice	0.13	0.33	0.00	0.00	0.00	0.00	1.00
MinPrice	0.03	0.17	0.00	0.00	0.00	0.00	1.00
Beliefs and information							
*Return*13	0.05	0.19	-0.87	-0.06	0.04	0.14	10.48
*Return*26	0.10	0.30	-0.93	-0.06	0.07	0.21	11.35
*Return*52	0.24	0.57	-0.96	-0.04	0.14	0.37	38.10
*Return*156	0.88	1.98	-1.00	0.13	0.48	1.08	151.71
Sentiment	100.54	17.25	51.00	92.60	103.80	108.20	144.70
*BHAR*2	-0.00	0.07	-0.85	-0.04	-0.00	0.03	2.02
*BHAR*13	-0.02	0.19	-3.93	-0.12	-0.02	0.08	10.17
*BHAR*26	-0.06	0.33	-10.84	-0.21	-0.04	0.11	10.34
Option portfolio effects							
GrantWeekBefore	0.02	0.13	0.00	0.00	0.00	0.00	1.00
GrantWeekAfter	0.04	0.19	0.00	0.00	0.00	0.00	1.00
PackageSize	0.05	0.09	0.00	0.00	0.01	0.05	1.00
FractionLeft	0.96	0.14	0.00	1.00	1.00	1.00	1.00
Institutional constraints							
BeforeAnnouncement	0.06	0.24	0.00	0.00	0.00	0.00	1.00
AfterAnnouncement	0.18	0.39	0.00	0.00	0.00	0.00	1.00
VestingWeek	0.01	0.11	0.00	0.00	0.00	0.00	1.00
Dividend	0.07	0.26	0.00	0.00	0.00	0.00	1.00
Mat8WeeksBefore	0.00	0.07	0.00	0.00	0.00	0.00	1.00
Control variables							
TimeValue	0.28	0.27	0.00	0.05	0.19	0.44	1.00
CEO	0.15	0.35	0.00	0.00	0.00	0.00	1.00
Maturity	4.94	2.33	0.00	3.00	5.00	7.00	41.00

Table 6: Hazard rates. The table displays the relative hazards defined as $exp\{\beta_i\} - 1$, where β_i is the estimated coefficient, for different variations of our baseline specification. Column (1) is the baseline model; column (2) does not split up grants by vesting date and uses the latest vesting date; (3) estimates the model before 2003; (4) estimates the model as of 2003. In addition to the independent variables shown, regressions include dummy variables for calendar years, vesting years, and seasonal effects (quarters). Asterisks indicate significance at the 10%-level (*), 5%-level (**), and 1%-level (***), respectively.

	Baseline (1)	Aggregated (2)	Pre 2003 (3)	From 2003 (4)
Preferences				
$Correlation$	0.03 ***	0.03 ***	0.06 ***	0.02 ***
$Volatility$	0.04 ***	0.05 ***	0.11 ***	-0.05 ***
$MaxPrice$	0.56 ***	0.60 ***	0.42 ***	0.53 ***
$MinPrice$	-0.49 ***	-0.56 ***	-0.25 ***	-0.56 ***
Beliefs and information				
$Return13$	0.11 ***	0.12 ***	0.09 ***	0.20 ***
$Return26$	0.06 ***	0.06 ***	0.10 ***	0.05 ***
$Return52$	-0.02 ***	-0.03 ***	-0.05 ***	-0.02 ***
$Return156$	0.02 ***	0.03 ***	-0.00	0.03 ***
$Sentiment$	0.10 ***	0.14 ***	0.21 ***	0.06 ***
$BHAR2$	-0.02 ***	-0.01 *	-0.03 ***	-0.02 **
$BHAR13$	-0.07 ***	-0.08 ***	-0.07 ***	-0.10 ***
$BHAR26$	-0.04 ***	-0.05 ***	-0.10 ***	-0.02 **
Option portfolio effects				
$GrantWeekBefore$	-0.25 ***	-0.24 ***	-0.40 ***	-0.15 ***
$GrantWeekAfter$	2.96 ***	3.32 ***	4.40 ***	1.91 ***
$PackageSize$	0.04 ***	-0.16 ***	-0.14 ***	0.15 ***
$FractionLeft$	-0.06 ***	0.00	0.20 ***	-0.10 ***
Institutional constraints				
$BeforeAnnouncement$	-0.63 ***	-0.60 ***	-0.59 ***	-0.66 ***
$AfterAnnouncement$	1.12 ***	1.18 ***	0.96 ***	1.23 ***
$VestingWeek$	2.81 ***	3.14 ***	2.94 ***	2.00 ***
$Dividend$	-0.01	-0.00	-0.06 **	0.01
$Mat8WeeksBefore$	2.39 ***	2.74 ***	2.42 ***	2.60 ***
Control variables				
$TimeValue$	-0.58 ***	-0.53 ***	-0.56 ***	-0.60 ***
CEO	0.13 ***	-0.00	-0.16 ***	0.39 ***
$Maturity$	-0.06 ***	-0.04 ***	-0.05 ***	-0.07 ***
σ_f^2	2.17 ***	1.70 ***	2.26 ***	3.43 ***
$Obs.$	26,100,542	11,122,792	4,920,341	21,180,201

Table 7: Likelihood-ratio tests for groups of variables. The table presents variations of regression (2) in Table 6. Each line reports the likelihood ratio test for removing a variable or a group of variables from the baseline regression. The LR-test statistics in column (1) test for the joint significance of each group of variables in the table. Under the null hypothesis, the likelihood ratios are distributed Chi-square. Column (2) reports the relevant cut-off values for the 1% significance level.

Group	LR	1% Chi-squared
All variables	55,824	42.98
Preferences	1,607	13.28
$Correlation$, $Volatility$	64	9.21
$MinPrice$, $MaxPrice$	1,565	9.21
Beliefs and information	2,237	20.09
$Return13$, $Return26$, $Return52$, $Return156$	1,110	13.28
$Sentiment$	64	6.63
$BHAR2$, $BHAR13$, $BHAR26$	499	11.34
Option portfolio effects	9,524	13.28
Institutional constraints	12,731	16.81
Control variables	19,565	11.34
$TimeValue$	17,150	6.63

Table 8: Option portfolio effects for different exercise thresholds. The table displays the relative hazards defined as $exp\{\beta_i\} - 1$, where β_i is the estimated coefficient, for different variations of our baseline specification: The column headings show the threshold for $Exercise = 1$, below this threshold $Exercise = 0$. In addition to the independent variables shown, regressions include dummy variables for calendar years, vesting years, and seasonal effects (quarters). Asterisks indicate significance at the 10%-level (*), 5%-level (**), and 1%-level (***), respectively.

	10%	25%	50%	100%
Option portfolio effects				
$GrantWeekBefore$	-0.30 ***	-0.32 ***	-0.34 ***	-0.38 ***
$GrantWeekAfter$	3.19 ***	3.42 ***	3.67 ***	3.96 ***
$PackageSize$	-0.07 ***	-0.16 ***	-0.26 ***	-0.32 ***
$FractionLeft$	-0.03 ***	0.05 ***	0.18 ***	
σ_f^2	2.16 ***	2.33 ***	2.54 ***	3.07 ***
$Obs.$	25,946,489	25,803,443	25,437,603	23,661,781

Table 9: Research design. The table presents variations of regression (1) in Table 6. Model (1) only includes option-weeks until the first exercise; in (2) *Exercise* only equals one if no stock is sold upon exercise; (3) replaces *Correlation* with *ISVolatility*.

	(1)	(2)	(3)
Preferences			
Correlation	0.04 ***	0.06 ***	
Volatility	0.07 ***	0.19 ***	0.26 ***
MaxPrice	0.53 ***	0.15 ***	0.55 ***
MinPrice	-0.48 ***	0.86 ***	-0.48 ***
ISVolatility			-0.18 ***
Beliefs and information			
Return13	0.11 ***	0.01	0.11 ***
Return26	0.06 ***	-0.03 **	0.06 ***
Return52	-0.03 ***	0.07 ***	-0.02 ***
Return156	0.02 ***	0.03 ***	0.02 ***
Sentiment	0.11 ***	0.07 **	0.11 ***
BHAR2	-0.02 ***	0.05 ***	-0.02 ***
BHAR13	-0.08 ***	-0.00	-0.07 ***
BHAR26	-0.04 ***	0.05 ***	-0.04 ***
Option portfolio effects			
GrantWeekBefore	-0.34 ***	0.17 **	-0.25 ***
GrantWeekAfter	3.29 ***	1.05 ***	2.96 ***
PackageSize	0.02 ***	0.02 *	0.04 ***
FractionLeft		0.01	-0.06 ***
Institutional constraints			
BeforeAnnouncement	-0.65 ***	-0.40 ***	-0.63 ***
AfterAnnouncement	1.26 ***	0.54 ***	1.12 ***
VestingWeek	2.49 ***	5.25 ***	2.81 ***
Dividend	-0.00	0.00	-0.01
Mat8WeeksBefore	3.01 ***	7.60 ***	2.39 ***
σ_f^2	2.38 ***	4.90 ***	2.17 ***
Obs.	24,118,236	26,100,542	26,100,542

Table 10: Specification issues. The table presents variations of regression (1) in Table 6. Model (1) uses clustered robust standard errors at the individual level rather than unobserved heterogeneity; (2) uses bootstrapped standard errors; (3) is the Weibull model.

	(1)	(2)	(3)
Preferences			
Correlation	0.04 ***	0.03 ***	0.03 ***
Volatility	-0.05 ***	0.04 *	0.04 ***
MaxPrice	0.65 ***	0.56 ***	0.52 ***
MinPrice	-0.57 ***	-0.49 ***	-0.49 ***
Beliefs and information			
*Return*13	0.09 ***	0.11 ***	0.11 ***
*Return*26	0.05 ***	0.06 ***	0.06 ***
*Return*52	-0.03 ***	-0.02 **	-0.02 ***
*Return*156	0.01	0.02 *	0.02 ***
Sentiment	0.11 ***	0.10 ***	0.09 ***
*BHAR*2	-0.02 **	-0.02 **	-0.02 ***
*BHAR*13	-0.07 ***	-0.07 ***	-0.07 ***
*BHAR*26	-0.05 ***	-0.04 ***	-0.04 ***
Option portfolio effects			
GrantWeekBefore	-0.15 **	-0.25 ***	-0.25 ***
GrantWeekAfter	3.41 ***	2.96 ***	2.99 ***
PackageSize	0.11 ***	0.04 ***	0.05 ***
FractionLeft	-0.17 ***	-0.06 ***	-0.06 ***
Institutional constraints			
BeforeAnnouncement	-0.63 ***	-0.63 ***	-0.64 ***
AfterAnnouncement	1.11 ***	1.12 ***	1.08 ***
VestingWeek	2.92 ***	2.81 ***	4.59 ***
Dividend	0.02	-0.01	0.00
Mat8WeeksBefore	2.51 ***	2.39 ***	2.53 ***
σ_f^2		2.17 ***	
Obs.	26,100,542	26,100,542	25,753,731

Table 11: Additional robustness checks. The table presents variations of regression (1) in Table 6. Model (1) uses incremental returns, i.e. with *Return*52 as the return from week 26 to 52 and with *Return*156 as the return from week 52 to 156; (2) splits up BHARs into their positive and negative components; (3) replaces *Correlation* with *Beta*; (4) uses clustered robust standard errors at the firm level rather than unobserved heterogeneity.

	(1)	(2)	(3)	(4)
Preferences				
Correlation	0.03 ***	0.03 ***		0.04 **
Volatility	0.04 ***	0.06 ***	0.02	-0.05 **
MaxPrice	0.56 ***	0.55 ***	0.56 ***	0.65 ***
MinPrice	-0.49 ***	-0.47 ***	-0.49 ***	-0.57 ***
Beta			0.05 ***	
Beliefs and information				
*Return*13	0.14 ***	0.11 ***	0.11 ***	0.09 ***
*Return*26	0.04 ***	0.06 ***	0.06 ***	0.05 ***
*Return*52	-0.01 ***	-0.01 ***	-0.02 ***	-0.03 **
*Return*156	0.02 ***	0.02 ***	0.02 ***	0.01
Sentiment	0.10 ***	0.10 ***	0.09 ***	0.11 ***
*BHAR*2	-0.02 ***		-0.02 ***	-0.02 *
*BHAR*13	-0.07 ***		-0.07 ***	-0.07 ***
*BHAR*26	-0.04 ***		-0.04 ***	-0.05 ***
*NegBHAR*2		0.04 ***		
*NegBHAR*13		-0.05 ***		
*NegBHAR*26		-0.02 **		
*PosBHAR*2		-0.07 ***		
*PosBHAR*13		-0.04 ***		
*PosBHAR*26		-0.04 ***		
Option portfolio effects				
GrantWeekBefore	-0.25 ***	-0.24 ***	-0.25 ***	-0.15
GrantWeekAfter	2.96 ***	2.96 ***	2.96 ***	3.41 ***
PackageSize	0.04 ***	0.04 ***	0.04 ***	0.11 ***
FractionLeft	-0.06 ***	-0.06 ***	-0.06 ***	-0.17 ***
Institutional constraints				
BeforeAnnouncement	-0.63 ***	-0.62 ***	-0.63 ***	-0.63 ***
AfterAnnouncement	1.12 ***	1.11 ***	1.12 ***	1.11 ***
VestingWeek	2.81 ***	2.82 ***	2.81 ***	2.92 ***
Dividend	-0.01	-0.01	-0.01	0.02
Mat8WeeksBefore	2.39 ***	2.40 ***	2.39 ***	2.51 ***
σ_f^2	2.17 ***	2.17 ***	2.17 ***	
Obs.	26,100,542	26,100,542	26,100,542	26,100,542

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