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Executive Stock Options: Exercises and Valuation

Inauguraldissertation

zur Erlangung des akademischen Grades

eines Doktors der Wirtschaftswissenschaften

der Universität Mannheim

Vorgelegt im Frühjahrssemester 2010

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Tag der Disputation:	11. November 2010

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Introduction

1 Overview

This dissertation analyzes early exercises of executive stock options and their impact on option valuation. Executive stock options (ESOs) are usually American style call options that companies grant to their executives as a performance based component of compensation packages. For the valuation of American options the exercise behavior plays a crucial role. Those options can be exercised before maturity and give thus more choice to the option holder compared to European options that can only be exercised at maturity.

How executives exercises ESOs is, however, in various respects different from how other investors would exercise comparable financial options. For instance, ESOs are often exercised before maturity even if the underlying stock does not pay dividends, which would be suboptimal for American options that are held by diversified investors. This makes usual valuation methods inapplicable for ESOs. The crucial difference between ESOs and most other financial options is, however, that ESOs are not traded on the open market. Thus, the only possibility for executives to cash in option value before maturity is early exercise.[1] Another difference to plain vanilla American options is that ESOs become first exercisable after meeting so-called vesting requirements. Most commonly, ESOs are cliff vested, i.e. they become vested (exercisable) after a prespecified time period (vesting period) beginning at the grant date.[2] If the executive leaves the firm before vesting her ESOs usually forfeit.[3] Also vested options forfeit short after the executive leaves the firm, but the executive may exercise the option before it forfeits. As those exercises are directly triggered by executive turnover I will refer to them as forced exercises. Understanding how executives exercise ESOs voluntarily and when firms force exercise (or forfeiture) is a prerequisite for the setup of a proper ESO valuation model. Reliable ESO values are not only important for firms that have to expense ESOs as compensation costs, but also for investors and regulators like the Financial Accounting Standards Board (FASB) that are interested in accounting procedures to reflect economic values.

This dissertation contributes to the area of executive compensation and specifically ESO valuation analyzing different aspects of ESO early exercises. In Chapter II, I construct an empirical model for ESO valuation that accounts both for turnover as a trigger for forced early exercise (or forfeiture) and voluntary exercise, and show that turnover induced early exercises have a major impact on ESO valuation. In Chapter III I analyze different motivations for executives to exercise ESOs voluntarily and evaluate their respective importance. I find that executives tend to select rationally from multiple exercisable option packages. In Chapter IV, I analyze fractional exercises, i.e. exercises of some options that represent only a proportion of the whole option package. I build up a theoretical model to show how the possibility of fractional exercise affects ESO valuation

[1] Executives can neither circumvent the sale constraint of ESOs by selling a replication portfolio of the ESO. This would imply short sales in the employer firm's stock which is forbidden by companies' governance rules.

[2] Other vesting criteria are, for instance, performance vesting (exercise possible after the performance target is met), or time vesting (options in an option package become ratably vested over time).

[3] See Dahiya and Yermack (2008) for an analysis of ESO treatments when managers retire, resign or die.

and executives' incentives to increase the stock price and test implications of the model empirically.

The main data source for this dissertation is the Insider Filing Data Feed (IFDF) provided by ThomsonReuters, which collects data from forms US insiders have to file with the Securities and Exchange Commission (SEC). IFDF contains holdings in insider securities, e.g. ESOs, and changes in holdings, e.g. exercises. The database is unique in its scope and enables me to analyze ESO exercises in more than 2,000 firms. To make sure that considered insiders are executives, I base my analysis only on the subset of people that are also part of Standard and Poor's ExecuComp database, which collects compensation data of top executives in large publicly traded US firms.

This overview is followed by an introduction into the subject of ESO valuation. I, however, relegate the detailed discussion of the literature to the respective Chapters II to IV. I close this introduction with an outline of the following chapters and a presentation of the main results.

2 Valuation of executive stock options

Background. In October 1972, the Accounting Principles Board (APB) issued its Opinion Number 25 "Accounting for Stock Issued to Employees". This accounting principle allowed companies to expense ESOs at their inner value at the grant date (intrinsic value method), i.e. the difference between the stock price and the option's strike price. Thus, no expense had to be reported for ESOs that were granted at the money (strike price equal to stock price). This practice was heavily criticized in the accounting literature (Boudreaux and Zeff, 1976; Smith and Zimmerman, 1976; Foster, Koogler, and Vickrey, 1991) but had still long time been in effect even after the publication of the Black and

Scholes (1973) model for the valuation of European options and the Merton (1973) modification that allows for continuously paid dividends. The Financial Accounting Standards Board (FASB) replaced the APB in 1973 as responsible organization for setting accounting standards for public companies. First in October 1995, the FASB issued its Status of Statement Number 123 "Accounting for Stock-Based Compensation" (SFAS 123) recommending a fair value method instead of the intrinsic value method suggested in APB Opinion 25. The fair value method allows to approximate ESO values with values of comparable traded securities or by the application of appropriate valuation models. For ESOs with maturities of usually around 10 years, comparable tradable options are, however, rare. This favors the application of valuation models. In SFAS 123, paragraph 288-297, the FASB provides an example ESO valuation in which it suggests to use an amended version of the Black-Scholes model. The FASB proposes to replace the time to maturity in the Black-Scholes formula with the expected lifetime of the option, given that it becomes vested, to account for the earlier exercise of ESOs compared to market traded options. This value, conditional on the ESO's vesting, is then multiplied with the probability of becoming vested, which usually coincides with the probability that the employee stays with the firm until the vesting date. This simplification implicitly assumes that ESOs are exercised or forfeit at distinct point in time and thus consciously neglects the influence of other circumstances, e.g. the stock price, on the occurrence of early exercise and forfeiture. Nevertheless, the FASB model is the nowadays common practice approach for the valuation of ESOs and thus the benchmark model for the later literature on ESO valuation.

Theoretical literature. Huddart (1994), Kulatilaka and Marcus (1994), and Jennergren and Näslund (1993) are among the first papers to analyze the impact of early exercise on the valuation of ESOs. They explicitly take into account that ESOs are more likely to be exercised early than comparable traded options and show, accordingly, that ESO values are lower than market values for comparable traded options but higher than the inner value. Huddart (1994) and Kulatilaka and Marcus (1994) explain ESO early exercise as an outcome of a utility maximizing strategy of a trade constrained employee. With early exercise the employee acquires newly issued stock that she can sell on the open market to invest the proceeds into a diversified portfolio. The employee's decisions to exercise stock options early trades off the objective to diversify the portfolio and the cost of giving up the time value of the option. The optimal exercise policy for the employee can then be described by a critical stock price threshold above which exercise is utility-optimal and below which the employee should further hold the option. While utility based models describe early exercise as a personal decision of the option holder, Jennergren and Näslund (1993) assume that employees face exogenous random shocks that trigger early exercise or forfeiture. They explain those shocks by immediate liquidity needs or employment turnover. While they assume the intensity of the stopping event to be constant, Carr and Linetzki (2000) assume the intensity to increase in the stock price supporting diversification and liquidity arguments. In turn Cuny and Jorion (1995) model the stopping event to decrease in the stock price consistent with higher turnover rates if the employer firm is doing badly.

The above theoretical literature mostly concentrates on voluntary early exercise and imposes rather restrictive assumptions: Executive turnover is mostly assumed to occur with constant intensity or, as in the case of Cuny and Jorion (1995), with moneyness as the only determinant. While the above literature considers employees with only one option, employees in the real world may hold portfolios of option packages each of which consists out of multiple options. The setup with one option completely neglects possible portfolio issues for voluntary exercise decisions and implicitly assumes that option packages are only exercised completely. Complete exercise of option packages would indeed be the optimal exercise strategy for market traded options. However, for employees who would otherwise prefer to sell a fraction of an option package, fractional exercise is a possibility to circumvent the no-sale restriction.

Early exercise. Huddart and Lang (1996) analyze employee stock option exercises in 7 companies and find that early exercise commonly destroys large fractions of options' theoretical market value. However, in contrast to the common assumption of complete exercise of option packages in the theoretical literature, they find first evidence that option packages are in fact split up and exercised in a multiple large transactions.[4] Besides utility theory also other aspects are found to have explanatory power for the timing of option exercises. Using a similar data set to Huddart and Lang (1996), Heath, Huddart, and Lang (1999) relate early exercises to behavioral and other preference factors. They find that employees behave as if they would expect long term stock price trends to persist and short term trends to revert. Thus employees further postpone exercises after positive long term returns and bring forward exercises after short term price run-ups.[5] Employees further seem to take past outstanding stock prices as reference points and increase exercise activity after the stock price crosses the respective reference point. Carpenter and Remmers (2001) find negative abnormal stock returns after ESO exercises in small firms, supporting the notion that executives exploit insider information by timing exercises.

So far, little is known about top executives and their motivations to exercise their stock options early. Although different exercise motivations have been analyzed, the explanatory power of those motivations has never been tested against each other. Compared to lower

[4]See Sautner and Weber (2009) for similar findings from German survey data.

[5]Malmendier and Tate (2005a,b) consider other behavioral biases. They regard the timing of exercises as an outcome of managerial overconfidence.

level employees, executives' compensation packages consist to a large extent of options. In addition, executives usually hold multiple option packages. It is, however, still unclear from the empirical literature how exercises in a portfolio of option packages are related to each other, e.g. if executives prefer to exercise their option packages in a certain order.

Empirical valuation. Carpenter (1998) and Bettis, Bizjak, and Lemmon (2005) combine theory and empiricism in calibrating their models to mean characteristics of data sets on early exercise. The quality of value estimates for ESOs from using such calibrated models relies, however, on the validity of the proposed model setup. Recent contributions of empirical valuation models are more flexible and better able to take the above mentioned characteristics of the exercise data into account. Armstrong, Jagolinzer, and Larcker (2007) estimate the probability of early exercise using hazard analysis. They use data on early exercises and forfeitures from 10 companies with 800 to 6,700 employees each. While forfeitures can easily be classified as forced events, they cannot always disentangle forced exercises from voluntary exercises. For their analysis, they consider exercises that represent an economically meaningful fraction of the initially granted number of options to the respective employee. Hazard analysis treats early exercise as an event and is thus well able to map employees' preference to exercise in few large transactions. Carpenter, Stanton, and Wallace (2008a) estimate the number of options exercised as a fraction of still available options of that package. They also have hand collected data on the employee level with almost 900,000 option grants from 47 firms. They base their analysis exclusively on voluntary exercises and exclude potential forced exercises around employee turnover dates. For their option valuation, they separately account for forced exercises and present results for a range of assumed constant turnover probabilities. The model of Carpenter, Stanton, and Wallace (2008a) implies continuous small exercises over time.

This, however, does not coincide with empirically observed large transactions, especially in a world, in which frequent portfolio monitoring appears costly.

The above discussed papers present different approaches to account for voluntary early exercises in the valuation of employee stock options. However, they abstain from estimating separate models for turnover induced forced exercise or cannot reliably disentangle forced exercises from voluntary ones. Although executive turnover is widely analyzed in the literature (Parrino, 1997; Kaplan, 1994; Kaplan and Minton, 2006; Weisbach, 1988; Weisbach, 1995) the application of turnover models on ESO valuation has received little attention. It is thus an open question how forced exercises affect ESO values and how important they are compared to voluntary exercises.

3 Outline of the thesis

Chapter II develops a model for the valuation of ESOs. I go beyond other valuation papers that exclusively focus on voluntary exercises, and conduct separate hazard analyzes on both voluntary exercise and employment turnover that I consider as a trigger for forced exercise or option forfeiture. My analysis is based on exercise and turnover data on almost 4,000 US executives. I apply the hazard estimates to forecast probabilities of voluntary exercise, forced exercise, and forfeitures for simulated stock price paths in a Monte Carlo simulation and estimate the value of a representative ESO. I find the common practice valuation approach suggested by the FASB to consistently underestimate ESO values. This makes the FASB approximation bias estimates of compensation expenses. I further use my model to analyze the impact of executive turnover on the valuation of ESOs and to compare it to the impact of voluntary exercise. According to my model, forced exercises (and forfeitures), induced by executive turnover, account for most of the valuation discount of ESOs to market traded options. Given this, I suggest that future efforts to create valuation models for executive stock options should give more consideration to turnover risk rather than voluntary exercises.

Chapter III analyzes how top executives exercise their stock options voluntarily. I run a horse race of competing explanatory approaches to identify the main variables that influence executives' timing decisions. I find that the time value of the option, characteristics of managers' option portfolios, and institutional factors (vesting dates, blackout periods) have a first-order impact on exercise behavior. Behavioral factors (e.g., trends in past stock prices) and timing based on inside information also influence stock option exercises, but are quantitatively less important. While there is evidence for some behavioral biases, managers seem to see through investor sentiment and tend to select rationally from their exercisable options.

Chapter IV develops a theoretical model in which an executive exercises her option package in fractions to diversify into other assets. Within the model, I find that fractional exercises affect ESO values considerably for companies with highly volatile stock returns. Fractional exercise also makes option packages provide more incentives for the executive to increase the stock price. Incentives are, furthermore, more stable over time compared to a model with full exercise (all options are exercised together). Full exercise models are thus not able to precisely estimate ESO values and provided incentives. Using US data on ESO exercises, I find that ESO exercises cluster at fractions of the option packages of 20%, 25%, 33%, and multiples of those percentage numbers - fractions that I also use as inputs for my model. The main characteristic of the model, that subsequent fractional exercises occur at higher stock prices, can be confirmed empirically. Analyzing option exercises, I further find large option packages to be more likely to be split up and owners of numerous option packages to have a preference for full exercise, which can be explained by monitoring costs. Finally, fractional exercise is more likely for high volatility of the employer firm's stock returns - an observation that is also borne out by my model. This finding confirms that fractional exercise is especially an issue for the valuation of ESOs with highly volatile underlying stock.

Chapter II

Executive Turnover and the Valuation of Stock Options

1 Introduction

In this paper I estimate empirical hazard models for exercises of executive stock options (ESOs).[1] As sources for early exercise, I consider executive turnover and voluntary exercises. Finally, I apply the results from my hazard analysis for the valuation of a representative stock option by Monte Carlo simulation, where I forecast future exercise probabilities for simulated stock price paths. I analyze and quantify the impact of the separate sources of early exercise on the option value within the model and relate the ESO value from the model to a common practice estimate.

In case of turnover the executive has to exercise her options within a short time period after she left the firm. If she abstains from doing so the option forfeits. Possible reasons for not exercising an option in such a case can be, for instance, that the option is out of the money and thus exercise does not pay off or the option is unvested and

[1] I thank Ernst Maug and seminar participants at the University of Mannheim for helpful comments and discussions. All tables are gathered at the end of the chapter.

exercise is simply not allowed. The second source of early exercise that has received more attention in the literature so far is voluntary exercise. Since ESOs cannot be sold or hedged, executives face an incomplete market problem.[2] The only possibility to cash in option value before maturity is early exercise. As a result, ESO exercises are subject to individual characteristics and preferences of the option holder concerning diversification, liquidity (consumption), and behavioral biases.

The objective of this paper is to develop a model for the valuation of ESOs that can be used by issuer firms to estimate their compensation expenses. I find that the valuation approach suggested by the Financial Accounting Standards Board (FASB) consistently underestimates ESO values. The FASB model implicitly assumes that ESOs are exercised or forfeit at a distinct point in time and thus consciously neglects the influence of other circumstances, e.g. the stock price, on the occurrence of early exercise and forfeiture. Conversely, I find voluntary exercise to be more likely for high stock prices when the forfeited time value is comparably low and turnover induced exercise to be more likely after poor past performance when the option is far out of the money and worth little. The lower expected loss in time value in my approach results in an ESO value that is higher than the corresponding FASB value.

The purpose of this paper is, furthermore, to analyze how and with which intensity either source of early exercise affects the value of ESOs. It thus contributes to a literature on ESO valuation that mostly concentrates on voluntary exercises. As a result from my Monte Carlo simulations, I identify executive turnover to cause most of the discount of an ESO in relation to a market traded option. Reasons for that are twofold. On the

[2] As short sales of the employer firm's stock is not allowed by firm's governance rules a complete hedge of ESOs is ruled out. Nevertheless, Bettis, Bizjak, and Lemmon (2001) identify 87 collar transactions and two equity swap of corporate insiders from January 1996 to December 1998 transaction and found that insiders reduced their effective ownership positions with these transactions on average by 25%. Also, executives could partially hedge their exposure by trading a correlated asset (see Carpenter, Stanton, and Wallace (2008b)).

one hand, turnover occurs with a higher probability than voluntary exercise. On the other hand, turnover also destroys more option value than voluntary exercise. This is in particular the case if options are unvested or out-of-the-money at the time of turnover in which case they forfeit. Voluntary early exercise destroys option time value, too. However, for high volatility of the underlying stock voluntary, early exercise even turns out to be value increasing in the presence of turnover risk, i.e. an ESO that, in the baseline case, is affected by both forced and voluntary exercise is valued higher than an ESO that is only affected by forced exercise with an assumed zero probability of voluntary exercise. The reason for this effect is that voluntary exercise prevents turnover induced early exercise in the future.[3] As the time value destroyed by voluntary exercises is lower than that destroyed by forced exercise, the prevention of forced exercise adds to the ESO value. This effect is strong enough to be visible in the above setup for highly volatile underlying stock returns.

The literature on executive turnover especially focuses on relation of performance and turnover. Executives that perform well face a lower likelihood of getting forced out of their job and thus have a longer tenure. The impact of performance on executive turnover has been analyzed in different respects. Kaplan (1994) and Engel, Hayes, and Wang (2003) compare different performance measure on their explanatory power. Kaplan (1994) finds past stock returns and earnings to have the strongest impact on turnover while he finds no effects of sales growth and earnings growth. Engel, Hayes, and Wang (2003) criticizes the inability of both accounting based and market based measures to measure current performance for different reasons. While accounting based measures are also determined by past management decisions, stock returns are influenced by market expectations about

[3] In line with most of the theoretical literature on ESO valuation I implicitly assume that all options of an ESO package are exercised at the same time. Early papers in this literature are Jennergren and Näslund (1993), Huddart (1994), and Kulatilaka and Marcus (1994). Later models can be found in Carpenter (1998) and Bettis, Bizjak, and Lemmon (2005).

the future. Another strand of this literature analyzes performance relative to a benchmark. Warner, Watts, and Wruck (1988) find that stock returns relative to the market are better to explain turnover than absolute stock returns. Morck, Shleifer, and Vishny (1989) find turnovers to be equally likely in troubled and healthy industries, indicating that industry specific shocks are filtered out for the turnover decision. Conversely, later papers as Kaplan and Minton (2006) and Jenter and Kanaan (2008) find that industry and market shocks are not completely filtered out and thus there are more turnovers in economic downturns. Weisbach (1988) further finds board composition to have an effect on executive turnover. A higher number of outside directors makes the CEO less entrenched, which makes it easier to force her out after bad performance. Also personal networks between executives play a role for turnover and hiring decisions, as Liu (2008) points out.

Most of the above papers on executive turnover base their main argument on forced turnover. Other reasons for turnover include retirement and voluntary turnover. Dahiya and Yermack (2008) identify retirement as one of the most important factors for ESO valuation.[4] They argue that a ten year option is in fact a five year option, if retirement is planned in five years and the option expires prematurely when the executive leaves the firm. In this paper, I consider retirement together with other turnover reasons as a stochastic event rather than a planned event. I, however, control for age as retirement should be more likely for older executives. I further include factors that specifically impact voluntary turnover. I find the value of unvested options to have a negative effect on turnover while I find no effect for vested options. This finding supports the notion that unvested options bind executives to employer firms as those options usually forfeit worthless when executives leave their firms.

While the above literature mostly concentrates on CEOs and aims to explain turnover

[4] Brickley (2003) argue that issues related to executive age could even have more explanatory power for turnover than performance.

in itself, I base my analysis on a broad base of also non-CEO executives and specifically focus on the application for ESO valuation. Due to this focus, I exclusively consider executives that hold ESOs at least for some time during their employment period, which is unusual for the above turnover literature. However, if executives without options have turnover probabilities that fundamentally differ from those of option holding executives, a turnover model on the basis of both groups of executives could actually bias my ESO valuation that crucially depends on the turnover model.

The first attempt to build an empirically validated valuation model for executive stock options was made by Carpenter (1998) and Bettis, Bizjak, and Lemmon (2005) who use option exercises for model calibration. In their models, the executive decides about early exercise as to maximize expected utility while at the same time facing random liquidity shocks.[5] Carpenter, Stanton, and Wallace (2008a) estimate fractions of the option package to be exercised for insiders of 40 firms and perform ESO valuations for a range of turnover probabilities, assumed to be constant. To the best of my knowledge, Armstrong, Jagolinzer, and Larcker (2007) are the first to apply hazard analysis for the purpose of ESO valuation. They infer employee turnover indirectly from option cancellations and focus their argument on voluntary exercise. They estimate company specific models using data for broad based option plans of 10 companies mostly from the technology sector. Klein and Maug (2010) analyze and compare different motivations for voluntary early exercises for a large number of executives in a broad sample of firms but do not apply their model to ESO valuation. My analysis of voluntary exercise is closely related to their approach.

The literature on ESO valuation either analyzes data sets with small numbers of firms

[5] The calibrated models build on earlier binomial models of Huddart (1994) in which the option holder maximizes expected utility by exercising options, and Jennergren and Näslund (1993) who assume exogenous shocks to trigger early exercise.

or exclusively concentrates on the analysis of voluntary exercises. This paper uses data on voluntary exercises and turnovers of executives. I analyze a data set with 53,162 option packages held by 3,649 executives in 1,264 firms for the years 1996 to 2008. I collect data on executive tenure and turnover from ExecuComp and data about option grants and exercises from the Insider Filing Data Feed (IFDF) of ThomsonReuters. My approach for ESO valuation combines the insights from the literature on voluntary exercises with those of the literature on executive turnover and provides the opportunity to evaluate the relative importance of either source of early exercise.

The paper is structured as follows. Section 2 describes the construction of the data set. Section 3 explains the applied methodology. Section 4 estimates the turnover model and Section 5 the model for voluntary early exercise. Section 6 performs Monte Carlo simulations for ESO valuation in which probabilities of exercise and forfeiture are estimated according to the hazard models for turnover and voluntary exercise from Sections 4 and 5. It relates the so calculated ESO values to the FASB approximation and discusses the impact of either source of early exercise on ESO valuation. Section 7 summarizes and concludes.

2 Data

I use two major databases for my analysis. For the turnover analysis I use annual data on employment periods and compensation from ExecuComp. For the analysis of voluntary early exercise I track executives' option portfolios using transaction data based on the SEC's (Securities and Exchange Commission) corporate insider filings. This transaction data is part of the ThomsonReuters database "Insider Filing Data Feed" (IFDF). I use the database from the year 1996 on because in this year the SEC amended its Securities and Exchange Act of 1934 and extended insider reporting obligations. I use the same set of executives for the analysis of executive turnover and voluntary early exercise. This will provide me with the opportunity to fully compare the respective impact of both sources of early exercise on ESO valuation in Section 6.

2.1 Data on executive turnover

I start with the 2008 version of ExecuComp and obtain 184,789 annual observations of company-executive combinations, 8,987 reported turnovers for 34,571 executives in 3,079 firms. The steps of the construction of the sample are summarized in Table II.1.

[Insert Table II.1 about here.]

First, I omit all employment relations with unreported joining date because of which I lose the largest part of my sample (122,015 observations). In the analysis I relate turnover to option portfolio values. As ExecuComp tracks option portfolios only from 1992 onwards, I drop managers who join their firm before 1992. As a result, my sample excludes executives that have been with their firms longer than 16 years (1992 to 2008). If executives with a longer tenure have systematically lower turnover probabilities, then the turnover probability in my sample should be higher than in the full sample. For the same reason, I also expect fewer executives to belong to owner families in my sample than in the full sample. Furthermore, I only keep annual observations from 1996 on to match the analysis period for the turnover analysis with that for the voluntary exercises. Because of the above period restrictions I lose 13,108 observations. I match the ExecuComp data to IFDF to have the same set of executives in the analysis of executive turnover and the analysis of voluntary early exercise.[6] I thus keep only persons who held ESOs for at

[6] I can match by person names and firms' CUSIPs. I match by first name, middle name, last name, and name affix ("Jr.", "Sr.", etc.). Sometimes one database contains the affix, whereas the other database

least some time during the sample period and thereby lose another 26,723 observations. As I analyze executive turnover as a trigger for forced ESO exercise or forfeiture, it also makes intuitively sense to concentrate on executives that also hold options. I finally match the data with stock price related data from CRSP and data on firm size from CompuStat. I drop 9,147 observations with missing data and end up with a final sample of 13,796 annual employment observations covering 841 turnovers for 3,649 executives in 1,264 firms.

To analyze possible differences between option granting firms in my sample with other ExecuComp firms that are not part of my sample, I compare key financial firm characteristics of the two groups of firms in Table II.2. For each characteristic I take the mean value over all years during my sample period for which there was data available. This gives me one observation per firm. Depending on the firm characteristic the number of firms ranges from 977 to 1,177 for my sample and from 993 to 1,546 for the comparison sample of ExecuComp firms that are not part of my sample. As measures of size I report the market capitalization of common stock, the book value of assets, sales, and the number of employees. As measures of growth options and profitability I further report the market to book ratio, the price earning ratio and the ratio of net income over sales. All accounting numbers are reported in million dollars. For each firm characteristic, I report the means for my sample, the difference between the means of my sample and the comparison sample, the median, and the difference between medians of my sample and the comparison sample.

[Insert Table II.2 about here.]

does not. In such cases, I match by first name, middle name, and last name. If the middle name is also not available in one database, then I match by first name and last name only.

None of the reported mean differences appear to be statistically significant. However, the median firm in my final sample is larger than the median firm in the comparison sample in terms of the market capitalization and the book value of assets. The medians for those accounting numbers are significantly different from each other at the 5%-level and the 1%-level, respectively. All other median differences are insignificant. Besides firm size, it seems that firms that grant options are not very much different from those that do not grant options. The results of my analysis should thus also hold for all other ExecuComp firms that are not part of my sample once they start granting options.

2.2 Data on voluntary exercises

I consider all exercises that occur before a date of executive turnover as voluntary exercises. The data set is close to the one in Klein and Maug (2010) but I only include executives that are also part of my turnover data.[7] I use data on option exercises from ThomsonReuters' IFDF from 1996 to 2008. I consider an option package to be the number of all ESOs that are equal in terms of option holder, underlying security (issuer), strike price, maturity, and vesting date. Time vested option grants are usually reported as separate option packages in IFDF. For instance, if an option grant has two different vesting dates then it is usually reported as two option packages with one vesting date, respectively. Time vested option packages that are not reported as separate packages and option packages with other more complicated vesting schemes have a missing vesting date in the database and are dropped from this analysis. Vesting schemes are of central importance for this analysis since voluntary exercise is only allowed after the option has become vested. The resulting data set consists only of option packages with a clear vesting date and includes only

[7]Klein and Maug (2010) identify and analyze different motivations to exercise options voluntarily conditional on selling acquired shares after exercise. In this paper I include all valuation relevant exercises irrespective of the treatment of acquired shares thereafter.

observations for which option packages are potentially exercisable. Thus, observations for which options are unvested or out of the money are not part of this analysis. The resulting data set has 5,928,571 weekly observations for 53,162 option packages for which I analyze 4,490 early exercises (excluding exercises at maturity).

3 Methodology

I analyze executive turnover and voluntary exercises using hazard analysis. The hazard rate of an event (turnover or voluntary exercise) is the instantaneous probability of the occurrence of the event conditional on no event having occurred before. Hazard analysis can easily deal with censored data which is present if for a subject of the analysis the beginning (left censoring) or the end (right censoring) of the time at risk is unobserved. Neglecting the right censoring by estimating unconditional probabilities using logit or probit models biases the estimates of the event probability downward as some events are simply not observed.[8]

Censoring. Employment histories for the turnover analysis are highly affected by censoring because ExecuComp only collects data for the five highest paid persons within a firm.[9] Thus, data is missing for persons who begin their employment or end their employment as a non-top employee even if they belonged to the top paid employees for some time in between. Also still being with a firm in 2008 technically counts as right censoring as I do not have information beyond that point in time. The relevant time span for the analysis of voluntary exercise is the time for which options are exercisable. This time

[8] Shumway (2001) shows that the hazard function approach and a dynamic logit approach are identical if all observations where no failure event takes place are included in the analysis. He also shows that standard logit analysis will not provide correct standard errors. For a broader discussion on hazard analysis please see Kiefer (1988), Lancaster (1990), or chapter 17 of Cameron and Trivedi (2005).

[9] They also amend data for at most 3 years in the past for officers who just temporarily do not meet this criterion.

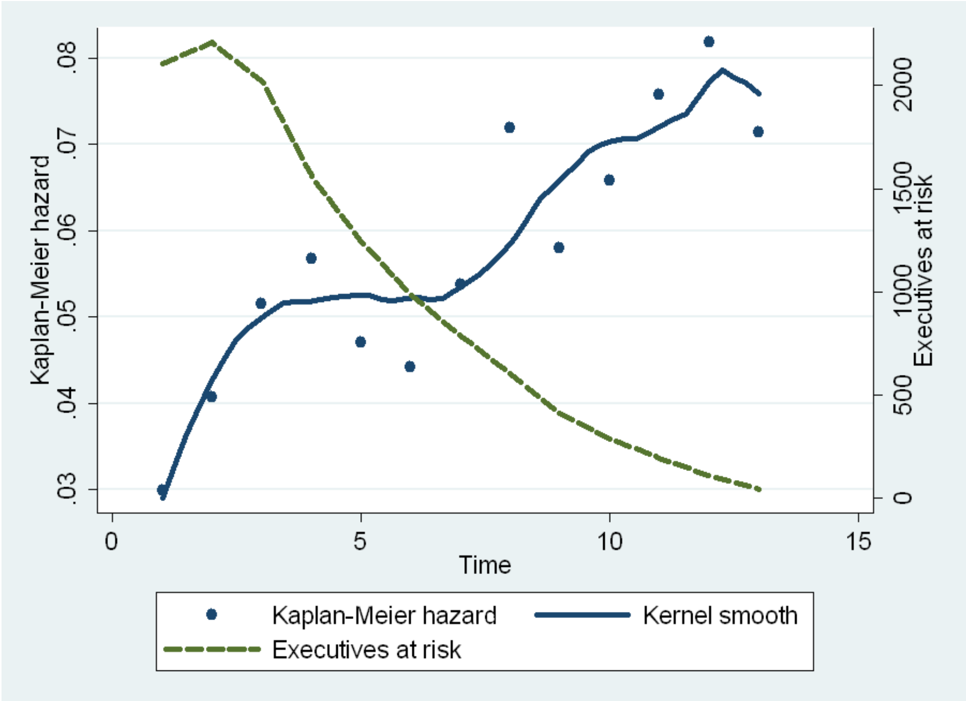
span starts with the vesting date. As I require each option package to have a known vesting date, option histories do not suffer from left censoring. A missing grant date is not relevant for the analysis because options can first be exercised at the vesting date. The period from the grant date to the vesting date is thus not considered here. However, right censoring is present whenever there is no record of the exercise of an option. Possible reasons for right censoring here are executive turnover, expiration or data limitations if the option package is still unexercised at the end of 2008. Commonly, former employees have to exercise their options within a specific time span after they left the firm and I thus do not consider those exercises to be voluntary. Consequently, I do not further track option packages after turnover and thereby also exclude exercise records on IFDF after turnover from my analysis. I also exclude the expiration week from the analysis, because at this point in time it is a dominant strategy to exercise in-the-money options and to let forfeit out-of-the-money options. Keeping those observations in an exercise probability model would bias the estimates.

Cox model. For my baseline specification in both the analysis of turnover and the analysis of voluntary exercises, I use a Cox proportional hazard model. The model is specified as follows.

$$h\left(t, x_t\right) \quad = \quad \lambda_t exp\left\{x_t'\beta\right\}, \tag{II.1}$$

where t is analysis time and x_t is the time-varying vector of variables. The vectors β and the time dependent parameter λ_t are estimates of the model. The Cox model belongs to the widely applied class of proportional hazard models in which the effect of each independent variable enters the hazard rate multiplicatively ($h(t, x_{1t}, x_{2t}){=}\lambda_t e^{\beta_1 x_{1t}} e^{\beta_2 x_{2t}}$). All proportional hazard models have two components. λ is referred to as the baseline

Figure II.1: **Empirical turnover rate.** The dots show the non-parametric Kaplan-Meier estimate of the empirical hazard rate for turnover and the solid line represents its kernel smoothed values over time (left scale). The dashed line shows the number of executives at risk for a given employment tenure (right scale).



hazard and solely depends on the time variable t, while $exp\{x_t'\beta\}$ is the relative hazard that depends on the time varying vector of covariates x_t. The Cox model as a semi-parametric model does not impose a specific functional form of the baseline hazard λ and thus provides maximum flexibility. A too restrictive functional form of the baseline hazard that is not borne out by the data may actually bias coefficient estimates.

Empirical turnover rate. Figure II.1 shows the empirical hazard rate for executive turnover (in the remainder of the paper referred to as the turnover rate) and its kernel smoothed values (dots and solid line) as a function of time in years since the beginning of the employment relation in year zero. The empirical hazard rate is the ratio of executives who leave their firms as a fraction of executives in the risk set. Looking at the kernel smooth, the empirical hazard rate is mostly increasing over time. However, this behavior over time is dominated by the two large increases from year one to year three and from year seven onwards. Between years three and seven the kernel smooth is rather stable (the raw empirical hazard rate is even decreasing from year four to six). An explanation for this behavior over time could be the existence of different turnover distributions for different turnover reasons. Gregory-Smith, Thompson, and Wright (2009) perform a competing risk analysis on executive turnover in the UK considering forced exit and retirement as turnover reason. They find that the forced turnover rate is low at the beginning of employment as long as little is known about the executive's ability. The forced turnover rate increases in the early phase of employment when the firm learns more about the executive's ability and it decreases thereafter as executives become more and more entrenched over time.[10] They find the retirement rate also to be low at the beginning of employment but steadily increasing over time as executives get older. They also find that the maximum retirement rate is higher than the maximum hazard of forced turnover. Combining their two sources of turnover leads then to a step function as displayed in Figure II.1. In the early phase of employment, the combined turnover rate increases as both the forced turnover rate and the retirement rate increase. After the first years, the decrease in the forced turnover rate is balanced by the increase in the retirement rate, leading a stable overall turnover hazard. Finally, in the late phase of employment, retirement becomes the dominant reason for executive turnover.[11]

For the valuation part of this paper, I take all turnover reasons to be equally relevant and implicitly assume that ESOs expire immediately at the turnover date.[12] However, Dahiya and Yermack (2008) point out that the exact rules about the period length after turnover during which options can still be exercised differ from firm to firm and across

[10] Also Bushman, Dai, and Wang (2010) find that CEOs who are forced out have a shorter tenure and are younger.

[11] Kaplan and Minton (2006) propose another classification of executive turnover. They divide turnovers into internal or board driven turnovers and external turnovers through takeover or bankruptcy. Unfortunately, I do not have data on reasons for executive turnover which prevents me from analyzing reason specific effects.

[12] See Carpenter (1998) and Cvitanić, Wiener, and Zapatero (2008) for similar assumptions.

turnover reasons. In general, longer exercise periods after turnover add to the ESO value as they destroy less time value. Accordingly, if exercise periods differ across turnover reasons, then also the option value destroyed by turnover differs across reasons. With the above assumption of immediate exercise, my valuation approach in Section 6 can just capture the compensation costs of ESOs that arise during the employment period. Additional ESO value that arises from longer exercise periods after turnover can be considered as a sort of severance payment as the executives then is no longer employee of the firm. This might also be a reason why exercise periods sometimes differ across turnover reasons. Also Jenter and Lewellen (2010) point out that algorithms for the classification of turnovers into the categories voluntary and forced, such as the popular scheme proposed by Parrino (1997), treat too many forced turnovers as voluntary.[13] Such misclassifications could also have an influence on the additional ESO value from exercise periods after turnover. My valuation approach disregards turnover reasons. The estimation of compensation costs of ESOs stops at the turnover date and is thus unaffected by reason specific exercise periods after turnover and potential classification errors.

The number of executives at risk (dashed line in Figure II.1) increases slightly at the beginning to decrease steadily thereafter and falls below 5% of the initial number of executives in year 11. The number of executives at risk is initially lower because of missing data in the early employment years. The decrease in the number of executives over time is a result of turnover as well as of censoring. As executives also drop out of the sample over time due to censoring, it is not possible to interpret the number of executives at risk as some kind of survivor function. Please also note that the initial number of executives is lower than the 3,649 executives in my data set as the early stage of employment for persons, who start as non-top five, is not recorded in ExecuComp.

[13]Although they expect voluntary turnovers to be unaffected by performance, they find that supposedly voluntary turnovers are more likely to occur after bad performance.

The flexibility of the Cox model offers advantages also for the analysis of voluntary exercises. Klein and Maug (2010) find high exercise activities short after the vesting date and clustering of exercises after periodic time intervals. They explain this clustering of exercises by regular grants of new options, after which executives exercise old ones to keep option holdings or exposure to stock price risk at a target level, and blackout periods around earnings announcement dates. Blackout periods prohibit exercises most commonly before announcement dates and exercises are thus postponed thereafter.

4 Executive turnover

In this section I develop and test hypotheses on executive turnover. My dependent variable $Turnover$ is one for an employment year with a turnover event and zero otherwise. Subjects of the analysis are employment relations between executives and firms. The time dimension t in my analysis is the time since the beginning of the employment relation in fiscal years. In the first fiscal year of employment t equals one. All covariates are recorded at the end of the preceding fiscal year.[14]

I arrange my independent variables into groups of returns, personal characteristics, and firm characteristics. I introduce the variables and discuss the tests group by group. Table II.3 provides a detailed overview of all variables and their definitions. Table II.4 presents descriptive statistics and Table II.5 presents the estimation results for the turnover hazard model.

[Insert Tables II.3, II.4, and II.5 about here.]

I express all variables except dummy variables as deviations from their means, scaled by their standard deviations. I report relative hazards for individual variables as $hr_i =$

[14]This is the usual setup in the literature and assures that all right hand side variables are recorded before turnover happens and are thus independent of the event.

$e^{\beta_i} - 1$ to ease interpretation.[15] Hence, if $e^{\beta_i} - 1$ equals 0.3, then this implies that a one standard deviation increase in x_i increases the probability of turnover in year t by 30% holding everything else constant. For dummy variables, $e^{\beta_i} - 1$ is simply the change in the turnover probability from flipping the dummy variable from zero to one. Table II.5 presents the baseline turnover specification as Model (1). Model (2) replaces stock returns by market adjusted stock returns, Model (3) removes market returns, and Models (4) and (5) split the sample on the Bebchuk, Cohen, and Ferrell (2009) entrenchment index to analyze whether the influence of my explanatory variables on turnover is structurally different in firms with high and low governance, respectively.

All models are estimated with clustered robust standard errors at the firm level to account for potential correlation between executive turnovers within a firm.[16] For all model specifications, I test the proportional hazard assumption of the Cox model. The line PH-test shows the p-value from testing the hypothesis that all coefficients within a model are jointly independent of analysis time. If the hypothesis is rejected, the model violates the assumption of a proportional hazard.[17] It is important to have a properly specified turnover model to estimate reliable option values in Section 6. This is the reason why I heavily rely on the proportional hazard test for the choice of my baseline model. The reported R^2 represents the adjusted proportion of explained variation for proportional hazard models for censored survival data (Royston, 2006).

[15]Conventionally, the relative hazard is defined as e^{β_i}, which then has the interpretation of a factor. The advantage of my definition is that a negative coefficient translates into a negative relative hazard while a positive coefficient translates into a positive relative hazard. I will thus discuss β coefficients and relative hazards interchangeably.

[16]I test all β-coefficients to be different from zero. * indicates statistical significance at the 10%-level, ** significance at the 5%-level, and *** significance at the 1%-level.

[17]See Hosmer, Lemeshow, and May (2008) for further specification tests.

4.1 Returns

Following the literature, I use stock returns as performance measures and market returns as benchmark to stock returns.[18]

Stock returns. I define $Return52$ as the return of the employer firm's common stock during the last fiscal year (52 weeks), $Return156Pos$ as the return during the last three years (156 weeks) if positive and zero otherwise, and $Return156Neg$ as the return during the last three years if negative and zero otherwise. If firms take past performance as a proxy for effort or ability, they should respond with a lower turnover rate on better performance. I thus expect the coefficients on all stock return variables to be negative. The coefficient of $Return52$ is negative and statistically significant at the 1%-level. If the firm's stock price decreases (increases) by one standard deviation (75% in one year, see Table II.4), then the turnover rate increases (decreases) by 21% in the baseline model.[19] The results for the long term returns are twofold. While the coefficient on $Return156Neg$ is negative and statistically significant at the 1%-level, the coefficient on $Return156Pos$ appears insignificant. This result indicates that firms evaluate long term returns asymmetrically.[20] While the turnover rate is unaffected by positive long term returns, companies punish their executives for negative long term returns by increasing the turnover rate. The impact of negative long term returns on turnover is also considerable in economic terms. If the stock price decreases by 25% (see Table II.4) in three years, then the turnover rate increases by 12%. Executives with negative track records should thus have

[18] One of the drawbacks of such approach is that it prevents me from explicitly modeling processes for accounting variables and their interrelation with stock returns in my valuation procedure in Section 6.

[19] The high standard deviation in my sample mostly results from the highly volatile period for stock returns around the year 2000.

[20] Gregory-Smith, Thompson, and Wright (2009) also split stock returns into multiple variables and find turnover to be more sensitive to returns in the lower quartiles of the distribution.

higher incentives to increase the stock price than executives with positive track records.[21] In untabulated results, I find no improvements to the above specification. Splitting also short term returns in their positive and negative components results in coefficients that are not statistically different from each other, but the model fits the proportional hazard assumption far less than the baseline model. The additional inclusion of the stock return during the last two years results in an insignificant coefficient (return as such or split up into positive and negative component) which is why I stick to one year for short term returns and three years for long term returns. Also using annual returns for the last three years, respectively, instead of the one year and the three year return does not change this result fundamentally. It, however, seems that the effect of the three year return in the baseline regression is mainly an outcome of the annual return from year -3 to year -2.

Market returns. Likewise I define $Market52$, $Market156Pos$, and $Market156Neg$ as the market return (CRSP value weighted index) during the last year, the market return during the last three years if positive and the market return during the last three years if negative, respectively. Optimal compensation contracts should not reward higher stock returns with a lower turnover probability if they are just a response to higher market returns and not a potential outcome of the executive's actions. If market returns serve as a benchmark for stock returns, I expect a countervailing effect for market returns and according coefficient values to be positive. The coefficients on $Market52$ and $Market156Neg$ are positive and statistically significant at the 1% level, while the coefficient on $Market156Pos$ is insignificant. The market returns coefficients seem thus to mirror the coefficients on the stock returns and to dampen their effects. While the coefficient on the short term stock return is significantly higher than that of the corresponding

[21] Kempf, Ruenzi, and Thiele (2009) also find mutual fund managers to react more on poor performance and decrease fund risk accordingly.

market return in absolute terms, the absolute coefficient values for the long term returns are not significantly different from each other. In contrast to Kaplan and Minton (2006) and Jenter and Kanaan (2008), I find no evidence that executives are excessively punished for bad market performance in the form of an increasing hazard rate after negative and equal returns in the stock and the market. I further analyze the relationship of stock and market returns in Model (2) where I replace stock returns with their market adjusted (stock return-market return) equivalents. Here, only the coefficient on the negative long term market return remains significant and positive. This implies that lower long term market returns lead to a reduction in the turnover rate which again does not support the notion that executives are punished for bad market performance. Similar to the baseline model, the asymmetric treatment of positive and negative long term market adjusted returns is visible though the coefficient of $MAdjusted156n$ is insignificant.[22]

4.2 Personal characteristics

Compensation. Peters and Wagner (2009) present two channels how the market value of executive compensation is connected with executive turnover. Executives pay packages do not only have to compensate for effort and costs of risk sharing, they also have to compensate for the risk and the associated costs of being fired. The latter include costs for searching for a new job as well as the loss in firm related human capital the executive invested in. An indirect cost of forced turnover is the loss in reputation that harms future employment and earnings opportunities. The other channel arises from a measurement error in the market value of compensation. ESO values that expire when the executive leaves the firm should be valued lower than comparable market traded options because the expected lifetime of ESOs is lower than the contractual time to maturity. Thus, values

[22] Please note that Model (2) cannot analytically be transformed to the baseline specification since long term returns are split up into their positive and negative components.

of ESOs that do no account for turnover risk overestimate true values.[23] Executives with more career concerns will demand a compensation package with a higher market value to compensate the higher probability of losing time value in case of turnover.

I define *Compensation* as the log of one plus total compensation as reported in ExecuComp and expect a positive relationship between *Compensation* and the turnover rate. Both the turnover rate and the compensation structure are a common outcome of the firm's compensation optimization and strongly related to each other. The effect of *Compensation* is both statistically significant and economically meaningful. A one standard deviation increase in *Compensation* increases the turnover rate by 88%. Regarding relative performance to other executives within a firm, neither the mean of total compensation nor the rank of the executive in terms of compensation (one for the executive with the highest compensation, two for the second highest, etc.) appear significant (results not tabulated).

Portfolio. If an executive leaves her firm, restricted stock and ESOs usually expire, destroying the time value of all stock price related securities. In this sense, unvested securities fully consist of time value as they are not allowed to be sold or exercised during the vesting period. Because of this, the willingness to leave the company voluntarily should decrease in the time value of securities held. Even if the executive is compensated for this by the new employer, it is less favorable for the latter to hire executives if the required compensation for forfeited option value is sufficiently high. As Dahiya and Yermack (2008) show, exact regulations on the treatment of unvested options are, however, firm specific and may depend on the turnover reason. They classify turnovers into resignations, retirements, and deaths. For 96% of resignations in their sample, they find that

[23]ExecuComp uniformly accounts for the valuation impact of early exercise by resetting the time to maturity for the Black-Scholes formula to 70% of the contractual agreed time.

unvested options forfeit, supporting my above argument that vested options fully consist of time value that forfeits when the executive leaves the firm. For retirements and deaths, results are mixed. In these cases, forfeiture, on the one hand, and immediate vesting, on the other hand, amount to about 80% of turnovers with forfeiture as the prevalent regulation for retirements and immediate vesting as the prevalent regulation for deaths. If retirements arise from personal considerations that are unrelated to the option portfolio values, different regulations for retirements will not affect my results.[24] For voluntary turnover other than retirement, Dahiya and Yermack (2008) show that forfeiture is the most prevalent regulation, supporting my above generalization.

Gibbons and Murphy (1992) and Bushman, Dai, and Wang (2010) find a relation between executive turnover and incentives from stock based payment. They find that explicit incentives from optimal compensation contracts are weaker if implicit incentives from career concerns are stronger.[25] This basically means that firms are able to substitute explicit incentives like stock based payments with implicit incentives in the form of career concerns. This incentive substitution effect is especially important if executives are incentivized with options as an option's delta (marginal effect on the option value from an increase in the stock price) varies with the stock price. If the stock price appreciates and the options gets deeper in the money, the delta of an ESO call increases, resulting in higher explicit incentives for the executive to, again, increase the stock price. As a result, the firm can drive down implicit incentives. Conversely, if the stock depreciates, the delta

[24]However, if options immediately vest at retirement, executives could retire to exercise otherwise unvested options, which could work against my above argument of a negative relation between the value of unvested options and turnover. In such a case, however, executives would relinquish future compensation just to exercise unvested options. I expect this possibility to be a small problem, also because forfeiture is still the prevalent regulation in case of retirement. Another possibility that I evaluate less likely is that companies fire executives to destroy option time and save compensation expenses. In such a case, the value of unvested options would be positively related to forced turnover.

[25]Gibbons and Murphy (1992) explain lower contractual incentives of younger managers with higher career concerns. Bushman, Dai, and Wang (2010) first estimate a turnover probability for each manager. In a second step they are able to show a negative effect of their turnover probability on contractual pay for performance sensitivities.

of the option portfolio decreases, resulting in lower explicit incentives. The firm may substitute this loss in explicit incentives by imposing a higher turnover rate and thereby increase implicit incentives.

I define the variable $RestStock$ as the log of one plus the market value of restricted stock, $OptUnvest$ as the log of one plus the market value of unvested in-the-money options, and $OptVest$ as the log of one plus the market value of vested in-the-money options.[26] The time value of restricted stock increases in the stock price, which is why I expect a negative effect on voluntary turnover. Incentive substitution should not play a role for restricted stock as its delta is unaffected by stock price changes.[27] The compound effect of $RestStock$ should thus be negative. Unvested options only consist of time value, resulting in a negative effect of $OptUnvest$ on voluntary turnover. Also the effect on forced turnover should be negative because of the incentive substitution effect. As a result, I expect a negative compound effect of the value of unvested options on the turnover rate and the coefficient of $OptUnvest$ to be negative.[28] For vested in-the-money options the time value decreases in the stock price and accordingly in the value of the option, resulting in a positive effect of $OptVest$ on voluntary turnover. As the incentive substitution effect is the same for vested options as for unvested options, $OptVest$ should have a negative effect

[26]All portfolio variables are based on ExecuComp. This has both advantages and disadvantages over tracking portfolios using IFDF. With IFDF I can only track portfolios for insiders starting from 1996 which would prevent me from including executives in my study who join their company before that year. Additionally, IFDF does not include data on vesting schemes other than cliff vesting, which means that options vest at a specific point in time. However, ExecuComp only collects data on in-the-money options. It is thus impossible to find out to what extent an increase in my option portfolio variables $OptUnvest$ and $OptVest$ results from a value increase of options that were in the money in the year before and from options that were out of the money before and got into the money this year. Also new option grants affect my variables which is not specific to using either ExecuComp or IFDF.

[27]Although this argument holds for the delta of the market price, the effect might be different for the stock price delta of executive's certainty equivalent of her restricted stock portfolio. For a risk averse executive the delta of the stock portfolio's certainty equivalent should decrease in the stock price. However, I do not expect firms to increase the turnover rate in response to a stock price increase as this would create perverse incentives for executives in the first place.

[28]Though different from my approach, also the turnover specification of Armstrong, Jagolinzer, and Larcker (2007) includes variables that are related to the option portfolio. They include the inner value of options and explicitly allow for negative values. Those variables, that are generated for different parts of the option portfolio, can be interpreted as distances of the stock price to the strike prices of the option portfolio (reference points).

on forced turnover. As a result, the compound effect of $OptVest$ is ambiguous.

The coefficient on $RestStock$ is insignificant, which does not support the existence of the time value effect. However, restricted stock holdings are a less important means of compensation in my sample and may thus be taken less into consideration by executives compared to options. For 62% of my annual observations restricted stock holdings are zero. Also, ExecuComp reports values for restricted stock irrespective of the stock price while it reports values for ESOs only if they are in-the-money. This again makes restricted stock look more important compared to ESOs. The coefficient on $OptUnvest$ is negative as expected, but both the time value effect and the incentive substitution effect could account for that. There is no significant effect on $OptVest$. If the incentive substitution effect is dominant, then both the coefficients on $OptUnvest$ and $OptVest$ should be negative, which is not what I observe. Conversely, for $OptVest$ it seems that the positive time value effect on voluntary turnover cancels out the negative incentive substitution effect on forced turnover. The negative effect of unvested options on turnover together with the insignificant effect of vested options support the notion that the value of unvested options ties executives to employer firms. This is, however, not the case for vested options. Executives may exercise them before they leave the firm voluntarily and retain at least the inner option value. However, without specific data on turnover reasons, I can only give an indication here and leave a deeper analysis of option portfolio effects on turnover to future research.

Ownership. I define $Owner$ to be one if the number of shares held by the executive as a fraction of outstanding options exceeds one percent and zero otherwise. Allen (1981) uses ownership as a measure for executive power and shows that more powerful CEOs are able to have a longer tenure within their firms.[29] As expected, the coefficient on *Owner* is negative and significant at the 1%-level. It is also economically meaningful: Executives who own more than 1% of outstanding shares have an 18% lower turnover rate. Another explanation could be that executives with high ownership stakes have already high implicit incentives. Thus explicit incentives in the form of career concerns are less important for their effort decision.

Other personal characteristics. I further include dummy variables on age, management level, and gender and define *Retirement* to be one for executives that are older than 60, CEO to be one for chief executive officers, and $Male$ to be one for male executives. For 30% of executives in my sample, I have no data on age. For those people, I define *Retirement* to be zero which, on the one hand, weakens the impact of this variable as I implicitly assume that those people are younger but, on the other hand, prevents me from reducing my sample size due to missing age data. I expect older executives to have a higher turnover rate due to retirement and thus a positive coefficient on *Retirement*.[30] CEOs are, on the one hand, more powerful than other executives, which could make them have a lower turnover rate. On the other hand, firing the CEO seems to be a more appropriate means for shareholders to change the policy of the firm. I thus do not expect a specific sign for the coefficient on CEO. I also do not have an expectation on the coefficient on $Male$. To control for networking effects, I define the control variables $EnterBefore$ and $EnterAfter$ as the number of executives that enter the company, respectively, before

[29]Salancik and Pfeffer (1980) analyze the impact of performance measures on tenure for different levels of executive ownership. In contrast to externally controlled and management controlled firms they do not find an effect of performance on tenure for owner managed firms. In my sample, ownership is not a major issue and for the majority of the sample lower than one percent.

[30]Dahiya and Yermack (2008) identify retirement as one of the most important factors on ESO valuation. Also Brickley (2003) suggests to put more weight on the proper modeling of age in analyzing turnover. The explicit modeling of tenure in this paper goes in this direction (see Figure II.1). Turnover papers that include variables on age are among others Engel, Hayes, and Wang (2003), Farrell and Whidbee (2003), and Gregory-Smith, Thompson, and Wright (2009).

and after the considered executive.[31] If executives have an influence on the company's hiring decisions they will support candidates they have a high opinion of. I expect a lower probability of turnover for executives with a higher number of initial supporters and thus a negative coefficient on $EnterBefore$. My expectation of $EnterAfter$ is ambiguous. On the one hand, an executive will become more entrenched the more networked new executives join the firm. On the other hand, if new executives do not support the current corporate policy, it is more likely that old executives leave the company voluntarily or are forced out.[32] I further control for the board size by $Executives$ as the number of executives that are followed by ExecuComp in a given year.

The coefficient on *Retirement* is positive as expected and statistically significant at the 1%-level. It indicates that over 60 year old executives have a 17% higher turnover rate than younger ones. It turns out that CEOs have a 31% lower turnover rate indicating that they are able to exploit their higher power. There is no significant gender effect. I also do not find evidence for a networking effect. While the coefficient of $EnterBefore$ is insignificant, the coefficient of $EnterAfter$ is positive and statistically significant at the 1%-level, supporting the idea that current executives lose support for their policy with the replacement of other executives. The effect is also economically large. After the replacement of one colleague with higher or equal tenure (standard deviation of 1.16), the turnover rate increases by 40%. Another argument, partially in the same direction, is that the more tenured executives are replaced, the higher is the probability that shareholders want to change corporate policy fundamentally and replace all top executives.[33] Furthermore, the total number of executives has a positive impact on the turnover rate

[31] As for most executives in the ExecuComp database there is no information about the time at which executives joined or left the firm, I calculate these variables by comparing the date of, respectively, the first and the last appearance in the database among executives within a given firm.

[32] See Liu (2008) for an analysis of the connectedness of CEOs in an employment network and its impact on turnover and hiring decisions.

[33] The results are qualitatively unaffected by the exclusion of *Retirement* to account for multicollinearity.

supporting Yermack (1996) who found lower turnover probabilities in companies with smaller boards.[34]

4.3 Firm characteristics

Parrino (1997) finds that forced turnover for CEOs is more likely in more homogeneous industries. He argues that in more homogeneous industries, human capital is rather industry than firm specific, which makes it easier for firms to find a successor after having fired an executive. Following Parrino (1997) I define $Homogeneity$ as the mean correlation of stock returns with industry returns and expect the coefficient to have a positive sign.[35] Bushman, Dai, and Wang (2010) decompose the stock return volatility in a systematic and an unsystematic component. They provide a theoretical model to show that firms' ability to learn about CEOs' skills decreases in systematic volatility and increases in idiosyncratic volatility.[36] I define $SysVolatility$ as the systematic component and $ISVolatility$ as the idiosyncratic component of the stock return volatility. For this, I estimate a market model for returns using the last 52 weekly observations of the stock return and the CRSP value weighted index. Accordingly, I expect a negative coefficient for $SysVolatility$ and a positive coefficient for $ISVolatility$. I control for firm size by $MCap$ as the log of one plus the market capitalization of the firm. I do not find any effect of industry homogeneity or the components of the stock return volatility on the turnover rate. However, the coefficient of $MCap$ is negative and significant at the 1%-level supporting Bushman, Dai, and Wang

[34] He connects this finding with his observation that firms with smaller boards perform better.

[35] This metric is estimated for all 2-digit SIC industries from stock returns of 35 to 50 firms in each industry. Industries with less than 35 firms get the value for the respective one-digit SIC industry. Parrino (1997) restricts the number of firms to a maximum of 50 as the metric systematically increases in sample size and could thus be biased for a higher number of firms. The industry return is defined as the equally weighted mean of the used stock returns. Shares are chosen randomly. In contrast to Parrino (1997), I use the measure as a continuous variable and base each value on the last 52 weekly return observations. In a continuous process shares that drop out because of missing data are replaced by other randomly chosen shares.

[36] They validate their hypothesis also empirically.

(2010), who find that firms that force out their CEOs are smaller and younger.[37]

In Model (3), I omit market returns and find the predicted effects for *SysVolatility* to be significant at the 5%-level but still no effect for *ISVolatility*. This indicates that in my baseline model some of those effects are captured in the market return variables. The coefficients on past stock returns are statistically weaker in this specification but only little affected.

Models (4) and (5) split the sample on the Bebchuk, Cohen, and Ferrell (2009) entrenchment index into high and low governance firms, respectively. Note that the results are not fully comparable to the baseline regression as both models only include observations for which the entrenchment index is available. For better governed firms, executive turnover is stronger related to short term performance. Also the impact of positive and negative long term returns on turnover appears more symmetric although both coefficients are insignificant. In worse governed firms, turnover is less connected to stock returns. This finding is consistent with Fisman, Khurana, and Rhodes-Kropf (2005) who argue that better governed firms are better able to draw the conclusions from poor performance and fire the CEO. The coefficient on *OptUnvest* is only significant at the 5%-level for worse governed firms while it is insignificant for better governed firms. A possible explanation is that voluntary turnover is relatively more common in worse governed firms while forced turnover is less likely. I further find CEOs to be more entrenched in worse governed firms, which supports the notion of worse control mechanisms in badly governed firms. In untabulated results, I do not find a significant effect on the entrenchment index as additional independent variable and thus no systematically higher turnover rate in better governed firms.[38]

[37] In untabulated results I find no significant effect of the number of employees as alternative proxy for firm size on the turnover rate. Other proxies like sales and assets would be problematic for financial firms in my sample which is why I do not take those proxies into consideration.

[38] Results are similar for the index of Gompers, Ishii, and Metrick (2003). Both indices are derived

4.4 Robustness checks

Table II.6 presents the results for several specification tests concerning the fundamental form of the hazard model. Model (1) is an exponential model. In contrast to the Cox model, it assumes the baseline hazard λ to be constant over time. Model (2) is estimated with shared frailty at the firm level instead of clustered standard errors. Shared frailty for hazard model is equivalent to random effects for linear models. While clustering standard errors is a means to control for unobserved heterogeneity of unknown type across individuals, frailty models introduce a firm specific parameter that scales the whole hazard curve similar to the baseline hazard λ.[39] Model (3) estimates the turnover rate clustering errors at the industry level (two digit SIC). Model (4) repeats the baseline estimation only with CEOs.

[Insert Table II.6 about here.]

The exponential model is the simplest hazard model and assumes the baseline hazard to be constant over time. Surprisingly, this rather restrictive assumption hardly impacts the coefficient estimates compared to my baseline model (Model (1) in Table II.5). However, for option valuation the complete turnover rate is important and not just relative effects as presented in this table. The proportional hazard test is specific to the Cox-model and not available here. Model (2) estimates a model with shared frailty at the firm level that allows for systematic differences in the level of the turnover rate across firms. The *Compensation* effect here is a little bit smaller while *EnterAfter* is stronger than in the baseline model, which indicates that the shared frailty captures some firm specific components of these variables. For the other coefficients there are only minor differences

from publications of the Investor Responsibility Research Center.

[39]This frailty parameter is assumed to be gamma distributed across firms. The frailty model is also known as mixed proportional hazard model. See Cameron and Trivedi (2005), chapter 18, for a discussion of unobserved heterogeneity in hazard models.

to the baseline model. The frailty model fulfills the proportional hazard assumption but has a worse fit in terms of the R^2 which is why I stick to my more general (in terms of unobserved heterogeneity) baseline model. Model (3) clusters standard errors at the level of the industry rather than the firm, and should thus have numerically equal coefficient values as the baseline model. Here, the significance levels for the short term stock and market returns are weaker in comparison to the baseline model while the significance levels of other coefficients are unaffected. The dispersion of stock returns within an industry is larger and thus error correction at the industry level rather than the firm level drives up the error term.[40] Repeating the baseline analysis with only CEOs in Model (4), short term returns turn out to be more important while the coefficients on long term returns are smaller in absolute terms and not significant anymore. Compensation has no impact on the turnover rate any more but there is a stronger effect on *OptUnvest*. The higher coefficient in absolute terms on *OptUnvest* could be explained by a lower probability of forced turnover (given turnover) and an accordingly higher influence of voluntary turnover because of the larger power of CEOs within the firm. Accordingly, the probability of turnover for voluntary reasons could be higher for CEOs making time value considerations an issue. The coefficient on *OptVest* is even lower now though still not significant, indicating that incentive substitution is also not an issue even considering CEOs only. Supporting the hypothesis of higher CEO power, CEOs also have a lower impact of ownership on their turnover rate.

[40] The adequacy of firm clustering in the baseline model is also supported by the finding that the between-firm variance of the turnover time is much higher than the between-industry variance.

5 Voluntary Exercise

In this section, I estimate the hazard rate of voluntary exercise. Subjects of this analysis are option packages. Analysis time t_w is measured in weeks since vesting. The data includes fractional exercises, which means that in one week some options of an option package are exercised while other options of the same package are further held. To simplify the valuation approach in Section 6, I only consider at most one representative exercise per option package.[41] I define my dependent variable *Exercise* to be one in the first week in which the exercised fraction exceeds 50% of the number of options held initially. After at least 50% of the option package is exercised, I consider the whole package as exercised and disregard all following weeks for this package. Keeping those follow-up observations would bias down the voluntary exercise rate as exercise according to my definition is not possible any more.

Klein and Maug (2010) and Armstrong, Jagolinzer, and Larcker (2007) require an exercise to represent a minimum fraction of an option package to be economically meaningful. With such a rule, minimum fraction sizes of 50% or less allow for multiple exercises per option package.[42] To get an understanding about why options are exercised it might be sensible to look at multiple large exercises of an option package. However, the correct valuation procedure with partial exercises in a hazard exercise world is unclear. The minimum fraction approach indicates only that the number of options exercised exceeds a certain threshold without explaining the size of the fraction exercise. My approach in turn does not analyze block exercises but aims at explaining which options packages are predominantly exercised early and which are not.[43] For the later valuation, I will treat

[41] For the impact of fractional exercise on the valuation and incentive effects of ESOs see Klein (2010).

[42] Klein and Maug (2010) require a minimum fraction of 25% in their baseline specification.

[43] Carpenter, Stanton, and Wallace (2008a) directly estimate the number of options exercised as a fraction of still held options as a continuous variable. Klein (2010) however find that people have a preference for few large exercises rather than for continuous exercises over time.

predominant exercise of an option package as full exercise. This treatment has two implications. On the one hand, it will underestimate the impact of voluntary early exercise for option packages of which a certain fraction but less than 50% is exercised early as they are considered unexercised. On the other hand, it will overestimate the impact of voluntary exercise for option packages of which more than 50% but less than 100% is exercised as they are considered completely exercised. I expect that both effects will cancel out each other and do not produce major distortions for my valuation approach in Section 6.

5.1 Results

Table II.7 provides a detailed overview of all variables used in the analysis of voluntary exercises and their definitions. Table II.8 presents descriptive statistics and Table II.9 presents the estimation results for the voluntary exercise model. As in Section 4, I express all variables except dummy variables as deviations from their means, scaled by their standard deviations and report relative hazards ($hr_i = e^{\beta_i} - 1$) instead of β-coefficients.

[Insert Tables II.7, II.8, and II.9 about here.]

Time value. Rational investors should exercise options in situations in which the loss in time value is small relative to the total value of the options. In utility based models the motivation to exercise options and to sell acquired shares accordingly stems from a trade-off between the benefits from a better diversified portfolio after exercise and the costs of giving up the options' remaining time value.[44] Nevertheless, the cost of giving up option time value also plays a role when the holder faces liquidity constraints. In such a case, the holder should prefer exercise over outside financing if the time value given

[44] These models start with Huddart (1994) and are further developed in Carpenter (1998) and Ingersoll (2006). Rogers and Scheinkman (2007) and Grasselli and Henderson (2009) present models in which option packages are exercised in separate fractions.

up falls below the cost of outside financing.[45] The time value of an ESO that forfeits at exercise is low whenever the option is deep in the money or close to maturity. Papers like Armstrong, Jagolinzer, and Larcker (2007) and Carpenter, Stanton, and Wallace (2008a) relate voluntary early exercise directly to moneyness and time to maturity. However, the relation of moneyness and the time to maturity on the option's time value is not linear and depends on the combination of both, together with the underlying's volatility.

Klein and Maug (2010) in turn measure the relative cost of early exercise as the time value divided by the total market value of the option and find this measure to be most powerful to explain voluntary exercise. They approximate market values by the Barone-Adesi and Whaley (1987) value for American options (in the remainder of the paper referred to as BAW value). Likewise, I define the variable $TimeValue35Min$ as the ratio of time value to total market value of the option and winsorize values at the lower tail at a value of 0.35.[46] $TimeValue35Min$ can thus take on values between 0.35 for options that are close to maturity or deep in the money, and a maximum of one for at-the-money options.[47] The coefficient on $TimeValue35Min$ has the expected negative sign and is economically large. A one standard-deviation (0.17 from Table II.8) increase in $TimeValue35Min$ reduces the likelihood of exercise by 64% in the baseline case.[48] The lost time value is thus an important criterion for executives to exercise ESOs voluntarily.

[45] Jennergren and Näslund (1993) and Kulatilaka and Marcus (1994) are the first models to apply exogenous exercise shocks on ESO valuation. In both papers the intensity of shocks is independent of the stock price. In Carr and Linetzki (2000) the intensity of exercise shocks is increasing in the stock price which is consistent with both diversification driven and liquidity driven exercises as described above.

[46] As inputs for the BAW value, I use the historical stock return volatility over the previous 52 weeks and the yields of zero-coupon government bonds with maturities of 1, 2, 3, 5, and 10 years as risk-free interest rates. For each option, I use the yield of the bond with a maturity that is closest to the maturity of the option itself.

[47] Note that I exclude out-of-the-money options for this analysis.

[48] Dahiya and Yermack (2008) argue that the time to maturity for ESOs is effectively shorter for older executives if the maturity date is after the retirement date. I might thus overestimate the time value of ESOs in my data set. However, the inclusion of *Retirement* (from the turnover regression) results in an insignificant effect (not tabulated).

Dividend capture. Dividend capture is the only rational motivation for early exercise of market traded options. After a dividend payment the stock price goes down decreasing the value of call options. However, an investor can exercise before the dividend payment and receive the stock together with the dividend right. This should also play a role for the ESOs in my sample as they are not dividend protected. I define the variable $Dividend1$ to be one in the week before a dividend payment if the option is no longer than 208 weeks (4 years) vested and zero otherwise. $Dividend2$ indicates dividend payments after week 208. Both coefficients have the expected positive sign and are economically large though dividend payments in the early phase have a stronger impact on the voluntary exercise rate. Whereas the voluntary exercise rate increases by 72% before a dividend payment until week 208 it increases only by 36% from week 208 on. This effect arises because the impact of dividends on the time value of the option is stronger the more dividend payments remain until maturity.[49]

Asymmetric Information. Executives in my sample may have private information about their employer firms that could be exploited by bringing forward early exercise before disclosures of negative news or by delaying exercises after disclosures of positive news.[50] I proxy for inside information by calculating future buy-and-hold abnormal returns for 2 and 13 weeks, respectively, after each analysis week.[51] These abnormal returns are captured in the variables $BHAR2$ and $BHAR13$. If abnormal future returns are related to insider information and if the executives in my sample exploit this information the coefficients on $BHAR2$ and $BHAR13$ should be negative. Consistent with the find-

[49] Also Barone-Adesi and Whaley (1987) show that their stock price threshold for early exercise increases in time.

[50] Carpenter and Remmers (2001), Huddart and Lang (2003), Brooks, Chance, and Brandon (2007), and Aboody, Hughes, Liu, and Su (2008) find exercise patterns consistent with this notion.

[51] I calculate abnormal returns from a linear regression model of stock returns on the returns of the CRSP value weighted index using data from the last 52 preceding weekly observations. 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).

ings in Klein and Maug (2010), both coefficients have the expected negative signs but only the coefficient on the 13 weeks abnormal return is significant. This indicates that executives do not dare to exploit insider information that materializes in the short term but feel safer to do that over a longer horizon.

5.2 Robustness checks

Alternative variable definitions. Model (2) of Table II.9 uses the non-winsorized variable $TimeValue$ instead of $TimeValue35Min$. The coefficient is now more negative which indicates a stronger dependence between the time value and voluntary exercise for lower time values. This model also replaces $Dividend1$ and $Dividend2$ with the variable $Dividend$ which is the sum of the two. Not surprisingly, the coefficient on $Dividend$ is between the ones for $Dividend1$ and $Dividend2$. Though this model now fits the data better in terms of the R^2 it is largely misspecified and the proportional hazard assumption can be rejected at the 1%-level. The results are similar if just the time value variable or the dividend variables are changed (results not tabulated).

Firm clustering. Model (3) clusters standard errors at the firm level instead of the executive level. Coefficient values are thus numerically equal to those in the baseline model. Correlation at the firm level could arise because of similarities in option contracts, compensation schemes or risk preferences across executives in a firm. The statistical significance of the coefficients is virtually unchanged to the baseline model. Though the proportional hazard test now has a lower p-value, the underlying hypothesis cannot be rejected at conventional significance levels. The quality of my specification thus does not crucially depend on error clustering.[52]

[52] Due to the size of the data set and computational constraints, I was unable to estimate a frailty model for this specification.

Alternative dependent variable. Model (4) considers only full exercises for the analysis. It redefines the dependent variable *Exercise* to be one if 100% of an option package is exercised during that week and zero otherwise. In case of a fractional exercise, the option is censored because exercise according to the above definition is literally not possible any more. Thus, all observations from the first fractional exercise on are no longer included in the analysis. The coefficients on both dividend variables are stronger than in the baseline model which indicates that dividend capture has a stronger impact for completely exercised option packages. All other coefficients are hardly different from the baseline model. Similar to Model (2), this model has a stronger R^2, but as the proportional hazard assumption can be rejected at the 1%-level, I disregard this model in the remainder of this paper.

6 Valuation

In this section I use the results from the turnover analysis in Section 4 and from the analysis on voluntary exercises in Section 5 to value a representative option package. The modeling of both sources of early exercise, turnover and voluntary exercises, offers me the opportunity to assess the influence of either source on valuation. I value the representative option by Monte Carlo simulation, performing the following steps:

1. Simulate paths of weekly future stock prices and future values of the stock market index under the risk neutral measure (drift equal to the risk-free rate). Make appropriate assumptions for the development of all other variables for a representative option.

2. Use the baseline turnover model and the baseline voluntary exercise model to forecast turnover rates and voluntary exercise rates as a function of the independent

variables of the respective models for each week t_w and for each draw i of the simulation.

3. Recover the unconditional probabilities of option termination (exercise or forfeiture) f_t^i from the hazard rates. (The technical details for this are found in the appendix.)

4. Calculate the expected payoff of the option conditional on exercise in week t_w given the simulated stock price S_t^i in run i of the simulation.[53]

Finally, I obtain the option value for one simulated stock price path i as:

$$ESOValue_0^i = \sum_{t=1}^{t=T} exp\left(-r_f t\right) f_t^i Max\left\{S_t^i - K, 0\right\}. \tag{II.2}$$

I do not fix the number of runs in the simulation. Rather, I repeat these steps for a total number of I paths, such that the standard deviation of the I values of $ESOValue$ amounts for less than 1% of the option value from the simulation. The option value itself is the mean of these I values. This approach provides me with estimates of the option value that are equally reliable across all parametrizations. The number of simulations necessary to reduce the standard deviation of $ESOValue$ below 1% ranges from 5,000 runs (20% volatility) to 94,000 runs (60% volatility). I simulate future stock price paths and consider a representative option with a 10-year term to maturity and a vesting period of 3 years, which is issued at the money at a stock price of $100. All other assumptions are listed in more detail in the Appendix.

[Insert Table II.10 about here.]

[53] Here I differ from Armstrong, Jagolinzer, and Larcker (2007), who simulate option terminations for each path such that there is an exercise in just one week of that path with 100% probability or no exercise for the full path. This is unnecessary, because the expected payoffs conditional on the stock price can be determined analytically given the probability of exercise, which also reduces simulation errors.

Table II.10 reports the simulation results. I report the BAW value for a market traded American option and the ESO value from my simulation. I further calculate ESO (not) as the value of an option that is only subject to voluntary exercises setting the turnover rate to zero and ESO (nov) as the value of an option that is only subject to turnover risk setting the voluntary exercise rate to zero. Rather than considering the above ESO values to be the results of realistic scenarios, I use ESO (not) and ESO (nov) to assess the impact of executive turnover and voluntary exercises on the pricing of ESOs. The difference between ESO (not) and the ESO value (subject to both sources of early exercise) then represents the additional pricing impact of turnover induced exercise. Usually, ESO (not) should be higher than the ESO value because ESO (not) is subject to only one source of early exercise. Likewise, the difference between ESO (nov) and the ESO value represent the additional pricing impact of voluntary early exercise. To further analyze the impact of the two sources of early exercise, I report P(turn) and P(vol) as the probabilities of turnover and voluntary exercise, respectively, and TV(turn) and TV(vol) as the expected ratio of time value to the BAW option value at turnover and voluntary exercise, respectively.[54] Finally, I provide the FASB (Financial Accounting Standards Board) value. The FASB procedure uses the Black-Scholes-Merton model, but replaces the term to maturity with an expected maturity given the option's vesting and corrects this value for forfeitures during the vesting period in the following way:

$$FASB = S_{t_v} BS(T_e) \tag{II.3}$$

Here, S_{t_v} is the survival probability at the vesting date t_v or simply the probability that the option becomes vested and does not forfeit before. BS represents the Black-

[54]I report probabilities and expected values formed under the valuation relevant risk neutral measure for an ESO that is subject to both sources of early exercise.

Scholes-Merton value of a European option, and T_e is the expected maturity given that the option becomes vested. According to SFAS 123 (290), S_{t_v} and T_e are expectations based on historically observed values. In contrast to the common practice of taking mean experienced values from one historically observed stock price path, I estimate both input factors again by simulation. Similar to Carpenter, Stanton, and Wallace (2008a), I simulate paths for the stock price and the market portfolio once again but under the true statistical measure and use a risk premium for market returns over the risk-free rate of 5% p.a.[55] Table II.10 reports a sensitivity analysis for the key parameters of the valuation: volatility, dividend yield, and beta with the market index.

Baseline parametrization. In my baseline case, which corresponds to line 3 in the Panels A and C and line 2 in Panel B of Table II.10, I obtain an ESO value of $43.02. This implies an ESO discount of about 18% compared to the corresponding BAW value of a market traded option. ESO (not) is 10% higher than the ESO value. Thus, setting the turnover rate to zero adds 10% to the option value compared to the ESO that is subject to both sources of early exercise. Conversely, setting the voluntary exercise rate to zero adds only 6% to the ESO value. This shows that turnover-induced exercises have a stronger impact on ESO valuation than voluntary exercises and account for more of the value difference between ESOs and market traded options (approximated by BAW). This finding is again confirmed by the turnover probability of 36% which is higher than the probability of voluntary exercise of 29%. Additionally, turnover-induced exercises also destroy more option value than voluntary exercises. Whereas turnover-induced exercises forfeit a time value that amounts to 85% of the total option value in expectations, voluntary exercises forfeit only 21% of the option value. The reason is that turnover may take place and is

[55] Armstrong, Jagolinzer, and Larcker (2007) take the mean lifetime of option packages in their sample as time to maturity. Canceled options are assumed to be exercised at half the time between cancellation and expiration.

even more probable if the option is out of the money. In the latter case 100% of the option value forfeits. Voluntary exercise is more likely when the time value is low corresponding to cases of relatively high stock price or relatively short time to maturity (see coefficient on $TimeValue35Min$ in Table II.9).

The FASB value of 39.83 underestimates the value of the option from the simulation by almost 10%. As the FASB value is the value of a European option, it implicitly assumes exercise or forfeiture after the expected lifetime, irrespective of the stock price. However, as I show in Sections 4 and 5, early exercise is indeed related to stock price related variables: On the one hand, executives favor voluntary exercise when the stock price is high and the loss in time value is accordingly low. Firms, on the other hand, are more tempted to fire executives after poor performance when stock price and ESO value are low. My valuation approach thus predicts stopping probabilities that are higher if the option is deep in the money or far out of the money, both cases in which the time value is comparably low. Consequently, stopping probabilities are lower for options around the money for which time values are comparably high. Lower expected losses in time value in my approach result in an ESO value that is higher than the FASB value, accordingly.

Volatility effects. Panel A of Table II.10 varies the annual stock return volatility from 20% to 60%. In the extreme case with 20% volatility, there is perfect correlation of stock returns and market returns (no idiosyncratic risk). This is the only parametrization for which voluntary exercises have a stronger impact on the ESO discount than turnover. The impact of turnover on valuation and the ESO discount increases in the volatility both through the probability of turnover and the lost time value at early exercise. The probability of turnover increases among others through the asymmetric impact of positive and negative long term returns and the higher probability of extreme stock prices in the future. While the executive is punished for negative long term returns, she is not rewarded for positive long term returns (see coefficients on $Return156Pos$ and $Return156Neg$ in Table II.5). The time value of the option increases in volatility and turnover-induced exercise forfeits relatively more option value accordingly. As turnover prevents voluntary exercise at a later stage, the probability of voluntary exercise decreases.

Comparing ESO (not) and ESO (nov) with the BAW value, both sources of early exercise forfeit time value compared to the value maximizing exercise policy for a market traded option. Intuitively, the model that combines both sources of early exercise should have a lower ESO value than the minimum of the other two. However, for a volatility of 60% the ESO value that combines both sources of risk is now higher than the value without voluntary early exercise. The inclusion of voluntary early exercise in addition to turnover induced exercise thus leads to a higher ESO value. The reason for this is that voluntary exercise prevents turnover-induced exercise in the future. Of course, voluntary exercise does not prevent executive turnover, but earlier voluntarily exercised options cannot be exercised again at turnover. As voluntary exercise forfeits very little option value on average compared to turnover induced exercise, the ESO gains value from this effect. Thus, in combination with turnover-induced exercise voluntary exercise is even able to add to the option value instead of destroying it. This result is also robust to the inclusion of a constant assumed turnover rate that I estimate from the data (results not tabulated).[56]

Dividend effects. The probabilities for both sources of early exercise slightly decrease in the dividend yield but remain more or less stable. Also the forfeited option

[56]Voluntary exercise then has a positive impact on valuation already for a volatility of 50%. In general, a constant turnover rate has an even stronger impact on valuation. In my semi-parametric model, turnover preferentially occurs after negative stock returns when the option is likely to be far out of the money. In this case only little option value is forfeited. Conversely, with a constant rate forced exercise occurs relatively more in states where much time value is forfeited.

value through turnover-induced exercise stays stable because stock returns in the turnover analysis (see Table II.5) are dividend adjusted. Voluntary exercises forfeit less option value with an increasing dividend yield, because the overall time value becomes smaller through future dividend payments while the volatility, which gives the chance for higher stock prices, stays the same. Though the ESO discount stays at about 20% of the BAW value for the whole range of dividend yields, voluntary exercises account less for it as the dividend yield increases. The ability of voluntary exercise to increase the ESO value, as described in the last paragraph, can also be found here for dividend yields from 3% on.

Beta effects. Holding the volatilities of stock returns and market returns at their baseline values, a β of zero implies zero correlation of stock and market returns and the stock return volatility to be completely idiosyncratic. For the maximum β of two, correlation with the market is perfect and the stock return volatility completely systematic. While the ESO value is \$43.59 for a β of zero, it decreases slightly to \$41.40 for a β of two. The CAPM-β has thus only little effect on the option value. Looking at the option values that exclude one respective source of risks, ESO (not) decreases relatively more than ESO (nov). Voluntary early exercise thus seems to account for most of the effect of decreasing ESO values in β. In the baseline model for voluntary exercise in Table II.9, β only enters abnormal returns. With a zero β stock returns are fully idiosyncratic and the executive can use insider knowledge to maximize the ESO value. In the other extreme case with a β of two in the simulation, there is perfect correlation of stock returns and market returns and stock returns technically exhibit no abnormal returns. Accordingly, there is no insider information that the executive could exploit. Thus, the valuation difference between the two extreme beta values of zero and two shows that the exploitation of insider information is a minor issue for the valuation of ESOs.[57]

For a wide range of parametrizations, executive turnover turns out to have a higher impact on option valuation than voluntary exercises, which even save option value instead of destroying it for high volatility and high dividend yield. Thus, turnover deserves more attention in the area of ESO valuation. The FASB value underestimates the option value from the simulation for all parametrizations. This result is qualitatively insensitive to the choice of the market risk premium as a crucial input for the calculation of expected values under the statistical measure. I find qualitatively similar results for risk premia in the range of 0-10% (results not tabulated).

7 Conclusion

I develop a model for the valuation of ESOs that issuer firms can use to estimate their compensation expenses. As ESOs are often exercised earlier than corresponding market traded options and may also forfeit after executive turnover, ESOs should also have a valuation discount compared to market traded options. Thus, for the valuation of ESOs, expectations about the exercise behavior of the executive are a central component. I consider two sources of early exercise. On the one hand, executives face the risk of forced early exercise due to turnover. On the other hand, they may exercise options voluntarily. I estimate empirical hazard models for both sources of early exercise. I use my estimates to predict exercise and forfeiture probabilities in a Monte Carlo simulation and apply the simulation for the valuation of a representative option.

Analyzing executive turnover, I find the turnover rate to be negatively related to firm performance. However, companies treat positive and negative long term performance

[57] Klein and Maug (2010) find that abnormal returns have only little explanatory power for voluntary exercises while they find time value to be most important.

asymmetrically. Firms are more likely to fire an executive after negative long term performance, while positive long term performance has no effect on the turnover rate. The turnover rate is positively related to compensation as executives facing career concerns will demand a compensation premium. I further find that the value of unvested options is inversely related to the turnover rate. This supports the notion that unvested options tie executives to employer firms and prevent voluntary turnover.

Analyzing voluntary exercises, I find the voluntary exercise rate to be negatively related to the the time value of the ESO. The time value is the fraction of the total option value that forfeits at exercise and can thus be considered as the cost of early exercise to the executive.

The ESO value from my simulation is higher than the corresponding FASB value. The FASB approach implicitly assumes exercise or forfeiture at a distinct point in time. My empirical analysis on voluntary exercises and executive turnover shows, however, that options are more likely to be exercised if they are deep in the money (voluntary exercise) or far out of the money (turnover). As in both cases the loss in time value is comparably low, my approach leads to a higher value than the FASB approach that assumes exercise and forfeiture to be unconditional of the stock price. As a result, the FASB approach consistently underestimates compensation expenses and it thus biases accounting figures.

The literature on ESO valuation so far has concentrated on voluntary turnover. I, however, find turnover induced early exercise to have a much stronger impact on ESO valuation than voluntary exercise. I even find voluntary exercise to save economic value for certain parametrizations as it prevents turnover-induced forced exercise in the future. Executive turnover has a stronger impact on ESO valuation than voluntary exercise as it appears more likely and forfeits more of the option's time value than voluntary early exercise. Given my findings, I suggest that future empirical valuation models for executive stock options should give more consideration to turnover risk. It could also be interesting to analyze how different reasons for executive turnover affect the valuation of ESOs but I leave this question for future research.

A Technical details for simulation and valuation

Assumptions for the representative option

- The stock price and the stock market index follow correlated geometric Brownian motions. For valuation purposes I set the drift rates equal to the risk-free rate (4.5% annualized). The stock pays a dividend in quarterly intervals (13 weeks) since the grant date of the option (the option is granted after the dividend payment in the grant week). The dividend yield relative to the stock price at the payment date is assumed to be 1% p.a.. I set the volatility of annual returns of the market index to 20% and that of the stock to 40%. The CAPM-beta is set to one. The market model for the calculation of abnormal returns is set up accordingly. All variables that depend on stock prices are calculated using simulated stock prices.

- The manager is not a CEO, male, and becomes 51 years old at the grant date.[58]

- There is always one executive that entered the firm before. After three years the first new executive enters the firm and the second after 6 years. After that no new executive enters the firm.

- The manager holds no restricted stock and only one option package consisting of the considered representative option. The initial value of this option portfolio (needed for the calculation of $OptUnvest$ and $OptVest$ over time) is the sample median of the total value of the in-the-money option portfolio. There are no other option grants during the representative option's maturity.

- The systematic and unsystematic risk factors are calculated from the following re-

[58] 51 is the median age in my sample of executives to join their employer firm.

lation between stock returns and market returns.

$$r_s = r_f + \beta(r_m - r_f) + \varepsilon \tag{II.4}$$

with r_s, r_f, and r_m as the stock return, risk-free rate, and market return, respectively. The variance of stock returns σ_s^2 can then be decomposed into its systematic and unsystematic component.

$$\begin{aligned} \sigma_s^2 &= Var\left[r_f + \beta * (r_m - r_f)\right] + Var\left(\varepsilon\right) \\ &= SysRisk^2 + RMSE^2 \end{aligned} \tag{II.5}$$

As r_f in the simulation is held constant this simplifies to

$$\begin{aligned} & SysRisk &= \beta\sigma_m \\ \Rightarrow \quad & RMSE &= \sqrt{\sigma_s^2 - \beta^2\sigma_m^2}. \end{aligned} \tag{II.6}$$

- All other variables (such as *Compensation*, *Owner*, *Executives*, *Homogeneity*, *FirmSize*) are set to their sample medians.

Early exercise

Denote by $h^{turnover}$ the executive turnover rate, which is the conditional probability that the option holder leaves the firm in period t if she was still with the firm at time $t-1$. The conditional probability of voluntary exercise in each interval is given by the hazard rate $h^{voluntary}$. I refer to the event that the option is either exercised or forfeited as "stopping" and denote the random stopping time by T. Then the so-called survival rate $S_t \equiv Pr\left(T > t\right)$ is the probability that the option is alive at time t (I drop the superscript

i for a specific path for ease of exposition). The survival rate is related to the two hazard rates in the following way.

$$S_t = (1 - h_t^{voluntary})(1 - h_t^{turnover})S_{t-1} \tag{II.7}$$

Consistent with my estimation procedure voluntary exercise is possible whenever no turnover takes place. Now denote by $f_t \equiv Pr\,(T = t)$ the probability that the option is exercised or forfeited in period t, which covers the time interval $(t - 1; t]$. Then I can recover f_t from the survival rate S_t as

$$f_t = S_{t-1} - S_t. \tag{II.8}$$

The survival probabilities observe the transition equation: The option is granted at $t = 0$, which implies that $S_0 = 1$. Given my assumptions, voluntary exercises can only occur if the option is in the money and after the vesting period, in all other cases $h_t^{voluntary} = 0$. The time intervals used in the simulation are measured in weeks. The turnover rate, however, was calculated on annual data. I estimate the turnover rate on an annual basis and assign the first week of each year with the turnover rate for the year. Thus every 52nd week since the option grant has a non-zero turnover rate. All other simulated points in time are not affected by turnover. If the option is vested and in the money at the time when the manager leaves the firm, then she exercises the options immediately. If the option is unvested or out of the money, then she forfeits the option.[59]

I use my estimated turnover rates, my estimated voluntary exercise rate, and $S_0 = 1$ as a starting value to compute S_t and f_t for all periods t and then insert the results into the valuation equation II.2.

[59]See Carpenter (1998) and Cvitanić, Wiener, and Zapatero (2008) for similar assumptions.

Tables

Table II.1: **Sample construction.** I report the number of (annual) employment observations, turnover events, persons, and firms. I drop persons without joining date and such who enter a firm before 1996 because tracking option holdings with IFDF is first possible from that year on. I further exclude persons who do not hold options (IFDF) during the sample period. Finally, I lose observations after matching the ExecuComp data with CRSP and CompuStat.

	Obs.	Turnovers	Persons	Firms
ExecuComp	184,789	8,987	34,571	3,079
No join date	122,015	5,794	23,131	446
Period restrictions	13,108	470	1,210	175
No option holders	26,723	1,448	5,049	731
No stock price information	9,147	434	1,532	463
Final sample	13,796	841	3,649	1,264

Table II.2: **Key financial firm statistics.** For each firm I, average the observations from 1996 to 2008 over all years for which I have data. Depending on the firm characteristic the number of firms ranges from 977 to 1,177 for my sample and from 993 to 1,546 for the comparison sample of ExecuComp firms that are not part of my sample. All accounting numbers are in million dollars. I report the means (medians) for my sample and the difference between the means (medians) of my sample and the comparison sample. Differences are tested to be different from zero and stars indicate significance levels.

	Mean	Δ Mean	Median	Δ Median	
Market capitalization	5,753	-186	1,390	210	**
Book value of assets	1,181	162	359	57	***
Sales	3,193	-113	894	86	
Employees	11,833	-1,862	3,520	-361	
Market to book ratio	4.06	0.02	2.89	0.01	
P/E ratio	18.54	-3.83	16.56	-0.21	
Net income/Sales	-0.07	-0.03	0.05	-0.00	

Table II.3: **Variable definitions and data sources for the turnover analysis.** The Table lists all variables for the turnover analysis in Section 4, their definitions, and data sources.

Variable	Description	Source
Returns		
$Return52$	Stock return over the past 52 weeks	CRSP
$Return156Pos$	Stock return over the past 156 weeks if positive, zero otherwise	CRSP
$Return156Neg$	Stock return over the past 156 weeks if negative, zero otherwise	CRSP
$Market52$	Market return over the past 52 weeks	CRSP
$Market156Pos$	Market return over the past 156 weeks if positive, zero otherwise	CRSP
$Market156Neg$	Market return over the past 156 weeks if negative, zero otherwise	CRSP
Personal characteristics		
$Compensation$	ln(1+total compensation)	ExecuComp
$RestStock$	ln(1+market value of restricted stock)	ExecuComp
$OptUnvest$	ln(1+market value of in-the-money unvested options)	ExecuComp
$OptVest$	ln(1+market value of in-the-money vested options)	ExecuComp
$Owner$	1 if the ownership in the employer firm is greater than 1%, zero otherwise	IFDF

Retirement	1 for executives older than 60, zero otherwise	ExecuComp
CEO	1 for chief executive officers, zero otherwise	ExecuComp
Male	1 for male executives, zero for females	ExecuComp
EnterBefore	Number of executives entered before	ExecuComp
EnterAfter	Number of executives entered after	ExecuComp
Executives	Total number of tracked executives	ExecuComp
Firm characteristics		
Homogeneity	Mean correlation of stock returns with an equally weighted industry index during the last 52 weeks	CRSP
SysVolatility	Annualized systematic volatility of stock returns (52 weeks) compared to the CRSP value weighted index	CRSP
ISVolatility	Annualized idiosyncratic volatility of stock returns (52 weeks) compared to the CRSP value weighted index	CRSP
MCap	ln(1+market value of outstanding common stock)	CompuStat

Table II.4: **Descriptive statistics on executive employment relations.** The table contains information on all variables in the baseline specification based on 13,796 executive-firm-year observations. See Table II.3 for all variable definitions.

	Mean	Std. Dev	Min.	First Quartile	Median	Third Quartile	Max.
Returns							
$Return52$	0.17	0.75	-0.98	-0.20	0.06	0.34	12.04
$Return156Pos$	0.85	2.84	0.00	0.00	0.23	0.87	101.94
$Return156Neg$	-0.15	0.25	-1.00	-0.23	0.00	0.00	0.00
$Market52$	0.07	0.19	-0.42	-0.07	0.16	0.20	0.41
$Market156Pos$	0.40	0.36	0.00	0.03	0.37	0.63	1.15
$Market156Neg$	-0.06	0.11	-0.33	0.00	0.00	0.00	0.00
Personal characteristics							
$Compensation$	12.52	4.46	-0.11	12.97	13.78	14.60	19.50
$RestStock$	4.54	6.42	0.00	0.00	0.00	12.53	18.38
$OptUnvest$	7.91	6.57	0.00	0.00	11.34	13.61	20.62
$OptVest$	7.82	6.78	0.00	0.00	11.12	13.87	21.33
$Owner$	0.05	0.22	0.00	0.00	0.00	0.00	1.00
$Retirement$	0.15	0.36	0.00	0.00	0.00	0.00	1.00
CEO	0.16	0.37	0.00	0.00	0.00	0.00	1.00
$Male$	0.93	0.25	0.00	1.00	1.00	1.00	1.00
$EnterBefore$	1.42	1.27	0.00	0.00	1.00	2.00	8.00
$EnterAfter$	1.15	1.16	0.00	0.00	1.00	2.00	7.00
$Executives$	6.10	1.38	1.00	5.00	6.00	7.00	12.00
Firm characteristics							
$Homogeneity$	0.13	0.03	0.04	0.11	0.13	0.15	0.24
$SysVolatility$	0.21	0.15	0.00	0.10	0.16	0.27	1.53
$ISVolatility$	0.42	0.24	0.08	0.25	0.36	0.53	3.35
$MCap$	14.09	1.56	4.51	13.13	14.00	15.04	19.96

Table II.5: **Turnover rates.** The table displays the relative hazards defined as where is the estimated coefficient for different specifications. Model (1) is the baseline turnover model. Model (2) replaces stock returns by market adjusted stock returns. Model (3) removes market returns. Models (4) and (5) split the sample on the Bebchuk, Cohen, and Ferrell (2009) entrenchment index into high and low governance firms, respectively.

	(1)	(2)	(3)	(4)	(5)
Returns					
$Return52$	-0.21 ***		-0.19 ***	-0.35 ***	-0.01
$Return156Pos$	0.03		0.05	0.15	-0.11
$Return156Neg$	-0.12 ***		-0.09 *	-0.12	-0.06
$Market52$	0.13 **	0.06		0.02	0.33 *
$Market156Pos$	0.06	0.03		-0.04	0.19
$Market156Neg$	0.19 ***	0.16 ***		0.35 **	-0.01
$MAdjusted52$		-0.32 ***			
$MAdjusted156p$		0.01			
$MAdjusted156n$		-0.13			
Personal characteristics					
$Compensation$	0.88 ***	0.90 ***	0.86 ***	0.52 **	1.16 ***
$RestStock$	-0.00	0.00	-0.01	0.03	0.03
$OptUnvest$	-0.11 **	-0.12 **	-0.10 **	-0.04	-0.16 *
$OptVest$	-0.01	-0.04	0.00	0.07	-0.10
$Owner$	-0.18 ***	-0.18 ***	-0.18 ***	-0.14 *	-0.08
$Retirement$	0.17 ***	0.17 ***	0.18 ***	0.13 *	0.14 **
CEO	-0.31 ***	-0.31 ***	-0.32 ***	-0.15	-0.40 ***
$Male$	0.10	0.11	0.09	0.11	0.06
$EnterBefore$	0.05	0.06	0.05	-0.07	0.03
$EnterAfter$	0.40 ***	0.40 ***	0.37 ***	0.32 ***	0.32 ***
$Executives$	0.09 ***	0.09 ***	0.11 ***	0.14 **	0.08
Firm characteristics					
$Homogeneity$	-0.04	-0.05	0.00	0.00	-0.02
$SysVolatility$	0.04	0.05	-0.08 **	0.03	0.09
$ISVolatility$	-0.03	0.00	-0.01	-0.05	0.04
$MCap$	-0.15 ***	-0.16 ***	-0.16 ***	-0.14 *	-0.21 **
$PH - test$	0.85	0.82	0.53	0.85	0.99
R^2	0.29	0.29	0.27	0.20	0.23
Obs.	13,796	13,796	13,796	3,250	3,251

Table II.6: **Turnover robustness.** The table displays the relative hazards defined as $exp\{\beta_i\} - 1$, where β_i is the estimated coefficient for different variations of the baseline specification. Model (1) is an exponential model (constant baseline hazard). Model (2) is estimated with shared frailty (equivalent to random effects for linear models) at the firm level instead of clustering standard errors. Model (3) clusters standard errors at the industry rather than the firm level. Model (4) repeats the baseline estimation with only CEOs.

	(1)	(2)	(3)	(4)
Returns				
$Return52$	-0.21 ***	-0.21 ***	-0.21 **	-0.35 **
$Return156Pos$	0.03	0.03	0.03	-0.01
$Return156Neg$	-0.12 **	-0.11 **	-0.12 ***	-0.07
$Market52$	0.15 ***	0.13 **	0.13	0.45 ***
$Market156Pos$	0.06	0.07	0.06	0.04
$Market156Neg$	0.18 ***	0.18 ***	0.19 ***	-0.11
Personal characteristics				
$Compensation$	0.89 ***	0.85 ***	0.88 ***	0.01
$RestStock$	-0.01	-0.01	-0.00	-0.04
$OptUnvest$	-0.10 **	-0.12 **	-0.11 **	-0.19 **
$OptVest$	-0.02	-0.01	-0.01	0.00
$Owner$	-0.19 ***	-0.18 ***	-0.18 ***	-0.10 *
$Retirement$	0.17 ***	0.18 ***	0.17 ***	0.25 ***
CEO	-0.31 ***	-0.33 ***	-0.31 ***	
$Male$	0.11	0.10	0.10	0.58
$EnterBefore$	0.07 *	0.07 *	0.05	0.04
$EnterAfter$	0.36 ***	0.43 ***	0.40 ***	0.27 ***
$Executives$	0.10 ***	0.08 **	0.09 ***	0.16 *
Firm characteristics				
$Homogeneity$	-0.03	-0.04	-0.04	-0.01
$SysVolatility$	0.04	0.04	0.04	-0.13
$ISVolatility$	-0.02	-0.04	-0.03	0.04
$MCap$	-0.16 ***	-0.15 ***	-0.15 ***	-0.08
$PH-test$		0.91	0.86	0.59
R^2	0.31	0.27	0.29	0.26
Obs.	13,796	13,796	13,796	2,386

Table II.7: **Variable definitions and data sources for the analysis of voluntary exercises.** The Table lists all variables for the analysis of voluntary exercises in Section 5, their definitions, and data sources.

Variable	Description	Source
$TimeValue35Min$	max(Ratio of time value to option value, 0.35)	IFDF / CRSP
$Dividend1$	1 in the week before a dividend payment date if available for options that have been vested for less than 4 years, zero otherwise	CRSP
$Dividend2$	1 in the week before a dividend payment date if available for options that have been vested for at least 4 years, zero otherwise	CRSP
$BHAR2$	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
$BHAR13$	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

Table II.8: **Descriptive statistics on option packages.** The table contains information on all variables in the baseline specification of the analysis of voluntary exercises based on 5,928,571 option package-week observations.

	Mean	Std. Dev	Min.	First Quartile	Median	Third Quartile	Max.
$TimeValue35Min$	0.45	0.17	0.35	0.35	0.35	0.49	1.00
$Dividend1$	0.03	0.18	0.00	0.00	0.00	0.00	1.00
$Dividend2$	0.01	0.09	0.00	0.00	0.00	0.00	1.00
$BHAR2$	-0.00	0.08	-0.84	-0.04	-0.00	0.03	1.92
$BHAR13$	-0.03	0.21	-2.60	-0.14	-0.03	0.08	6.56

Table II.9: **Voluntary exercise rates.** The table displays the relative hazards defined as $exp\{\beta_i\} - 1$, where β_i is the estimated coefficient for different variations of the baseline specification. Model (1) is the baseline model. Model (2) replaces $TimeValue35Min$ with its non-winsorized counterpart and compresses the two dividend variables into one variable. Model (3) clusters standard errors at the company level instead of at the personal level. Model (4) considers only exercises of complete option packages.

	(1)	(2)	(3)	(4)
$TimeValue35Min$	-0.64 ***		-0.64 ***	-0.65 ***
$Dividend1$	0.72 ***		0.72 **	0.96 ***
$Dividend2$	0.36 *		0.36 *	0.46 *
$BHAR2$	-0.03	-0.03	-0.03	-0.03
$BHAR13$	-0.16 ***	-0.15 ***	-0.16 ***	-0.18 ***
$TimeValue$		-0.97 ***		
$Dividend$		0.45 **		
$PH - test$	0.49	0.00	0.20	0.00
R^2	0.35	0.39	0.35	0.38
Obs.	5,928,571	5,928,571	5,928,571	5,633,832

Table II.10: **Simulation results.** The table reports the BAW value of a market traded option, the ESO value from my model, the ESO value without turnover risk ESO (not), the ESO value without voluntary exercises ESO (nov), the probability of turnover and voluntary exercise in the combined model (P(turn) and P(vol)), the time value as a fraction of the BAW value at turnover-induced and voluntary exercise (TV(turn) and TV(vol)), and the FASB value. I show comparative statics for different values of the underlying stock's volatility (Panel A), dividend yield (Panel B), and the market β (Panel C), leaving all other parameters at their base values (time to maturity=10 years, vesting period = 3 years, σ_S = 40% p.a., dividend yield = 1% p.a., $\beta = 1$).

	BAW	ESO value	ESO (not)	ESO (nov)	P(turn)	P(vol)	TV(turn)	TV(vol)	FASB
Panel A: Volatility									
0.20	35.70	26.83	29.84	30.60	0.31	0.39	0.72	0.24	24.71
0.30	44.22	35.37	39.13	38.20	0.34	0.34	0.80	0.22	32.46
0.40	52.63	43.02	47.53	45.39	0.36	0.29	0.85	0.21	39.83
0.50	60.44	51.71	56.86	52.41	0.39	0.25	0.88	0.21	46.67
0.60	67.44	59.17	64.89	58.43	0.42	0.22	0.91	0.21	52.89
Panel B: Dividend Yield									
0.00	58.92	47.77	53.23	51.72	0.37	0.29	0.84	0.23	44.66
0.01	52.63	43.02	47.53	45.39	0.36	0.29	0.85	0.21	39.83
0.02	47.71	38.99	42.85	39.70	0.37	0.28	0.85	0.19	35.81
0.03	43.49	35.42	38.72	34.69	0.37	0.27	0.85	0.18	32.11
0.04	39.77	32.16	34.96	30.26	0.37	0.26	0.86	0.16	28.73
Panel C: CAPM β									
0.00	52.63	43.59	47.93	45.69	0.36	0.30	0.86	0.21	39.99
0.50	52.63	43.35	47.80	45.53	0.36	0.30	0.86	0.21	39.92
1.00	52.63	43.02	47.53	45.39	0.36	0.29	0.85	0.21	39.83
1.50	52.63	42.31	46.89	45.16	0.37	0.29	0.84	0.22	39.72
2.00	52.63	41.40	46.05	44.85	0.38	0.28	0.83	0.22	39.44

Chapter III

How Do Executives Exercise Their Stock Options?

1 Introduction

The objective of this paper is to investigate the comparative explanatory power of the different approaches that have been advanced in the literature to explain stock option exercises.[1] Little is known empirically about the motivations of top executives to exercise their stock options early, and the few papers that address stock option exercise behavior empirically are mostly based on samples of non-executive employees from a small number

[1]This chapter is based on joint work with Ernst Maug. Therefore I retain the personal pronoun “we”, used in the original paper, throughout this chapter. All tables are gathered at the end of the chapter. We are grateful to David Allen, Sasson Bar-Yosef, Ingolf Dittmann, Louis Ederington, Alex Edmans, Rüdiger Fahlenbrach, Michael Schill, Mark Shackleton, Mark Wahrenburg, and David Yermack as well as to seminar participants at Australian National University, Edith Cowan University, Hong Kong University of Science and Technology, Lancaster University, the University of Melbourne, the University of Technology Sydney, the University of Queensland (Brisbane), the Humboldt-Copenhagen Conference 2009, the Sixth Accounting Research Workshop (Bern), the conference on Individual Decision Making, High Frequency Econometrics and Limit Order Book Dynamics (Coventry), the X. Symposium zur ökonomischen Analyse der Unternehmung (Vallendar) for helpful comments and discussions. We thank the collaborative research centers SFB 649 on "Economic Risk" in Berlin, the SFB 504 "Rationality Concepts, Decision Making and Economic Modeling", and the TR/SFB 15 “Governance and the Efficiency of Economic Systems” in Mannheim for financial support.

of firms.[2] We distinguish three explanatory approaches. The first approach argues that the benefits from diversification motivate early exercises.[3] The second approach focuses on a range of behavioral factors and attributes early exercises to overconfidence or to the misinterpretation of past stock prices.[4] Finally, the third approach argues that executives have inside information that allows them to time their option exercises.[5] These explanations are not mutually exclusive and it is conceivable that more than one or even all three contribute to the explanation of stock option exercise behavior. In this paper, we offer a comprehensive analysis that compares the different approaches. We also add to the existing approaches and, importantly, we explicitly incorporate the fact that executives typically choose from a portfolio of exercisable options and do not only decide on whether or not to exercise one single option. Finally, we quantify the incremental contribution of each of the explanatory approaches we consider.

This paper focuses on the exercise decisions of top executives. The question of what motivates executives to exercise their stock options late or early is important. First, managers make key corporate decisions, so it is crucial to understand whether their personal decisions are rational or if they are subject to behavioral biases and if so, which ones. Second, managers' stock option exercises are relevant because managers receive a large portion of their incentive pay in the form of stock options. These incentive plans work as planned only if compensation committees properly forecast managers' decisions to hold or

[2]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 (2008a) have data from almost 900,000 option grants from 47 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.

[3]This literature focuses mostly on the valuation of stock options. 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 utility-based models include Carr and Linetzki (2000), Henderson (2005), and Ingersoll (2006).

[4]Prominent examples for the behavioral approach include Heath, Huddart, and Lang (1999) and Malmendier and Tate (2005a,b).

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

exercise options. Moreover, if managers make biased or even irrational exercise decisions regarding their options, then they may also not be properly incentivized by these options. Finally, models to value executive stock options should include the empirically relevant reasons for the timing of exercise decisions.

We analyze a data set with 200,636 option packages of 13,588 executives at 1,994 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 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.

We find that a number of behavioral factors identified in the literature have a first-order impact on stock option exercise decisions. In particular, our findings are consistent with reference-dependence and with executives believing in mean-reversion. However, in contrast to Heath, Huddart, and Lang (1999), we find only mixed evidence that executives extrapolate long-term trends. In addition to the variables they consider, we also include 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. Most of the reactions to past stock prices and to sentiment differ significantly if managers follow an exercise-and-hold strategy instead of an exercise-and-sell strategy. The results for the exercise-and-hold strategy admit several interpretations, including exercise date backdating (Cicero, 2009). In the Conclusion we argue that while we find some results that support behavioral biases, there is no evidence for outright irrationality.

Managers tend to choose the option with the lowest time value when selecting which of multiple exercisable options to exercise. They choose the option with the lowest time value in 54% of all cases and if they make errors, these errors are generally small, whereas large errors are infrequent. Exercise patterns depend also on the composition of the option portfolio: Managers are more likely to exercise a particular option if they have fewer alternatives and whenever they receive new grants. Managers also seem to have a target dollar value that they would like to receive from exercising, so they either frequently exercise small fractions of their option grants, or they exercise larger fractions and less frequently.

The results for the diversification motive are somewhat mixed. Managers exercise options earlier if the options have a lower time value and if compensation packages include more deferred compensation, which exposes managers to firm-related risk. Both findings are consistent with the predictions of utility theory. On the other hand, 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. In the Conclusion we argue that the diversification motive is important, but it may not be adequately captured by standard utility models so that more theoretical work is needed here.

We find support for the notion that managers time their option exercises because of private information, but they are cautious not to make use of information that is released shortly after they exercise. Institutional factors such as vesting periods and blackout periods are relevant and, in fact, have a first-order impact on exercise decisions. We subject our specifications, variable definitions, and the econometric model to a range of robustness checks.

Our approach permits us to quantify the contributions of the different explanations advanced in the literature. We show that the time value of the option, option portfolio effects, and institutional constraints are of first-order importance for explaining exercise behavior. Behavioral explanations are statistically highly significant, but less important, and the timing of exercises based on inside information has much less explanatory power compared to all other approaches.

We contribute to the literature on stock option exercises at the methodological as well as the substantive level. At the methodological level, we use hazard analysis, which allows us to properly incorporate censoring and to avoid biases from the fact that of the 200,636 option packages in our data set, only 10.5% are not censored.[6] At the substantive level, our approach allows us to develop a comprehensive analysis of stock option exercise behavior. Existing contributions in the literature focus on only one approach and then include the variables associated with that particular approach.

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 somewhat 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 where managers hold on to the stock, which turns out to be important. We confirm the other findings of Heath, Huddart, and Lang (1999), but show that the incremental explanatory power of behavioral variables is lower than that of several competing explanations. A related conclusion holds for the asymmetric information approach cited above, for which we confirm the main findings, but which adds only moderate explanatory power relative to other theories.

Ours is the first paper to test some of the predictions of utility theory for exercise behavior directly.[7] Previous research on the diversification motive by Carpenter (1998) and

[6] Armstrong, Jagolinzer, and Larcker (2007)is 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.

[7] Armstrong, Jagolinzer, and Larcker (2007) include the ratio of stock price to strike price, which approximates time value. In contemporaneous research, Carpenter, Stanton, and Wallace (2008a) include the stock's beta, which is similar to our inclusion of correlation.

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 benchmarking valuation models, but does not permit any inference about the incremental explanatory power of utility theory and cannot test whether the suggested variables have the influence on stock option exercises predicted by the theories.

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 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.

Section 2 describes the construction of our data set. Section 3 provides details on the methodology. Section 4 integrates hypothesis development with a presentation of the main results of the paper. Section 5 extends our analysis and offers some robustness checks. Section 6 concludes with a discussion of our findings.

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).[8] 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.[9] 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,

[8]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.

[9]"Withholding securities" is IFDF's terminology for a transaction where insiders can pay an option's strike price at exercise with stock. IFDF separates this transaction: 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.

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. For our baseline sample we also require that the sale of at least some of the stock is reported in the same insider filing as the exercise. This condition is relevant because several hypotheses we discuss below are predicated 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.[10] We consider the exercises not associated with stock sales separately as a robustness check. In total, we obtain 2,110,570 option packages associated with 255,065 exercises by 135,355 insiders. The steps of the construction of the sample are summarized in Table III.1.

[Insert Table III.1 about here.]

We match the IFDF data to the 2008 version of ExecuComp to obtain additional information about the executives themselves.[11] From ExecuComp we obtain the beginning and the end of employment with the company, the fiscal year end, and annual data on total compensation, the sum of base salary and bonus, the Black-Scholes value of options granted, and the value of restricted stock granted. We lose 1,796,164 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. Missing observations in dollar denominated variables in ExecuComp are set to zero.

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

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

We match this data with stock price data from CRSP. We lose another 15,282 option packages 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. We therefore omit all option packages (97,924 in total) that are out of the money for the entire period between the vesting date and maturity for which we have data. We restrict our analysis to exercises where the sale of some of the acquired shares is reported in the same filing. In our baseline specification and in Table III.1 we count only exercises for at least 25% of the initial option package. (We consider other definitions later.) Because of these restrictions we lose 564 option packages and 17,148 exercises. Our final sample covers 200,636 option packages from 13,588 executives and 1,994 firms. For these options IFDF records 27,319 exercises of at least 25% of the initial grant.

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.

[Insert Table III.2 about here.]

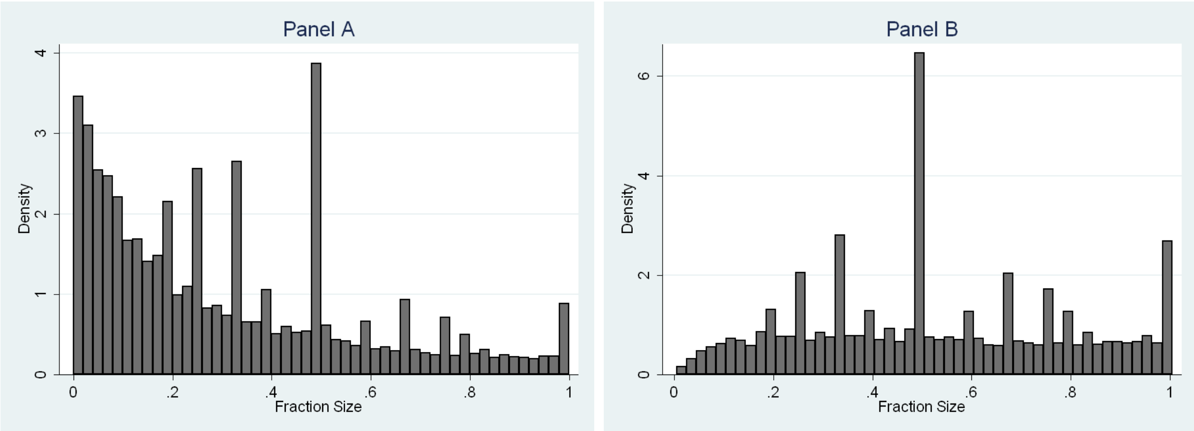
The subjects of our analysis are option packages. Table III.2 provides descriptive statistics for option packages at the vesting date for those options that are in the money for at least one week during the period between the vesting date and the earlier of the maturity date and the date until which 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.[12] 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 \$0.71 million on average (median: \$0.07 million). Of the 200,636 option packages in our sample, 153,845 or 77% are in the money at the vesting date with an average stock price to strike price ratio of 10.37. (The median is only 1.28, a few firms have very large stock price increases between the grant date and the vesting date). The dividend yield is 0.92% on average and it is 0% for 61% of all option packages at vesting, and therefore also for the median package.

Executives sometimes exercise only a fraction of the option package. Of the 38,956 exercises in our sample, 59% are for a fraction of less than 100% of the initial grant, 44% are for less than 50%, 30% 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 27,319 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, 59% of an option package is exercised if at least some options are exercised early.

Figure III.1 shows two histograms of the fraction sizes for partial exercises. In Panel A the bars in the histogram are proportional to the frequency of exercises for the particular

[12] 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 III.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.



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 treat these as multiple grants, one for each vesting date. 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 where an option package is out of the money.[13] We only include options where the vesting date is available, so the standard left censoring problem considered in hazard analysis (options where the

[13]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).

beginning of their relevant lifetime cannot be observed) does not exist for our data set.[14] However, for 16% 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.[15] Option packages without a grant record account for 73% of the exercises in our sample and we retain these observations, because otherwise a large number of observed exercises would be lost. Grant dates are not important for our analysis because for our purposes we count options' lifetime from 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.

[Insert Table III.3 about here.]

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. 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 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.

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

[15] 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.

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.[16] We therefore take the date when an executive leaves the firm (which we obtain from ExecuComp) as the censoring date. All exercises after this date - some but not all of which are recorded on IFDF - are therefore not included in our data set. Observations are censored if insiders return options to the issuer because of 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. Finally, all options that are still alive at the end of December 2008 are right censored because the coverage of our version of IFDF ends on that date.

Table III.3 shows the relative importance of right censoring reasons for our sample. If some portion of an option package is disposed of early (through exercises or gifts) while the remaining part is censored, we report the option package in the table as censored only if the larger part is censored. The major reason for right censoring (64.0% of the sample) is that the database records only exercises until December 2008. From the remaining 36.0%, only about one quarter (9.6% of the sample) of the options expire, most of them out of the money.

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

3 Methodology

We analyze stock option exercise patterns by CEOs and other insiders by using hazard analysis.[17] To fix ideas, denote by $f(t, x_t)$ the probability density function for the event that 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. Our definition of *Exercise* implies that the same option package can be exercised more than once (multiple spell analysis) and our econometric analysis accounts for this fact. We keep options in the analysis as long as at least an economically significant fraction of the number of options initially granted (25% in the baseline case) is left, otherwise the option package is censored.

The hazard approach offers major advantages.[18] In particular, hazard analysis can easily deal with censored data. Neglecting the right censoring in our data we mentioned above biases 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 87.2% of all option packages in the sample (see Table III.3). 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

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

[18] Carpenter, Stanton, and Wallace (2008a) 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. Second, Carpenter et. al. 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. Almost all results are robust to this decision, but for choices from option portfolios small exercises are different from large exercises.

cannot include censored observations.[19]

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

$$h(t, x_t) = \lambda_q exp\{x_t'\beta\}\nu, \qquad \text{(III.1)}$$

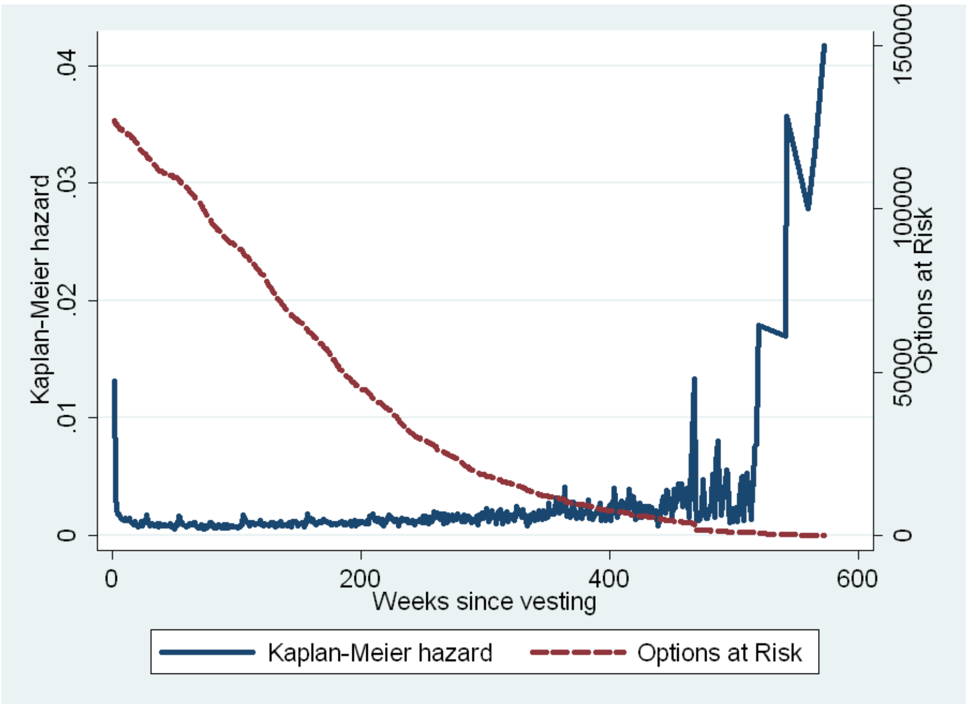
where x_t is the time-varying vector of variables, λ_q are scalars for prespecified time intervals q, β is a vector of coefficients, and ν is a multiplicative random error that varies across individuals. The expression for $h(t, x_t)$ has three components.

The first component is λ_q and is referred to as the baseline hazard, which gives the 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 on the baseline hazard over time. For instance, the widely used Weibull model assumes a monotonic baseline hazard and violations of this assumption may bias coefficients. The second factor in equation (III.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 (III.1) is the individual error term ν, which models unobserved heterogeneity. Unobserved heterogeneity is an important characteristic of our data. While we include a large number of variables in x_t to control for as many effects as possible, there are still individual factors that influence exercise decisions and which we cannot observe. These factors include preference parameters and unobserved manager characteristics like risk aversion or managers' holdings of non-firm related assets. Ignoring unobserved het-

[19] 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 where 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.

Figure III.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 at least 25% 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.



erogeneity when it is present can bias the estimates of the parameters of interest β. We therefore estimate a mixture model, where heterogeneity is modeled as a multiplicative individual error term ν that is common for all option grants of the same manager and distributed gamma.[20] This specification is comparable to a random effects model for linear panel data. We have 13,588 individuals in our analysis, which precludes the use of fixed effects.

Hazard rate models are defined in continuous time, so we have to use a discrete-time approximation. We follow Heath, Huddart, and Lang (1999) and use weekly observations. We estimate the baseline hazard for intervals of 13 weeks each.

Figure III.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

[20]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.

to the number of unexercised options 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 III.2 also shows the number of options that are still alive at any point in time. It takes 342 weeks (about 6 1/2 years) for this number to fall below 10%, and 417 weeks (8 years) to fall below 5% of the original sample. With a 3-year vesting period, 7 years after vesting corresponds to a 10-year maturity at the grant date. We observe some erratic behavior of the empirical hazard rate about 9 years after vesting, when less than 3,500 option packages or 2.71% of the original sample are still alive.

4 Hypothesis development and analysis

In this section we develop the hypotheses, grouped by the competing explanatory approaches, i.e., utility theory, behavioral theories, option portfolio effects, and asymmetric information. We integrate hypothesis development with the presentation of the results for ease of exposition. For each explanatory approach, we introduce the variables associated with each hypothesis and then immediately discuss the tests. Table III.4 provides a detailed overview of all variables and their definitions. Table III.5 presents descriptive statistics and Table III.6 presents the estimation results for our hazard model.

[Insert Tables III.4, III.5, and III.6 about here.]

Dependent variable: Exercise. The unit of investigation for our study is an option package. Sometimes managers receive options with different conditions, such as strike prices or vesting periods, with the same grant at the same date and we treat these as separate packages, so all options in one package have the same strike price and are subject to the same vesting conditions. The dependent variable in all our regressions is the dummy variable $Exercise_t$, which assumes a value of one if options in the package are exercised at time t and zero otherwise. We report results for the event where the manager exercises at least 10%, 25%, 50%, or 100% of the options originally granted in one option package. Hence, $Exercise_t$ equals one if the fraction exercised as a percentage of the initial package is at least as large as the respective threshold. Option packages where less than this percentage is left are then dropped from the analysis. We often focus on results where the exercise threshold is set to 25%, which we treat as the baseline case, but always report the other specifications to document robustness.

We report relative hazards for individual variables as $hr_i = exp\{\beta_i\} - 1$ to facilitate interpretation.[21] We express all 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.

4.1 Utility theory

Measures of risk. The starting point of utility theory is the observation that insiders exercise their stock options early because their investment in their own company's securi-

[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.

ties 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 manager can hedge the market risk of the stock by trading in the stock market, whereas she cannot hedge the idiosyncratic risk of the firm.[22] 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. The coefficient on *Correlation* should therefore be negative. We report below on robustness checks for other variables that may capture the same effect, notably the firm's beta and firm-specific risk.

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. However, it is in line with rank-dependent preference theories, which predict that individuals combine diversified portfolios with undiversified holdings in individual stocks (Polkovnichenko 2005, Barberis and Huang 2008). Polkovnichenko (2005) shows that consumers have such portfolios.

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

[22]Cai and Vijh (2005) present a utility based ESO valuation model where the manager can invest in the risk-free money market account and two correlated risky assets: the firm's stock and the market portfolio. They show that managers value options subjectively higher when the the correlation between returns of the stock and the returns of the market portfolio is higher. Carpenter, Stanton, and Wallace (2008b) derive a similar result in the context of their model.

risk-averse, so we cannot make an unambiguous prediction here. $Volatility_t$ is defined as the standard deviation of stock returns calculated over the 52 weeks preceding week t. The coefficient on $Volatility$ is small and significant only at the 10% level, which suggests that the two effects are about equally strong.

Time value. Exercising their stock options early allows insiders to diversify their portfolio, in particular when they sell the stock they receive from exercising their options. Models based on utility theory analyze the trade-off between the benefits from diversification and the costs of giving up the remaining time value of the option.[23] We therefore define the variable $TimeValue$, which is defined as the time value of the option, divided by its Barone-Adesi and Whaley (1987) value. $TimeValue$ can take values between zero for options that are close to maturity or deep in the money, and one for 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, which confirms the predictions of utility theory.

4.2 Option portfolio effects

New option grants. Managers may respond to the arrival of new option grants by exercising more of their existing options. This would always happen if managers have some target ownership of stock options, so that a new option grant increases their holdings above their target level.[24] Managers may have such a target ownership because of portfolio considerations or from stock ownership guidelines.[25] From the point of view of utility

[23] These models start with Huddart (1994) and Kulatilaka and Marcus (1994), but include also later models like Ingersoll (2006), models of partial exercise (Rogers and Scheinkman, 2007), or models of the exercise of multiple options (Grasselli and Henderson, 2009).

[24] 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.

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

theory, managers would exercise their existing options if they receive a new grant simply because new option grants increase the exposure of the manager to firm risk. We 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.

The coefficient on $GrantWeekAfter$ implies that the likelihood of exercising options in the week of or in the week after a new option grant is 339% higher than usual. By comparison, the impact of $GrantWeekBefore$ is negative, but has a lower impact in absolute terms. It is possible that we underestimate the last effect because we do not have grant dates for all option grants in our sample. If grant date information is not available the dummy variable is incorrectly set to zero for some observations, which biases the coefficient towards zero. Also, reported grant dates may differ from actual grant dates if options are backdated (e.g., Heron and Lie, 2007). In this case, the negative effect of $GrantDateBefore$ may be contaminated by the positive effect of $GrantDateAfter$ if the week after the reported grant date is in fact the week before the actual grant date. Overall, this evidence is consistent with the notion that managers try to keep their option holdings at some target level.

Characteristics of the option portfolio. We capture the substitution between different packages the manager has available for exercise. The implicit assumption is that managers have decided to exercise some options for reasons explained by other factors, such as the motive to diversify or behavioral reasons, and they then select which option to exercise. We capture this substitution effect with $PortfolioSize$, which is the number of other exercisable option packages the manager has at the same time. The coefficient should be negative because any option package is less likely to be exercised if more alternatives are available. $PortfolioSize$ has a highly skewed distribution with a median of 13 packages and a mean of 41.4. The substitution effect is significant: For the baseline case, a one standard deviation (= 68 packages) increase in $PortfolioSize$ reduces the likelihood for any particular exercisable package to be exercised by 31%. The effect is significantly larger for exercises of larger fractions.

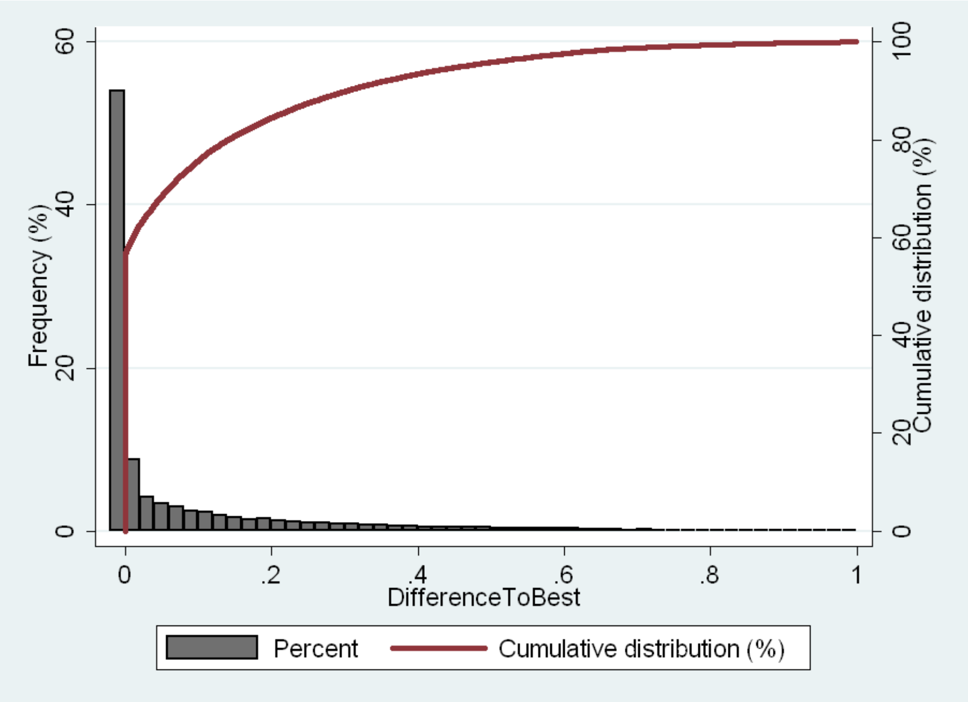
We want to investigate how the characteristics of managers' option portfolios affect their selection among the options they have available. Managers always forego some of the time value of the option, but we expect them to prefer exercising options with a lower time value.[26] We define *LowestTV* to be one if the option package under consideration has the lowest time value of all available option packages. The coefficient on *LowestTV* is negative, but small in absolute value. This is surprising because we would expect a positive coefficient here. However, based on our regressions we cannot directly infer whether managers make rational decisions conditional on exercising at least one option. The hazard regression estimates the conditional probability of exercise conditional of *LowestTV* = 1, whereas the question about the rational selection of options from a multi-option portfolio is about the probability that *LowestTV* = 1 conditional on exercise. While these two conditional probabilities are related through Bayes' rule, inference on one cannot be linked directly to inference on the other.

To further investigate the rationality of choices from multi-option portfolios we define *DifferenceToBest* as the difference in $TimeValue$ between the option package managers actually select for exercise and the exercisable option package with the lowest time value.[27]

[26]The only paper we are aware of that analyzes option portfolios is Grasselli and Henderson (2009). In their model, 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.

[27]If managers exercise multiple options simultaneously, then they naturally exercise options with a higher time value as well. In this case *DifferenceToBest* is positive if they exercise options from a package while options from another package with a strictly lower time value remain unexercised.

Figure III.3: **Optimality of exercises.** The figure shows a normalized histogram and the cumulative distribution of the variable *DifferenceToBest*, which is defined as the difference in $TimeValue$ between the option package with the lowest $TimeValue$ at the time of exercise and the $TimeValue$ of the option package actually chosen. The bars of the histogram are calculated as percentage frequencies.



If managers select the optimal package, *DifferenceToBest* equals zero, otherwise it is some positive number between zero and one because $TimeValue$ is also defined on the unit interval. We can therefore not include this variable in the hazard regressions. Figure III.3 plots a histogram and the cumulative distribution function for *DifferenceToBest*.

In 53.9% of all cases *DifferenceToBest* equals zero, which implies that managers choose the option with the lowest time value when exercising from a multiple-option portfolio. For 75.7% of all exercises *DifferenceToBest* is smaller than 0.10 and for 83.8% of all exercises it is smaller than 0.20. Hence, managers make errors when selecting which option package to exercise from, but they make predominantly small mistakes. Figure III.3 also reveals that the likelihood of unnecessarily giving up time value declines rapidly as the size of the mistakes increases. Even these errors may be overstated because managers are presumably risk-averse, whereas *DifferenceToBest* expresses the size of the error from the point of view of a diversified investor. We therefore conclude that managers tend to select options for exercise rationally. While they make some mistakes, they pay attention to the time value that is at stake and avoid large errors.

Small versus large exercises. We hypothesize that managers have a target dollar level for option exercises, which can be reached either by exercising large parts of small grants, or small parts of large grants. The comparison of Panel A and Panel B of Figure III.1 suggests this interpretation. To test this hypothesis 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 t, scaled by the value of the manager's entire stock-dependent portfolio. Table III.6 shows that the coefficient on $PackageSize$ is always negative and significant at the 1% level, but it depends on the exercise threshold. The coefficient decreases from -0.07 (threshold=10%) to -0.33 (threshold=100%). Hence, executives are more likely to exercise larger grants in smaller fractions, whereas they exercise smaller grants in larger fractions, so the impact of $PackageSize$ has a stronger negative impact for large exercises. This finding is consistent with the hypothesis that managers have a target dollar value for option exercises.

We define $FractionLeft$ as the fraction of the initially granted option package that managers still hold and find that a one standard deviation increase in $FractionLeft$ (0.11 from Table III.5) increases the probability of exercise by 6% in the baseline case. The impact of this variable also depends on the exercise threshold: If a larger fraction of the original grant is left, then it is possible and therefore also more likely that managers exercise a larger fraction. The coefficients on $PortfolioSize$, $PackageSize$, and $FractionLeft$ all change as we increase the exercise threshold from 10% to 100%. Hence, most option portfolio effects depend on the exercise threshold, whereas all other effects in Table III.6

are more or less independent of how we define economically significant exercises.

4.3 Behavioral explanations

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.[28] 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 become optimal for them to exercise the option and sell the stock now. By contrast, if managers believe a positive trend to continue, then exercising now is not optimal. The psychological literature does not specify when a trend has to be regarded as short (and therefore mean-reverting) and when it has to be regarded as long. We use four periodicities for past returns to explore the dependence of exercise 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 III.5) over the past three months, then the likelihood of exercising the option increases on average by 12% in our baseline case. The results are similar for a 26-week interval.

The results for long-term trend extrapolation are more mixed. This hypothesis is supported by the coefficient on $Return52$: If it increases by one standard deviation, then the likelihood of exercise falls by only 3%. By contrast, the coefficient on 3-year returns

[28] 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).

$Return156$ is positive, which contradicts the notion of trend extrapolation. While the effect is small, it is consistent across all definitions of the dependent variable. 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 (results not tabulated). Our findings are therefore consistent with managers believing in short-term mean reversion, but ambiguous with respect to long-term trend extrapolation.

Reference prices. 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 or simply because managers pay more attention to their stock when it breaches the past trading range.[29] 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. From Table III.5, the stock price is above its 52-week maximum in 12% of all option-weeks and below its 52-week minimum in only 3% of all option-weeks. This asymmetry arises because we include only option-weeks where the option is in the money.

The dummy variable $MaxPrice$ is consistently significant with positive coefficients,

[29] 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. The attention hypothesis can explain our evidence if managers are predominantly contrarian.

whereas the coefficients on $MinPrice$ are always negative, as expected. The likelihood that managers exercise their options increases by 58% if their company's stock trades above its 52-week maximum and the probability of exercise decreases by 55% if the stock trades below its 52-week minimum. This finding supports the notion that managers use salient stock prices like minima and maxima to form reference points, and then exercise their options if the stock trades above or below these reference points. Alternatively, they may be contrarian and pay more attention to their stock when it breaks out of its 52-week trading range (see Huddart, Lang, and Yetman (2009) study on volume and price patters in the stock market).

We repeated our analysis with different definitions of the extreme prices, where $MinPrice$ is replaced by the 10th percentile of all prices of the past year, and $MaxPrice$ is replaced by the 90th percentile (results not tabulated). The effect on the 90th percentile is stronger than that on $MaxPrice$, while that on the 10th percentile is weaker than that on $MinPrice$, but in both cases the direction and significance of the results remain the same.

Investor sentiment. Many authors have documented the impact of investor sentiment on asset prices.[30] 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). For the purpose of our analysis we adopt the view of Lemmon and Portniaguina (2006) and use the consumer

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

confidence index as an indicator of investor sentiment. In untabulated results we also use the sentiment indicator of Baker and Wurgler (2006) and obtain very similar results; we report the results for the consumer confidence index here because it is available for our entire sample period. 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 they act like rational investors who believe that sentiment temporarily distorts stock prices. Our sample covers slightly more bullish option-weeks than bearish ones, with *Sentiment* having a median of 103.6 (mean 99.7), which is 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 11% 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; then managers exercise their stock options earlier. Conversely, managers seem to anticipate high returns when sentiment is low and then exercise later.

4.4 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.[31] We proxy for inside information by calculating buy-and-hold abnormal returns for, respec-

[31] See Carpenter and Remmers (2001), Huddart and Lang (2003), Brooks, Chance, and Brandon (2007), and Aboody, Hughes, Liu, and Su (2008). Bartov and Mohanram (2004) relate the stock price patterns around exercises to earnings management.

tively, 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 they expect negative news to materialize, then the coefficients on $BHAR2$, $BHAR13$, and $BHAR26$ should all be negative.[32]

We find that the coefficients on all buy-and-hold abnormal returns are significant and negative as predicted 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 (results not tabulated).[33] We find that the resulting coefficients are very similar for the negative and 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. The negative and the positive component of $BHAR2$ then partially cancel each other and the coefficient on $BHAR2$ in Table III.6 is accordingly much smaller than those on $BHAR13$ and $BHAR26$. Our interpretation is that managers are less likely to exercise options if disclosures are imminent, irrespective of whether they reveal good news or bad news, probably to conform with insider trading prohibitions.

[32] 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 BAHRs are weighted with a larger number of options than firm-weeks followed by positive BHARs.

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

4.5 Institutional variables and constraints

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 therefore define *Dividend* as a dummy variable, which equals one in the week before and the week of a dividend payment. We expect the coefficient on *Dividend* to be positive. The coefficients on *Dividend* are negative and small. 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 III.2); they may therefore not play a major role.[34]

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. We therefore 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 260%. This is consistent with the notion that the vesting constraint is binding. We can also observe the importance of the vesting restriction from Figure III.2, which shows that the hazard rate is unusually high immediately after the vesting date.

Black-out periods. Most firms restrict trading of insiders by imposing black-out periods where insiders are not allowed to trade. Bettis, Coles, and Lemmon (2000) show that

[34]In other specifications (not tabulated) we also included the dividend yield and the exercise boundary of the BAW-model. The dividend yield is also insignificant, and the coefficient on the BAW-boundary has the opposite (negative) sign of that implied by the dividend capture hypothesis.

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 where 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. If stock option exercises respond to trading restrictions for the company's stock, then we expect the coefficient on $BeforeAnnouncement$ to be negative and the coefficient on $AfterAnnouncement$ to be positive.

Trading restrictions because of blackout periods seem to be 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 65% below their normal rate in the baseline case. In the week after earnings announcements, exercises are 129% above their usual level. Our evidence therefore indicates that managers shift exercises from the period before earnings announcements to the period immediately after the announcement.

4.6 Control variables

Heterogeneity across individuals. We need to model the time dependence of exercise decisions as current exercise decisions may depend on past exercises (occurrence dependence). For example, managers may augment their regular income with regular option exercises or they may have different subjective costs of paying attention to their option portfolio. We therefore expect that managers who have exercised their options in many smaller tranches in the past will continue to do so and exercise more frequently and smaller fractions. We define $ExercisesLastYear$ as the number of exercises during the last 52 weeks. The coefficient on $ExercisesLastYear$ is positive as we would expect if this captures some of the heterogeneity across managers, but the effect is economically small and declines in the exercise threshold that defines the dependent variable. Hence, managers who exercised frequently last year also exercise small fractions of their grants more frequently this year.

Exercise behavior may depend on the status of the manager in the hierarchy of the firm. Since we match the IFDF data to ExecuComp, we have only data on the top five executives. We distinguish between the CEO and the other top executives and expect that CEOs are more likely to hold options for incentive reasons and to be subject to ownership guidelines compared to other managers. Also, CEOs may be subject to the illusion from control and believe the stock price to rise and therefore their stock options to be undervalued. Any of these reasons would reduce their exercise rates compared to those of other managers. We therefore include a dummy variable that equals one for CEOs. The coefficient on CEO is small and never significant, so CEOs seem to behave like other managers after controlling for the characteristics of their portfolio and in a model with random individual effects. In unreported results we also specify a model that allows for heterogeneity at the firm level and we run the model separately for CEOs and for non-CEOs to see if the impact of certain variables differs. We obtain similar results to the baseline case for both subsamples.

The variance σ_f^2 measures the variation of the random effects ν in equation (III.1) in the model and it is significant in all specifications. Individual effects are therefore important and they are only partially captured by observed past exercise behavior and cannot be related to other observed characteristics. Other observables would potentially include managers' age and their tenure on the job, but these are available only for a small subset of our sample.

Time and seasonal effects. We include $Maturity$, which is the remaining maturity of the option. Note that the baseline hazard is a function of the time since the vesting date, which is closely related. However, different option packages have different maturities, so the time since vesting does not imply the same value for $Maturity$ for all options. We also expect that managers exercise their options close to the maturity date. We define $Maturity8WeeksBefore$ as a dummy variable, which equals one in the eight weeks before the maturity of the option and zero otherwise. We expect that many managers exercise their options shortly before maturity, so the coefficient on this variable should be both positive. The coefficients on both, $Maturity$ and $Maturity8WeeksBefore$ confirm our expectation that there are more exercises close to maturity. We also inspected the estimates of the baseline hazard rate and found that it is mostly increasing in the lifetime of the option and therefore decreasing with maturity.

4.7 Overall evaluation

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.

[Insert Table III.7 about here]

In Table III.7 we proceed as follows. Our baseline specification is again model (2) in Table III.6. We then remove individual variables or groups of variables and perform a likelihood ratio test. The LR-test statistics in column (1) in Table III.7 test for the joint significance for each group of variables in the table. For example, the test for "Utility" is for the joint exclusion of all variables suggested by utility theory, and the test for "$Volatility$" is for the exclusion of $Volatility$ from the baseline model. Under the null hypothesis, the likelihood ratios are distributed Chi-square and column (2) reports the relevant cut-off values for the 1% significance level.

The quantitative importance of the variables suggested by **utility theory** is very large, but attributable almost entirely to $TimeValue$. Moreover, the predictions on $TimeValue$ are not specific to utility theory. In fact, any explanatory approach we consider above implies a trade-off between the costs and benefits of early exercise. Independently of whether exercises are motivated by the desire to diversify, behavioral reasons, or inside information, we would always expect that managers pay attention to the opportunity costs of exercising their stock options early and hence to the time value of their options. The prediction regarding $Volatility$ is specific to utility theory, but has much less explanatory power. Overall, our findings for utility theory are mixed and contradict some implications of the theory, but support others. We conclude that the motive to diversify has some, although only moderate explanatory power, but that this motive is poorly captured by conventional utility theory. In the Conclusion we speculate that alternative models of attitudes to risk may reconcile these findings.

The explanatory power of the **option portfolio effects** is very large. These effects have been neglected in previous studies, but they are empirically of first-order importance. The **behavioral** variables also have significant explanatory power, although it is much lower than those of $TimeValue$, option portfolio variables, or institutional variables. It is attributable almost entirely to variables related to past stock returns. By contrast, *Sentiment*, while highly significant, explains comparatively less of the variation in exercise behavior. Variables related to **asymmetric information** are significant at all conventional significance levels, but are quantitatively less important than those associated with any of the other explanatory approaches. Finally, the variables representing institutional constraints are jointly of first-order importance.

5 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 also discuss some robustness checks that we performed but do not tabulate here to conserve space.

5.1 Research design

Include only first exercises. Managers exercise their stock options in fractions over time. It is therefore 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 $FranctionLeft$ and $ExercisesLastYear$, but these variables may not adequately account for time dependence. In column (1) of Table III.8 we estimate a model where we include only the first exercise of each option package to avoid potential distortions from the time dependence of sequential exercises. Here we include all exercises and not only those above a certain threshold in order to make sure that we always capture the first exercise for each package and not only the first economically significant exercise.[35] Coefficient estimates and significance levels for this robustness check are very similar to

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

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, 12% 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 III.8 we rerun our baseline regression on this complementary sample, which includes only observations not associated with stock sales.[36] 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 $Return52$ both change signs. This finding is consistent with the interpretation given in Section 4.3 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. So, after a short-term upward trend, which managers expect to revert, there is a lower probability to exercise and hold and after a long-term upward trend, which they expect to continue, there is a higher probability to exercise and hold.

Interestingly, the coefficient on $MinPrice$ changes signs and the effect is economically very large: Executives are 107% 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

[36]Veenman, Hodgson, van Praag, and Zhang (2008) compare abnormal stock returns following exercises where stock is sold with exercises where 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 where shares are sold indicate bad news, whereas exercises where shares are held indicate good news.

lower capital gains tax rate. The result is a V-shaped price pattern, where the minimum price is reached on the exercise date. Of course, as in the exercise-and-sell sample, this finding may also indicate a contrarian belief so that executives are more likely to exercise and then hold the stock when the price is at a one-year low.

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 III.8 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 17%. 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 $ISVolatility$ (results not tabulated). Our results on $Correlation$ are therefore robust.

5.2 Specification issues

[Insert Table III.9 about here.]

Clustered robust standard errors. Another important issue for our estimation procedure is cross-grant correlation (see also Carpenter, Stanton, and Wallace, 2008a), which may occur because the 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 III.9 we estimate a model with clustered standard errors at the manager level instead of unobserved heterogeneity.

The results are largely the same as in the baseline case except for three variables. The coefficient on $Volatility$ now suggests that the impact on option value is actually stronger than the diversification effect. The coefficient on $PortfolioSize$ remains negative, but becomes much larger in absolute value, and the effect of CEO, which was insignificant before, is now significant and negative, suggesting that CEOs exercise options later than other managers. We obtain the same results if we cluster standard errors at the firm level rather than at the manager level (not tabulated). It seems that these three variables now pick up some of the unobserved heterogeneity since $PortfolioSize$ and CEO pick up individual effects and $Volatility$ picks up firm effects. If this interpretation is correct, the results for the baseline regression with unobserved heterogeneity are more reliable because otherwise the coefficients on firm-specific or individual-specific variables are biased as they capture unobservable individual effects.

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, but the standard errors become larger as expected. Some variables drop in significance below the 5%-level, notably $Return156$, and $BHAR2$. None of our main conclusions is affected if these variables are insignificant.

Inverse Gaussian distribution. The baseline model uses a gamma distribution to model the random effect ν in equation (III.1). In column (3) we show an alternative specification with an inverse Gaussian distribution, another distribution often applied to mixture models. The results are virtually identical with those in the baseline model.

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 (4) of Table III.9 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.

6 Conclusion

We analyze managers' decision to exercise stock options using hazard analysis and compare the explanatory power of different approaches to analyzing exercise behavior. *Utility theory* has significant explanatory power, but the results are mixed. Managers exercise later if the option has a high time value, which indicates that they rationally take into account opportunity costs. Also, the positive impact of volatility on early exercise is consistent with the predictions of utility theory. On the other hand, if the stock is more correlated with the stock market index, then managers consistently exercise their options earlier rather than later, contrary to what utility theory would predict. We argue above that the findings on the time value of the option are not specific to utility theory because any motive for early exercise has to take into account the opportunity costs of exercising early. The findings on correlation are consistent with the view that managers wish to combine a diversified portfolio with some undiversified holdings that have a chance of high positive returns. This observation coincides with the predictions of theories based on rank-dependent preferences, but it is unclear why a managers' own firms' securities would be particular suitable for such a portfolio. More work is needed to understand exercise patterns and the simultaneous significance of variables that indicate a desire to diversify and those that indicate the opposite.

Option portfolio effects are important and differ somewhat with respect to fractional exercises of small parts of option grants and exercises of large parts. Managers' choices when selecting an option from a portfolio of multiple options are optimal or close to optimal in the large majority of cases. Managers seem to maintain their option portfolios at some target level and exercise options when new options are granted. Selections of options from multiple-option portfolios tend to be rational and only a small number of exercises reflects larger mistakes. Overall, the composition of the option portfolio and its change through new option grants is of first-order importance.

Several *behavioral hypotheses* have significant explanatory power, although it is lower than that of the time value of the option or of option portfolio effects. We show evidence that is consistent with managers believing in mean reversion and evidence consistent with reference-level behavior. However, while these behavioral biases play a role, managers seem to see through investor sentiment.

We find evidence for exercising based on *asymmetric information* consistent with the previous literature, but this approach to exercise behavior has much less explanatory power than any of the other approaches. Some *institutional factors* like blackout periods or vesting periods are important and have a first-order effect on exercise behavior. We also find that exercise decisions vary greatly across managers for reasons that we cannot fully capture with our variables. Some managers seem to exercise their stock options in a small number of large exercises, whereas others seem to exercise in small fractions, but more frequently.

Several authors have suggested exogenous shocks as an additional explanation for the early exercise of stock options, for example when managers make major consumption decisions or when they leave the firm. We believe that these factors also have an impact, but we do not have data that would allow us to investigate them in a large sample.[37]

Finally, we address the rationality of managers' stock option exercises. Poteshman and Serbin (2003) interpret their results for behavioral biases as evidence for irrationality, but their setting is exchange traded options and does therefore not carry over to non-tradable options held by executives. Managers' choices from their option portfolios are mostly optimal. Similarly, reference dependence can be reconciled with loss aversion and indicates that choices may be the outcome of preferences other than those used in standard utility models. The same interpretation would also apply to the findings on correlation if our interpretation of that effect is correct. Importantly, managers seem to rationally take advantage of prices that are distorted by investor sentiment. Overall, we find some evidence that managers are subject to behavioral biases, but conclude that there is little evidence for irrationality.

[37]Liu and Yermack (2007) hand collect data on CEO's home purchases, which may represent the most important source of liquidity needs for CEOs. Their data cover only a very small part of our data set.

Tables

Table III.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	2,110,570	255,065	135,355	12,800
Observations lost because of:				
Missing compensation data	1,796,164	187,527	118,667	10,546
No stock price information	15,282	2,034	830	159
Options never exerciseable	97,924	21,037	2,252	99
Exercise restrictions	564	17,148	18	2
Final sample	200,636	27,319	13,588	1,994

Table III.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)	198,548	0.71	20.88	0.02	0.07	0.31
Time to maturity (years)	200,636	7.39	2.00	6.35	7.96	8.98
Stock price/Strike price	200,038	10.37	1,689.63	1.01	1.28	1.81
Volatility	198,548	0.40	0.20	0.26	0.36	0.49
Dividend yield (%)	200,636	0.92	1.80	0.00	0.00	1.37
Interest rate (%)	200,636	4.45	0.89	3.92	4.41	4.89

Table III.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. 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	2,286	1.1
Expired out of the money	17,138	8.5
Holder left firm	22,985	11.5
Alive in Dec. 2008	128,378	64.0
Other Disposal	8,526	4.2
No censoring	21,323	10.6
Total	200,636	100.0

Table III.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
Utility theory		
$Correlation$	52 weeks correlation of stock returns with returns on the CRSP value weighted index	CRSP
$Volatility$	Annualized volatility of stock returns (52 weeks)	CRSP
$TimeValue$	Ratio of time value to option value (using BAW values)	IFDF
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
PortfolioSize	Number of other exerciseable option packages	IFDF
PackageSize	Value of current option package / portfolio value	IFDF
FractionLeft	Fraction of the option package that is still left	IFDF
LowestTV	1 for the option package with the lowest ratio of time value to inner value if at least one other exercisable package has a strictly higher ratio of time value to inner value, zero otherwise	IFDF
Behavioral explanations		
*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
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

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
Asymmetric information		
$BHAR2, BAHR13, BAHR26$	Buy and hold abnormal return in the following 2 / 13 / 26 weeks; Expected returns result from a regression of stock returns on the CRSP value weighted index using a 52 weeks estimation window	CRSP
Institutional variables		
Dividend	1 in the week before a dividend payment date if available, zero otherwise	CRSP
$VestingWeek$	1 in the week of and in the week after vesting, zero otherwise	IFDF
$BeforeAnnouncement$	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
Control variables		
$ExercisesLastYear$	Number of economically meaningfull exercises during the last year	IFDF
CEO	1 if option holder is chief executive officer of the issuer, zero otherwise	IFDF
$Maturity$	Time to maturity in years	IFDF
$Mat8WeeksBefore$	1 in the last 8 weeks before maturity	IFDF

Table III.5: **Descriptive statistics on option packages.** The table contains information on all variables in the baseline specification based on observations for 25,803,443 option package-weeks. See Table III.4 for all variable definitions.

	Mean	Std. Dev	Min.	First Quartile	Median	Third Quartile	Max.
Utility theory							
$Correlation$	0.47	0.17	-0.53	0.37	0.49	0.59	0.96
$Volatility$	0.35	0.16	0.05	0.24	0.32	0.42	3.23
$TimeValue$	0.28	0.27	0.00	0.05	0.19	0.44	1.00
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
$PortfolioSize$	41.39	67.93	0.00	6.00	13.00	46.00	558.00
$PackageSize$	0.04	0.09	0.00	0.00	0.01	0.05	1.00
$FractionLeft$	0.97	0.11	0.25	1.00	1.00	1.00	1.00
$LowestTV$	0.23	0.42	0.00	0.00	0.00	0.00	1.00
Behavioral explanations							
$Return13$	0.05	0.19	-0.84	-0.06	0.04	0.14	10.48
$Return26$	0.10	0.29	-0.93	-0.06	0.07	0.21	10.92
$Return52$	0.22	0.54	-0.96	-0.04	0.14	0.36	38.10
$Return156$	0.85	1.94	-1.00	0.12	0.47	1.06	151.71
$MaxPrice$	0.12	0.33	0.00	0.00	0.00	0.00	1.00
$MinPrice$	0.03	0.18	0.00	0.00	0.00	0.00	1.00
$Sentiment$	99.70	16.98	51.00	92.50	103.60	107.50	144.70
Asymmetric information							
$BHAR2$	-0.00	0.07	-0.84	-0.04	-0.00	0.03	2.02
$BHAR13$	-0.02	0.19	-2.60	-0.12	-0.02	0.08	10.17
$BHAR26$	-0.05	0.32	-7.40	-0.21	-0.04	0.11	10.34
Institutional variables							
$Dividend$	0.07	0.26	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
$BeforeAnnouncement$	0.06	0.24	0.00	0.00	0.00	0.00	1.00
$AfterAnnouncement$	0.18	0.38	0.00	0.00	0.00	0.00	1.00
Control variables							
$ExercisesLastYear$	0.71	2.18	0.00	0.00	0.00	0.00	51.00
CEO	0.16	0.36	0.00	0.00	0.00	0.00	1.00
$Maturity$	4.88	2.31	0.00	3.00	5.00	7.00	41.00
$Mat8WeeksBefore$	0.00	0.07	0.00	0.00	0.00	0.00	1.00

Table III.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: 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).

	10%	25%	50%	100%
Utility theory				
$Correlation$	0.03 ***	0.03 ***	0.03 ***	0.03 ***
$Volatility$	0.01	0.02 *	0.03 **	0.03 **
$TimeValue$	-0.58 ***	-0.58 ***	-0.59 ***	-0.60 ***
Option portfolio effects				
$GrantWeekBefore$	-0.30 ***	-0.32 ***	-0.34 ***	-0.38 ***
$GrantWeekAfter$	3.15 ***	3.39 ***	3.65 ***	3.97 ***
$PortfolioSize$	-0.25 ***	-0.31 ***	-0.36 ***	-0.57 ***
$PackageSize$	-0.07 ***	-0.16 ***	-0.27 ***	-0.33 ***
$FractionLeft$	-0.02 ***	0.06 ***	0.18 ***	
$LowestTV$	-0.03 **	-0.03 **	-0.02	0.01
Behavioral explanations				
$Return13$	0.12 ***	0.12 ***	0.12 ***	0.12 ***
$Return26$	0.07 ***	0.08 ***	0.07 ***	0.07 ***
$Return52$	-0.02 ***	-0.03 ***	-0.03 ***	-0.04 ***
$Return156$	0.01 **	0.01 **	0.01	0.00
$MaxPrice$	0.58 ***	0.58 ***	0.58 ***	0.57 ***
$MinPrice$	-0.53 ***	-0.55 ***	-0.56 ***	-0.54 ***
$Sentiment$	0.09 ***	0.11 ***	0.13 ***	0.14 ***
Asymmetric information				
$BHAR2$	-0.01 **	-0.01 **	-0.02 ***	-0.02 ***
$BHAR13$	-0.08 ***	-0.09 ***	-0.09 ***	-0.11 ***
$BHAR26$	-0.04 ***	-0.04 ***	-0.05 ***	-0.04 ***
Institutional variables				
$Dividend$	-0.01	-0.01	-0.02	-0.02
$VestingWeek$	2.65 ***	2.60 ***	2.61 ***	2.48 ***
$BeforeAnnouncement$	-0.66 ***	-0.65 ***	-0.64 ***	-0.59 ***
$AfterAnnouncement$	1.25 ***	1.29 ***	1.29 ***	1.28 ***
Control variables				
$ExercisesLastYear$	0.07 ***	0.04 ***	0.03 ***	0.02 ***
CEO	0.06 **	0.03	0.01	-0.02
$Maturity$	-0.07 ***	-0.08 ***	-0.11 ***	-0.14 ***
$Mat8WeeksBefore$	2.70 ***	2.82 ***	2.93 ***	3.28 ***
σ_f^2	2.05 ***	2.22 ***	2.42 ***	2.86 ***
Obs.	25,946,489	25,803,443	25,437,603	23,661,781

Table III.7: **Likelihood-ratio tests for groups of variables.** The table presents variations of regression (2) in Table III.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
Utility theory	9,225	13.28
$Correlation$	29	6.63
$TimeValue$	9,035	6.63
$Volatility$	20	9.21
Option portfolio effects	6,600	16.81
$GrantWeekBefore$, $GrantWeekAfter$	5,885	9.21
$PortfolioSize$, $PackageSize$, $FractionLeft$, $LowestTV$	664	13.28
Behavioral explanations	2,542	18.48
$Return13$, $Return26$, $Return52$, $Return156$	730	13.28
$MaxPrice$, $MinPrice$	777	9.21
$Sentiment$	81	6.63
Asymmetric information	303	11.34
Institutional variables	7,002	13.28
$VestingWeek$	1,448	6.63

Table III.8: **Research design.** The table presents variations of regression (2) in Table III.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)
Utility theory			
Correlation	0.04 ***	0.08 ***	
Volatility	0.03 **	0.20 ***	0.21 ***
TimeValue	-0.59 ***	-0.61 ***	-0.58 ***
ISVolatility			-0.17 ***
Option portfolio effects			
GrantWeekBefore	-0.34 ***	0.06	-0.32 ***
GrantWeekAfter	3.45 ***	1.16 ***	3.39 ***
PortfolioSize	-0.34 ***	-0.35 ***	-0.31 ***
PackageSize	-0.16 ***	-0.17 ***	-0.16 ***
FractionLeft		0.15 ***	0.06 ***
LowestTV	-0.02	0.10 ***	-0.03 **
Behavioral explanations			
*Return*13	0.12 ***	0.03 *	0.12 ***
*Return*26	0.07 ***	-0.05 **	0.08 ***
*Return*52	-0.03 ***	0.06 ***	-0.03 ***
*Return*156	0.01 **	0.04 ***	0.01 **
MaxPrice	0.56 ***	0.20 ***	0.58 ***
MinPrice	-0.54 ***	1.07 ***	-0.55 ***
Sentiment	0.12 ***	0.02	0.11 ***
Asymmetric information			
*BHAR*2	-0.02 **	0.04 ***	-0.01 **
*BHAR*13	-0.09 ***	-0.00	-0.09 ***
*BHAR*26	-0.04 ***	0.02	-0.04 ***
Institutional variables			
Dividend	-0.01	0.10 *	-0.01
VestingWeek	2.54 ***	5.57 ***	2.60 ***
BeforeAnnouncement	-0.65 ***	-0.41 ***	-0.65 ***
AfterAnnouncement	1.30 ***	0.61 ***	1.29 ***
Control variables			
ExercisesLastYear	0.04 ***	0.01	0.04 ***
CEO	0.02	0.11	0.03
Maturity	-0.09 ***	-0.15 ***	-0.08 ***
Mat8WeeksBefore	2.86 ***	8.94 ***	2.82 ***
σ_f^2	2.34 ***	5.65 ***	2.22 ***
Obs.	24,871,452	25,781,798	25,803,443

Table III.9: **Specification issues.** The table presents variations of regression (2) in Table III.6. Model (1) uses clustered robust standard errors at the individual level rather than unobserved heterogeneity; (2) uses bootstrapped standard errors; (3) uses an inverse Gaussian frailty distribution; (4) is the Weibull model.

	(1)	(2)	(3)	(4)
Utility theory				
Correlation	0.02	0.03 **	0.04 ***	0.03 ***
Volatility	-0.08 ***	0.02	-0.00	0.02
TimeValue	-0.49 ***	-0.58 ***	-0.59 ***	-0.60 ***
Option portfolio effects				
GrantWeekBefore	-0.29 ***	-0.32 ***	-0.32 ***	-0.33 ***
GrantWeekAfter	3.52 ***	3.39 ***	3.43 ***	3.41 ***
PortfolioSize	-0.67 ***	-0.31 ***	-0.36 ***	-0.35 ***
PackageSize	-0.07 ***	-0.16 ***	-0.17 ***	-0.15 ***
FractionLeft	-0.05 ***	0.06 ***	0.06 ***	0.05 ***
LowestTV	-0.02	-0.03	-0.05 ***	-0.03 **
Behavioral explanations				
Return13	0.09 ***	0.12 ***	0.11 ***	0.12 ***
Return26	0.07 ***	0.08 ***	0.08 ***	0.08 ***
Return52	-0.04 ***	-0.03 ***	-0.03 ***	-0.03 ***
Return156	0.00	0.01	0.01 *	0.01 *
MaxPrice	0.69 ***	0.58 ***	0.59 ***	0.54 ***
MinPrice	-0.63 ***	-0.55 ***	-0.55 ***	-0.55 ***
Sentiment	0.09 ***	0.11 ***	0.10 ***	0.09 ***
Asymmetric information				
BHAR2	-0.01	-0.01	-0.01 **	-0.01 **
BHAR13	-0.09 ***	-0.09 ***	-0.09 ***	-0.09 ***
BHAR26	-0.05 ***	-0.04 **	-0.04 ***	-0.04 ***
Institutional variables				
Dividend	-0.00	-0.01	-0.00	0.00
VestingWeek	2.61 ***	2.60 ***	2.59 ***	4.45 ***
BeforeAnnouncement	-0.66 ***	-0.65 ***	-0.65 ***	-0.66 ***
AfterAnnouncement	1.27 ***	1.29 ***	1.29 ***	1.24 ***
Control variables				
ExercisesLastYear	0.16 ***	0.04 ***	0.05 ***	0.04 ***
CEO	-0.18 ***	0.03	0.06 **	0.03
Maturity	-0.09 ***	-0.08 ***	-0.09 ***	-0.09 ***
Mat8WeeksBefore	3.05 ***	2.82 ***	2.81 ***	3.01 ***
σ_f^2		2.22 **	5.17 ***	2.19 ***
Obs.	25,803,443	25,803,443	25,803,443	25,457,502

Chapter IV

Fractional Exercises of Executive Stock Options

1 Introduction

In this paper I consider the problem of finding the optimal exercise policy for an executive stock option (ESO) package that consists of separately exercisable options.[1] The early exercise policy of American options is a crucial factor for valuation and subject of a large theoretical literature. Fractional exercise has thus a potential impact on valuation and on the ability of ESOs to incentivize executive by exposing them to stock price risk. These effects are especially important for issuer firms that need early exercise-adjusted ESO values for accounting purposes. In addition, firms granting ESOs as an incentive device need to know the ability of ESOs to provide incentives when they decide about the magnitude of options granted.

There is empirical evidence that ESOs are exercised before maturity even if the under-

[1]I am grateful to Ernst Maug, David Yermack, Christian Schlag, Tim Adam, Martin Widdicks as well as to seminar participants at the Workshop on Corporate Governance and Executive Compensation (Mannheim) and the DGF Doctoral Workshop (Frankfurt) for helpful comments and discussions. I thank the collaborative research centers SFB 649 on "Economic Risk" in Berlin and the SFB 504 "Rationality Concepts, Decision Making and Economic Modeling" in Mannheim for financial support.

lying stock does not pay dividends and that ESO packages are often exercised in fractions.[2] Analyzing data on executive stock option early exercises in the last decade, I find that 47.7% of ESO early exercises are fractional exercises and 34.8% of all exercised ESO packages are subject to fractional exercise. Hereby, executives favor fraction sizes that are multiples of 20%, 25%, and 33%.[3]

The objective of this paper is to investigate the implications of fractional exercise on the valuation and the incentive effects of ESOs and to find out which firms and which managers are mostly affected by fractional exercise. I develop a model with constant relative risk aversion (CRRA) utility to price executive stock options in a non-recombining binomial tree setting. The risk averse and trade constrained executive exercises a fraction of her ESO package and sells all acquired shares accordingly if the additional utility from diversification exceeds the disutility from sacrificing the option's time value. The exercise of one option makes the overall portfolio less risky decreasing the marginal utility of diversification from another option exercise. It may thus happen that only a fraction of the option package (some options) is exercised early at a point in time.

This paper considers an executive who can exercise discrete fractions to maximize the utility at the ESOs maturity. I infer the exercise policy using a dynamic programming approach, which is able to cope with the interdependence of fractional exercises.[4] Interdependence of fractional exercises arises for two reasons. First, past fractional exercises

[2]Huddart and Lang (1996) find that option packages are exercised most common in fraction sizes of 25%, 50%, 75% and 100%. Also Sautner and Weber (2009) report that employees exercise options in few large transactions.

[3]Empirical papers that estimate the fraction of the option package to be exercised so far do not take this clustering into account. Huddart and Lang (1996) estimate the number of options to be exercised as a fraction of the initially granted number of options using a Tobit model. Carpenter, Stanton, and Wallace (2008b) estimate the number of options to be exercised as a fraction of all still unexercised options using a logistic transformation of this fraction as dependent variable. Other empirical papers that report the existence of fractional exercise are among others Heath, Huddart, and Lang (1999), Hallock and Olson (2006), Armstrong, Jagolinzer, and Larcker (2007), and Klein and Maug (2010).

[4]Moving backwards in the tree, I infer the optimal exercise fraction now for each possible exercise history. For all but the first iteration of this procedure (at maturity of the option), the optimal exercise policy reaction in the future is taken from the preceding iteration.

have an impact on the current wealth position and the relative exposure to stock price risk. This again influences the future exercise policy. Second, the decision upon exercise is determined by weighing the expected utility of exercise against the expected utility of no exercise, both of which are affected by the future exercise policy. So the current exercise decision depends also on the future exercise policy. The interdependence of exercise decisions makes an ESO in this setting a strongly path dependent claim. This means that the ESO value at any point in time and at any stock price does not solely depend on these state variables but on the whole stock price history since the grant date. My model allows for vesting periods and exogenous stopping states (executive turnover or liquidity driven exercises) that trigger exercise or forfeiture.

The exercise policy is an outcome of an incomplete market problem since managers are not allowed to sell or hedge ESOs mostly due to short selling constraints in the stock. Most of the theoretical literature on ESO valuation implicitly assumes that all options of an ESO package are exercised completely.[5] The idea for a single exercise boundary stems from the valuation of market traded American options. Here, the exercise policy maximizes the expected payoff in the future (under the risk-neutral measure). Thus, if it is optimal to exercise one option it is also optimal to exercise all other options with the same characteristics. As outlined above, this does not have to hold for ESOs held by trade constrained and risk averse executives.

Regarding ESO values, I identify two opposing effects of fractional exercise on the objective ESO value (cost to the firm). The first fractions are exercised at lower stock prices than in a complete exercise model, because the holder has to sacrifice less time value in exchange for a more diversified portfolio. Later fractions are exercised at higher

[5]Early papers in this literature are Jennergren and Näslund (1993), Huddart (1994), and Kulatilaka and Marcus (1994). Later models can be found in Carpenter (1998) and Bettis, Bizjak, and Lemmon (2005).

stock prices because past fractional exercises lower the need to diversify. Also empirically, subsequently exercised fractions are exercised at higher stock prices than the first exercised fraction - a pattern that is characteristic for a diversification motivation and that cannot be explained by other motivations such as liquidity needs.

The fractional exercise model predicts substantially higher objective values for highly volatile underlying stock and for executives with relatively high exposure to stock price risk compared to the corresponding complete exercise model. Options holders benefit more from fractional exercise for higher stock return volatility. This explains my empirical findings for executives in the ExecuComp database that fractional exercise becomes more likely and fraction sizes decrease as volatility increases. In the presence of transaction costs, at some point the benefits from fractional exercise outweight additional transaction costs and option holders switch from complete exercise to fractional exercise. Furthermore, the fractional exercise model predicts incentives that are substantially higher and more persistent over time than the complete exercise model.[6] Thus complete exercise models potentially overestimate the costs of incentives provided by ESOs.

The complete theoretical literature on fractional exercise relies on utility theory and focuses on subjective values (value of the ESO to the employee) and objective values of option packages. The most common utility function in this literature is CARA utility.[7] For CARA utility the early exercise policy is independent of wealth and thus indepen-

[6]Assume that the executive exercises half of her option package. After having exercised the first half of the package and being more diversified now, the remaining half of the option package is still worth more to the executive than half the personal value of the whole package. The remaining half thus also provides more than half of the incentives of the whole package before.

[7]Grasselli (2008) uses a discrete time setting with discrete fractions of the option package. Grasselli and Henderson (2009) and Rogers and Scheinkman (2007) use a continuous time framework and also discretize the size of the fraction to be exercised. Using CARA utility, they show that the threshold level of a fraction of the option package increases in the number of fractions already exercised. Grasselli and Henderson (2009) consider an option package with infinite maturity and analyze among other things the optimal fraction to be exercised at a time for an exogenously given maximum number of early exercises over the option package's lifetime. Henderson and Hobson (2007) use the same framework and solve for an exercise policy where fractions of the option package are exercised continuously as the stock price increases.

dent of the fractional exercise history. The value of the option package and the exercise policy depend only on the current state variables stock price, time to maturity and the unexercised fraction of the option package (weak path dependence). Jain and Subramanian (2004) use a time additive CRRA utility function that triggers fractional exercise more as a result of consumption smoothing rather than diversification. To the best of my knowledge only Murphy (2007) uses a model with CRRA utility at maturity of the option package to estimate costs for the firm. He uses an approximate dynamic programming technique that samples from a Monte Carlo simulation and provides results for the case in which non-option wealth can be invested in bonds only.

Section 2 describes the complete exercise model, extends it to the case of fractional exercise, and explains the dynamic programming approach. Section 3 discusses results and provides comparative statics. Section 4 analyzes fractional exercise behavior empirically and tests implications of the model. Section 5 concludes.

2 The model

My base model is the model of Bettis, Bizjak, and Lemmon (2005) that bases on earlier work of Carpenter (1998) and Huddart (1994). The model uses a binomial tree setting and only allows for complete exercise. Like most other models in this area, it abstracts from dilution effects through the issue of new shares after ESOs exercise, strategical exercise induced by reload agreements, or interim changes in the option characteristics by repricings. I stick to those simplifying assumptions also in my extended framework, in which I allow for fractional exercise.

2.1 Base model

The executive owns one ESO and has a utility function with constant relative risk aversion (CRRA) of the following form.

$$U(W_T) = \begin{cases} \frac{W_T^{1-\gamma}-1}{1-\gamma} & \text{for} \quad \gamma \neq 1 \\ \ln W_T & \text{for} \quad \gamma = 1 \end{cases} \tag{IV.1}$$

W_T is total wealth at the option package's maturity at time T. The executive can trade in the underlying stock and in the money market account. The issuer firm's stock has an expected annual return μ and a return volatility σ for given incentives of the option package. The money market account has an annual risk free return r.

There are two sources of ESO early exercise. First, the executive has a probability of turnover with constant annual intensity θ. When the executive leaves the firm, she has the opportunity to exercise the option package immediately, otherwise the option package forfeits. Unvested option packages forfeit in any case.[8] The second source is voluntary early exercise. The option holder chooses the exercise policy for the option package and the investment policy for the initially owned funds to maximize her utility at time T. Initial wealth and proceeds from early exercise are invested in a portfolio consisting of shares and the money market account. The resulting optimal exercise policy X^* and the investment policy I^* can be described as follows.

$$(X^*, I^*) = \underset{X,I}{argmax} \left\{ EU(W_T) | X, I \right\} \tag{IV.2}$$

In this general specification the optimal exercise policy and the optimal investment

[8] Usually insiders have to exercise their ESOs within a certain period of time after they leave the firm, otherwise their ESOs forfeit. Dahiya and Yermack (2008) show that the exact regulations also depend on why a manager left the firm.

policy would have to be inferred simultaneously. To simplify the problem of finding the optimal exercise policy and at the same time to avoid continuous hedging of the option package the model of Carpenter (1998) blinds out the problem of finding the optimal investment policy and assumes that initial non-option wealth W_0 and proceeds from early exercise are invested into a Merton portfolio (Merton, 1971) that consists of positions in the stock and in the money market account.[9] The executive chooses her optimal share α of non-option wealth invested in the stock irrespective of the option package. The remaining non-option wealth is invested in the money market account. For CRRA, α is independent of W_t and constant over time.[10] The optimal investment policy with constant investment weights $\bar{I}$ is now independent of the exercise policy. The optimal exercise policy can thus be described as follows.

$$X^* = \underset{X}{argmax} \left\{ EU(W_T) | X, \bar{I} \right\}, \tag{IV.3}$$

Note that α is not utility optimal as long as the executive holds the ESO. Usually, the executive would hold a lower share of wealth invested in the stock to dynamically hedge the option subject to her short selling constraint. However, the models of Carpenter (1998) and Bettis, Bizjak, and Lemmon (2005) want to concentrate basically on the exercise policy and keep other issues simple while still allowing for the investment in risky securities apart from the option. A constant α has the convenient property that the dynamics of non-option wealth are path independent. In addition, the above setup ensures that the subjective option value for an underdiversified executive is strictly below

[9] Some papers in the literature forbid trading in the underlying stock but allow non-option investments in the market portfolio which leads to a partial hedge of the option package. Cai and Vijh (2005), Henderson (2005), and Carpenter, Stanton, and Wallace (2008b) show for complete exercise that the objective value of the option package increases in the correlation between stock and market returns because a higher correlation (lower idiosyncratic risk) improves the performance of the partial hedge. Grasselli (2008) and Grasselli and Henderson (2009) allow for fractional exercise and investments in the market portfolio but use CARA utility, which eases determination of the exercise policy.

[10] See Appendix A.2 for the derivation of α in a binomial tree setting.

the market value of the option (for a diversified investor). In the model, the firm's stock is the only risky investment opportunity. As the executive chooses the investment weights herself, the investment in the firm's stock should be interpreted as an investment in the market portfolio that has nothing to do with compensation or the firm's motive to incentivize the executive.

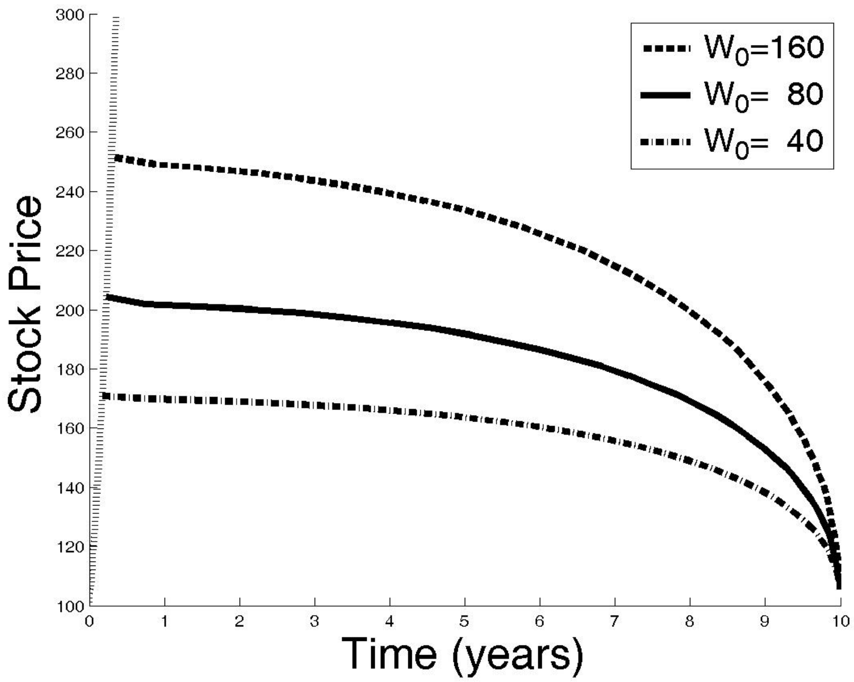
Exercise policies for the ESO package are inferred from a binomial tree model, where the holder exercises the option package if the expected utility from exercise exceeds the expected utility from further holding the option package. In this base model, the exercise policy can be inferred by backward deduction. The expected utility from further holding the option package is then a probability weighted average of the expected utility of having the option package in the next instant of time and the expected utility of exercising the option package or letting it forfeit because of executive turnover. I use a continuously compounded annual interest rate $r = .04$, a statistical drift rate $\mu = .08$, an initial stock price $S_0 = 100$, and an instantaneous return volatility $\sigma = 0.3$. The option package has a strike price equal to the stock price at the grant date $K = S_0 = 100$, a maturity of $T = 10$ years, and no vesting period. The ESO holder faces a turnover rate of $\theta = 0.03$, has risk aversion $\gamma = 2$, and initial non-option wealth $W_0 = 80$. The estimate of the termination rate is based on Bettis, Bizjak, and Lemmon (2005). I choose the value for non-option wealth W_0 to match the representative CEO in Dittmann and Maug (2007). They use ExecuComp data for the years 1992-2000 and find an about 1:2 relation between (early exercise adjusted) option wealth and non-option wealth for their representative CEO. They also find that executives hold a significant amount of restricted stock. However, I simply count the value of restricted stock holdings to non-option wealth and keep the stock as freely chosen investment opportunity. With a Black-Scholes option value of

40.87, I choose the base value of initial non-option wealth $W_0 = 80$.[11] According to the assumptions on the investment portfolio, $\alpha = 22.5\%$ of the non-option wealth is invested in the stock and $1 - \alpha$ in the money market account. Remember that investment weights depend solely on the dynamics of available securities and the degree of risk aversion.

The higher the stock price is the higher is the exposure to stock price risk because of the asymmetric payout structure of the option. The potential benefits from diversification thus increase in the stock price. Conversely, the time value of the option package decreases in the stock price. If the stock price is high enough the benefits from diversification outweigh the sacrifice of time value and the option package is exercised. Figure IV.1 shows exercise boundaries for different values of initial wealth for a step size $h = \frac{1}{104}$ years. The nodes in the binomial tree that are at or above the boundary represent combinations of stock price and time to maturity, for which complete exercise is preferred over further holding the option package. The dots at the left side represent the highest reachable stock prices in the tree. Intuitively, the exercise boundaries are declining in time because the loss in time value through exercise becomes lower the closer the option package gets to maturity. Figure IV.1 also shows that the exercise boundary shifts upward as initial non-option wealth increases. With higher (lower) initial (non-option) wealth the portfolio as a whole has a relatively lower (higher) exposure to stock price risk and the CRRA investor exercises at a higher (lower) stock price level. If a vesting period is introduced, during which early exercise is not possible, the exercise boundary during the vesting period disappears but the exercise boundary after the vesting period remains unchanged, because the exercise policy in the base model is path independent. This changes, when I extend the framework for the additional possibility of fractional exercise.

[11] ExecuComp takes all times to maturity times .7 to account for the value impacts of early exercise. The Black-Scholes value of a ten(seven) year option is 49.38(40.87).

Figure IV.1: **Exercise boundaries for different levels of wealth** with $T = 10$ years, $r = .04$, $\mu = .08$, $\sigma = .3$, $K = S_0 = 100$, $\theta = 0.03$, $\gamma = 2$; $h = \frac{1}{104}$

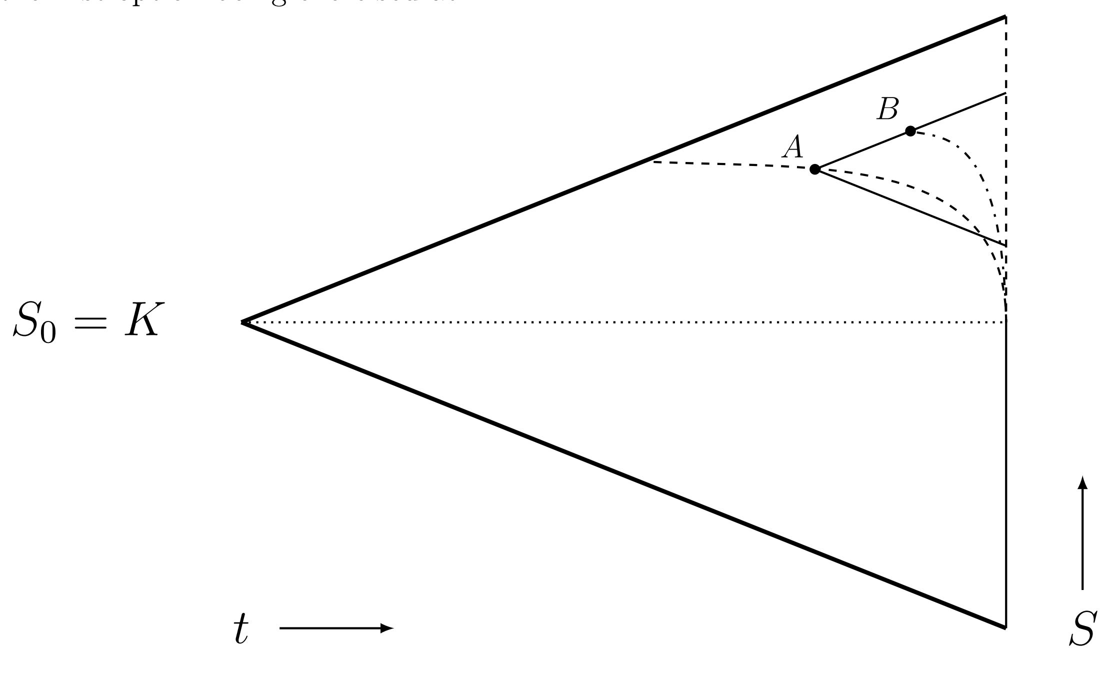


2.2 Fractional exercise

The executive is now able to exercise a fraction of her option package and keep the rest of it. The initially granted option package consists of a predefined number of equal options that are themselves indivisible. At each point in time the investor can exercise a number of options that reaches from 0 to the number of still unexercised options. Without loss of generality I normalize the number of shares underlying the initially granted option package to one. For an option package with initially four options one option corresponds to a fraction of 25% of the option package and has 0.25 underlying shares. At one point in time the option holder could thus exercise one, two, three, or four options corresponding to fractions of 25%, 50%, 75% and 100%. The assumed fraction sizes are supported by the empirical findings in Section 4.

Figure IV.2 sketches the exercise policy for an ESO package with two indivisible options in a binomial tree model. The big triangle bounds the binomial tree setting in which time emerges in the horizontal axis while the stock price emerges in the vertical axis. The option package is granted at the money ($S_0 = K$). Hence, the dotted horizontal line divides the binomial tree setting in an upper area in which the stock can be exercised and a lower area where the option package forfeits in case of executive turnover. The first option of the option package is exercised if the stock price crosses the dashed curve that goes through point A. If the first option is exercised at point A then the exercise threshold for the second option is described by the dash-dotted upper curve beginning at point B. This conditional relationship is described by a sub-tree beginning at A. Because of the limitations of the binomial tree, there is a minimum time distance of the first exercise and the second exercise defined by the time difference of the points A and B.

Figure IV.2: **Fractional exercise policy.** The great triangle is the sketch of a binomial tree. The option package is granted at the money and consists of two separately exercisable options. The dashed lines through A is the exercise boundary for the first option. The dash-dotted line beginning at B is the exercise boundary of the second option conditional on the first option being exercised at A.



Past exercises and the reinvestment of the proceeds influence future wealth and with this the future exposure to stock price risk. As a result, the exercise boundary for the second option is conditional on the time and stock price at exercise of the first option.

To illustrate this conditionality let us think about an exercise of the first option later than in A. This has two effects. On the one hand, there is a foregone reinvestment return because the first option is exercised later. On the other hand, the first option is exercised at a lower stock price because its boundary is decreasing in time. Both effects cause a relatively higher exposure to stock price risk after the first exercise at any time and stock price compared to the exercise in A. The resulting conditional exercise boundary for the second option then turns out to be lower than the one through B. Also the exercise policy for the first option is conditional on the planned exercise policy of the remaining options, which makes the exercise policies of all options interdependent and values of ESO packages path dependent.

I use a non-recombining binomial tree setting for ESO valuation to capture the path dependence induced by fractional exercise. For a given overall portfolio composition (number of options, non-option wealth), exercise decisions can still be deduced by backward induction (comparing exercise utilities with holding utilities). However, the portfolio composition itself is an outcome of exercise decisions in the past (number of exercised options, stock price and time at exercise). Here, a Monte Carlo simulation, is not able to properly account for path dependence as it could only solve for exercise boundaries with predefined functional forms. I infer the optimal exercise policy using a dynamic programming approach (see Appendix A.3 for an example). After creating the non-recombining binomial tree, I create all possible exercise policies depending just on time and not on the stock price. Note that there exists also one exercise policy where options are never exercised. In addition to the voluntary exercise policy there is a constant probability of executive turnover in the next period (next step in the tree) with annual intensity $\theta = 0.03$. In the case of executive turnover all remaining options are exercised if the option package is vested and in the money and forfeit otherwise. The algorithm starts at the option package's maturity and goes backward from iteration to iteration. It works as follows. Beginning at the options' maturity, for each node I compare all exercise policies with the same history in the past and keep the one that generates the highest expected utility for each exercise history and path. These best exercise responses for given stock price histories combined with given exercise histories can be interpreted as a discrete reaction function. In the complete exercise model this is much simpler, because the only possible exercise history for which exercise is still possible is no past exercise. In the next step (going backward) for each node I only take exercise policies into consideration that are part of the path's reaction function. I repeat with this procedure until I reach the initial node.

This dynamic programming approach could in principle also be used to value option portfolios with different option packages instead of multiple options of one and the same option package.[12]

3 Results

I analyze option packages with one, two, three, four, and five options of equal size. In Section 4 I show that this is consistent with empirical observable preferences for fractions that are multiples of 20%, 25%, and 33%. The main setting and the baseline parametrization ($T = 10$, $r = .04$, $\mu = .08$, $\sigma = .3$, $K = S_0 = 100$, $\theta = 0.03$, $\gamma = 2$, $W_0 = 80$) is that from Section 2. I use a non-recombining binomial tree setting with 15 steps which implies a step length of 8 months for a ten year option package.[13]

[12] This issue is also discussed by Dennis and Rendleman (2004) and Murphy (2007). Dennis and Rendleman (2004) solve a dynamic programming problem for European ESOs that arises when taking dilution into account.

[13] I choose 15 steps to keep the problem feasible in terms of computational resources. 15 steps already imply 32,769 stock price paths and 20,349 possible exercise policies for an option package with 5 options. In the first iteration of the algorithm every possible exercise policy applies to every stock price path. From iteration to iteration the number of nodes decreases by 50%, while the number of non-dominated exercise policies decreases by a lower percentage.

3.1 Exercise policy

The exercise policy is a collection of optimal exercise decisions for each stock price path. To reduce the amount of information, I describe the exercise policy by the stock price at exercise and the time to early exercise for each option separately. To form expectations, I first calculate the exercise probability at each possible combination of time and stock price. I also take forced exercise due to turnover into account, whenever the option package is vested and in the money. In a second step, I multiply the stock price (time) in each node with the exercise probability for that node and divide that number by the overall probability of early exercise for the respective option. Table IV.1 describes the exercise policy by the stock price at exercise for an option package with one, two, three, four, and five options, respectively. Remember that the size of each option depends on the initial number of options within the option package. The table provides the expected stock price at early exercise for each option separately, the expected stock price at early exercise for the option package as a whole $\bar{S}$, and the early exercise probability for the option package as a whole P_e. For instance, if the option package consists of two options and one option is exercised for sure while the other option in not exercised, the exercise probability on the level of the whole option package is 50%. The expected stock price at exercise for the option package as a whole is thus equal to an exercise probability weighted average of the numbers for all separate options.

[Insert Table IV.1 about here.]

Comparing option packages with one and two options (each package underlies one share) one can exactly see the interdependence of exercises that was motivated in Section 2.2. Splitting a large option into two smaller options makes the first option to be exercised at a 10.9% lower stock price and the second option to be exercised at a 14.1% higher stock price. Being able to exercise only one half of the option package instead of the complete option package makes it cheaper to diversify as only half of the option package's time value is sacrificed. The exercise of the first option again lowers the exposure to stock price risk and induces the holder to exercise the second option at a higher stock price. The same argument applies when changing from the model with two options to the model with four options as the latter contains the model with two options as a special case. Please note that the stock price at early exercise only serves as a linear approximation for the exercise boundary.[14] I do not provide exercise boundaries here as the exercise policy is path dependent and thus general option specific boundaries do not exists. $\bar{S}$ and P_e measure the compound effect of the stock price at exercise and the early exercise probability. Fractionally exercised option packages are exercised at higher stock prices with a lower (weighted) early exercise probability. The option package with five options is exercised early with a probability of 61.4% (complete exercise 65.6%) at a 3.1% higher stock price compared to the complete exercise model. However, the relationship between the number of options and the expected stock price at exercise is not monotone. As this may be a result from discretizing time and exercise fractions, I put more attention to models that include each other. All models with multiple options include the one (indivisible) option model because executives that stick to an all or nothing exercise policy can just treat multiple options as one bigger option. Similarly, the model with four options also includes the model with two options. Comparing the models with one, two, and four options there is a positive relationship between the number of options and the stock price at exercise. However, the differences between models are economically weak

[14] At the same points in time the second option is exercised at the same stock price or a higher one than the first option. However, for some parametrizations the expected stock price at exercise for the second option can be lower than that for the first option. This may happen if in the early stage early exercises of the second option are at stock prices that are beyond the scope of the binomial tree while the stock prices at exercise for the first option are not. If then close to maturity both options are exercised at low stock prices, the second option has a lower expected stock price at exercise than the first option.

and the fact that a monotone relationship can be observed here does not mean that this has to be the case in general, because of the two opposing effects described above.

Table IV.2 describes the time dimension of the exercise policy. It provides times to early exercise (conditional on early exercise) for each option separately and the expected time to early exercise for the option package as a whole $\bar{t}$. The expected lifetime for the option package as a whole $\bar{t}_l$ is the expected time until early exercise, forfeiture or maturity, whichever comes first. As a result, $\bar{t}$ is strictly lower than $\bar{t}_l$ as the latter includes options that are not exercised early with a realized lifetime equal to the option package's maturity.

[Insert Table IV.2 about here.]

Table IV.2 gives a similar picture for the time to early exercise as Table IV.1 for the stock price at exercise. The first option of the option package with two options is exercised 22.0% earlier than in the complete exercise model because it takes a shorter time in expectations to reach a lower stock price where the exposure to stock price risk approaches a critical level. The second option is exercised 24.7% later at a higher stock price. With this the times to early exercise react stronger to fractional exercise than the stock prices at early exercise. Fractionally exercised option package are exercised earlier (conditional on exercise) but live longer because of the lower probability of early exercise (see Table IV.1). The option package with five options is exercised 2 months earlier but lives 1 month longer than an option package with just one big option. Again just comparing models that include each other (one, two, and four options) the time to early exercise decreases while the expected lifetime increases in the number of options. Note that the probability of early exercise for the first option is higher than that for the fifth option because there is a higher probability of crossing lower stock prices (not tabulated).

With fractional exercise, the first options are exercised earlier with a higher probability while later options have a lower probability of early exercise as they are exercised at higher stock prices. Overall, fractional exercise leads to a shorter time to early exercise (conditional on early exercise) but to a longer expected lifetime of the option package.

3.2 Incentives

Now, I analyze the influence of fractional exercise on incentives provided by the option package. The subjective value SV is the minimum amount of money that the executive would accept in exchange for the option package at the grant date. In line with Hall and Murphy (2002), I measure incentives to increase the stock price as the increase in SV if the stock price increases by 1\$.[15] The more sensitive the subjective value is to movements in the stock price, the higher is the incentive to exert effort to increase the stock price and with this the subjective value.[16] In the remainder of the paper, I refer to this incentive measure as the subjective delta Δ^s.

$$\Delta_t^s = \frac{\partial SV_t}{\partial S_t} \tag{IV.4}$$

This incentive measure can be considered as one part of a complete effort model with an optimal incentive level.[17] To analyze incentives for different stock prices and different points in time, I calculate subjective deltas for every node in the binomial tree from the total differential.[18] Options that are exercised do not provide incentives in the same node

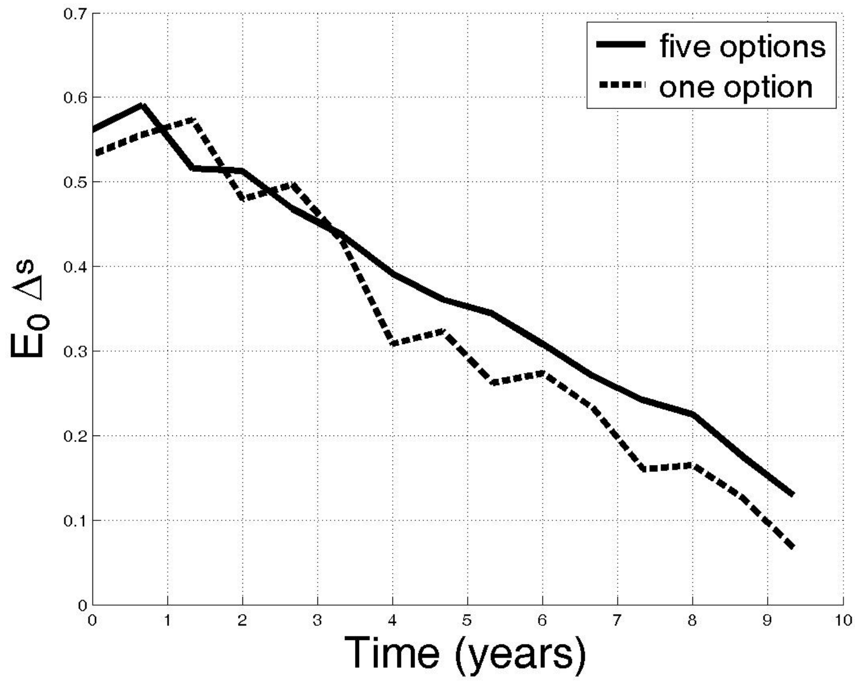
[15] Hall and Murphy (2002) analyze the impact of managerial characteristics and option characteristics on incentives in a one period model.

[16] See Bebchuk and Fried (2004) for a critical position on incentive pay. According to them, stock price dependent executive pay packages are a consequence of rent extraction by executives and not a consequence of firms' intention to incentivize their executives.

[17] Dittmann and Maug (2007) provide a complete effort model and use the utility adjusted pay to performance sensitivity as a measure for incentives.

[18] I increase the stock price in all nodes by 0.01%, which results in a new initial stock price of 100.01, and recalculate all subjective values. From the resulting values I subtract the initial values and divide it by the absolute stock price shift in every node. For simplicity, I assume that the exercise policy is not

Figure IV.3: **Subjective delta over time.** The figure compares expected subjective deltas (calculated from the total differential) for the models with one and five options over time. Options that are exercised until and including the respective node have a subjective delta of zero.

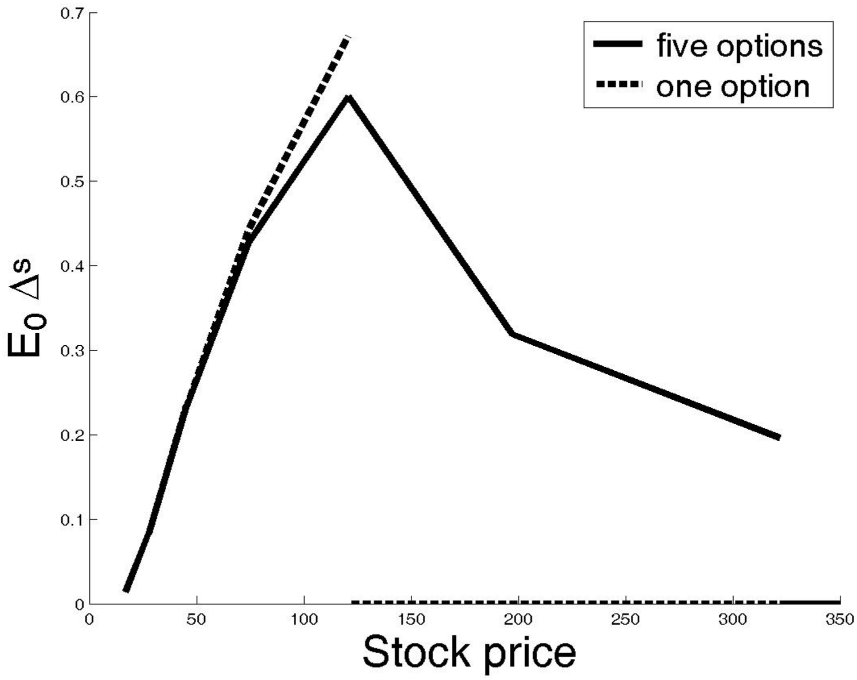


and nodes where the whole option package has already been exercised have a subjective delta of zero. Figure IV.3 shows the evolution of the (initially) expected subjective delta over time for the complete exercise and the model with five options.

At the beginning of the option package's lifetime the expected subjective delta of the complete exercise model is sometimes higher than that of the model with five options because in some states, options in the five options model are already exercised while there is no exercise for the complete option package yet. Later, after the third year, the expected delta of the model with multiple options is consistently higher than that of the model with one option because there are states in which the complete option package is already exercised while some options of the five options model remain unexercised. The exercise of one out of multiple options lowers the risk for the whole portfolio. Thus, after

structurally affected by such a small shift in stock prices. This means if one option is (not) exercised at a stock price of 200 then it is still (not) exercised at the shifted stock price of 200.02. This simplification also prevents unreasonable subjective deltas.

Figure IV.4: **Subjective delta after 5 years for different stock prices.** The figure compares expected subjective deltas (calculated from the total differential) after 5 years for the models with one option and five options for different stock prices. options that are exercised until and including the respective node have a subjective delta of zero. Subjective deltas are zero right of each curve.



the exercise of the first out of five options the subjective delta of the remaining options is greater than $\frac{4}{5}$ of the subjective delta of the whole option package before exercise. The same holds for the subjective value. In a nutshell, fractional exercise models predict a longer persistence of incentives and also a higher mean incentive level.

Figure IV.4 compares the models with one option and five options in terms of the (initially) expected subjective delta in the first node after year five for different stock prices. The subjective delta in the complete exercise model is increasing in the stock price for stock prices up to about 120$. The model with five options has a lower expected subjective delta than the complete exercise model for stock prices up to about 120$ because there are paths in which some options are exercised before. At higher stock prices the whole option package in the complete exercise model is exercised and provides no subjective delta any more. The subjective delta in the model with five options is also decreasing for greater stock prices. But this happens much slower, because options are exercised separately and the remaining options still provide incentives. As a result, the model with five options predicts incentives for stock prices up to about 330 while the complete exercise model predicts incentives for stock prices only up to about 120$.

3.3 Comparative statics

Allowing for fractional exercise changes the exercise policy and the option package's ability to provide incentives. The early exercise policy itself is also a major value determinant, because non-dividend induced early exercise destroys (market-) time value. In the following, I analyze the impact of fractional exercise on values of the option package and incentives provided by the option package. For this I consider two different incentive measures. The first incentive measure is the subjective delta Δ_o^s at the grant date ($t = 0$). Hall and Murphy (2002) use the subjective delta as an incentive measure and find that the early exercise feature for American style ESOs makes incentives cheaper for firms compared to European ESOs. However, they do not take into account that incentives are gone after early exercise and that firms potentially then have to reincentivize their executives. For this reason, I additionally analyze the initially expected subjective delta for the point in time when half of the option package's lifetime is over $E_0\Delta_5^s$ (first node after five years in the binomial tree) as a representative measure for future incentives. In the remainder of the section, I refer to this as the future subjective delta.

Table IV.3 shows the subjective value SV, the objective value OV, and the FASB (Financial Accounting Standards Board) value $FASB$. The subjective value is the value of the package for the employee. The objective value OV is the market value of the option package given the exercise policy of the executive and can be interpreted as costs for the firm. The FASB value is the Black-Scholes value of a European option package where the time to maturity is replaced by the expected lifetime $\bar{t}_l$. The FASB model is widely used for ESO valuation and serves here as a benchmark. Furthermore, Table IV.3 presents the subjective delta at the grant date Δ_0^s, the future subjective delta $E_0\Delta_5^s$, the expected stock price at exercise $\bar{S}$, and the expected lifetime $\bar{t}_l$. Panel A provides these results for different numbers of options in an option package (with one underlying share) for the baseline parametrization. The other panels adjust one parameter, leaving all other parameters at their baseline values.

[Insert Table IV.3 about here.]

Baseline parametrization. For the baseline parametrization in Panel A, the subjective value is weakly increasing in the number of options because an option holder cannot be worse off if the number of choices is increasing. However, the objective value remains stable and shows no significant differences for different numbers of options.[19] This even holds true if only the models with one, two, and four options are considered. In Table IV.1, I show that dividing the option package into separate options shifts thresholds of some options upwards and the thresholds for other options downwards. Upward shifts of exercise thresholds have a positive impact on the objective value, while the downward shifts have a negative impact. Comparing the models with five options with the complete exercise model both effects mostly cancel out each other. This effect is not surprising as both the stock price at exercise and the expected lifetime remain rather stable for different numbers of options. However, the result is different from that found in the related literature. Grasselli and Henderson (2009) find up to 15% higher objective values for fractionally exercised option packages while Murphy (2007) finds objective values that are nearly twice as high for fractional exercise compared to complete exercise. Surprisingly,

[19] The standard deviation for the objective value in the binomial tree model is about 0.22.

the easier FASB model fits the objective value from the utility model quite well. The expected lifetime $\bar{t}_l$ and accordingly the FASB value remain stable for different numbers of options. The two incentive measures subjective delta and future subjective delta are higher in all fractional exercise models than in the complete exercise model. However, the initial subjective delta reacts far less on fractional exercise than the future subjective delta. Thus, regarding only the initial subjective delta underestimates incentive effects of fractional exercise that emerge over the whole lifetime of the option package. The inclusion of fractional exercise leaves objective values unaffected for a wide range of parametrizations around the baseline case.[20] However, Panels B and C show parametrizations where this is not the case.

Higher risk aversion. Panel B assumes a constant relative risk aversion of $\gamma = 5$. The main difference to the baseline parametrization is that the objective value in the model with five options is now 22.5% higher than in the complete exercise model. Here, the utility gain from diversification through exercise of the first option is so high that the upwards shift of the exercise threshold for the second option overcompensates the lower exercise threshold for the first option. The reason is that exercise thresholds are bound below by the strike price but not bound above. This results in higher stock prices at exercise and longer expected lifetimes in models with fractional exercise (models with more than one option). Compared to the baseline parametrization, the objective value here is lower for all numbers of options. The reason is that the option package is exercised earlier at a lower stock price, because the executive has a higher additional utility from diversification. Consistently, the subjective value of the option package is lower, because the executive

[20]In untabulated results, I considered the following ranges of input variables, leaving all other variables at their baseline values: $\gamma \in [0.5, 1, 2, 3]$, $W_0 \in [40, 58, 160]$, $\mu = [6\%, 8\%, 10\%, 12\%]$, $\sigma = [10\%, 20\%, 30\%, 40\%, 50\%, 60\%]$, vesting period $\in [0, 2, 4, 6]$, and dividend yield $\delta \in [0, 1\%, 2\%, 3\%, 4\%, 5\%]$

values risky claims subjectively lower than in the baseline parametrization. Incentives are lower initially and in the future in comparison to the baseline parametrization. However, the future subjective delta decreases relatively more compared to the initial subjective delta, because the early exercise probability is higher than in the baseline parametrization and only unexercised options provide incentives after the fifth year.

Higher volatility. Panel C assumes a stock return volatility $\sigma = 70\%$. Compared to the baseline parametrization, fractional exercise has a much higher effect on the subjective value. Here, the subjective value is 9.6% higher in the model with five parts than in the complete exercise model while the same number for the baseline parametrization is only 3.3%. If exercises are subject to transaction costs and monitoring costs, we should observe more fractional exercise and smaller fractions for more volatile underlying stock, for which the additional benefits from fractional exercise outweigh the additional transaction costs. As in the case with higher risk aversion, the objective value in the model with five options is 25.7% higher than in the complete exercise model because the upwards shift of the exercise threshold for the second option overcompensates the lower exercise threshold for the first option. The objective value is higher than in the baseline parametrization for all numbers of options, because a higher volatility increases the probability of reaching higher stock prices in shorter time. There are two effects of volatility on the subjective value and on the exercise policy. On the one hand, a higher volatility implies a higher risk of the payoff of the option package leading to a lower subjective value. On the other hand, a higher volatility implies a higher expected payoff of the option package, because of the asymmetric payoff structure, leading to a higher subjective value. In this case the expected payoff effect is stronger making the subjective value increase in volatility.[21] However, the expected lifetime for all models is consistently lower compared to the baseline parametrization. In the complete exercise model, the expected stock price at early exercise for $\sigma = 70\%$ is 11.9% lower than in the baseline parametrization. Thus, the risk effect also affects the objective value via the exercise policy but is sufficiently weak to be outweighed by the expected payoff effect. For all fractional models the expected stock price at early exercise is higher than in the baseline parametrization. The FASB model overestimates the objective value for all numbers of options, but fits better for fractional exercise models than for the complete exercise model. Incentives are lower than in the baseline parametrization (except the initial subjective delta in the complete exercise model), because of the executives risk aversion. The initial subjective delta for the complete exercise model is higher than in the baseline parametrization because the option package is exercised earlier (lives shorter) and accordingly has a higher probability of early exercise (not tabulated). The initial subjective delta is thus a misleading measure of incentives over time as it is especially high just because of the short incentive maturity. Additionally, as in the case with higher risk aversion in Panel B the higher probability of early exercise has a negative effect on the future subjective delta.

Higher probability of executive turnover. Panels D and E show cases in which fractional exercise has only little influence on the objective value. Panel E assumes a turnover rate $\theta = 15\%$. Executive turnover leads to forced exercise of all remaining options if the option package is vested and in the money or forfeiture otherwise, destroying the ESO's time value immediately. So, both the subjective value and the objective value are lower here than in the baseline parametrization. Incentives decrease for all fractional exercise models. For complete exercise the initial subjective delta even increases compared

[21]For lower volatilities between 10% and 20% (10% steps) the payoff effect is stronger making the subjective value decrease in volatility (not tabulated) .

to the baseline parametrization because of the closer expected exercise. The stock price at exercise and the expected lifetime are lower for two reasons. On the one hand, the higher turnover rate triggers exercise or forfeiture directly. On the other hand, the higher possibility of executive turnover in the future decreases the subjective value of holding the option package, which leads to lower exercise thresholds (effects are not separately tabulated). The influence of fractional exercise on the objective value is especially low for high θ as options are exercised together because of executive turnover and because thresholds for voluntary exercise are closer together.

Vesting period. Panel E introduces a 6 year vesting period. The subjective value decreases compared to the baseline parametrization, because vesting periods restrict the possibilities to early exercise. There are four effects of vesting periods on the objective value. First, executive turnover during the vesting period leads to forfeiture of the option package, which has a negative effect on the objective value. This could be one reason for firms to introduce vesting periods. Second, vesting periods in itself prohibit voluntary exercises and lengthen the ESOs expected lifetime, which has a positive effect on the objective value. Third, the vesting date is the only point in time when options can be exercised above their respective (path dependent) exercise thresholds. Usually, they would be exercised at the threshold. However, during the vesting period exercise is not allowed such that the stock may cross the threshold level without the option being exercised. If at the end of the vesting period options are exercised above their thresholds, this causes a windfall cash inflow to the holder, which again has a positive impact on the objective value. The fourth effect is indirect and only applies to fractional models. In the case when options are exercised above their exercise thresholds at the vesting date the windfall cash inflow shifts the threshold for the remaining options upward. Those remaining options now have a still longer expected lifetime than without vesting period, which has a positive impact on the objective value.[22] However, the impact of fractional exercise on the objective value is also lowered because of the potential exercise of multiple options at the vesting date. The compound effect of the vesting period on the objective value is weak, although the stock price at early exercise is higher and the expected lifetime of the option package is longer. The vesting period causes a lower initial subjective delta by limiting early exercise but a higher future subjective delta because of the higher survival rate of options.[23] This case again shows that the initial subjective delta alone delivers misleading estimates for long term incentives.

4 Empirical analysis

This section analyzes early exercises for a large set of executives. It tests the implications of the fractional exercise model and discusses alternative motivations for fractional exercise other than diversification.

4.1 Data

The following analysis is based on the SEC's (Securities and Exchange Commission) corporate insider filings. This transaction data is part of the ThomsonReuters database "Insider Filing Data Feed". I consider an option package as the number of all ESOs that are equal in terms of option holder, underlying security (issuer), strike price, maturity, and vesting date. Time vested option grants are usually reported as separate option packages.

[22] Due to the low precision of the binomial tree, this effect cannot be observed here. The minimum shift of a threshold stock price is $\frac{u}{d} = 1.64$ where u and d are upward and downward parameters in the binomial tree. The new threshold stock price would thus have to be at least 1.64 times as high as the usual threshold if the effect is strong enough.

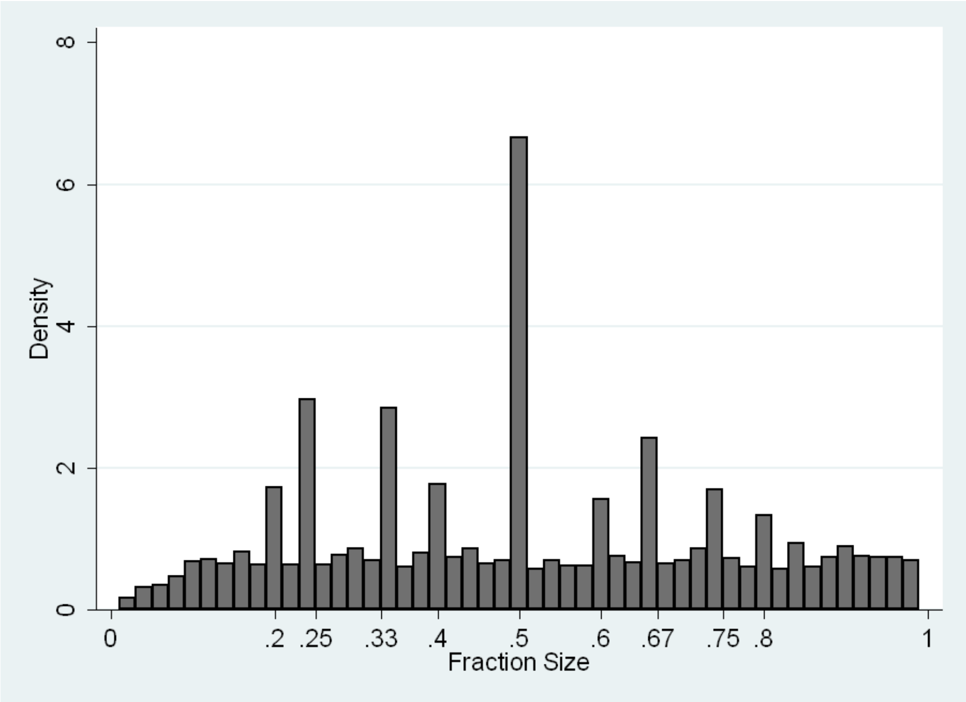
[23] Also Hall and Murphy (2002) find that European style options provide less incentives in terms of the subjective delta than American style ones. However, they remark that this static view does not take incentives in the future into account.

For instance, if an option grant has two different vesting dates then it is usually reported as two option packages with one vesting date, respectively. Time vested option packages that are not reported as separate packages and option packages with other more complicated vesting schemes have a missing vesting date in the database and are dropped from the analysis. I measure the fraction exercised as the share of exercised options relative to the number of initially granted options. I do not consider exercised fractions less than 1% of the initially granted option package as exercises. Likewise I count exercises above 99% as full exercises. To be sure about the number of granted options, I restrict my analysis to option packages with reported grant transactions. The resulting data set contains 23,993 early exercises (excluding exercises at maturity) for 19,445 option packages of 8,739 insiders in 2,431 firms from 1996 to 2006.

4.2 Descriptive statistics

Of all analyzed exercise transactions, 47.7% are fractional exercises of the initially granted option package. With this, fractional exercise plays a role for 34.8% of all early exercised option packages. Figure IV.5 shows the distribution of exercised fraction sizes in relation to the initially granted number of options for fraction sizes less then one (no complete exercises). The height of the bars is weighted by the fraction size itself. For instance, a bar that represents 2 exercises of 25% each is as high as one that represents one exercise of 50%. Figure IV.5 shows that ESO holders especially prefer to exercise fractions with sizes of multiples of 20%, 25%, and 33% supporting the assumptions in the theoretical part of this paper. Grasselli and Henderson (2009) show that exercises of large blocks of option packages can be explained by transaction costs. In such a setting, the executive faces a tradeoff. On the one hand, exercising small proportions often keeps diversification at a desired level while sacrificing a minimum of option time value. On the other hand,

Figure IV.5: **Early exercised fraction sizes.** The height of the bars is weighted by the fraction size itself. For instance, a bar that represents 2 exercises of 25% each is as high as one that represents one exercise of 50%. Fraction sizes of one are excluded (no complete exercises).



larger blocks minimize transaction costs. Transaction costs do not exclusively consist of monetary costs but also of effort for portfolio monitoring leading to infrequent portfolio supervision and cognitive limitations that let managers choose "tangible" fraction sizes that are near the optimum instead of the optimal fraction itself. Another reason might be that firms could demand minimum fractions to be exercised to limit their transaction costs, but I do not have data on such regulations.

4.3 Exercise policy

According to my model, subsequent exercises occur at higher stock price thresholds than previous ones.[24] Fractional exercise make the executive better diversified, and shifts up the exercise threshold for the remaining options. Table IV.4 provides a detailed overview

[24]Grasselli and Henderson (2009) also find that subsequent exercises occur at higher stock prices than the previous one. However, their thresholds are only time dependent while mine depend also on the exercise history.

of all variables and their definitions. Table IV.5 presents univariate statistics and Table IV.6 presents estimation results to describe exercise thresholds.

[Insert Tables IV.4, IV.5, and IV.6 about here.]

In Models (1) and (2) of Table IV.6 the dependent variable is moneyness (stock price over strike price) at exercise. While Model (1) is a regression on the full sample of exercises, Model (2) bases on the subsample of exercises of executives from the ExecuComp database. As ExecuComp only includes the top 5 executives of a company the sample size decreases drastically from 23,993 in Model (1) to 7,259 exercises in Model (2). Voluntary exercise decisions of the option holder trade off the benefit of diversification against the foregone time value of the option. I thus use the ratio of inner value to the theoretical value of the option package as the dependent variable in Models (3) and (4) using the same samples as in the Models (1) and (2), respectively.[25] Both moneyness and inner value ratio are monotonically increasing in the stock price but the inner value ratio might be better able to capture the loss in (subjective) time value through exercise. Explanatory variables of interest are a dummy for the second and all following exercises of an option package $SndExercise$, a dummy for fractional exercise $FracExercise$, and the remaining fraction of the option package before exercise $FractionLeft$. I expect a positive coefficient on $SndExercise$ because, according to my model, after the first exercise the executive is better diversified and exercises the second and all following fractions at higher stock price thresholds. Consistently, I expect a negative coefficient on $FractionLeft$ because a higher unexercised fraction implies a lower level of diversification and a lower exercise threshold. I do not have any expectations on $FracExercise$ because my model only analyzes the impact of fractional exercise rather than explaining why option packages are exercised in fractions. I also include other control variables that I explain further below.

[25] Market values for options are calculated using the Barone-Adesi/Whaley model for American options.

All regressions include annual dummies. Standard errors are clustered at the level of the firm to capture the correlation between exercises that may be influenced by events like vesting dates, grant dates, or firm specific regulations like blackout periods that are common to all options packages issued by the same firm.[26]

In Model (1), the coefficient on $SndExercise$ indicates that fractional exercises after the first exercise occur at a 0.43 higher moneyness than the first exercise. This approves the implications of increasing stock price thresholds in the theoretical model. Surprisingly, the coefficient on $FracExercise$ shows that all fractional exercises occur at higher stock prices, including the first exercise. Regarding the model, a possible explanation for this finding is that executives with a higher probability of turnover exercise option packages completely and at lower stock prices (see Panel D in Table IV.3). Unfortunately, I am not able to estimate the probability of executive turnover on the firm level. I further include the time to maturity of the option package and the return volatility during the last 52 weeks (weekly compounded). As in the theoretical model, the stock price at exercise increases in volatility. The coefficient on $Volatility$ is statistically significant at the 1%-level. As proxies for the exposure to the firm's stock, I employ among others the number of vested option packages $VestOptions$ and the number of unvested option packages $UnvOptions$. The negative coefficient on $VestOptions$ implies that the executive accepts a lower stock price at exercise to diversify her portfolio. However, the number of unvested option packages $UnvOptions$ has no effect of the stock price at exercise. Maybe people do not consider unvested options as exposure because they cannot exercise them anyway. In addition, there is only little variation in $UnvOptions$ (see Table IV.5). I further use the number of option packages from which options are exercised $ExPacks$ as a proxy for the urgency of exercise. The coefficient on $ExPacks$ has the expected negative

[26] I use the following notation for statistical significance: *** significant at the 1%-level, ** significant at the 5%-level, and * significant at the 10%-level.

sign, indicating that when executives need a big amount of cash, then they accept a lower stock price to exercise options. However, the coefficient is insignificant. Other control variables are $AfterVesting$ as a dummy for the vesting date being no longer than 7 days ago, $AfterGrant$ as a dummy for the last option grant being no longer than 7 days ago, and $Dividend$ as a dummy for the next dividend date being no longer than 7 days in the future. From the theoretical model, I expect a higher moneyness at vesting because this is the only point in time when options can be exercised above their threshold for voluntary exercise as they cannot be exercised before. However, this effect cannot be measured here. The coefficient on $AfterGrant$ indicates that executives accept a lower moneyness at exercise short after a new option grant. At these points in time, they are more likely to exercise to outbalance the additional exposure from the new grant. Another interpretation is that executives have target option holdings. Before dividend payments, option holders accept lower stock prices at exercise to capture the soon paid out dividend. The coefficient on $Dividend$ is highly significant and also appears high in economic terms.

Model (2) includes only exercises of executives from the ExecuComp database but has two additional independent variables based on ExecuComp data. I use the last compensation income at market values $Income$ as a proxy for wealth and the ratio of share based payment (shares and options) to the total compensation package $Exposure$ as a proxy for the exposure to the firm's stock price risk. Based on the theoretical model in Section 2, I expect a positive coefficient on $Income$ and a negative coefficient on $Exposure$. It turns out that neither $Income$ nor $Exposure$ have an impact on the moneyness at exercise.

Models (3) and (4) use the inner value ratio as dependent variable. As $Maturity$ and $Volatility$ are already part of the inner value ratio, they are excluded as independent variables. The second fractional exercise is still exercised at a higher stock price threshold (now defined by the inner value ratio) than the first exercise. However, now the first fractional exercise is no longer exercised at a higher threshold than a complete exercise. The number of option packages represented by $VestOptions$ and $UnvOptions$ has no influence on the inner value ratio. The number of option packages of which options are exercised at the same time $ExPacks$ has a negative and highly significant coefficient which indicates that executives accept a lower stock price if exercise is urgent. In the ExecuComp subsample, $Income$ has still no effect on the exercise threshold while the coefficient on $Exposure$ is now negative as expected and significant at the 5%-level, supporting diversification as a motivation for early exercise. The coefficient on $Dividend$ indicates that dividend capture is not a driving force here and that the coefficient in Models (1) and (2) overestimates the effect of dividends on the exercise threshold.

Comparing the models with moneyness and inner value ratio as exercise threshold variables, it turns out that most effects are relevant for one dependent variable only. However, the coefficient on $SndExercise$ is robust over all specifications. I thus see the exercise policy of my theoretical model empirically confirmed.

4.4 Relevance of fractional exercise

In Table IV.7 I analyze reasons for fractional exercise. Models (1) and (2) perform logit regressions. The dependent variable here is a dummy that is one if the first exercise of an option package is a fractional exercise and zero otherwise. The analysis takes place at the level of the option package. I only use the values of the dependent variables at the first exercise because this is the point in time when the decision about fractional exercise of the whole package is made. Models (3) and (4) estimate the size of the exercised fraction using a tobit model. Censoring levels for the exercised fraction ranges are 1% and 100%. This analysis takes place at the level of exercises. In addition to the variables used in Table IV.6 I add $OptionSize$ as a measure of size of the option package, being the number of underlying shares of the option portfolio as a percentage of outstanding shares.

[Insert Table IV.7 about here.]

Consistent with Table IV.6 the logit regression results in Models (1) and (2) indicate that fractional exercise happens more likely at higher stock prices. Fractional exercise also happens longer before maturity. Close to maturity there is less time value to lose which favors full exercise. The coefficient on $ExPacks$ indicates that the more option packages are exercised at the same time the less likely is fractional exercise. The coefficient on $OptionSize$ is positive and significant at the 1%-level. The idea behind $OptionSize$ is that larger option packages are more likely to be split up because a fractional exercise of a large option package could have the same impact on portfolio risk (diversification) as the complete exercise of a smaller option package. Additionally, people with a low number of option packages are more likely to exercise in fractions because they have a better overview about their option portfolio. This could also explain the negative coefficient on $UnvOptions$. The number of vested option packages, however, does not influence the decision to exercise option packages fractionally. Around specific events like short after vesting and short before dividend payments executives favor complete exercise. According to the utility model complete exercise short after vesting occurs if the stock price at the vesting date is above all fraction specific exercise thresholds. Model (2) includes the ExecuComp variables $Income$ and $Exposure$. Both coefficients turn out to be insignificant. However, the reduction of the data set to the top five executives changes some other coefficients. From the findings in Section 3.3, I expected a positive sign of Volatility on the likelihood of fractional exercise. However while this is the case for the ExecuComp subsample it does not hold for the full sample. Both coefficients are significant at the 5%-level but the coefficient for the ExecuComp subsample is economically stronger.

The effect of soon dividend payments vanishes.

Models (3) and (4) perform tobit regressions with the size of the exercised fraction of the option package as the dependent variable. In these regressions $FractionLeft$ is a control variable rather than an explanatory variable because at most the fraction of the option package that is left can be exercised. Consistent with the findings from Models (1) and (2), the size of the exercised fraction decreases in moneyness and time to maturity. $Volatility$ has the expected negative effect on the fraction size (significant at the 1%-level) in the ExecuComp subsample while the coefficient is now insignificant in the full sample. The coefficients on $OptionSize$ are significant at the 10%-level and show that relatively large option packages are more likely to be split up and exercised in fractions. Consistent with Models (1) and (2) exercised fractions are larger short after vesting and short before dividend payments.

4.5 Alternative motivations for fractional exercise

As additional candidate motivations to exercise option packages in fractions, other than the diversification motivation discussed earlier, I identify liquidity shocks, time vesting, exploitation of insider information, and dilution. I discuss their potential impact on observed fractional exercises in my sample further below.

Liquidity shocks. Executives could exercise options just because they incur a negative liquidity shock. Accordingly, they could exercise as many options as they need to offset this shock. To the best of my knowledge, the whole literature that explains early exercise of ESOs as a result of exogenous shocks assumes that option packages are exercised completely.[27] But with regard to Table IV.6, this cannot explain why subsequent fractional

[27] In Jennergren and Näslund (1993) employees exercise due to exogenous shocks, which occur with constant intensity. They interpret these shocks twofold. Either the employee leaves the firm - then she has to exercise all options or they forfeit - or she incurs a liquidity shock if the option package is vested

exercises occur at higher stock price thresholds than the first exercise.

I do not believe that a purely mechanical relation between a liquidity shock and option exercise is reasonable since investors usually also have other assets that they can sell to meet the liquidity shock and do not necessarily have to exercise options. As a consequence, liquidity shocks should affect the whole portfolio. The decision to exercise options is then again a matter of portfolio rebalancing and with this determined by the diversification argument. This makes liquidity shocks a motivation of second order.

Time vesting. Huddart and Lang (1996) observe fractional exercise but they assign option transactions to the same option package if they are only equal in terms of the strike price and the maturity. Thus they cannot exclude that fractional exercise is a result of time vesting (different options of one package have different vesting periods). If an option package becomes vested in fractions then even the exercise of all vested options counts as a fractional exercise, even if the remaining fraction cannot be exercised. This measurement problem, however, vanishes, when all options are vested and no options have been exercised before.

For my sample, I can exclude time vesting schemes as a candidate explanation for fractional exercise, because I define option packages also by a fixed vesting date. My strict definition even understates the relevance of fractional exercise. Consider the case of a time vested option grant with two vesting dates but everything else equal. According to my definition, the two parts of that grant belong to different option packages even after the last vesting date. However, after both are vested they should be considered as one

and in the money. Mixed models that combine a diversification motivation with exogenous shock are Carpenter (1998) and Bettis, Bizjak, and Lemmon (2005). Carr and Linetzki (2000) expand the model of Jennergren and Näslund (1993) by an additional stopping event. They distinguish between exercise or forfeiture due to executive turnover and exercise due to the desire for liquidity or diversification. The probability for the latter is assumed to be positive only when the option package is vested and in the money and zero otherwise. All these papers assume that option packages are exercised completely as a response to an exogenous shock.

package because the vesting period is not relevant any more for future exercise decision. This effect may, however, be weak because with 88.3% the majority of option packages belongs to option grants with only one vesting date and are thus not subject to time vesting. 5.8% of the option packages belong to option grants with 2 different vesting dates and only 5.9% belong to option grants with 3 or more different vesting dates.

Insider information. Executives with insider information may not want to give information to the market by carrying out large trades. Instead, they may want to cover their private information and split exercises into multiple transactions. Splitting trades, the insider faces the following tradeoff. On the one hand, multiple small transactions have potentially smaller stock price impact. On the other hand, besides higher transaction costs the insider faces the risk that the price moves against her while doing her trades.[28]

If exercise smoothing is the main reason for fractional exercise, then there should be far less fractional exercises after recombining smoothed exercises. First, I measure exercise smoothing by the time distance between an exercise to the previous exercise in the same option package. Indeed 37.5% of follow-up early exercises (after the first exercise) occur 7 days or less after another exercise. Second, to check the impact of exercise smoothing, I combine all exercises with a time distance of 7 days or less to the next exercise of the same option package. I do not restrict the time distance between the first exercise and the last exercise as long as the time distance between ordered exercises is at most 7 days. For instance, I combine 3 exercises over 15 days in one exercise, in which the second exercise happens 7 days later than the first one and the third exercise happens 7 days after the second one. As a result of this procedure still 42.5% (before 47.7%) of all exercises are fractional exercises while fractional exercise plays a role for

[28] Kyle (1985) presents a model on insider trading in the stock market where large trades have a higher price impact than small ones. Barclay and Warner (1993) find that prices react most on medium-sized trades which is consistent with the hypothesis that informed traders are concentrated in this size category.

33.3% (before 34.8%) of all early exercised option packages. Although the effect of exercise smoothing on fractional exercise is measurable, it only explains a small proportion of the fractional exercise activity. The main reason is that after adjusting for exercise smoothing some smaller fractional exercises combine to larger fractional exercises instead of complete exercises. The regression results in Tables IV.6 and IV.7 are robust to this adjustment of exercise fractions (results untabulated).

Dilution. At ESO exercise the firm receives a cash inflow from the executive and issues new shares. This new share issue dilutes the claims of existing shareholders. Bühler and Koziol (2002) and Koziol (2004) observe sequential exercises for market traded warrants. They treat complete exercise for one warrant holder as sequential exercise if others further hold the warrant and explain this phenomenon by heterogeneous transaction costs among warrant holders. These sequential exercises at the market level do not have anything to do with fractional exercises on the individual level in my analysis. However, Linder and Trautmann (2006) present a theoretical model and show that fractional warrant exercise indeed can be optimal for individual holders.[29] According to their model fractional exercise is optimal only if dilution is considerable, the warrant is close to maturity, or the interest rate is low. For instance, for a dilution of 50% and one year time to maturity fractional exercise is optimal for interest rates below 4%. This implies a negative sign on $Maturity$ and a positive sign on *OptionSize* in Model (1) of Table IV.7. The coefficient on $Maturity$ is positive against this prediction. The coefficient on *OptionSize* is positive and in line with this theory. However, looking at Table IV.5 the fact that dilution (*OptionSize*) is less than one percent on average casts additional doubt on the relevance of this issue.

[29]This work goes back to Emanuel (1983) who shows that fractional exercise can be optimal if one investor holds all warrants and dilution is sufficiently high.

5 Conclusion

I develop a theoretical model that allows for fractional exercise of option packages. Fractional exercise of ESOs gives more choice to the executive compared to the complete exercise model and is thus favored by the executive. Given my model, I show that the complete exercise model systematically underestimates incentives to increase the stock price at the grant date and in the future, compared to my fractional exercise model. This could be of interest for firms that issue ESOs as incentive devices. I further find that the complete exercise model underestimates objective ESO values in cases with high volatility of the underlying stock price or if the executive exhibits high risk aversion.

In the empirical part, I find that subsequent fractional exercises occur at higher stock prices than the first exercise, which confirms the exercise policy from the theoretical model. Also the most preferred fraction sizes of 20%, 25%, 33% and multiples of those percentage numbers coincide with assumed fraction sizes in the model. I find that large option packages are more likely to be exercised in fractions and owners of numerous option packages to have a preference for full exercise. Fractional exercise is also more likely for highly volatile underlying stock. This finding is supported by the model and confirms that fractional exercise is especially an issue for the valuation of ESOs with highly volatile underlying stock. The major implications of my model that explains fractional exercise as a means of portfolio diversification are robust to alternative candidate explanations for fractional exercise.

A Binomial tree approach

A.1 Moves in the tree for equal probabilities

Following Cox, Ross, and Rubinstein (1979) the binomial tree is constructed such that the expected stock price as well as the return volatility in the tree approach their empirical counterparts in the limit as the step size approaches zero. With u as an upward move, d as a downward move, and n as an arbitrary number of time steps with length h the following two equations have to hold

$$E[\ln(\frac{S_n}{S_0})] = [p \ln \frac{u}{d} + \ln d]n = (\mu - \delta)n \tag{IV.5}$$

$$Var[\ln(\frac{S_n}{S_0})] = np(1-p)[\ln \frac{u}{d}]^2 = \sigma^2 nh \tag{IV.6}$$

Setting the statistical upward probability $p = \frac{1}{2}$ and solving for u and d returns

$$d = \frac{2e^{\mu-\delta}}{e^{2\sigma\sqrt{h}} + 1} \text{ and } u = d * e^{2\sigma\sqrt{h}}$$

A.2 Wealth portfolio

To maximize Wealth in T from one time step h before, the CRRA investor has the following maximization problem. p is the upward probability in the tree, u is an upward step, d is a downward step, δ is the dividend rate (set to zero), and h is the step length.

$$
\begin{aligned}
E_{T-h}U(W_T) &= \{p[\alpha u e^{\delta h} + (1-\alpha)e^{rh}]^{1-\gamma} + (1-p)[\alpha d e^{\delta h} + (1-\alpha)^{rh}]^{1-\gamma}\}\frac{1}{1-\gamma} \\
\frac{\partial E_{T-h}U(W_T)}{\partial \alpha} &= p[\alpha u e^{\delta h} + (1-\alpha)e^{rh}]^{-\gamma}](u e^{\delta h} - e^{rh}) + (1-p)[\alpha d e^{\delta h} + (1-\alpha)^{rh}]^{-\gamma} \\
& \quad (d e^{\delta h} - e^{rh}) = 0 \\
\Leftrightarrow \quad & \quad p[\alpha u e^{\delta h} + (1-\alpha)e^{rh}]^{-\gamma}](u e^{\delta h} - e^{rh}) \\
&= (1-p)[\alpha d e^{\delta h} + (1-\alpha)^{rh}]^{-\gamma}(e^{rh} - d e^{\delta h}) \\
\Leftrightarrow \quad & \quad \left(\frac{p}{1-p}\frac{u e^{\delta h} - e^{rh}}{e^{rh} - d e^{\delta h}}\right)^{-\frac{1}{\gamma}}[\alpha u e^{\delta h} + (1-\alpha)e^{rh}] = \alpha d e^{\delta h} + (1-\alpha)e^{rh} \\
\Leftrightarrow \quad & \quad \alpha = \frac{[1 - (\frac{p}{1-p}\frac{u e^{\delta h} - e^{rh}}{e^{rh} - d e^{\delta h}})^{-\frac{1}{\gamma}}]e^{rh}}{[(\frac{p}{1-p}\frac{u e^{\delta h} - e^{rh}}{e^{rh} - d e^{\delta h}})^{-\frac{1}{\gamma}}u - d]e^{\delta h} + [1 - (\frac{p}{1-p}\frac{u e^{\delta h} - e^{rh}}{-d e^{\delta h} + e^{rh}})^{-\frac{1}{\gamma}}]e^{rh}}
\end{aligned}
$$

α is time independent for CRRA utility. Wealth in t can be described as a function of wealth in s and the stock prices in both points in time, unless there are cash inflows from exercise in the time interval $[s, t]$. In a binomial tree setting wealth in t can be expressed in the following way.

$$W_t = W_s[\alpha u + (1-\alpha)e^{rh}]^i[\alpha d + (1-\alpha)e^{rh}]^{t-s-i}, \tag{IV.7}$$

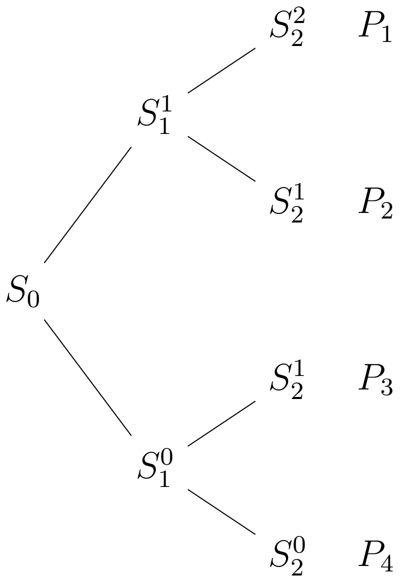
where i is the number of upward steps in the binomial tree to get from S_s to S_t. i again can be computed from S_s and S_t.

$$S_t = S_s u^i d^{t-s-i} \Leftrightarrow (\frac{u}{d})^i = \frac{S_t}{S_s d^{t-s}} \Leftrightarrow i = \frac{\ln \frac{S_t}{S_s d^t}}{\ln \frac{u}{d}} \tag{IV.8}$$

A.3 Example

This is a very small example for dynamic programming for the pricing of option packages. Take a two step non-recombining stock price tree. S_t^i is the stock price after t steps with

i upward moves. P_j are stock price paths. The number of paths in a general environment is 2^{n-1}, where n is the number of points in time on the tree.



Assume that an option package consists of 2 indivisible options of equal size. Then Y_n is the set of possible exercise policies. In this case, it consists of three sub-matrices: one policy without exercise, policies with a sum of $\frac{1}{2}$ exercised option packages, and policies with a sum of one exercised option package.

$$Y_n = \begin{bmatrix} \begin{pmatrix} 0 & 0 & 0 \end{pmatrix} \\ \\ \begin{pmatrix} 0 & 0 & \frac{1}{2} \\ 0 & \frac{1}{2} & 0 \\ \frac{1}{2} & 0 & 0 \end{pmatrix} \\ \\ \begin{pmatrix} 0 & 0 & 1 \\ 0 & \frac{1}{2} & \frac{1}{2} \\ 0 & 1 & 0 \\ \frac{1}{2} & 0 & \frac{1}{2} \\ \frac{1}{2} & \frac{1}{2} & 0 \\ 1 & 0 & 0 \end{pmatrix} \end{bmatrix}$$

In general, the number of exercise policies where k options are exercised in n points in time is $\binom{n-1+k}{k}$.[30] Remember that it is possible to exercise more than one option per instant in time. So, the whole number of possible exercise policies for an option package with N options is $\sum_{k=0}^{N}\binom{n-1+k}{k}$. For instance a model with 10 years á 1.5 (2) steps per year has 32,768 (1,048,576) stock price paths. An option package with 5 options then generates 20,349 (65,780) possible exercise policies in this model.

Let us come back to the easier model with just two time steps and two options. To find the right exercise policy for each path I proceed as follows. I group the policies by common exercise history in all but the last instants in time. Policies with common history are for instance

$$\begin{pmatrix} 0 & 0 & 0 \\ 0 & 0 & \frac{1}{2} \\ 0 & 0 & 1 \end{pmatrix}.$$

For each path, I take the policy that generates the highest (expected) utility. In the last step for a given exercise history, this is simple because the policy that generates the highest expected utility also generates the highest payoff. So, it is always utility optimal to exercise remaining options that expire in the money and not to exercise options that expire out of the money. As a result, the best exercise policies for paths that end in the money

$$Y_{i,n-1} = \begin{pmatrix} 0 & 0 & 1 \\ 0 & \frac{1}{2} & \frac{1}{2} \\ \frac{1}{2} & 0 & \frac{1}{2} \\ \frac{1}{2} & \frac{1}{2} & 0 \\ 0 & 1 & 0 \\ 1 & 0 & 0 \end{pmatrix}$$

[30] Combination with repetition.

while those for paths that end out of the money are

$$Y_{i,n-1} = \begin{pmatrix} 0 & 0 & 0 \\ 0 & \frac{1}{2} & 0 \\ \frac{1}{2} & 0 & 0 \\ \frac{1}{2} & \frac{1}{2} & 0 \\ 0 & 1 & 0 \\ 1 & 0 & 0 \end{pmatrix}.$$

In the last but one instant in time I again group the exercise policies by common history in the past and take, in each node, that policy that generates the highest expected utility for a given history and a given optimal future reaction. One common history in this step ($t = 1$) could be again no exercise (in $t = 0$). If you decide to exercise half an option package now because it generates the highest utility for a given exercise history and an optimal reaction in the future, then you will exercise the other half of the option package at maturity if it ends in the money and let it forfeit if it ends out of the money as determined in the step before. If you proceed in that manner until the initial point in time you end up with the (one) optimal exercise policy for each path.

Tables

Table IV.1: **Stock price at early exercise** for one, two, three, four, and five options, respectively. The table provides the statistic for each option separately and for the whole option package ($\bar{S}$), and the early exercise probability P_e.

Options	$1st$	$2nd$	$3rd$	$4th$	$5th$	$\bar{S}$	P_e
1	190.17	–	–	–	–	190.16	0.66
2	169.36	216.88	–	–	–	191.72	0.66
3	165.63	190.17	244.52	–	–	195.44	0.62
4	165.63	172.00	200.73	268.06	–	195.13	0.62
5	165.63	169.36	190.17	209.08	288.60	195.97	0.61

Table IV.2: **Time to early exercise** in years for one, two, three, four, and five options, respectively. The table provides the statistic for each option separately and for the whole option package ($\bar{t}$), and the expected lifetime of the whole option package $\bar{t}_l$.

Options	$1st$	$2nd$	$3rd$	$4th$	$5th$	$\bar{t}$	$\bar{t}_l$
1	4.71	–	–	–	–	4.71	6.01
2	3.67	5.87	–	–	–	4.71	6.01
3	3.53	4.71	5.58	–	–	4.50	6.07
4	3.53	3.74	5.12	6.03	–	4.45	6.05
5	3.53	3.67	4.71	5.52	5.88	4.51	6.12

Table IV.3: **Option values and incentives.** The table provides the subjective value SV, the objective value OV, the $FASB$ value, initial incentives Δ_0^s and expected future incentives $E_0\Delta_5^s$, the stock price at exercise $\bar{S}$, and the expected lifetime of the ESO in years $\bar{t_l}$ for an ESO package consisting out of one to five options and for different parametrizations. The baseline parametrization assumes $T = 10$ years, no vesting period, $r = .04$, $\mu = .08$, $\sigma = .3$, $K = S_0 = 100$, $W_0 = 80$, and $\gamma = 2$.

Options	SV	OV	$FASB$	Δ_0^s	$E_0\Delta_5^s$	$\bar{S}$	$\bar{t_l}$
Panel A: Base Case							
1	26.98	37.97	37.60	0.53	0.26	190.16	6.01
2	27.67	37.59	37.61	0.56	0.34	191.72	6.01
3	27.79	37.77	37.82	0.56	0.32	195.44	6.07
4	27.84	37.52	37.73	0.56	0.32	195.13	6.05
5	27.88	37.83	37.99	0.56	0.34	195.97	6.12
Panel B: Risk Aversion $\gamma = 5$							
1	16.92	22.90	26.18	0.49	0.07	134.94	3.14
2	18.19	28.02	30.24	0.42	0.12	149.53	4.06
3	18.21	29.37	31.34	0.40	0.13	154.24	4.33
4	18.36	28.84	31.07	0.41	0.13	153.44	4.26
5	18.37	28.06	30.50	0.42	0.14	151.28	4.12
Panel C: Volatility $\sigma = 70\%$							
1	29.22	38.62	54.65	0.59	0.09	167.48	3.87
2	31.73	47.09	60.21	0.50	0.15	200.45	4.87
3	31.68	49.53	61.64	0.47	0.15	211.87	5.15
4	32.04	47.72	61.67	0.50	0.16	209.64	5.16
5	32.03	48.56	62.11	0.48	0.16	213.15	5.25
Panel D: Termination Probability $\theta = 15\%$							
1	20.30	26.20	26.71	0.55	0.14	153.23	3.26
2	20.30	26.20	26.71	0.55	0.14	153.23	3.26
3	20.51	26.69	27.14	0.55	0.16	155.45	3.35
4	20.51	26.32	26.85	0.56	0.16	153.95	3.29
5	20.52	26.44	26.95	0.55	0.16	154.47	3.31
Panel E: Vesting Period 6 years							
1	22.23	38.12	41.59	0.38	0.64	205.87	7.23
2	22.40	37.66	41.30	0.39	0.66	203.07	7.14
3	22.47	38.22	41.88	0.39	0.65	212.72	7.32
4	22.49	38.38	42.00	0.38	0.65	213.55	7.36
5	22.50	38.10	41.80	0.39	0.66	209.95	7.30

Table IV.4: **Variable definitions and data sources.** The Table lists all variables, their definitions, and their sources used in the analysis.

Variable	Description	Source
Moneyness	Stock price/Strike price	IFDF
SndExercise	One for all but the first exercise of the option package, zero otherwise	IFDF
FracExercise	One if only a fraction of the initial option package is exercised, zero otherwise	IFDF
FractionLeft	Fraction of the initially granted option package that is left over	IFDF
Maturity	Time to maturity (years)	IFDF
Volatility	Annualized volatility of stock returns (52 weeks)	CRSP
VestOptions	Number of vested options packages	
UnvOptions	Number of unvested options packages	
ExPacks	One if options of more than one option package are exercised, zero otherwise	
OptionSize	Underlying shares of the option package as a percentage of outstanding shares in the month before	CRSP
AfterVesting	One from the vesting day until 7 days after, zero otherwise	IFDF
AfterGrant	One from the day of a new grant until 7 days after, zero otherwise	IFDF
Dividend	One in the week before a dividend payment date (if available), zero otherwise	CRSP

Table IV.5: **Univariate statistics on option exercises.** All variable definitions are contained in Table IV.4. The table contains information on all variables at the time of exercise.

	Mean	Std. Dev	Min.	First Quartile	Median	Third Quartile	Max.
Moneyness	2.4	1.8	1	1.3	1.8	2.6	13
SndExercise	.2	.4	0	0	0	0	1
FracExercise	.47	.5	0	0	0	1	1
FractionLeft	.92	.19	.011	1	1	1	1
Maturity	5.5	2.8	0	3.5	6	7.9	19
Volatility	.38	.23	.052	.23	.32	.45	4.6
VestOptions	3.1	3.6	0	1	2	4	41
UnvOptions	.53	1.7	0	0	0	0	19
ExPacks	.4	.49	0	0	0	1	1
OptionSize	.097	.43	2.4e-07	5.5e-03	.021	.069	48
AfterVesting	.057	.23	0	0	0	0	1
AfterGrant	.049	.22	0	0	0	0	1
Dividend	.05	.22	0	0	0	0	1

Table IV.6: **Exercise thresholds and fractional exercise.** The table provides OLS regressions with clustered standard errors at the individual level. In Models (1) and (2) moneyness at exercise is the dependent variable while in Models (3) and (4) the ratio of time value over the option value (market values calculated with the Barone-Adesi/Whaley option value) is the dependent variable.

	$\frac{S}{K}$	$\frac{S}{K}$	$\frac{S-K}{BAW}$	$\frac{S-K}{BAW}$
$SndExercise$	0.43 ***	0.60 ***	0.05 ***	0.06 ***
$FracExercise$	0.24 ***	0.24 ***	0.01	0.00
$FractionLeft$	-0.08	0.15	-0.03 *	-0.03
$Maturity$	-0.02 **	-0.00		
$Volatility$	3.06 ***	4.47 ***		
$VestOptions$	-0.02 **	-0.02 *	-0.00	-0.00
$UnvOptions$	0.01	-0.00	-0.00	-0.00
$ExPacks$	-0.04	-0.11	-0.04 ***	-0.05 ***
$Income$		0.00		0.00
$Exposure$		0.27		-0.06 **
$AfterVesting$	-0.10	-0.14	-0.03	-0.03
$AfterGrant$	-0.31 ***	-0.24 ***	-0.09 ***	-0.05 *
$Dividend$	-0.30 ***	-0.34 ***	-0.02	-0.01
$Constant$	0.55 **	0.23	0.72 ***	0.82 ***
R^2	0.20	0.22	0.14	0.17
N	23,993	7,259	23,993	7,259

Table IV.7: **Fractional exercise versus complete exercise.** Models (1) and (2) estimate logit models with a fractional exercise dummy as dependent variable (one for fractional exercise, zero otherwise) while Models (3) and (4) estimate tobit models on the exercised fraction of the option package.

	$FracEx$	$FracEx$	$Fraction$	$Fraction$
$FractionLeft$			1.30 ***	1.02 ***
$Moneyness$	0.02 ***	0.03 ***	-0.03 ***	-0.02 ***
$Maturity$	0.02 ***	0.03 ***	-0.03 ***	-0.03 ***
$Volatility$	-0.09 **	0.23 **	-0.00	-0.34 ***
$ExPacks$	-0.28 ***	-0.27 ***	0.39 ***	0.29 ***
$OptionSize$	0.73 ***	1.00 ***	-0.15 *	-0.38 ***
$VestOptions$	0.00 **	0.00	0.00	0.00 *
$UnvOptions$	-0.02 ***	-0.04 ***	0.04 ***	0.05 ***
$Income$		-0.00		0.00
$Exposure$		0.04		-0.07
$AfterVesting$	-0.09 ***	-0.12 ***	0.13 **	0.19 ***
$AfterGrant$	-0.01	-0.02	0.06 *	0.05
$Dividend$	-0.05 **	0.01	0.07 **	-0.04
$Constant$			-0.23	-0.19
R^2	0.14	0.16	0.22	0.26
N	19,445	5,513	23,993	7,259

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Erklärung

Hiermit erkläre ich, die vorliegende Arbeit selbstständig angefertigt zu haben. Ich habe alle Hilfsmittel vollständig und deutlich angegeben.

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