Why do Employees Exercise Stock Options Early?

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Abstract

Models of early exercise of employee stock options invariably assume that exercise decisions are driven by risk-averse employees seeking to rebalance their undiversified portfolios. Using the entire history of stock option grants and a 10-year panel of over 10,500 option exercises from over 3,800 employees in five companies with a plausible proxy for outside wealth (home prices measured at the employee Zip Code level), we find scant evidence that actual exercise decisions are driven by diversification concerns. While we find some evidence consistent with variations of the disposition effect (early exercise driven by employees seeking to lock in a realized gain), our evidence primarily supports the hypothesis that liquidity-constrained employees exercise early to satisfy consumption rather than diversification objectives. Our key test shows that employees are more likely to exercise following increases in home prices, a result that is consistent with liquidity motives for exercising, but inconsistent with diversification or disposition. In addition, we analyze how exercise behavior is impacted by recent grants of options and restricted stock, and consider the plausibility of risk-aversion parameters implied by diversification, the fact that employees often exercise all exercisable options (from the same or different grants) at the same time.

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1. Introduction

According to standard option-pricing theory (Merton, 1973), investors holding exercisable call options should delay exercise until expiration (or, sometimes, just before a large dividend payment). In practice, however, employees receiving options on their company's stock as part of their compensation package routinely exercise those options long before expiration.[1] The fact that employees typically exercise options well before expiration has garnered the attention of researchers for three broad reasons. First, voluntary early exercise provides insights on how and why individuals make financial decisions. Second, the timing of option exercise has implications for how employees subjectively value the equity compensation they receive, which in turn has important implications for the effectiveness and efficiency of equity compensation in achieving attraction, retention, and motivation outcomes.[2] Third, the likelihood that employees will exercise early has direct implications for both the company's opportunity cost of granting options and the financial-accounting expense companies report when granting options.[3]

Early exercise is costly to employees because of the opportunity cost of deferring payment of the exercise price and related taxes and the forfeiture of any remaining "time value" of options. However, theoretical models of early exercise suggest that risk-averse employees may rationally exercise early (immediately selling the shares acquired) to diversify their

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[1] Empirical papers documenting early-exercise behavior for non-executives include Huddart and Lang (1996); Heath, Huddart and Lang (1999); and Carpenter, Stanton and Wallace (2019). A larger number of papers have focused on early-exercise decisions for executive officers, including Hemmer, Matsunaga and Shevlin (1996); Carpenter and Remmers (2001); Bartov and Mohanram (2004); Bettis, Bizjak and Lemmon (2005); Malmendier and Tate (2005, 2008); Aboody, Hughes, Liu, and Su (2008); Cicero (2009); Brooks, Chance and Cline (2012); and Izhakian and Yermack (2017).

[2] See, for example, Armstrong, 2008; Hall and Murphy, 2002; and Bettis et al., 2005.

[3] Theoretical research in valuing employee stock options based on predicted exercise behavior include Huddart (1994), Carpenter (1998), Carr and Linetsky (2000), Leung and Sircar (2009), and Carpenter, Stanton and Wallace (2010).

exposure to firm risk.[4] To date, virtually all theoretical and most empirical research on employee option exercise behavior has focused on employees' diversification motives, and the central tradeoff of the benefits from diversification against the costs of forfeiting remaining time value by exercising early. In this paper, we use a proprietary dataset containing exercises on 15,289 option grants to 3,816 employees in five companies to assess whether diversification motives are in fact the primary driver of exercise decisions for top executives as well as lower-level managers. Ultimately, we conclude that actual exercise behavior is largely explained by factors other than diversification.

A large theoretical literature has produced a number of predictions under the "Diversification Hypothesis" that risk aversion and diversification are preeminent factors underlying early exercise. For example, the Diversification Hypothesis predicts that increases in outside wealth cause employees to delay exercise (since a smaller percentage of their wealth is tied to employer stock prices), while increases in employer equity leads to earlier exercise. In addition, diversification motives will lead to fractional exercises over the term of an option rather than exercising all available options at the same time. Also, early exercise will depend on grant-specific factors such as the ratio of the current stock price to the exercise price ("price-to-strike ratio") and remaining option term, and therefore options from multiple grants will be exercised at different times.

While prior empirical studies generally interpret their findings as broadly supporting diversification motives, there has been little attempt to distinguish between diversification and other, potentially more important, explanations. For example, employees with in-the-money options may exercise for "liquidity" to make major purchases. Moreover, behavioral factors, such as Barberis and Xiong's (2012) "Realization Utility," where investors sell winning investments early to lock-in or realize a gain, could also be consistent with early exercise. Indeed, many implications of the diversification, realization utility, and liquidity motivations for early exercise have similar predictions, making empirical tests for the relative importance

[4] See, for example, Huddart (1994); Marcus and Kulatilaka (1994); Carpenter (1998); Hall and Murphy (2002); Jain and Subramanian (2004); Grasselli and Henderson (2009); Rogers and Scheinkman (2007); and Carpenter, Stanton and Wallace (2010).

of these different explanations difficult.[5] For example, a recent run-up in share prices, which prior studies interpret as a "behavioral" explanation for early exercise (e.g., Heath, Huddart, and Lang, 1999; Carpenter, Stanton, and Wallace, 2019) increases the fraction of the employee's portfolio tied to stock prices (suggesting early exercise under the diversification explanation), but also increases wealth (suggesting early exercise under the liquidity explanation) and provides an opportunity to realize a "gain" under the realization-utility explanation.

Additional challenges to testing the diversification hypothesis are data limitations on important model inputs. For example, while data on inside wealth is generally available for top executives through public disclosures (and sometimes for lower-level employees through proprietary datasets), data on outside wealth are generally unavailable. In this paper, we exploit novel data employee home addresses at the Zip Code level (which frequently differ from the location of company headquarters) as a plausible proxy for outside wealth which allows us to construct tests to discriminate among the Diversification, Realization Utility, and Liquidity Hypotheses. Changes in home values (which we measure at the Zip Code level) represent changes in employee illiquid outside wealth, and are predicted to be *negatively* related to exercise decisions under the Diversification Hypothesis, since an increase in home values reduces the employee's relative exposure to firm-specific risk (i.e., the employee becomes more diversified). Changes in home values should be *positively* related to exercise decisions under the Liquidity Hypothesis, since an increase in home values increases overall wealth (providing consumption incentives) but not liquidity. Changes in home values should be *unrelated* to exercise decisions under the Realization Utility Hypothesis, since behavioral theory predicts individuals consider investments on an asset-by-asset basis, and thus gains on houses and options would be evaluated separately. Ultimately, we find that increases in home values are associated with earlier exercise, providing strong support for the Liquidity Hypothesis over either of the other two hypotheses.

[5] Jin and Kothari (2008) make a similar observation in their analysis of whether CEO stock sales are driven primarily by tax concerns or other factors.

Another unique aspect of our data (relative to the samples analyzed by Huddart and Lang (1996, 2003), Armstrong et al. (2007), and Carpenter, Stanton and Wallace (2019)) is comprehensive information on *all* equity grants (i.e., restricted stock grants as well as option grants), which allows us to conduct additional novel tests of the Diversification Hypothesis. Under the Diversification Hypothesis, both recent stock and option grants should be positively related to exercise (since the new grants increase the employee's wealth tied to company shares, thus decreasing diversification), but the coefficient on recent option grants should exceed the coefficient on recent stock grants: since options represent a levered claim on the equity of the firm (through the convexity of the payout), a given dollar-grant in options (based on Black-Scholes values) creates more exposure to stock-price risk than the same dollar grant in restricted stock units ("RSUs"). We find that early exercise is positively related to recent grants of restricted stock, but unrelated to recent option grants, again inconsistent with the Diversification Hypothesis.

We conduct several sets of analyses to further examine whether diversification concerns are likely to be the primary driver of early exercise decisions. First, similar to prior studies (e.g., Huddart and Lang, 1996), we present summary statistics showing that employees routinely exercise their options well before expiration. In contrast to Bettis, Bizjak and Lemmon's (2005) finding that at the median top executives' early exercises result in a sacrifice of only 10% of the remaining Black-Scholes value of options, we find that the opportunity cost of early exercise in our sample, particularly below the top-executive level, is much larger: among employees below the top-executive level, the median exercise sacrifices over 25% of the Black-Scholes value of the option, and at the third quartile exercises result in a loss of over 40% of the Black-Scholes value.[6]

Assuming CRRA utility and using home prices as a proxy for outside wealth, we estimate the risk-aversion coefficients required to justify early exercise decisions (and resulting forfeiture of option value) if those decisions, indeed, were driven by diversification concerns. We find that top-level executives (who tend to exercise late and therefore capture a greater

[6] Bettis et al. (2005) imply that a 10% sacrifice is a modest penalty for early exercise, but we note it is exactly the same penalty employees take for early withdrawals from 401(k) accounts, a practice widely viewed as suboptimal.

fraction of remaining option value) have implied risk aversion parameters lower than typically assumed in the literature (more than half of the executives have risk-aversion coefficients of $\rho = 0$ or $\rho = 1$). In contrast, we find that nearly half of the exercises of non-executives imply risk-aversion coefficients $\rho > 10$, and coefficients $\rho > 25$ for roughly a fourth of our sample. These implied risk aversion coefficients are well above the ranges that most economists consider reasonable, suggesting that exercise decisions are driven by factors other than diversification. Moreover, since we estimate implied risk-aversion coefficients for each exercise decision, we can test for consistency in coefficients across exercises on different dates for the same individual. We document significant variation in implied risk-aversion coefficients across exercise events within individuals, casting doubt on the CRRA-utility framework as a way to model exercise decisions.

We also document that employees (particularly non-executives) regularly exercise options from different grants (with different grant dates and exercise prices) at the same time, which is inconsistent with the Diversification Hypothesis which predicts exercise decisions will be based on grant-level factors such as the price-to-strike ratio and remaining term. Thus, even holding constant outside wealth (which does not vary within individuals on the same date), the CRRA-utility framework would imply different risk aversion coefficients for an employee on the same date under the assumption that exercises are driven by diversification motives. Contrary to the diversification hypothesis, we find that non-executives cluster their exercises across multiple grants in the sense that conditioning on having exercised an option from another grant within the past seven days an employee is over 50 times more likely to exercise. Also, we show that individuals often exercise all vested options from a single grant at once, which contrasts with the fractional exercises predicted under the Diversification Hypothesis. These "block exercises" typically occur well past vesting dates and therefore do not simply reflect pent-up demand (which could be consistent with diversification).

Collectively, our results suggest that diversification motives are not the primary factor underlying employees' early exercise decisions, notwithstanding the prominence of diversification in the prior literature. Instead, our evidence appears more consistent with a more-obvious, but curiously under-studied, explanation: employees with in-the-money options exercising for consumption rather than diversification purposes.

The remainder of this paper is organized as follows. Section 2 summarizes the relevant theoretical and empirical literature and discusses the three broad explanations for early exercises we examine. Section 3 describes our data. Section 4 presents descriptive statistics and our tests to distinguish among explanations for early exercise, and Section 5 concludes.

2. Early Exercise: Theory, Evidence, and Testable Implications

2.1. Theories Explaining Early Exercise

Research on early exercise must inevitably make assumptions about the behavior employees will follow when exercising their options. Common across all theories (and for all employees) is the idea that employees exercising early do so only when the perceived benefits of early exercise exceed the cost. One clear benefit of early exercise—assuming immediate sale of the shares acquired via exercise—is immediate access to the spread between the market and exercise (or "strike") price of the option (the "intrinsic value").[7] The clear costs include the opportunity cost of deferring payment of the exercise price and related taxes and the forgone "option value". We focus on three broad groups of explanations: the Diversification Hypothesis, the Realization Utility Hypothesis, and the Liquidity Hypothesis.

2.1.1. The Diversification Hypothesis

As emphasized in the Introduction, the dominant explanation proposed for early exercise is diversification: risk-averse and undiversified employees exercise early to rebalance their portfolios and reduce their exposure to firm risk. Under the Diversification Hypothesis, more risk-averse employees will exercise earlier (because they perceive a larger benefit of diversifying). In addition, assuming (plausibly) that absolute risk aversion declines with wealth (e.g., CRRA Utility), these models generally predict that the propensity to exercise for diversification purposes should increase with the fraction of the employee's wealth correlated with company stock prices. Thus, employees will be less likely to exercise following increases

[7] Since rational employees would prefer to pay the exercise price (and related taxes) later rather than sooner, it is generally irrational to exercise early and to subsequently hold the stock acquired. Exceptions include exercises for tax purposes (the gain upon exercising a non-qualified stock option is taxed as ordinary income, while the subsequent gain on shares is taxed at a generally lower capital-gains rate), exercises to satisfy ownership requirements (since option holdings are typically not included in such requirements), and exercises to obtain voting power.

in outside wealth (because they become less exposed to company risk), and more likely to exercise following new equity grants or increases in stock prices (because they become more exposed). Assuming (again, plausibly for our sample) that the cost of exercising and selling the acquired shares is relatively low, the Diversification Hypothesis predicts continual portfolio rebalancing based on changes in the ratio of inside to outside wealth.

2.1.2. The Realization Utility Hypothesis

The disposition effect is the well-documented tendency of investors to hold losing investments too long and sell winning investments too soon.[8] Barberis and Xiong (2012) propose that these tendencies can be explained by "Realization Utility," where investors derive utility from *realized* (rather than unrealized) gains and losses on assets they own. Thus, investors derive utility on the date that they sell a winning investment and can delay experiencing negative utility by postponing sales of losing investments.

For our purposes, Barberis and Xiong's (2012) Realization Utility Hypothesis—that investors (with sufficiently positive time discount rates) sell winning investments too early to lock-in or realize a gain—maps closely into early exercise decisions.[9] Barberis and Xiong argue that investors with realization utility are more likely to sell shares when prices exceed historical highs, consistent with Heath, Huddart, and Lang's (1999) finding that employees exercise after short-term stock-price run-ups or when stock prices reach a local maximum (such as the highest stock price observed over the past year).

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[8] Classic references include; Shefrin and Statman (1985); Odean (1998); and Barberis and Xiong (2009); closely related is Kahneman and Tversky's (1979) "prospect theory" in which individuals assess gains and losses differently. We are grateful to Cary Frydman and Tom Chang for their insights on how the disposition effect relates to early-exercise decisions.

[9] Chang, Solomon, and Westerfield (2016) propose that the tendency to hold losing investments too long is driven by cognitive dissonance, as the investor's beliefs about being a skilled stock picker is at odds with the reality of an ex post bad investment. However, the cognitive dissonance explanation is not relevant for options because they are granted as part of compensation and not as an investment choice. In addition, the tendency to hold losing investments too long is not applicable to options since out-of-the-money options are generally never exercised (although Fos and Jiang (2016) document surprising cases where CEOs exercise out-of-the-money options on thinly traded stock to obtain voting power, such occurrences are clearly the exception).

2.1.3. The Liquidity Hypothesis

Perhaps the most-obvious, but curiously least-studied, explanation for early exercise is that employees with in-the-money options, but with limited other liquid assets, exercise in order to make major purchases such as college tuition, home remodeling, automobiles, vacations, etc. The tendency to exercise early for consumption purposes will be especially strong when exercisable in-the-money options account for a large fraction of liquid wealth. Moreover, under the "Liquidity Hypothesis," an increase in illiquid outside wealth (such as an increase in home prices) will lead to early exercise, since overall wealth has increased (providing consumption incentives) and exercising options is plausibly a more efficient way to fund consumption than selling or refinancing a home, or paying interest on a home-equity line of credit.

2.2. Empirical Factors Predicting Early Exercise

2.2.1. Common Factors Across Theories

The assumptions researchers make about explanations for early exercise are reflected in the "control" variables researchers have to predict exercise behavior. Table 1 summarizes the control variables used in several empirical studies of exercise behavior based on public data generally available only for top-level executives (Panel A) and studies based on proprietary data covering all option recipients at a more limited set of companies (Panel B).[10] As shown in both panels of Table 1, researchers studying early exercise invariably include controls for the intrinsic value, the remaining option value, and (sometimes) the time remaining until expiration (which is highly correlated with the remaining option value after controlling for intrinsic value).

Also common across all hypotheses, and most research in Table 1, is the idea that employees (as well as outside investors holding tradable options) are more likely to exercise prior to an ex-dividend date (i.e., the last date when the stock price incorporates the value of the upcoming dividend). Absent other concurrent information, stock prices should predictably

[10] While exercise data are publicly available only for executive officers who are subject to Section 16 reporting requirements, Core and Guay (2001) infer exercises for non-executive officers using annual aggregate exercise data at the firm level and subtracting exercises from executives.

fall by the amount of the dividend on the ex-dividend date, so an employee contemplating an exercise (for diversification, realization utility, or liquidity) will rationally do so before rather than just after an ex-dividend date.

Finally, since options can only be exercised if they are, indeed, exercisable, there are predictable spikes in exercise following vesting events (typically occurring on grant-date anniversaries). These spikes presumably reflect pent-up demand for exercising, regardless of whether that demand for exercise was for diversification, realization utility, or liquidity.

2.2.2. Diversification Factors Predicting Early Exercise

Employee stock options are non-tradable and held by risk-averse employees who are often inherently undiversified, with their financial as well as human capital tied disproportionately to the success of their firm. Early exercise (with subsequent sales of the shares acquired upon exercise) allows employees to diversify their portfolio by reducing their exposure to company stock-price risk.

A challenge in the empirical literature on early exercise is that researchers, at most, have data on the employee's equity portfolio (or sometimes only the employee's option portfolio), and not on the employee's outside wealth (i.e., wealth not directly correlated with company stock prices). This data limitation confounds attempts to distinguish between diversification and liquidity motives. Carpenter et al. (2019), for example, proxy for employee total wealth using the Black-Scholes value of the employee's portfolio of options, and interpret their finding of a negative relation between exercise and this proxy for wealth as being consistent with the diversification hypothesis. However, increases in the value of the employee's option portfolio (holding constant other forms of wealth) increases the employee's exposure to company stock-price risk which should, *ceteris paribus*, increase rather than decrease exercise propensities.

Lacking data on outside wealth, most empirical studies of the diversification hypothesis have focused on the relation between early exercise and the riskiness of the option portfolio. Huddart and Lang (1996) find that exercise is negatively related to stock-price volatility for top-level executives (which they define as employees ranking in the top 5% of option recipients), but positively related to volatility for lower-level managers and employees. In

contrast, Carpenter et al. (2019) find a *positive* relation between exercise and volatility for top-level executives (again defined by option holdings), and a negative relation for lower-level executives.[11] Focusing only on top executives (i.e., Form 4 filers), Izhakian and Yermack (2017) find that exercise is negatively related to stock-price volatility, but positively related to their proxy for ambiguity (defined as attitude towards mean-preserving spreads in probabilities).

Ultimately, tests of the diversification hypothesis based on stock-price volatilities are inherently problematic, because increases in volatilities simultaneously increase both the riskiness of the option portfolio (suggesting an increase in early exercise) and the remaining option value of the option grant (suggesting a decrease in early exercise). Indeed, the expected utility model in Carpenter et al. (2010) predicting exercising behavior for a risk-averse employee, shows that the relation between early exercise and volatility is ambiguous.

2.3. Psychological Factors Predicting Early Exercise

Heath, Huddart and Lang (1999) document that exercise decisions depend on recent price movements (e.g., the stock return in the three weeks before exercise) and whether the current stock price is above the highest stock price observed over the prior year. They interpret the former result as suggesting that option holders expect short-term trends to mean-revert, hence they exercise following stock-price run-ups since they expect stock prices to decline in the near term. They interpret the latter result as reflecting a psychological reference point from Kahneman and Tversky's (1979) Prospect Theory, in which the utility function is concave for gains above some reference point but convex for losses below the reference point. The predictions from Prospect Theory are similar to those from Barberis and Xiong's (2012) "realization utility," in which investors enjoy a burst of utility based on the size of a realized gain (and a burst of negative utility following a realized loss).

As evident from Table 1, researchers after Heath, Huddart and Lang (1999) have routinely included recent stock-price run-ups and recent price milestones as control variables

[11] The signs on the coefficients on volatility for lower and top-level managers in Carpenter, et al. (2019) curiously flip in their 22-firm subsample analysis where they have actual data on employee titles (instead of inferring level by the value of the option portfolio).

in explaining early exercise, typically classifying these variables as "behavioral" or "psychological." However, ascribing "behavioral" explanations for the positive relation between stock-price increases and option exercise is problematic because this relation is also consistent with both the diversification and liquidity hypotheses. Holding constant the intrinsic value (or the ratio of the intrinsic value to the option value, as Heath, Huddart and Lang do), the three-week run-up in stock prices implies that (1) the spread was higher now than three weeks before, encouraging exercise now; (2) the employee is less diversified than three weeks before (i.e., holding outside wealth constant, the fraction of wealth tied to stock prices increased during that three week period), also encouraging exercise now; and (3) the employee's wealth has increased, raising demands for liquidity that can be satisfied by exercising options.

Separate from the psychological factors predicting early exercise are those predicting later exercise. Malmendier and Tate (2005, 2008) and others, for example, assume that executives who *fail* to diversify by exercising early do so because of irrational positive beliefs about future returns (i.e., "managerial overconfidence"). Underlying this proxy for overconfidence is the assumption that diversification is the primary driver of exercise decisions, which is concerning given the lack of supporting evidence.

2.4. Testable Implications

Table 2 summarizes the empirical predictions for early exercise under the Diversification, Realization Utility, and Liquidity Hypotheses. The controls used across most existing studies (e.g., the ratio of intrinsic to Black-Scholes values, the remaining term, pending dividend, or recent vesting event) measure the economic benefit and cost of early exercise; these variables are useful in explaining early exercise but are not helpful in distinguishing among the explanations. Similarly, early exercise is predicted to be positively related to recent stock-price run-ups or surpassing historical maximums under all three hypotheses. While many of the predictions in Table 2 are common across all three hypotheses, our empirical analyses, described in Section 4, are designed to enable us to test those cases when the predictions differ across two or all three of the different hypotheses.

3. The Data

Our analysis of early exercise decisions is based on exercise data from 15,289 option grants held by 3,816 managers in five firms from (roughly) 2004-2014. Our data source is a major (but anonymous) plan administrator of option and other equity plans for all employees at the five firms. Because sharing data is time intensive for the administrator, the administrator selected a subset of five firms from among the clients they serve. While selection bias is a natural concern, we were not involved in the sample selection process and the administrator was not aware of our research agenda beyond our interest in the determinants of exercise behavior. The five firms span several industries, different size groups, and different penetration of option grants. Our five sample firms are involved in Crude Petroleum and Natural Gas Production (SIC 1311), Industrial Chemicals (SIC 2811), Petroleum Refining (SIC 2911), Commercial Banks (SIC 6022), and Healthcare Services (SIC 8090). Average 2004-2014 revenues for our five firms ranged from $390 million to $25 billion (with a median average of about $1 billion).

The interquartile range of employees in our sample is 810 to 5,194. Option and RSU grants in our sample are concentrated among mid-level to upper-level managers (averaging about 15% of the workforce, though the precise percentage varies by company and year). This is a smaller percentage of total employees than in Huddart and Lang (1996, 2003) and Carpenter, Stanton and Wallace (2019), likely reflecting difference in our sample periods. In particular, following the peak of the Dot.Com bubble in 2000, firms moved from broad-based stock option plans to restricted stock and performance share plans, while simultaneously limiting participation to more senior-level employees.

Our data on option exercises begins on a staggered basis from 2004 to 2010 (reflecting when our data source began administering the plans), but ends in 2014 for all five companies. However, we have complete grant and vesting data for all stock option and time-lapsed or performance-based restricted stock units (RSUs) for all employees receiving equity compensation during our sample period, and also have personnel records (e.g., hiring and termination dates) for all employees during our sample period (regardless of whether the employees receive equity grants). Importantly, the personnel data also include the Zip Code

(or country code, for non-domestic employees) associated with the home address of the employee.[12]

A critical variable in our analysis (used as our proxy for outside wealth) is *Home Price*. Since we do not have specific employee addresses, we proxy for *Home Price* using the monthly median home value in the employee's Zip Code as estimated by Zillow.[13] We implicitly assume that employees are homeowners rather than renters. This assumption seems plausible based on average ownership in employee Zip Codes (with a 25th to 75th percentile range of 66% to 85%), and the fact that our option participants are mid- to upper-level managers with ages typically associated with home ownership (the interquartile age range in our sample is 46.6 years to 57.2 years). We also suspect (but cannot check) that our typical managerial participant lives in an above-median-valued home in the Zip Code, but we assume that geographical variation in higher percentiles (e.g., the 75th percentile home price) is highly correlated with geographical variation in the median.

Because variation in home prices is a key requirement for our research design (described below), Figures 1 – 5 present the geographic dispersion of domestic employees in our five-company sample. Panel A of each figure depicts the dispersion for all employees, while Panel B restricts the sample to employees participating in company stock-option plans. The size of the bubbles is based on the Jenks natural breaks classification method and reflects the relative number of employees in in each county.[14] Overall, about 43% of employees holding options live in the same MSA as the corporate headquarters; 94% of option recipients live in the United States (only two of our sample companies had option recipients living outside the United States). Empirical studies in corporate finance routinely assume that employees are collocated with the company headquarters (see, for example, Kedia and Rajgopal (2009); Anderson, Banker and Ravindran (2000)). Our data offers a cautionary tale for this common assumption:

[12] All personnel data, including Zip Codes, was included as a header file and therefore reflects the most recent information at the time the data were shared (i.e., we unfortunately do not have time series data on employee locations).

[13] Data on median home values by Zip Code were obtained from https://www.zillow.com/research/data/. When home values are not available for a given Zip Code, we use the geographically closest Zip Code with Zillow data.

[14] The Jenks method seeks to minimize each class's average deviation from the class mean, while maximizing each class's deviation from the means of the other classes.

large and mid-size publicly traded companies often have operations (and employees) across several different states and countries.

Our unit of analysis is the daily exercise decision by individual employees with respect to specific option grants. We exclude exercise outcomes subsequent to employee resignations or terminations, since post-departure exercises are mechanical and unrelated to our early exercise hypotheses.[15] After this exclusion, our full sample includes 13,871,148 employee-grant-day observations, representing 3,632 employees, 14,702 separate grants, and 10,570 exercise events.

While our data offers advantages over the prior literature—especially the new data on employee locations and the rich data on other grants—there are limitations of our data beyond the relatively small number of firms in the sample. First, with the exception of a handful of executives that can be matched to publicly available proxy data, we do not have data on other aspects of the individual's compensation beyond equity compensation. Second, (as discussed above) we do not have access to employee home addresses beyond the Zip Code level, and consequently estimate home values at the Zip Code level rather than at the individual address level. Third, while we can measure the individual's holdings of options and restricted shares on a daily basis, we do not have data on the individual's unrestricted shareholdings or stock purchases and sales (including sales of previously restricted shares following the lapse of restrictions). Importantly, however, we note that diversification cannot be a rational explanation for early option exercise for an employee who simultaneously holds unrestricted shares. Since our primary focus is testing the Diversification Hypothesis, this data limitation will not undermine our ultimate conclusion.

4. Analyses and Results

4.1. Descriptive Statistics

As evident from Table 1, much of the evidence on employee early exercise is based on data for top-level executives publicly disclosed in Form 4s. However, Huddart and Lang (1996) and Carpenter et al., (2019) show that patterns of exercise behavior and relations with several

[15] In particular, unvested options are typically forfeited upon departure, and departing employees are typically required to exercise vested options within three months following departure.

control variables differ between executives and lower-level managers. Accordingly, throughout this paper we present much of our analyses for both groups of employees separately, with an emphasis on the lower-level managers, with results for executives presented for comparability purposes. We designate an employee as an "Executive" if she is either (a) an employee designated as an insider or holds a C-level title; or (b) has holdings of stock and options ever in the top 1% of all company employees; "Non-Executives" include all other option recipients. Table 3 reports sample means and medians for our primary variables. As shown in the table, the median top executive in our sample of option recipients is older with longer tenure than the median non-executive. In addition, the median top executive holds RSUs and options worth $864,000 (valuing RSUs using closing stock prices and value options using Black-Scholes), while the median non-executive has RSU and options worth $62,800.[16] Somewhat surprisingly, the non-executives in our sample live in Zip Codes with higher median prices ($258,700 for executives and $310,500 for non-executives). Assuming that outside wealth equals the median home price in the employee's Zip Code, the median executive holds 77.7% of total wealth in company equity, while the median non-executive holds only 14.2% of wealth in company equity.

Table 3 suggests that the probability that an individual will exercise options from a given grant on a given day is only 0.080% and 0.074% for executives and non-executives, respectively. This probability is not, however, reflective of employee exercise behavior because it includes days when there is no meaningful exercise decision: days when options were not exercisable (i.e., not yet vested) and days when the stock price was below the exercise price. Exercise probabilities for the subsample of days when options were both vested and in-the-money (i.e., options were "available" to be exercised) are 0.132% and 0.224% for executives and non-executives, respectively.

Table 4 reports sample means for the 10,570 exercise events in our sample, grouped by executive level and the fraction of full term that had lapsed between grant and exercise. Executives exercising options in our sample (Panel A) realized approximately 88% of the

[16] Black-Scholes values are computed using average dividend yields over the prior three years, stock-price volatilities over the prior 48 months. Risk-free rates are extracted from U.S. Treasuries with maturities closest to the remaining term of the option (i.e., 1,2, 3, 5, 7, or 10 years).

underlying Black-Scholes value upon exercise (i.e., they sacrifice roughly 12% of the underlying value by exercising early), which is very similar to the finding in Bettis et al. (2005). Executives exercising within the first 25% of the full term realize only 70.6% of the Black-Scholes value upon exercise, while executives exercising between 25%-50% and 50%-75% through the full term respectively realize 72.4% and 82.7% of the Black-Scholes value upon exercise. Executives waiting until at least 75% of the full term has lapsed (e.g. after 7.5 years for 10-year options) realize over 98% of the Black-Scholes value upon exercise.

In contrast, non-executives (Panel B of Table 4) exercise earlier and tend to leave more "money on the table" by exercising early. Overall non-executives sacrifice more than 28% of the Black-Scholes value of their options upon exercise. Non-executives exercising within the first 25% of the full term realize only 49.7% of the Black-Scholes value upon exercise, while non-executives exercising between 25%-50% and 50%-75% through the full term respectively realize 68.7% and 76.9% of the Black-Scholes value upon exercise. Non-executives waiting until at least 75% of the full term has lapsed realize only 82% of the Black-Scholes value upon exercise.

Table 4 shows that, conditional on exercise, non-executives are more likely than executives to exercise 100% of vested options from a given grant on a single date, rather than exercising only a fraction of available options from the grant. In particular, 69.5% of exercise events for non-executives were "block exercises," compared to 52.6% for executives. Not surprisingly, block exercises are most common for exercises early in the term. For example, block exercises accounted for over 85% of exercises for non-executives exercising in the first 25% of the option term (e.g., in the first 2.5 years of a 10-year option).

Finally, Table 4 shows that executives exercise later than non-executives: over half of all executives held their options through at least 75% of the full term, while less than a fourth of non-executives held options as long. We suspect that the tendency of executives to exercise later reflects a variety of factors. For example, purchases and sales of company shares by top executives are heavily scrutinized by shareholders and the business press (causing delays in early exercise), while similar transactions for lower-level managers are largely under the radar. In addition, while lower-level executives may need to exercise options to fund major

purchases, top executives can plausibly fund such purchases using savings or sales of liquid assets without resorting to inefficient early exercise. The results in Table 4 (indicating stark differences in exercise behavior for executives and non-executives) suggest that inferences based on exercise behavior for top-executives may not be directly applicable to lower-level managers, and reinforce the importance of analyzing exercise behavior for executives and non-executives separately.

4.2. Regression Analysis

4.2.1. Early Exercise and Changes in Housing Prices

Under the Diversification Hypothesis, an increase in outside wealth (i.e., wealth not correlated with company stock prices) should reduce exercise propensities, since the employee's overall wealth portfolio has become more diversified. Under the Liquidity Hypothesis, an increase in outside wealth will increase consumption demand. Whether the increased consumption demand is financed through option exercise depends, in part, on whether the increase in outside wealth can be directly spent (for example, exercise will likely decrease if an employee wins a cash lottery, since consumption can be financed more efficiently by spending the lottery winnings than by exercising options). Finally, under the Realization Utility Hypothesis, there should be no relation between changes in outside wealth and exercise behavior, since behavioral theory predicts individuals consider investments on an asset-by-asset basis.

To distinguish between the Diversification, Liquidity, and Realization Utility Hypotheses, we use changes in home values. An increase in the value of an employee's home represents an increase in outside wealth that cannot be directly spent to finance increased consumption. The increased value can be indirectly spent through refinancing or home equity lines of credit, but these transactions involve costs (including interest) that plausibly exceed the opportunity cost of exercising in-the-money options. We therefore predict that, under the Liquidity Hypothesis, exercise propensities will increase subsequent to increases in home values. In contrast, under the Diversification Hypothesis, exercise propensities should decrease subsequent to increases in home values, while there should be no relation between home prices and exercise behavior under the Realization Utility Hypothesis.

We test for the effect of home prices on exercise propensities using the following specification:

$$Exercise\ Pct_{i,j,t} = \alpha_i + \beta \Delta Ln(Home\ Value)_{i,t-T} + (Control\ Variables)_{i,j,t} + \varepsilon_{i,j,t} \quad (1)$$

where $\Delta Ln(Home\ Value)_{i,t-T}$ is the change in home values over the prior T months. Our dependent variable *Exercise Pct* is 100 times the fraction of vested shares from a particular grant exercised on a particular day, and the coefficient α_i represents employee-level fixed effects to control for employee-specific time-invariant exercise propensities.[17] The Control Variables in (1) generally follow the literature and include variables common across all theories of early exercise (regardless of whether the exercise is driven by diversification, liquidity, or beliefs about future stock prices). Following Heath, Huddart and Lang (1999), we use the ratio of the intrinsic value to the option value (which we measure using the Black-Scholes formula) as a sufficient statistic for tradeoff between realizing (and locking in) gains but sacrificing future value.[18] We account for pending dividends with a dummy variable indicating an ex dividend date within the next two weeks. We also include a proxy for recent stock-price run-ups (which we measure as the stock return over the prior month) and recent vesting of the focal grant (which we measure as a dummy variable indicating that a portion of the grant became exercisable within the prior month). As noted in Table 2, we expect positive signs for both proxies under the Diversification, Realization Utility, and Liquidity Hypotheses. Following Carpenter et al. (2019), we include the employee's age to capture age-related changes in risk attitudes or consumption preferences. Finally, we include the employee's total wealth (measured as the sum of the median home price in the employee's Zip Code and the

[17] Given the size of our dataset and our use of employee-level fixed effects, we estimate (1) using ordinary least squares rather than the "fractional logistic" approach adopted by Carpenter et al. (2019). Our results, however, are robust to replacing *Exercise Pct* with a dummy variable indicating an exercise on that day, which is not surprising given the evidence in Table 4 that, conditional on exercising, employees tend to exercise all available shares.

[18] Heath, Huddart and Lang (1999) use the Barone-Adesi and Waley (1987) methodology for American options, but report that results are unchanged using Black-Scholes. One difference in the methodologies is that the ratio of intrinsic value to the Black-Scholes value is not necessary bounded by one for options that are sufficiently in the money for firms that have sufficiently high dividend yields.

value of the employee's equity portfolio), and the value of the employee's equity value as a fraction of total wealth.[19]

Table 5 reports the results of estimating equation (1) for T = 1, 3, 6, 12, 24, 36, 48, and 60 months. The regressions include employee fixed effects and standard errors are clustered at the employee level. We exclude observations where the market price is below the exercise price, or all options from the particular grant are unvested, since there is no meaningful exercise decision on such days. In addition, since our focus is on "early exercise" rather than any exercise (and since the decision to exercise in-the-money options held until full term is not particularly interesting), we further restrict our analysis to the first 75% of the term (e.g., the first 7.5 years for 10-year options). Finally, since we only have house prices for U.S. Zip Codes, we exclude observations from employees located outside of the U.S.

The estimated coefficients on the control variables generally follow our predictions. In particular, exercise is positively related to *Spread/Value*, pending dividend payments, prior-month stock returns, and a dummy variable indicating that some portion of the focal option vested (i.e., became exercisable) during the prior 30 days. The coefficient on age is positive and significant, suggesting that employees tend to exercise earlier as they get closer to retirement. Exercise propensities decrease with our proxy for total wealth, but increase with the ratio of equity value to total wealth.

Our key interest in Table 5 is the estimated coefficients on changes in home values. The estimated coefficients for T= 1, 3, 6, 12, 24, 36, and 48 are positive and significant, which is consistent with the Liquidity Hypothesis but inconsistent with both the Diversification Hypothesis and Realization Utility Hypothesis. Interestingly, the magnitude and significance of the coefficient on ΔLn(Home Value) is highest for the most recent changes and lower for longer-term changes, and is actually negative (but insignificant) for T=60 (i.e., the five-year change in home values).

[19] To avoid any mechanical relation between exercise and the post-exercise value of the equity portfolio, we measure portfolio values as of the end of the prior trading day.

4.2.2. Early Exercise and New Equity Grants

New equity grants in either RSUs or option grants represent a shock to employee wealth (suggesting an increase in exercise under the Liquidity Hypothesis) and also increases the employee's exposure to company stock-price risk (suggesting an increase in exercise under the Diversification Hypothesis). We therefore expect that exercise propensities should be positively related to recent equity grants. We estimate the effect of new grants on exercise propensities using the following specification:

$$Exercise\ Pct_{i,j,t} = \alpha_i + \beta(Equity\ Grant\ in\ Last\ Month)_{i,t} + (Control\ Variables)_{i,j,t} + \varepsilon_{i,j,t} \quad (2)$$

Column (1) of Table 6 presents results from estimating equation (2) including *Equity Grant in Last Month* (scaled by the value of the employees' holdings of options and restricted stock just prior to the new grant). The coefficient of $\beta = 0.0871$ is positive but insignificant, which is inconsistent with either the diversification or liquidity hypotheses.

A major challenge in testing the effect of recent grants on exercise propensities is that new grants are often concurrent with vesting dates for existing options. This concurrence reflects the fact that the grant dates for RSU or option grants coincide with Board (or Compensation Committee) meeting dates, often at a pre-determined meeting each year, and that vesting for option grants typically occur on grant-date anniversaries. To control for the concurrence of new equity grants and vesting of the "focal" option (i.e., the grant for which we analyze exercise decisions), we re-estimate equation (2) after excluding observations in the 30 days following vesting. As shown in column (3) of Table 6, the coefficient on *Equity Grant in Last Month* becomes positive and significant after excluding these observations.

As noted above, the positive relation between exercise propensity and new equity grants is consistent with both the Diversification and Liquidity Hypotheses. The predictions from these two hypotheses differ, however, based on whether the new equity grants are in the form of RSU grants or option grants. We test for differential effects of RSU and option grants using the following specification:

$$Exercise\ Pct_{i,j,t} = \alpha_i + \beta_1(RSU\ Grant\ in\ Last\ Month)_{i,t} + \beta_2(Option\ Grant\ in\ Last\ Month)_{i,t} + (Control\ Variables)_{i,j,t} + \varepsilon_{i,j,t} \quad (3)$$

Since options represent a levered claim on the equity of the firm (through the convexity of the payout), a given dollar-grant in options (based on Black-Scholes values) creates more exposure to stock-price risk than the same dollar grant in RSUs.[20] Therefore, to the extent that exercise decisions are driven by diversification concerns, we expect that the coefficient on recent option grants should exceed the coefficient on recent stock grants (i.e., $\beta_1 < \beta_2$). On the other hand, since a given dollar-grant in either RSUs or options increases employee wealth by the same dollar amount, we expect no difference in the coefficients β_1 and β_2 under the Liquidity Hypothesis.

Columns (2) and (4) of Table 6 report results from estimating equation (3). Column (2) uses all employee-grant-date observations (conditional on the options being vested and in-the-money), while column (4) excludes observations within 30 days following a vesting event. The coefficient β_1 on RSU grants is positive and significant in both regressions, while the coefficient β_2 on option grants is negative and insignificant in both regressions. The prediction that $\beta_2 > \beta_1$ under the Diversification Hypothesis is clearly rejected in all specifications (since the point estimates indicate that $\beta_1 > \beta_2$); indeed, β_1 is significantly greater than β_2 in both regressions.

While we predicted $\beta_1 = \beta_2 > 0$ under the Liquidation Hypothesis, we speculate that $\beta_2 = 0$ is plausibly consistent with the Liquidation Hypothesis. In particular, since RSUs retain significant value even following stock-price declines, employees will likely perceive a recent grant of time-lapse restricted shares as an increase in their wealth, triggering an immediate demand to increase consumption. However, it is plausible that a recent grant of at-the-money

[20] This statement is clearly true when comparing option grants with time-lapse restricted stock grants, but is not necessarily true for performance shares (i.e., equity grants vesting only upon achievement of performance triggers). The vesting information in our data suggest that nearly all of the equity grants in our sample (with the exception of some to top-level executives) are time-lapse rather than performance-based. This finding is consistent with the fact that performance shares were introduced primarily to satisfy proxy-advisory firms (Institutional Shareholder Services, for example, recommends that at least 50% of all equity grants be performance based) and deductibility under Section 162(m) of the Internal Revenue Code (which restricts deductibility of non-performance-related pay—including time-lapse restricted shares—to $1 million); both of the factors apply only to top-level "proxy-named" executives.

options (with a grant-date intrinsic value of zero) will not be perceived as an increase in spendable wealth, given the possibility that stock prices fall and the option expires worthless.

Overall, we view the results in Table 6 as supporting the Liquidity Hypothesis over the Diversification Hypothesis.

4.3. Implied Risk-Aversion Coefficients under the Diversification Hypothesis

4.3.1. Methodology

The large gap between the realized spread and the Black-Scholes value at exercise (particularly for non-executives) shown in Table 4 suggests either that the employees in our sample must be highly risk averse, or that factors other than diversification concerns are driving early exercise decisions. In this section we estimate the level of risk aversion implied by the observed exercise behavior given CRRA utility, the employee's observed equity portfolio (stock options and RSUs), and outside wealth.[21] We then ask whether the implied risk-aversion coefficients (which are specific to each individual grant on each exercise date) are reasonable both in terms of estimated levels and how they vary for a single individual across exercise events. While there is no single accepted definition of "reasonable" relative risk-aversion coefficients, economists typically assume ranges from 1-5 (e.g., Chetty, 2003; Gandelman and Hernandez-Murillo, 2015), which we take as our basis for comparison.[22] Anomalies in implied risk-aversion coefficients (in levels or within-individual variation) provide circumstantial evidence that exercise decisions are driven by factors other than portfolio rebalancing.

As noted in the Introduction, most models of early exercise assume a utility function (usually constant relative risk aversion, CRRA) and predict exercise behavior for individuals holding a given grant of options and also holding both inside wealth (i.e., additional stock and options from prior grants) and outside wealth invested in non-employer-related assets. Key model inputs include assumptions about risk-aversion coefficients, inside and outside wealth,

[21] Our approach is akin to using the Black-Scholes formula to extract implied volatilities from actual option prices.

[22] In a widely cited study, Friend and Blume (1975) estimate risk-aversion coefficients in the range of two to three based on portfolio holdings of individuals. While some economists have argued that coefficients of 20 or higher are required to solve the "equity premium puzzle" (see, for example, Mehra and Prescott, 1985; Kandel and Stambaugh, 1991; Campbell and Cochrane, 1999), Lucas (1994) claimed that any "resolution" of the equity premium puzzle will have to use risk-aversion coefficients in the neighborhood of 2.5 or lower to be convincing.

and additional assumptions about how outside wealth is invested (e.g., risk-free assets, the market portfolio, etc.). Our underlying model in this section follows Hall and Murphy (2002) and is similar to traditional binomial option valuation (Cox et al., 1979) with two major differences. First, while binomial price ‘‘trees’’ under the traditional model are based on expected returns equal to the risk-free rate (reflecting that option holders perfectly hedge the risk of options), price trees under our modified approach are based on CAPM expected returns, $E(r) = r_f + \beta E(r_m - r_f)$.[23] Second, while under the traditional approach the payout from exercising is compared to the expected value of holding for another period, under our modified approach we compare the expected utility from exercising (and holding cash until the final period) to the ‘‘expected’’ expected utility from holding the option for another period.

We treat the actual exercise date for a specific grant as the first node on a binomial tree with 100 nodes lasting until the expiration. For simplicity, we assume that the focal grant is exercised in its entirety or not at all and assume that all other holdings of restricted stock and options from other grants (or unvested options from the focal grant) are held until expiration of the focal option.[24] In addition, we assume that stock acquired through exercise is sold immediately, with the cash proceeds invested at the risk-free rate and held until expiration. We employ a backward-induction algorithm where an employee exercises at any period t if the expected utility from exercise is greater than the expected utility from holding the option to the next period. The exercise decision in the final period (i.e., final node) is trivial since all in-the-money nodes will be exercised while out-of-the-money nodes will be worthless. Proceeding recursively, we can determine the lowest level of risk aversion that would motivate an individual to exercise at the “first” node (i.e., on the actual exercise date at the actual stock price and exercise price).[25]

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[23] The risk-free rate, r_f, is estimated as the yield on U.S. treasuries with maturities closest to the remaining term on the option. The market return, r_m, is the monthly stock value-weighted return from CRSP, and β’s are estimated using monthly returns over the prior 48 months. In addition, we estimate stock-price volatilities as the mean monthly volatility over the prior 48 months, and estimate dividend yields over the prior 36 months.

[24] These simplifying assumptions make the solution tractable, but also reflect in part the fact that the employee is expected to receive future grants even as prior grants become vested.

[25] In practice, we estimated exercise decisions at each actual exercise date assuming risk-aversion coefficients ranging from 1 to 25. We determined implied risk-aversion as the lowest coefficient that would motivate exercise. For example, if exercise is predicted at $\rho=6$ but not at $\rho=5$, we estimate the risk-aversion coefficient as $\rho=6$. When exercise (on an actual exercise date) is not predicted at $\rho=25$, we assume that $\rho > 25$. On the other extreme, when

4.3.2. Implied Risk-Aversion Coefficients

Figure 6 depicts the distribution of implied risk-aversion coefficients estimated from the algorithm described above, for top executives (Panel A) and non-executives (Panel B). The figure is based on 9,600 exercise events from 1,918 individuals. The number of exercise events and employees is smaller than those described in Table 4 because estimating risk-aversion coefficients requires our proxy for *Home Price*, which is only available for employees domiciled in the United States. Panel A shows that over half (54%) of top executives have implied risk-aversion coefficients of ρ=0 (13%) or ρ=1 (41%); another 26% have an implied risk-aversion coefficient of ρ=2. One interpretation of these data (which correspond to modest or non-existent levels of risk aversion) is that top executives are not very risk averse, in spite of holding substantial fractions of their wealth in company stock or options. Another interpretation is that factors other than diversification (e.g., shareholder scrutiny, underestimating outside liquid assets, or Malmendier-Tate (2008) managerial overconfidence) drive executive exercise decisions.

In contrast to the exercise decisions of top-level executives, which imply risk aversion coefficients below standard levels based on the CRRA-utility model, the exercises of lower-level employees imply levels of risk aversion much higher than are typically assumed to be plausible. In particular, Panel B of Figure 6 shows that nearly three-fourths of exercises suggest coefficients exceeding ρ=3, and nearly one-fourth of non-executive exercises imply risk-aversion coefficients exceeding ρ=25 (which is the highest we considered in our tests). Risk-aversion coefficients of this magnitude would predict that individuals would never cross a street, even on a crosswalk on a green light, and suggest that factors beyond diversification explain their decisions to exercise early.

A valid concern about the results in Figure 6 relates to our assumption that outside wealth is equal to the median home price in the employee's Zip Code. Given the ages of the employees in our sample (interquartile range of 47.4 to 58.8 years) and home ownership rates (interquartile range of 66% to 85% in our covered Zip Codes), we are comfortable with the

exercise *is* predicted with ρ=1, we assume that the individual is risk-neutral (i.e., ρ=0) if at least 95% of the option term has expired, and otherwise assume ρ=1.

assumption that our option-recipient sample are likely homeowners. We are less comfortable with our assumption that the employees in our sample, particularly the more senior managers, have no assets beyond the value of their home (e.g., such executives likely hold portfolios of other assets beyond home equity, suggesting our implied risk-aversion coefficients are too low) or that employees, particularly less senior managers, own 100% of the equity in their homes (e.g., such executives may be heavily mortgaged with few other assets, suggesting our implied risk-aversion coefficients are too high). While maintaining the assumption that outside wealth is proportional to home value, in the Appendix Figures A1 and A2 we replicate Figure 6 with the respective assumptions that outside wealth equals 200% or 50% of Zip Code-level median home prices. While the extreme results (i.e., Panel A from Figure A1 and Panel B from Figure A2) are closer to supporting the Diversification Hypothesis, the implied coefficients for top executives remain "too low" while those for non-executives remain "too high" to support the Diversification Hypothesis. For example, in Panel B of Figure A2, nearly half of estimated risk aversion coefficients are over ρ=5, with nearly a third over ρ=10 and 15% exceeding ρ=25.

4.1.2 Within-Individual Consistency

While an individual's risk-aversion parameters can evolve over time (older individuals tend to be more risk averse), risk-aversion coefficients are not expected to vary wildly over short periods of time. Therefore, if diversification is the primary driver of early exercise, we should expect little variation in estimated risk-aversion for a given individual across exercises in our sample.

Our sample of 9,600 exercise events (and hence 9,600 implied risk-aversion coefficients) includes 386 employees (49 executives and 337 non-executives) who exercised exactly once during our sample period, and 1,532 employees (405 executives and 1,127 non-executives) who exercised more than once. Since we define exercise events at the grant level (i.e., a specific option grant at a specific grant-date and exercise price), the "more than once" subsample includes employees both exercising a specific grant at different dates and exercising different grants on the same date. This subsample of employees with multiple exercise events and event-specific estimates of risk aversion allows us to analyze within-individual variations in risk-aversion.

Table 7 summarizes the within-individual variations in risk-aversion coefficients for our 1,532 executives and non-executives with multiple exercise events. The table shows, for each executive group, the interquartile (i.e., 75th to 25th percentile) and max-to-min (i.e., 100th to 0th percentile) range of implied risk-aversion coefficients, grouped by the number of exercises. The table suggests large variations in implied risk aversion among employees with multiple exercise events. For non-executive employees, the average difference between lowest to highest implied risk aversion coefficients within individuals who exercise twice is 7.5, and this range increases for employees with more exercise events, with a difference of 14.3 for non-executives with 5 or more exercise events.

Even if it were reasonable to expect some variation in underlying risk-aversion parameters within individuals over an extended period of time (e.g., our sample period covers roughly ten years), it is less likely risk aversion would vary within a short period. In our sample, we find that roughly a third of all exercises occur within 30 days of an exercise from another grant. Moreover, the mean difference in implied risk aversion between exercises (for the same individual) which occurred within 30 days of each other is over six and a half for lower-level managers. That we find such large variation in implied risk aversion even for exercises that are within a month of each other suggests diversification is not driving these exercise decisions. Importantly, for these exercises, outside wealth is held roughly constant (i.e., outside wealth is not expected to change considerably within a 30-day period).

4.4. Clustering Across Exercises

Because grant-specific factors such as exercise price and time-to-maturity are important inputs to models of early exercise under the Diversification Hypothesis, options from different grants (i.e., with different grant dates and different exercise prices) are generally expected to be exercised at different times. However, as noted in the prior subsection, a large fraction of the exercises in our sample exhibit temporal "clustering." In fact, we find that employees in our sample often exercise options from different grants on the same date. For example, conditional on both exercising and having more than one option available to exercise, we find that 15% of exercise dates (and 22% of exercise months) correspond to exercises of multiple

grants. Clustered exercises are especially pronounced for non-executives in our sample, where 22% of exercise dates (and 29% of exercise months) correspond to exercises of multiple grants.

While exercising options from different grants on the same day (or otherwise close together) is inconsistent with the Diversification Hypothesis, such temporal clustering is consistent with the Realization Utility Hypothesis, since recent price run-ups or surpassing price milestones will increase the realizable value of multiple option grants on the same underlying stock. Such clustering of exercises is also consistent with the Liquidity Hypothesis, since employees wanting to finance major purchases may need to exercise options from different grants.

To examine more formally whether the propensity to exercise is greater conditional on exercising an option from another grant (which would suggest such exercises are likely driven by factors other than diversification), we conduct t-tests of the difference in mean exercise rate for subsamples depending on how recently an option from another grant was exercised. Table 8 shows the exercise probabilities conditional on options from another grant being exercised within a specific window (7, 14, 21, or 30 days). For both executives and non-executives, we find an exercise probability of approximately 0.1% for subsamples that did not follow an exercise of another grant within the 30-day period. But, conditional on observing an exercise from another grant, the exercise probability increases many times over (the unreported t-statistics testing the equivalence of the exercise probability with that in the left-adjacent column range from $t=47$ to $t=210$).

For executives, Table 8 shows a mean exercise probability of .43% for the subsample following 30 days of another exercise, compared to a rate of .1% for the subsample that did not follow another exercise within 30 days. Thus, for Top Executives, the rate of exercise is over four times greater following a recent exercise, and the difference is highly statistically significant (t-stat of 47.02). Moreover, the difference in exercise rates is even more pronounced as the window for recent exercises we examine gets smaller; exercise rates are over ten times greater (t-stat of 85.92) following within seven days of an exercise from another grant.

Table 8 also shows that among lower-level managers the effect of clustering is much more dramatic. Within 30 days of another exercise, the exercise rate is 2%, which is 20 times

greater than the rate (.1%) when not preceded by another exercise within 30 days. Again, we find the clustering is even more clear for smaller windows, as the rate of exercise within seven days of a previous exercise is over 50 times greater than when not preceded by an exercise within seven days (5.42% vs. .11%).

Because vesting dates across grants are often close to each other, pent-up demand for diversification could be a potential explanation for at least some of the clustering of exercises we document. However, when we exclude observations that occur within 30 days of a vesting event (untabulated), we continue to find nearly identical results as those reported in Table 8, suggesting pent-up demand is not driving clustering. Along with our finding of large variation in implied risk aversion for exercises that occur close to each other reported in the previous section, our finding that employees cluster their exercises suggests that grant-specific factors expected to be of primary importance under the Diversification Hypothesis, are not the main drivers of early exercise decisions.

4.5. Block Exercises

Grasselli and Henderson (2009) argue that utility-based models do not predict "block exercises," in which employees exercise all available options from a grant. Rather, they show that diversification motives will cause employees to employ a gradual series of fractional exercises because risk aversion causes each additional option held to be worth less to the individual; as the number of options held decreases due to fractional exercise, the threshold price to exercise remaining options increases.[26] Analogously (but in the context of stock sales rather than option exercises), Odean (1998) argues that investors seeking to rebalance their portfolios will sell some, but not all of their position in a given stock. He therefore interprets 100% sales of a position in a particular stock as evidence for the disposition effect rather than rebalancing. Thus, we examine the tendency of employees, conditional on exercise, to exercise all available options from a given grant.

Figure 7 depicts both the prevalence of early exercise and block exercises by time since the most recent vesting event for executives (Panel A) and non-executives (Panel B). While

[26] Grasselli and Henderson's (2009) model suggests that if the act of exercising is costly (e.g., due to the mental effort of deciding whether to exercise), employees may still exercise in blocks.

block exercise immediately following vesting may reflect pent-up demand and thus could be consistent with diversification, we find that block exercises generally constitute 50% or more of all exercises for executives long after vesting, which is inconsistent with the Diversification Hypothesis. Block exercises for non-executive managers are even more prevalent, especially for exercises occurring well after vesting. For example, for exercises that occur more than three years after vesting (which makes up 22% of exercises), nearly 80% are block exercises. Based on the intuition from Odean (1998) and the model from Grasselli and Henderson (2009), we interpret the prevalence of block exercises in our data as further evidence that early exercise, particular among non-executive employees, is not driven primarily by diversification concerns.

5. Conclusion

Theoretical and empirical studies of executive and employee early exercise have routinely assumed that exercise is primarily driven by portfolio concerns: risk-averse employees exercise early (immediately selling the acquired stock) to diversify their portfolios. Indeed, even studies analyzing additional explanations for early exercise (such as psychological factors or inside information) routinely control for portfolio factors, and Malmendier and Tate's oft-used measure of managerial overconfidence explicitly assumes that rational (non-overconfident) managers *should* exercise early based on portfolio concerns. Using novel data that includes rich information on all equity grants and employee locations (allowing for a proxy for outside wealth based on Zip Code-level home values), we offer empirical support that exercise decisions are driven not by diversification motives but rather by liquidity: in-the-money exercisable options provide an access to cash to make major purchases. While we do not challenge the view that risk aversion and (lack of) diversification effects employees' subjective valuation of their equity holdings, we find little evidence that employees make exercise decisions to reduce their exposure to company stock prices.

References

Aboody D, Hughes J, Liu J, Su W. Are executive stock option exercises driven by private information? *Review of Accounting Studies*. 2008 Dec 1;13(4):551-70.

Anderson MC, Banker RD, Ravindran S. Executive compensation in the information technology industry. *Management Science*. 2000 Apr;46(4):530-47.

Armstrong, C. The incentives of equity-based compensation and wealth. 2008 Working Paper.

Armstrong C, Jagolinzer AD, Larcker DF. Timing of employee stock option exercises and the cost of stock option grants. Rock Center for Corporate Governance Working Paper. 2007 Jun 1(34).

Barberis N, Xiong W. Realization utility. *Journal of Financial Economics*. 2012 May 1;104(2):251-71.

Barone-Adesi G, Whaley RE. Efficient analytic approximation of American option values. The *Journal of Finance*. 1987 Jun;42(2):301-20.

Bartov E, Mohanram P. Private information, earnings manipulations, and executive stock-option exercises. *The Accounting Review*. 2004 Oct;79(4):889-920.

Bettis JC, Bizjak JM, Lemmon ML. Exercise behavior, valuation, and the incentive effects of employee stock options. *Journal of Financial Economics*. 2005 May 1;76(2):445-70.

Black, Fischer, and Myron S. Scholes, 1973, The pricing of options and corporate liabilities, *Journal of Political Economy* 81, 637–659.

Bova, F and M. D. Vance. Uncertainty avoidance and the timing of employee stock option exercise. *Journal of International Business Studies*. 50: 740-757.

Brooks R, Chance DM, Cline B. Private information and the exercise of executive stock options. *Financial Management*. 2012 Sep; 41(3):733-64.

Campbell, J.Y., Cochrane, J., 1999. By force of habit: a consumption-based explanation of aggregate stock market behavior. *Journal of Political Economy* 107, 205–251.

Carpenter JN. The exercise and valuation of executive stock options. *Journal of Financial Economics*. 1998 May 1;48(2):127-58.

Carpenter JN, Remmers B. Executive stock option exercises and inside information. *Journal of Business*. 2001 Oct;74(4):513-34.

Carpenter JN, Stanton R, Wallace N. Optimal exercise of executive stock options and implications for firm cost. *Journal of Financial Economics*. 2010 Nov 1;98(2):315-37.

Carpenter JN, Stanton R, Wallace N. Employee Stock Option Exercise and Firm Cost. *Journal of Finance*. 2019.

Carr P, Linetsky V. The valuation of executive stock options in an intensity-based framework. *Review of Finance*. 2000 Dec 1;4(3):211-30.

Chang TY, Solomon DH, Westerfield MM. Looking for someone to blame: Delegation, cognitive dissonance, and the disposition effect. *The Journal of Finance*. 2016 Feb;71(1):267-302.

Chetty, Raj. A new method of estimating risk aversion. No. w9988. National Bureau of Economic Research, 2003.

Cicero DC. The manipulation of executive stock option exercise strategies: Information timing and backdating. *Journal of Finance*. 2009 Dec;64(6):2627-63.

Core JE, Guay WR. Stock option plans for non-executive employees. *Journal of Financial Economics*. 2001 Aug 1;61(2):253-87.

Cox, J.C., Ross, S.R., Rubinstein, M., 1979. Option pricing: a simplified approach. Journal of Financial Economics 7, 229–263.

Detemple J, Sundaresan S. Nontraded asset valuation with portfolio constraints: a binomial approach. *Review of Financial Studies*. 1999 Jul 2;12(4):835-72.

Fos V, Jiang W. Out-of-the-money CEOs: Private control premium and option exercises. *Review of Financial Studies*. 2015 Nov 14;29(6):1549-85.

Friend, I., Blume, M.E., 1975. The demand for risky assets. American Economic Review 65 (5), 900–922.

Gandelman N, Hernandez-Murillo R. Risk Aversion at the Country Level. *Federal Reserve Bank of St. Louis Review*. 2015;97(1):53-66.

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

Hall BJ, Murphy KJ. Optimal exercise prices for executive stock options. *American Economic Review*. 2000 May;90(2):209-14.

Hall BJ, Murphy KJ. Stock options for undiversified executives. *Journal of Accounting and Economics*. 2002 Feb 1;33(1):3-42.

Heath C, Huddart S, Lang M. Psychological factors and stock option exercise. *Quarterly Journal of Economics*. 1999 May 1;114(2):601-27.

Heron, R., Lie, E. Do stock options overcome managerial risk aversion? Evidence from exercises of executive stock options. *Management Science*. 2017 63: 3057-3071.

Hemmer T, Matsunaga S, Shevlin T. The influence of risk diversification on the early exercise of employee stock options by executive officers. *Journal of Accounting and Economics*. 1996 Feb 1;21(1):45-68.

Huddart S. Employee stock options. *Journal of Accounting and Economics*. 1994 Sep 1;18(2):207-31.

Huddart S, Lang M. Employee stock option exercises an empirical analysis. *Journal of Accounting and Economics*. 1996 Feb 1;21(1):5-43.

Huddart S, Lang M. Information distribution within firms: evidence from stock option exercises. *Journal of Accounting and Economics*. 2003 Jan 1;34(1-3):3-1.

Izhakian Y, Yermack D. Risk, ambiguity, and the exercise of employee stock options. *Journal of Financial Economics*. 2017 Apr 1;124(1):65-85.

Jin L, Kothari SP. Effect of personal taxes on managers' decisions to sell their stock. *Journal of Accounting and Economics*. 2008 Sep 1;46(1):23-46.

Kahneman, D., Tversky, A. Prospect theory: an analysis of decision under risk. *Econometrica*. 1979 47, 263–292.

Kandel, S., Stambaugh, R.F., 1991. Asset returns and intertemporal preferences. *Journal of Monetary Economics* 27, 39–71.

Kedia S, Rajgopal S. Neighborhood matters: The impact of location on broad based stock option plans. *Journal of Financial Economics*. 2009 Apr 1;92(1):109-27.

Klein, Daniel, and Ernst Maug, 2011, How do executives exercise stock options? Working paper, University of Mannheim.

Kulatilaka N, Marcus AJ. Valuing employee stock options. *Financial Analysts Journal*. 1994 Nov 1;50(6):46-56.

Lambert RA, Larcker DF, Verrecchia RE. Portfolio considerations in valuing executive compensation. *Journal of Accounting Research*. 1991 Apr 1;29(1):129-49.

Leung T, Sircar R. Accounting for risk aversion, vesting, job termination risk and multiple exercises in valuation of employee stock options. *Mathematical Finance*. 2009 Jan;19(1):99-128.

Lucas, D., 1994. Asset pricing with undiversifiable risk and short sales constraints: deepening the equity premium puzzle. *Journal of Monetary Economics* 34, 325–341.

Malmendier U, Tate G. CEO overconfidence and corporate investment. *Journal of Finance*. 2005 Dec;60(6):2661-700.

Malmendier U, Tate G. Who makes acquisitions? CEO overconfidence and the market's reaction. *Journal of Financial Economics*. 2008 Jul 1;89(1):20-43.

Mehra, R., Prescott, E.C., 1985. The equity premium: a puzzle. Journal of Monetary Economics 15, 145–161.

Merton RC. Theory of rational option pricing. *Bell Journal of Economics and Management Science*. 1973; 4(1).

Meulbroek LK. The efficiency of equity-linked compensation: Understanding the full cost of awarding executive stock options. *Financial Management*. 2001 Jul 1:5-44.

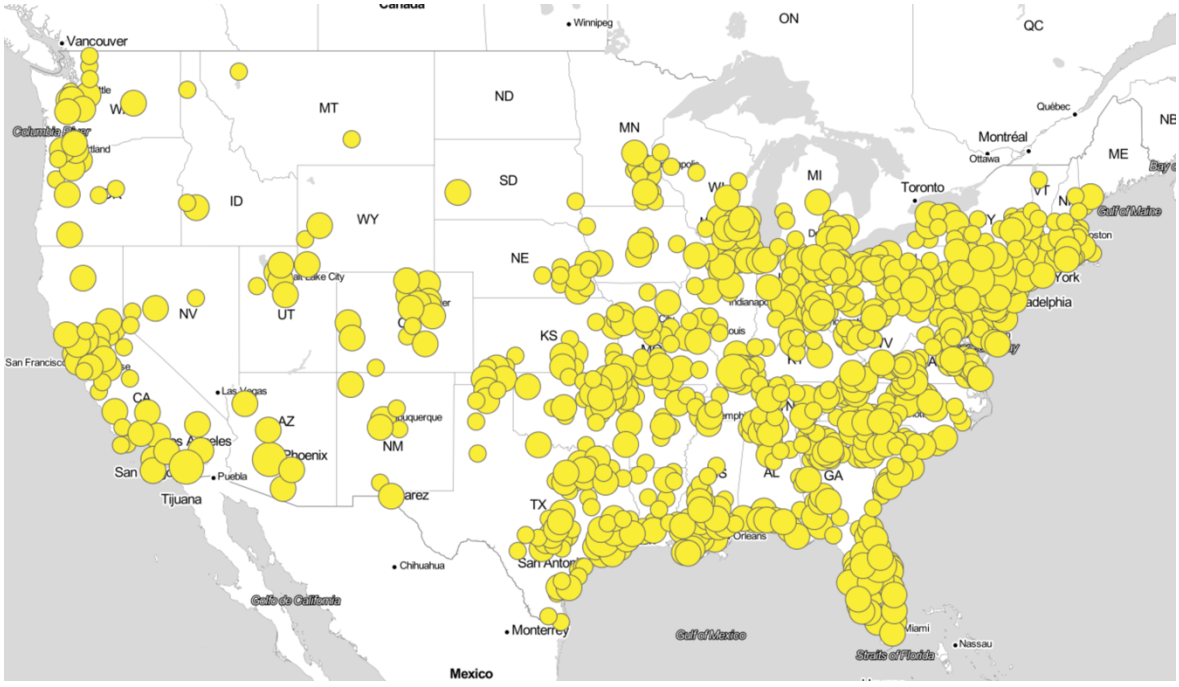
Odean T. Are investors reluctant to realize their losses?. The Journal of finance. 1998 Oct;53(5):1775-98.

Papke LE, Wooldridge JM. Econometric methods for fractional response variables with an application to 401 (k) plan participation rates. *Journal of Applied Econometrics*. 1996 Nov;11(6):619-32.

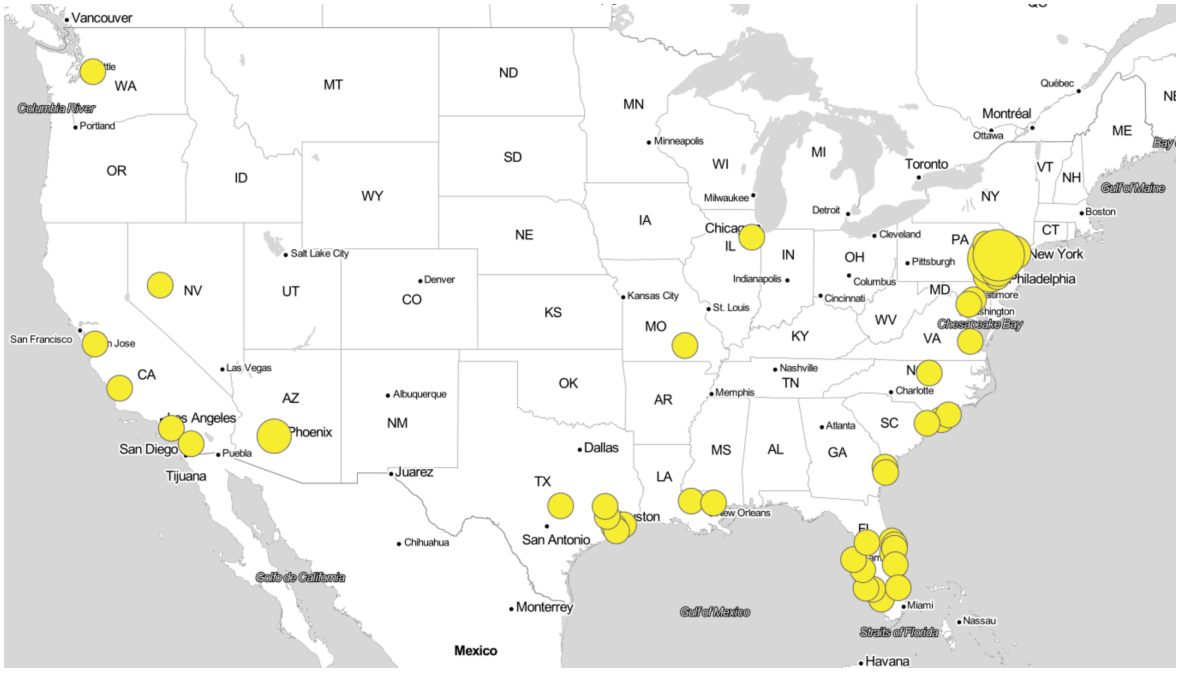
Shefrin H, Statman M. The disposition to sell winners too early and ride losers too long: Theory and evidence. *The Journal of finance*. 1985 Jul;40(3):777-90.

Figure 1 Geographic Dispersion of Domestic Employees, Company C1

PANEL A: ALL EMPLOYEES



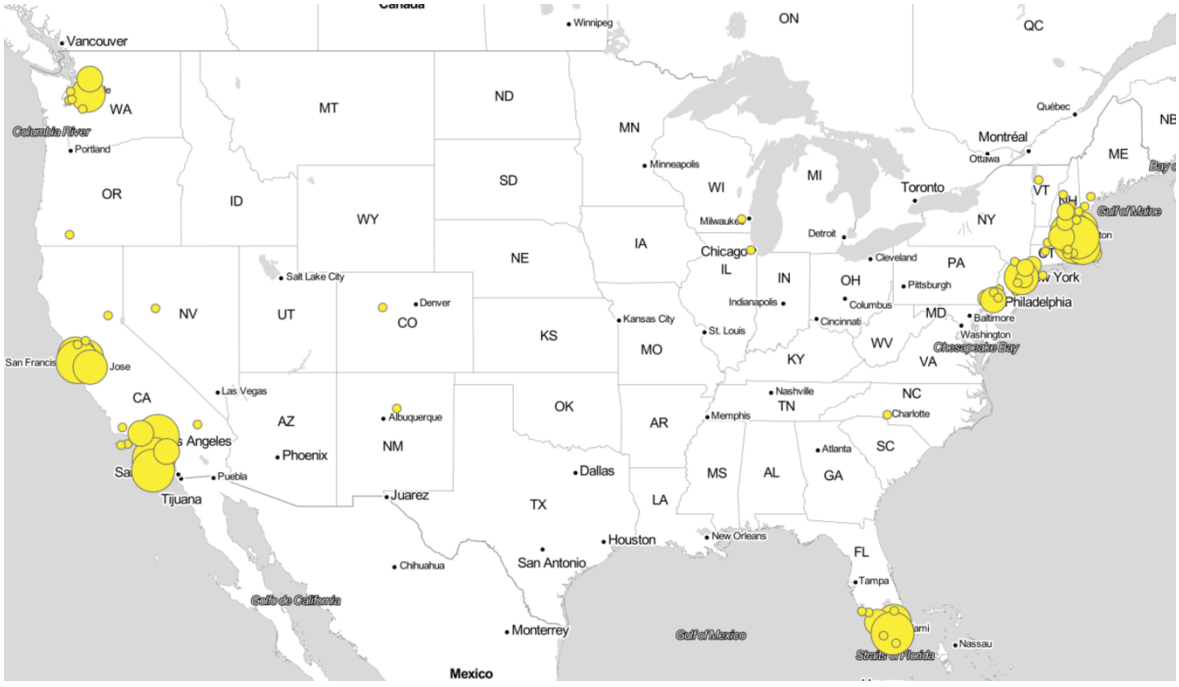
PANEL B: EMPLOYEES WITH STOCK OPTION GRANTS



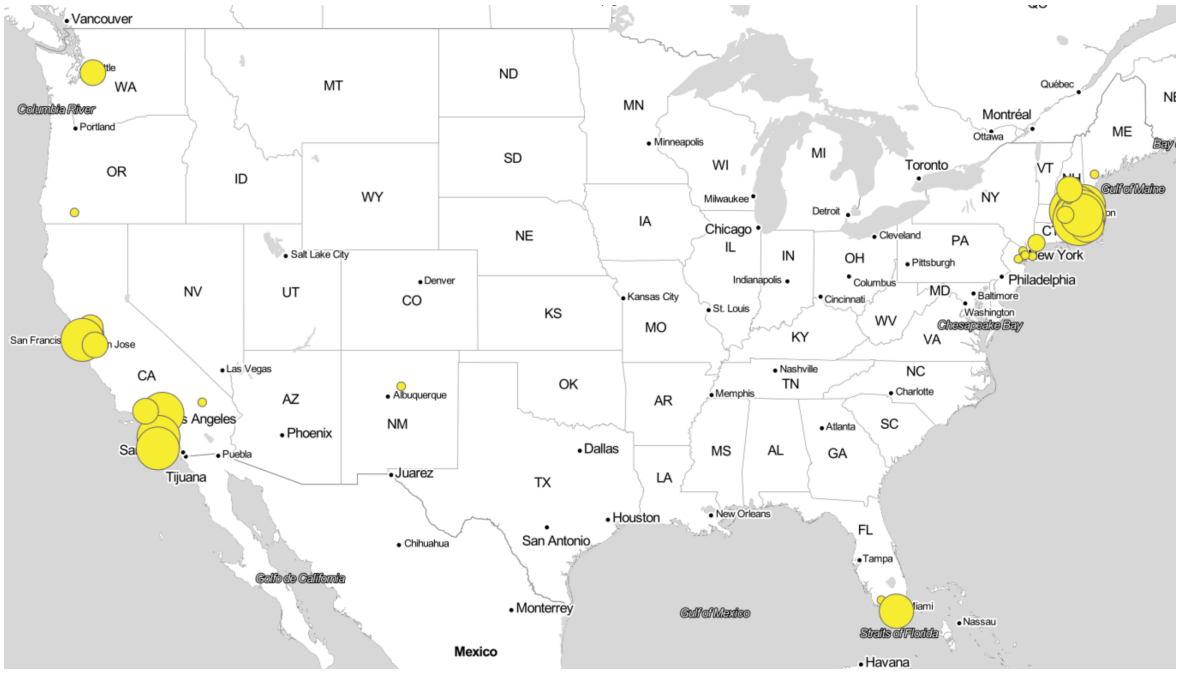
Note: Company C1, headquartered in Pennsylvania, has 844 employees with option grants, including 244 international employees (not depicted). Exercise data are available from September 2006 through August 2014.

Figure 2 Geographic Dispersion of Domestic Employees, Company C2

PANEL A: ALL EMPLOYEES



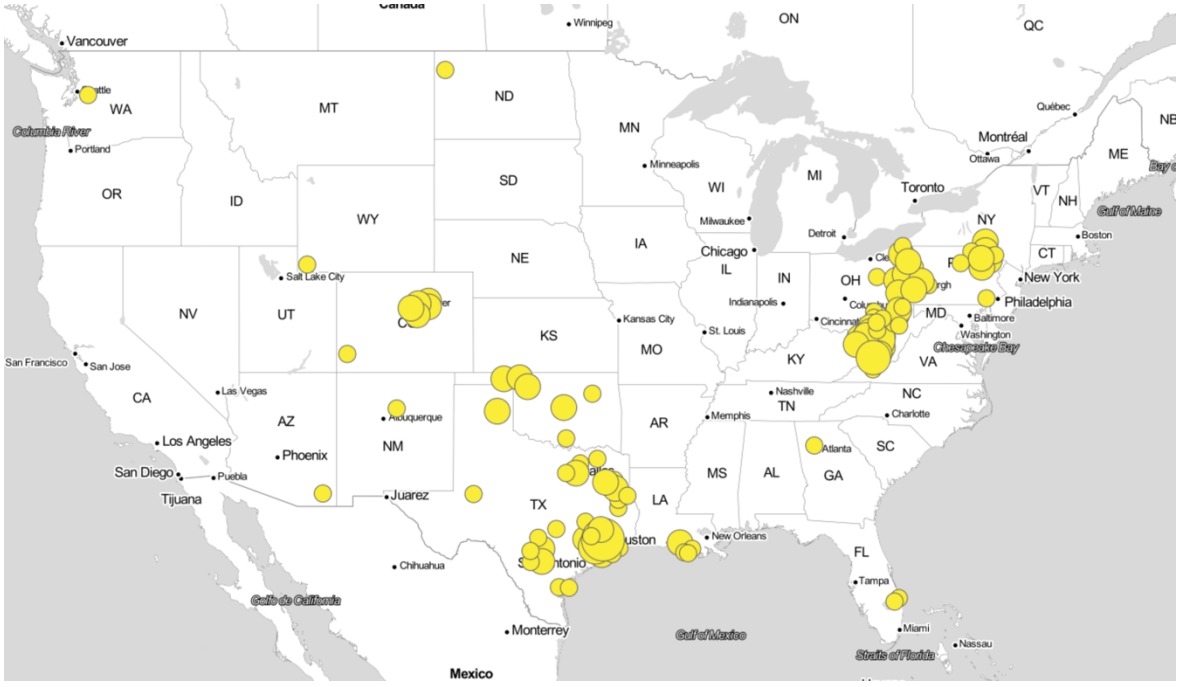
PANEL B: EMPLOYEES WITH STOCK OPTION GRANTS



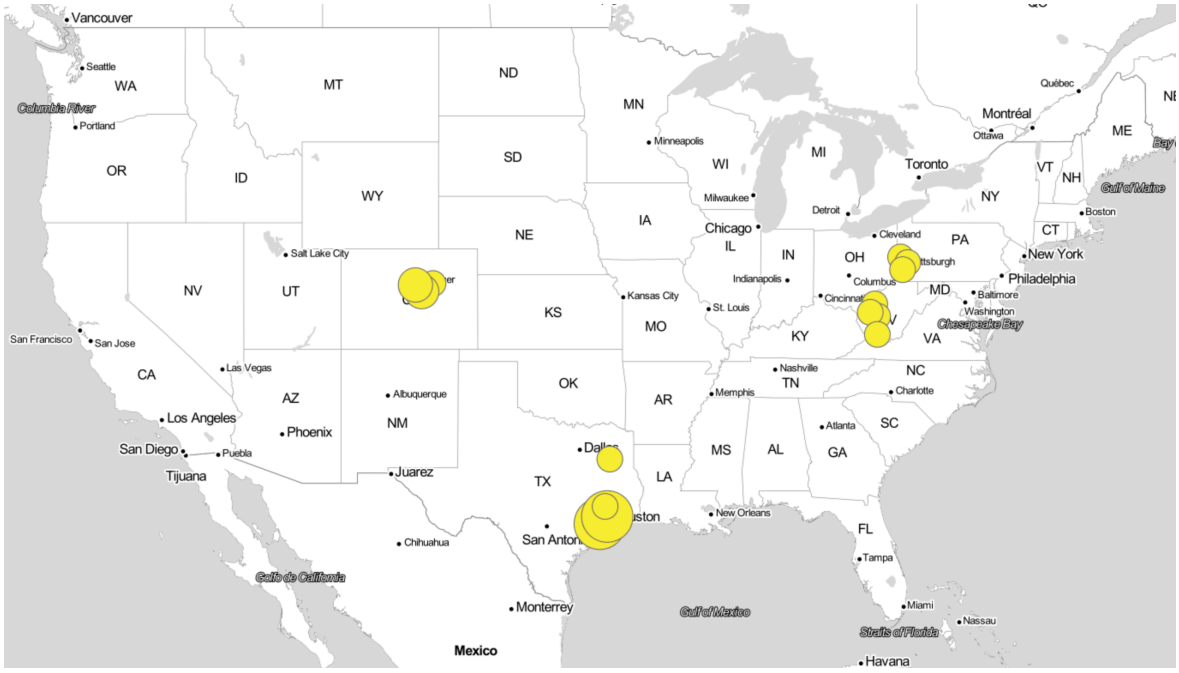
Note: Company C2, headquartered in Boston, MA, has 614 U.S. employees with option grants. Exercise data are available from January 2004 through August 2014.

Figure 3 Geographic Dispersion of Domestic Employees, Company C3

PANEL A: ALL EMPLOYEES



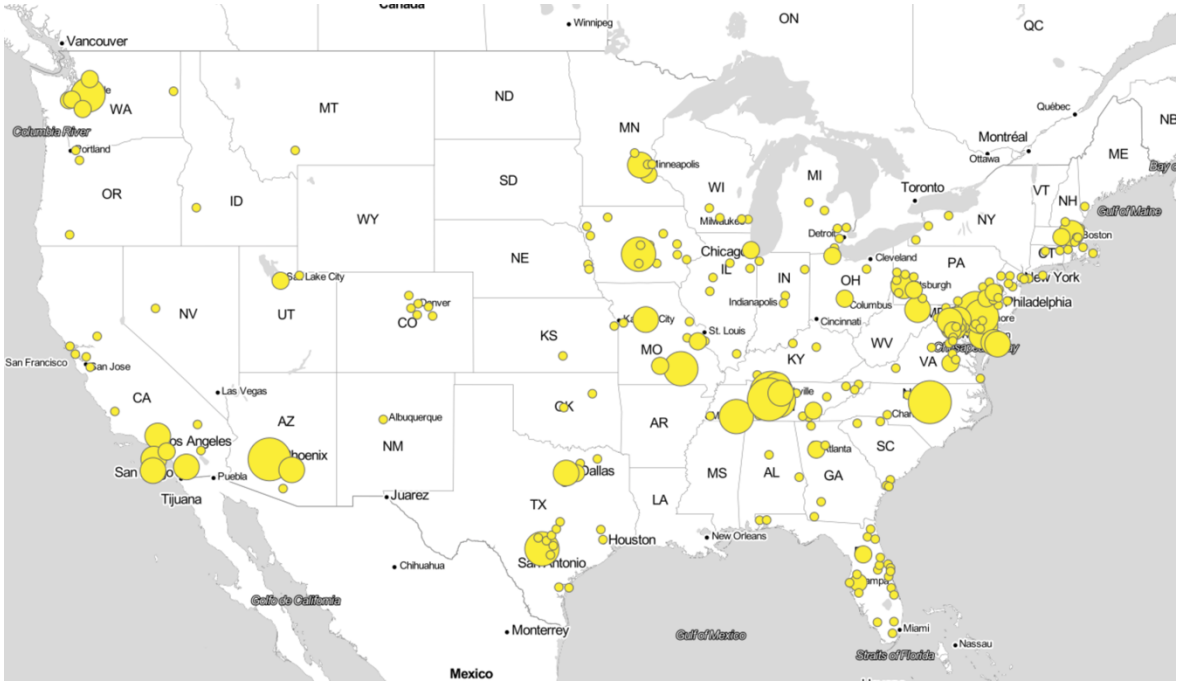
PANEL B: EMPLOYEES WITH STOCK OPTION GRANTS



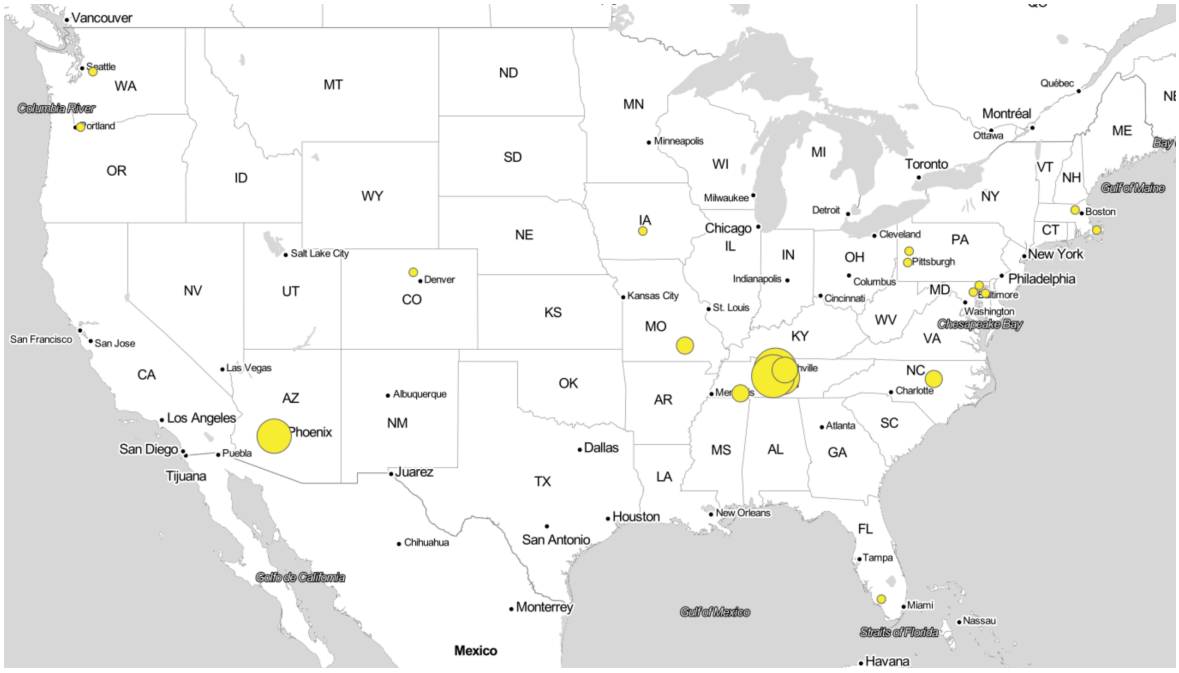
Note: Company C3, headquartered in Houston, TX, has 95 U.S. employees with option grants. Exercise data are available from January 2006 through August 2013.

Figure 4 Geographic Dispersion of Domestic Employees, Company C4

PANEL A: ALL EMPLOYEES



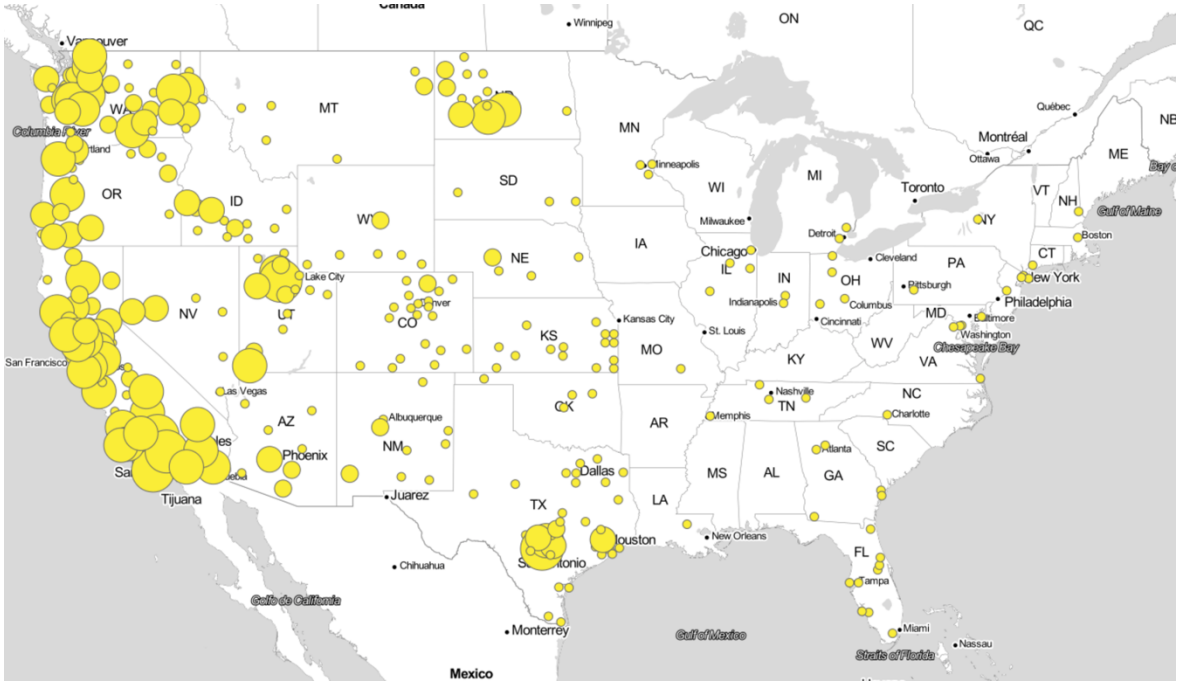
PANEL B: EMPLOYEES WITH STOCK OPTION GRANTS



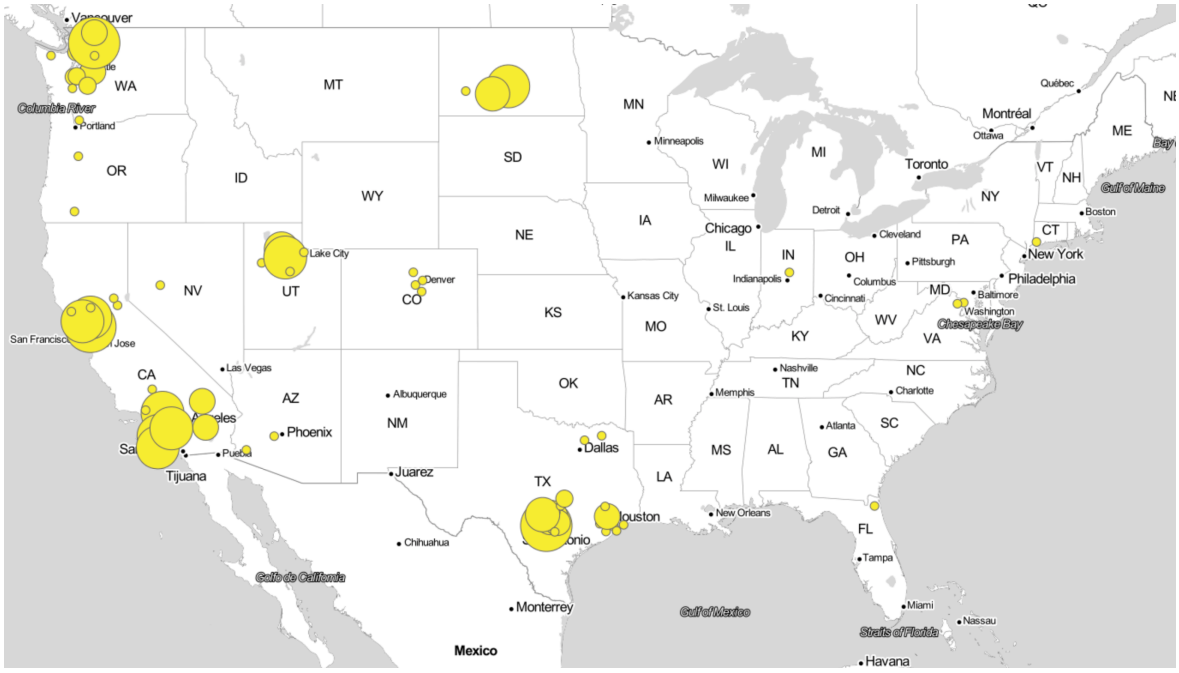
Note: Company C4, headquartered in Tennessee, has 476 employees with option grants, including 10 in Hawaii and 1 international (not depicted). Exercise data are available from June 2010 through August 2014.

Figure 5 Geographic Dispersion of Domestic Employees, Company C5

PANEL A: ALL EMPLOYEES



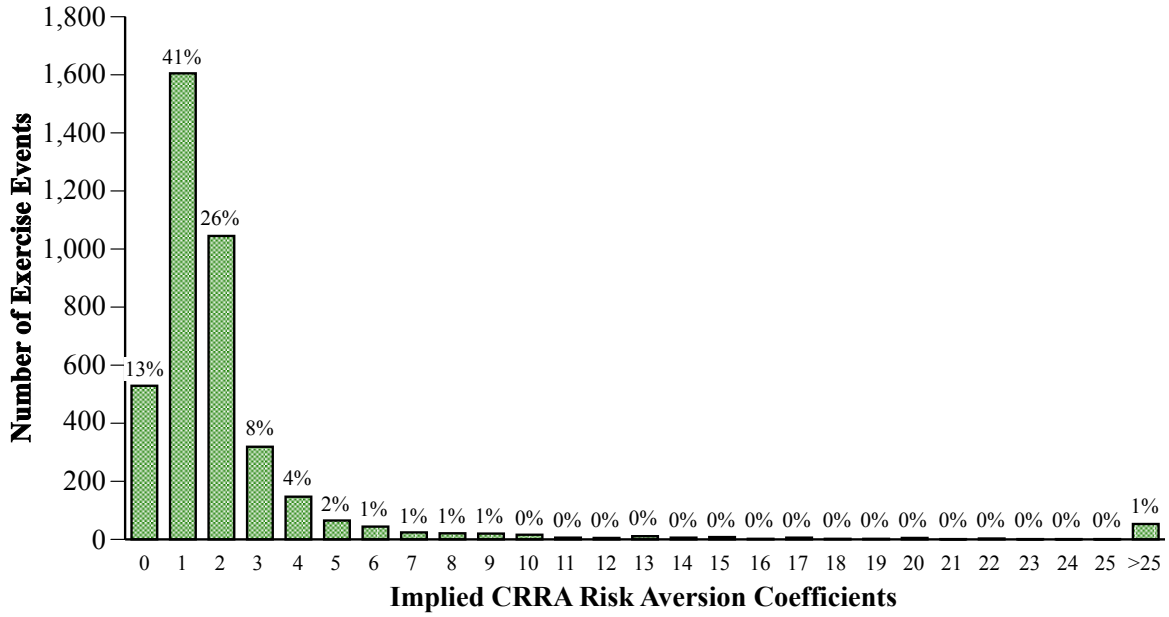
PANEL B: EMPLOYEES WITH STOCK OPTION GRANTS



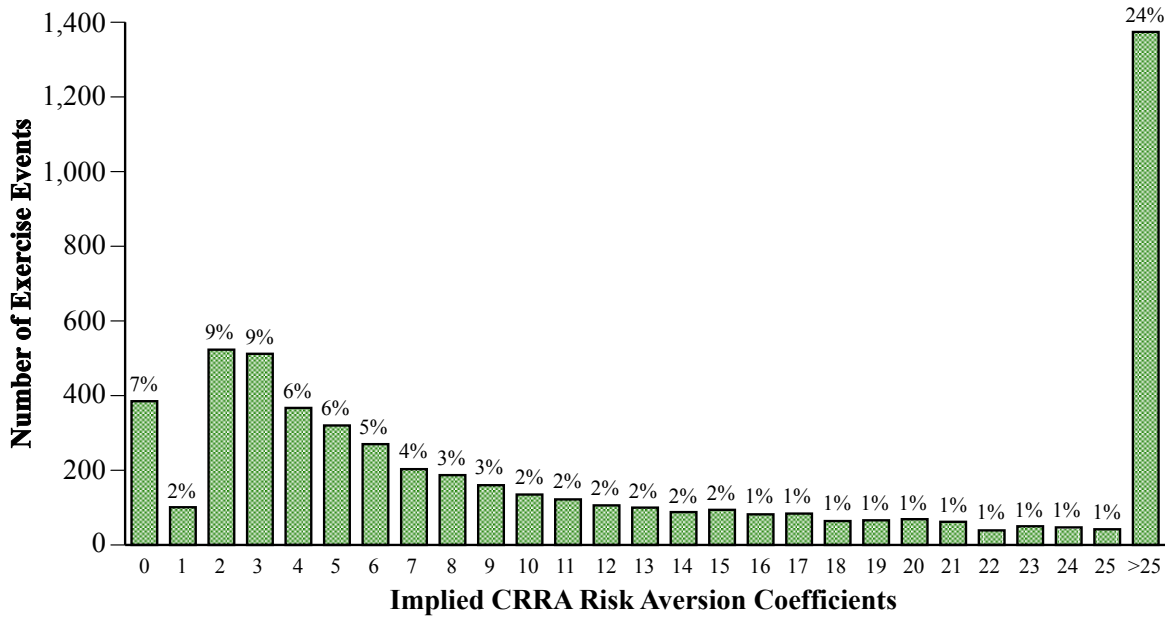
Note: Company C5, headquartered in San Antonio, TX, has 1,589 employees with option grants, including 62 in Alaska, 103 in Hawaii, and 12 internationals (not depicted). Exercise data are available from November 2004 through August 2014.

Figure 6 Implied Risk Aversion Coefficients assuming Constant Relative Risk Aversion (CRRA) Utility and Outside Wealth equal to Median Home Price in Employee's Zip Code

PANEL A: TOP EXECUTIVES



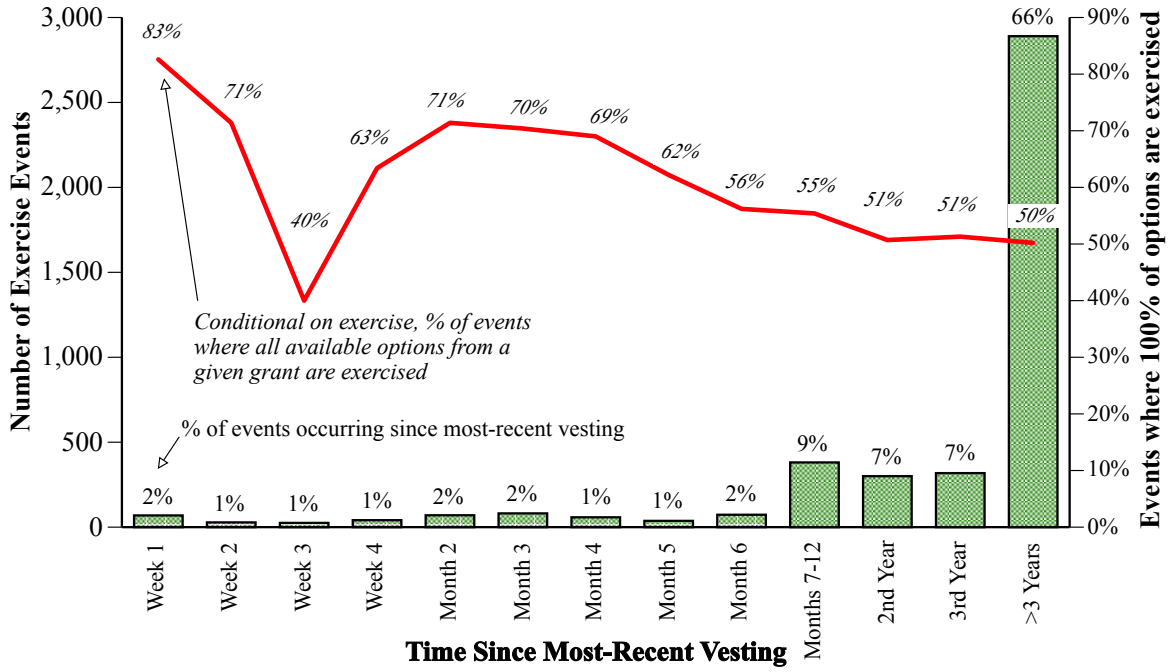
PANEL B: NON-EXECUTIVES



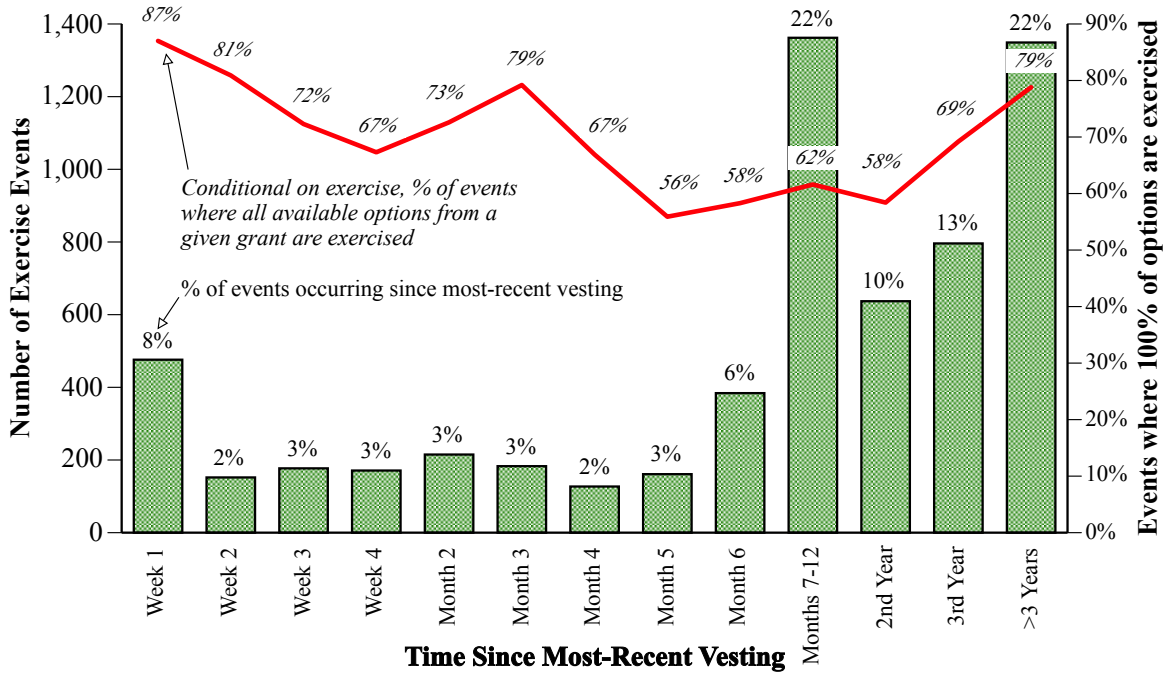
Note: Top Executives defined as either (a) employee designated as insider or holds C-level title; or (b) employees' holdings of stock and options is ever in the top 1% of all employees between 2004-2011.

Figure 7 Option Exercises following Vesting

PANEL A: EXECUTIVES



PANEL B: NON-EXECUTIVES



Note: Top Executives defined as either (a) employee designated as insider or holds C-level title; or (b) employees' holdings of stock and options is ever in the top 1% of all employees between 2004-2011.

Table 1 Dependent and Independent Variables used in Prior Studies of Early Exercise

PANEL A. Studies based on Publicly Available Data

	Hemmer Matsunaga & Shevlin (1996)	Core & Guay (2001)	Bettis, Bizjak & Lemmon (2005)	Klein & Maug (2011)	Heron & Lie (2017)	Izhakian & Yermack (2017)
Number of Firms	74	1,236	3,966	2,008	–	3,222
Number of Executives	65	–	–	14,000	–	20,665
Dependent Variable[a]	T-t	n/A	T-t	(0,1)	T-t	n/A
Standard Controls						
Price / Exercise Price						
Intrinsic Value / Option Value		X		X		
Time Remaining until expiration				X		X
Pending Dividend			Div Yield	1 week	Div Yield	1 month
Recent Vesting Event				2 weeks	Days since	1 month
Pending Cancelation Event				X		
Portfolio Factors (Diversification)						
Stock-price volatility	X		X	X	X	X
Expected Ambiguity						X
Correlation with Market						
Black-Scholes option risk						
Black-Scholes portfolio value						
Recent Option Grant		X		X		
"Psychological Factors"						
Price above n^{th} percentile for year			90^{th}	100^{th}	100^{th}	
Recent stock-price run-up				X	X	1 month

continued

Table 1 ***continued***

PANEL B. Studies based on Proprietary Data

	Huddart & Lang (1996)	Heath, Huddart & Lang (1999)	Huddart & Lang (2003)	Armstrong, Jagolinzer & Larcker (2007)	Carpenter, Stanton & Wallace (2019)	Bova & Vance (2019)
Number of Firms	7	7	7	10	88	1
Number of Employees	58,316	58,316	58,316	23,000	290,000	292
Dependent Variable[a]	n/N	n/N	n/N	(0,1)	n/A	(0,1)
Standard Controls						
Price / Exercise Price	X			X	X	X
Intrinsic Value / Option Value		X	X			
Time Remaining until expiration				X	X	X
Pending Dividend				Div Yield	2 weeks	
Recent Vesting Event	3 months	6 months	6 months	1 month	2 weeks	
Pending Cancelation Event	X	X	X			
Portfolio Factors (Diversification)						
Stock-price volatility				X	X	X
Expected Ambiguity						
Correlation with Market					X	X
Black-Scholes option risk					X	
Black-Scholes portfolio value					X	
Recent Option Grant						
Proxy for Risk Aversion						X
"Psychological Factors"						
Price above n^{th} percentile for year		100^{th}	100^{th}	90^{th}	90^{th}	90^{th}
Recent stock-price run-up	X	X				

[a]Dependent variable coded as:
(0,1) = Dummy variable if options were exercised
n/N = Options exercised as fraction of original grant
n/A = Options exercised as fraction of options available to exercise
T-t = Time remaining until expiration (conditional on exercise)

Table 2 Early Exercise Behavior predicted under Diversification, Realization Utility, and Liquidity

Variable	Diversification Hypothesis	Realization Utility	Liquidity Hypothesis
Ratio of Intrinsic Value to Black-Scholes Value	> 0	> 0	> 0
Time remaining until expiration	< 0	< 0	< 0
Pending dividend	> 0	> 0	> 0
Recent vesting event	> 0	> 0	> 0
Recent run-up in stock prices	> 0	> 0	> 0
Stock price surpasses recent maximum	> 0	> 0	> 0
Stock-price volatility	?		
Option Portfolio (Black-Scholes)	?		> 0
Exercise 100% of available options ("Block Exercises")			
Immediately upon vesting	> 0	> 0	> 0
Long after vesting		> 0	> 0
Exercise different grants at same time ("Clustering")		> 0	> 0
Change in Home Price	< 0		> 0
Recent Equity Grant	> 0		> 0
$\beta^{Option} > \beta^{Stock}$	Yes		No

Table 3 Summary Statistics based on Employee-Grant-Day

	Top Executives *666 Individuals* *5,781 Grants* *5,460,132 Grant-Days*		Non-Executives *2,966 Individuals* *8,921 Grants* *8,411,016 Grant-Days*	
Variable	Mean	Median	Mean	Median
Daily exercise probability (unconditional)	0.080%	0.00%	0.074%	0.00%
Daily exercise probability (vested and in-the-money)	0.132%	0.00%	0.224%	0.00%
Ratio of Intrinsic Value to Black-Scholes Value	42.0%	41.8%	22.4%	0.0%
Remaining Term (Years)	5.9	6.1	5.4	5.4
Current fraction of Term (%)	38.8%	36.4%	35.9%	33.3%
Dividend in next two weeks (%)	14.8%	0.0%	12.4%	0.0%
Equity grant in the past month	8.7%	0.0%	4.8%	0.0%
Age	53.1	53.2	50.7	51.4
Tenure	17.7	17.7	10.9	9.1
Stock option portfolio ($000)	$1,507.1	$696.5	$110.7	$51.4
Unvested restricted stock portfolio ($000)	$514.1	$70.0	$34.3	$1.3
Options and unvested equity ($000)	$2,021.1	$864.0	$145.0	$62.8
Median House Price (ZipCode level) ($000)	$320.6	$258.7	$400.5	$310.5
Equity as % of (Equity + House) Portfolio	70.8%	77.7%	21.7%	14.2%

Note: Top Executives defined as either (a) employee designated as insider or holds C-level title; or (b) employee's holdings of stock and options is ever in the top 1% of all company employees.

Table 4 Sample Means based on Exercise Events, based on Early Exercise Subsets

Variable	All Exercises	Fraction of Full Term upon Exercise			
		< 25%	25% to 50%	50% to 75%	> 75%
PANEL A. TOP EXECUTIVES					
Sample size (number of exercise events)	4,374	417	661	1,006	2,290
Percent of subsample		9.5%	15.1%	23.0%	52.4%
Ratio of Intrinsic to Black-Scholes Value	88.2%	70.6%	72.4%	82.7%	98.3%
Block exercises of focal grant	52.6%	59.0%	59.9%	49.5%	50.7%
Remaining Term (Years)	3.0	7.8	5.7	3.5	1.0
Current fraction of Term (%)	67.6%	1.9%	38.9%	64.1%	89.4%
Age	54.2	52.3	51.4	53.5	55.7
Tenure	19.2	8.4	14.3	19.3	23.3
PANEL B. NON-EXECUTIVES					
Sample size (number of exercise events)	6,196	686	2645	1,349	1,516
		11.1%	42.7%	21.8%	24.5%
Ratio of Intrinsic to Black-Scholes Value	71.7%	49.7%	68.7%	76.9%	82.2%
Block exercises of focal grant	69.5%	85.3%	67.0%	60.7%	74.7%
Remaining Term (Years)	3.9	8.1	5.0	3.0	0.8
Current fraction of Term (%)	53.0%	14.2%	37.7%	62.2%	88.9%
Age	50.6	48.4	49.3	51.7	52.7
Tenure	11.8	12.1	11.0	12.6	12.2

Note: Data based on sample of 10,570 employee-grant-day observations where options were exercised. Top Executives defined as either (a) employee designated as insider or holds C-level title; or (b) employee's holdings of stock and options is ever in the top 1% of all company employees.

Table 5 Effect of Changes in Zip Code-Level House Prices on Early Exercise

	Dependent Variable: Percentage of exercisable options exercised							
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Ratio of Spread To Value	0.3048*** (22.42)	0.3044*** (22.36)	0.3045*** (22.29)	0.3048*** (22.17)	0.3023*** (21.83)	0.2947*** (20.93)	0.3002*** (20.70)	0.3084*** (20.94)
Dividend in next 2 weeks	0.0116** (2.19)	0.0115** (2.16)	0.0118** (2.21)	0.0120** (2.23)	0.0123** (2.25)	0.0131** (2.39)	0.0127** (2.31)	0.0132** (2.39)
Stock Return in Prior Month	0.6986*** (21.93)	0.6997*** (21.92)	0.6997*** (21.91)	0.7009*** (21.85)	0.7037*** (21.77)	0.6938*** (21.44)	0.6891*** (21.22)	0.6883*** (21.18)
Option vested in Prior Month	0.2043*** (12.88)	0.2059*** (12.91)	0.2069*** (12.91)	0.2071*** (12.86)	0.2064*** (12.67)	0.1991*** (12.19)	0.2046*** (12.31)	0.2048*** (12.34)
Age	0.0107*** (7.12)	0.0106*** (7.02)	0.0106*** (7.00)	0.0107*** (7.12)	0.0113*** (7.47)	0.0132*** (8.14)	0.0133*** (7.33)	0.0103*** (5.20)
Ln(Total Wealth)	-0.0871*** (-5.20)	-0.0881*** (-5.21)	-0.0893*** (-5.23)	-0.0910*** (-5.19)	-0.0979*** (-5.40)	-0.1029*** (-5.44)	-0.0987*** (-5.24)	-0.0853*** (-4.59)
Equity Value / Total Wealth	0.4043*** (6.73)	0.4050*** (6.69)	0.4107*** (6.75)	0.4201*** (6.80)	0.4436*** (6.99)	0.4485*** (6.89)	0.4385*** (6.71)	0.4046*** (6.11)
ΔHome Values 1 month	0.8930*** (3.02)							
ΔHome Values 3 months		0.4005*** (3.44)						
ΔHome Values 3 months			0.1968*** (2.85)					
ΔHome Values 12 months				0.0831** (2.04)				
ΔHome Values 24 months					0.0699*** (2.87)			
ΔHome Values 36 months						0.0905*** (4.41)		
ΔHome Values 48 months							0.0472*** (2.64)	
ΔHome Values 60 months								-0.0095 (-0.55)
Sample Size	4,320,226	4,308,852	4,289,043	4,246,280	4,161,628	4,073,730	3,972,394	3,957,563
Employee FE	2,724	2,723	2,722	2,720	2,712	2,700	2,654	2,578

Note: Regressions include employee fixed effects. Robust t-statistics in parentheses: *, ** and *** denote significance at a 0.10, a 0.05 and a 0.01 level. Standard errors are clustered by employee. ΔHome Values are calculated as ΔLn(Median House Price) based on Zillow estimates at the Zip Code level. Total wealth is defined as the estimated home price plus the value of unvested restricted holdings and unexercised stock options (measured using the Black-Scholes formula).

Table 6 Effect of New Equity Grants on Exercise Behavior

	Dependent Variable: Percentage of exercisable options exercised			
	All Observations		Exclude observations for vesting month	
	(1)	(2)	(3)	(4)
Ratio of Spread to Value	0.3061***	0.3060***	0.2195***	0.2198***
	(22.46)	(22.46)	(21.47)	(21.49)
Dividend in next 2 weeks (Dummy)	0.0115**	0.0114**	0.0138***	0.0135***
	(2.17)	(2.15)	(2.69)	(2.62)
Stock Return in Prior Month	0.7000***	0.7010***	0.6422***	0.6396***
	(21.84)	(21.80)	(21.60)	(21.61)
Option vested in Prior Month	0.1978***	0.1976***		
	(11.98)	(11.96)		
Age	0.0111***	0.0108***	0.0082***	0.0078***
	(7.51)	(7.42)	(6.24)	(5.96)
Ln(Value of Home + Equity Portfolio)	-0.0877***	-0.0876***	-0.0433***	-0.0435***
	(-5.23)	(-5.22)	(-3.00)	(-3.01)
Equity / Total Portfolio	0.4150***	0.4150***	0.3427***	0.3426***
	(6.88)	(6.88)	(6.33)	(6.33)
Equity Grant in last month (as % of Equity Portfolio)	0.0871		0.2515***	
	(1.26)		(3.83)	
RSU Grant in last month (as % of Equity Portfolio)		0.3654**		0.9100***
		(2.05)		(4.51)
Option Grant in last month (as % of Equity Portfolio)		-0.0092		-0.0262
		(-0.11)		(-0.37)
F-test for equality of RSU and Option Grant coefficients		*3.26*		*16.17*
		p=.071		*p < .01*
Sample Size	4,325,962	4,325,962	4,093,044	4,093,044
Employee Fixed Effects	2,725	2,725	2,625	2,625

Note: Value of Equity Portfolio is the daily value of unvested restricted holdings and unexercised stock options (measured using the Black-Scholes formula). Home values are estimated as the monthly median value of houses in the employee's Zip Code. Robust t-statistics in parentheses: *, ** and *** denote significance at a 0.10, a 0.05 and a 0.01 level. Standard errors are clustered by employee.

Table 7 Range of Implied Risk-Aversion Coefficients for Individuals with Multiple Exercise Events

	Top Executives		Non-Executives	
	Interquartile Range	Max to Min Range	Interquartile Range	Max to Min Range
2 Exercise Events	2.2	2.2	7.5	7.5
3 Exercise Events	3.1	3.1	12.1	12.1
4 Exercise Events	1.9	2.6	8.4	12.3
5 or more Exercise Events	1.6	4.5	6.9	14.3

Note: Top Executives defined as either (a) employee designated as insider or holds C-level title; or (b) employee's holdings of stock and options is ever in the top 1% of all employees.

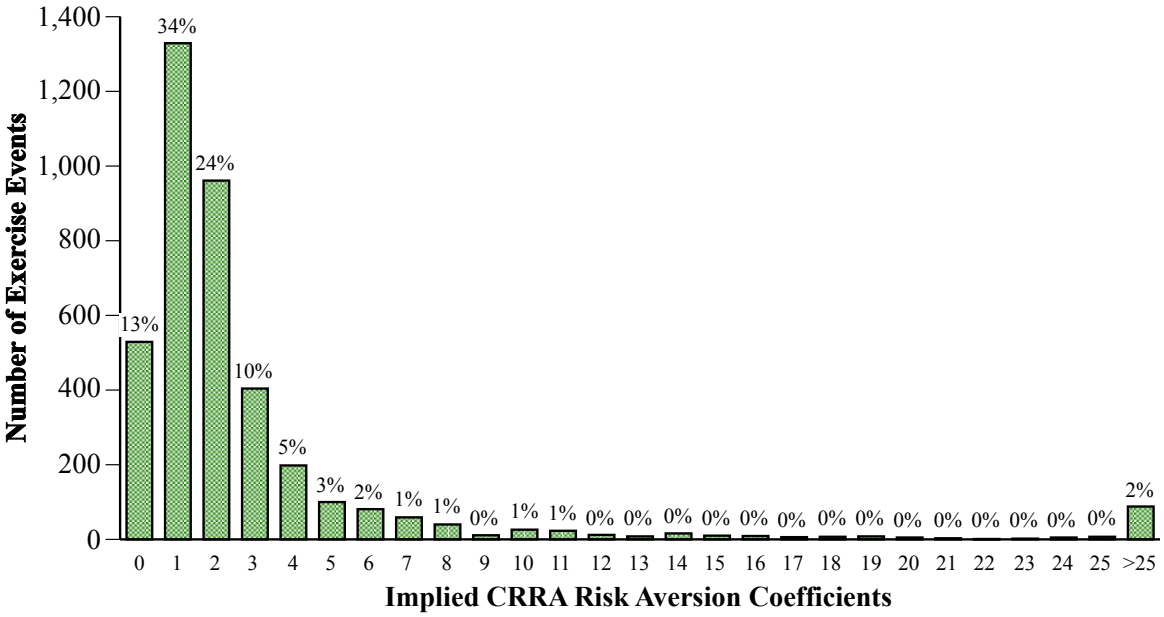
Table 8 Exercise probabilities conditional on whether any other grant was exercised within specified window

	Top Executives		Non-Executives	
Window Size	No other grant exercised within window	Another grant exercised within window	No other grant exercised within window	Another grant exercised within window
7 days	0.10%	1.15%***	0.11%	5.42%***
14 days	0.10%	0.73%***	0.10%	3.45%***
21 days	0.10%	0.55%***	0.10%	2.59%***
30 days	0.10%	0.43%***	0.10%	2.00%***

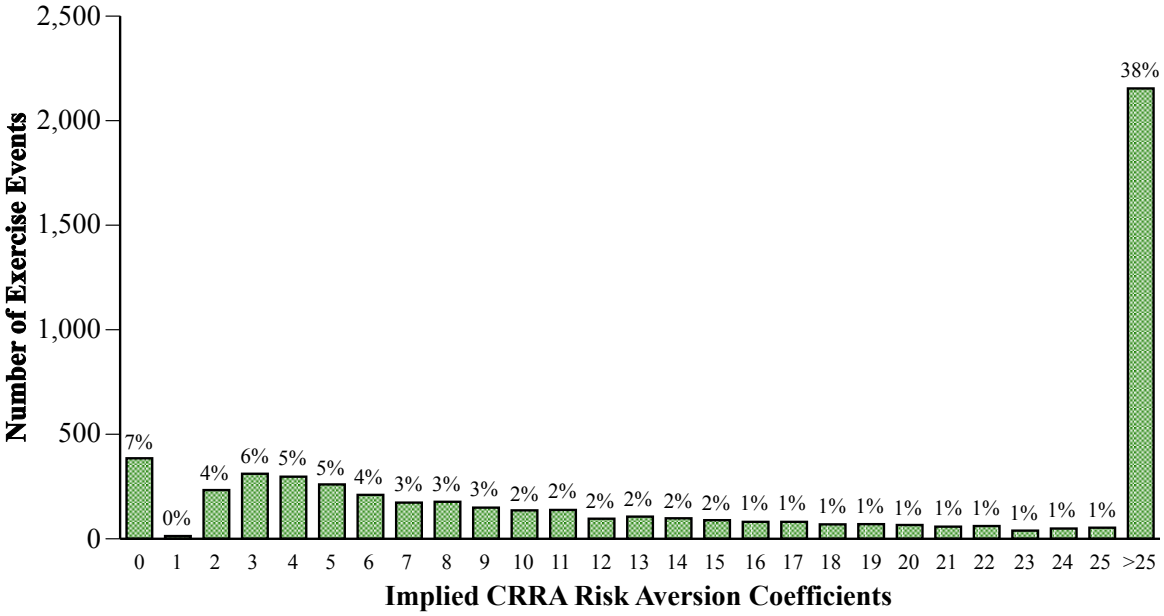
Note: Top Executives defined as either (a) employee designated as insider or holds C-level title; or (b) employee's holdings of stock and options is ever in the top 1% of all employees. *** denotes that the exercise probability is different from the probability in the left-adjacent column at the 0.0001 level.

Figure A1 Implied Risk Aversion Coefficients assuming Constant Relative Risk Aversion (CRRA) Utility and Outside Wealth equal to 200% Median Home Price in Employee's Zip Code

PANEL A: TOP EXECUTIVES



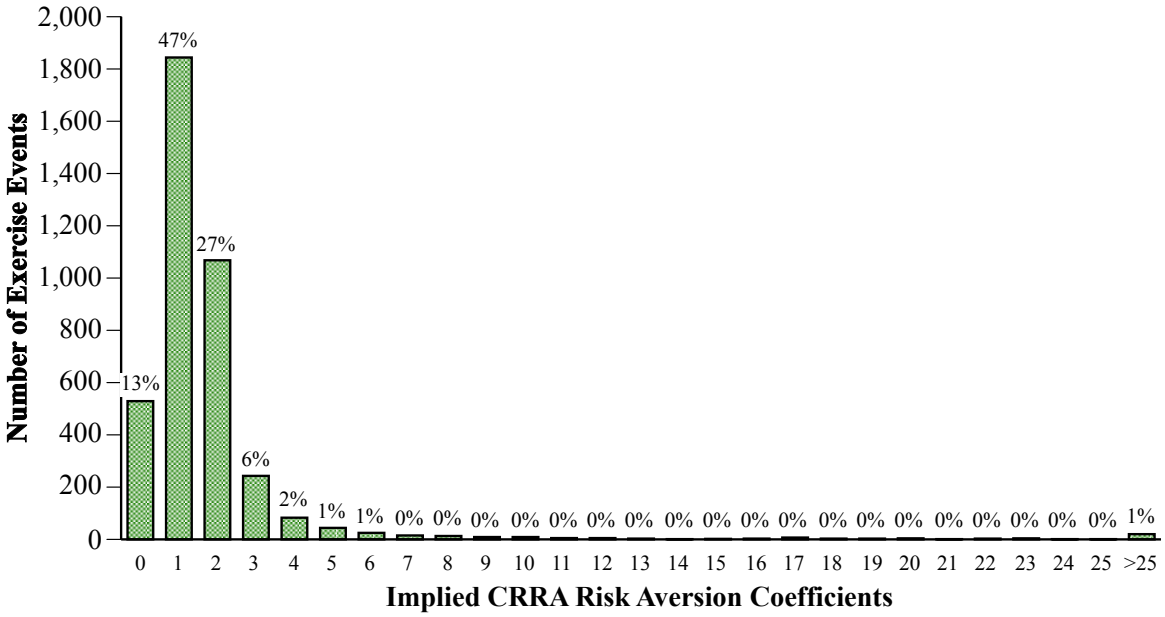
PANEL B: NON-EXECUTIVES



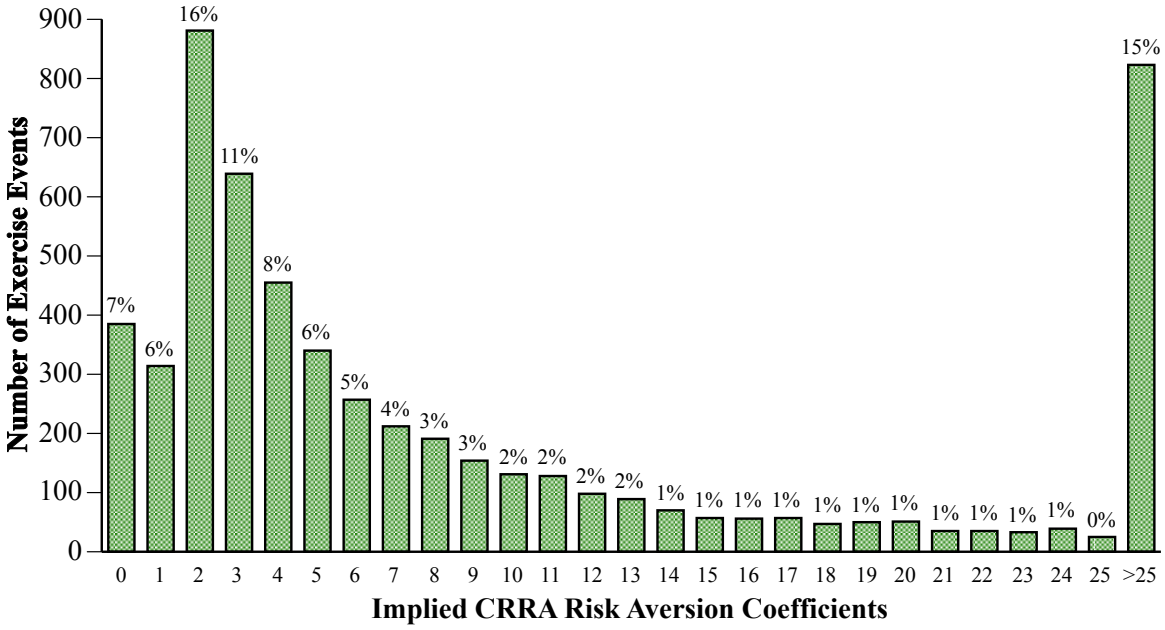
Note: Top Executives defined as either (a) employee designated as insider or holds C-level title; or (b) employees' holdings of stock and options is ever in the top 1% of all employees between 2004-2011.

Figure A2 Implied Risk Aversion Coefficients assuming Constant Relative Risk Aversion (CRRA) Utility and Outside Wealth equal to 50% Median Home Price in Employee's Zip Code

PANEL A: TOP EXECUTIVES



PANEL B: NON-EXECUTIVES



Note: Top Executives defined as either (a) employee designated as insider or holds C-level title; or (b) employees' holdings of stock and options is ever in the top 1% of all employees between 2004-2011.