This study aims at: (1) developing an index to measure CEO risk tolerance using publicly available data, and (2) examining the association between this index and investment in risky projects. Using relative pay-at-risk as a proxy for risk preference (tolerance) is a new proposition and is supported by having significant association with CEOs’ socio-demographic variables—the variables often studied in connection with risk aversion. Furthermore, this risk preference indicator has a positive association with risk-taking behaviour as proxied by R&D expenditures. The in-sample estimation and out-of-sample predictions support (a) using relative pay-at-risk as a valid proxy for risk tolerance, and (b) finding statistically significant positive association between this measure and R&D expenditures. The association has different degrees of strength for nine out of 11 industries.

Key words: Determinants of R&D; Incentive Pay; Risk Aversion; Risk Tolerance; Risky Investments.

The extant literature in organization theory and behaviour suggests that the strategies taken, and decisions made, on behalf of a business enterprise reflect the decision-making styles and values of top executives in general, and of the CEO in particular (Hambrick and Mason, 1984; Hambrick, 2007). In a recent study, Boivie et al. (2011) reiterate this phenomenon, as they write ‘...by virtue of the power and privileges inherent in the position, a CEO has more actual influence than any other individual organization member over policy decisions’ (p. 553).

Investing in research and development (R&D) is one of the strategic decisions that falls under that influence, especially because R&D activities consume resources with significant implications for future performance. In exerting that influence on R&D activities, top management formulates risk-taking strategies in its own styles and according to its own risk preferences.
This study employs CEO risk tolerance as an indicator of corporate risk appetite, developing a metric for the measurement of risk tolerance (inverse of risk aversion), and examines its impact on investment in R&D projects. The empirical tests use a sample of 6,479 firm/year observations (5,404 observations for first difference), consisting of all firms on the ExecuComp database, that satisfy all other data requirements for the period 1993 to 2009.\(^1\) These tests are conditioned on other firm-specific determinants of R&D—firm size, profitability, growth rates, leverage, relative cash flow volatility, and firm age. The empirical analysis is based on in-sample estimation and out-of-sample (hold-out) tests, as well as validation of the measure of risk metric adopted in this study.

The results show that investment in R&D is significantly higher for enterprises that are headed by CEOs who have relatively higher degrees of risk tolerance (i.e., lower degree of risk aversion). More specifically:

1. The index used as a proxy for risk tolerance is associated with socio-demographic variables that are known in the literature as determinants of individual risk preference. These variables are the CEO’s Age, Tenure (firm-specific knowledge, which is used as a proxy for education), Income, and Wealth (equity ownership in the firm).
2. There is a significant positive association between the change and intensity of investment in R&D and the estimated metrics of CEOs’ tolerance for risk taking.

RESEARCH PROBLEM AND MOTIVATION

Of the numerous economic value drivers, R&D takes on particular significance for several reasons. First, the assumption often invoked is that CEOs (the agents) are risk averse because they have employment contracts that do not allow them to diversify their human capital. On the other hand, shareholders, the principals, can be considered risk neutral because they can diversify their exposure to idiosyncratic (enterprise-specific) risk by diversification. This posited difference in risk-taking disposition between owners and managers gives rise to different investment preferences: owners prefer that the firm invests in all positive net present value (NPV) projects, whereas managers ration taking on risky projects consistent with their risk appetite.

Thus, in the absence of appropriately designed incentive systems, managerial actions could reflect managers‘ own risk preferences and entail sacrificing some otherwise profitable projects. This behaviour may manifest itself in requiring higher hurdle rates for high-risk projects (Stein, 1996), or redesigning and redirecting their R&D strategies to improve their own short-term performance. For example, in recent years, the CEOs of GlaxoSmithKline, Pfizer, and AstraZeneca announced the termination of some of their R&D projects after spending hundreds of millions of

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\(^1\) Retail enterprises, public utilities, insurance companies and banks do not usually undertake R&D and are therefore excluded.
dollars on these projects. If CEOs have the power to terminate projects under these circumstances, they must also have the ability to initiate others.\textsuperscript{2}

Notably, the implied myopia is not mitigated by incentive contracts, as they are currently designed, because the instruments used in incentive schemes have conflicting consequences. For example, a rise in enterprise risk taking increases the value of executive stock options, but decreases the values of owned and restricted stocks that are granted as incentive compensation (Ryan and Wiggins III, 2002; Ross, 2004; Parrino \textit{et al.}, 2005).

Second, while R&D is a discretionary activity (NSF, 2004, pp. 4–14), it is highly costly. The latest comprehensive statistics published (in 2010) by the National Science Foundation (NSF) show that the U.S. business sector has invested approximately $270 billion in R&D in 2007 (NSF, 2010, pp. 4–19), reflecting a significant increase from the $197 billion spent in 2002 (NSF, 2004, pp. 4–12). The chemical industry (including pharmaceuticals) is the business sector in the NSF industry classification having the largest R&D expenditures—$56 billion—followed by the computer and software industries. On average, the ‘cost of developing an innovative new drug is more than $800 million, including expenditures on failed projects and the value of forgone alternative investments’ (CBO, 2006, p. 19).\textsuperscript{3}

Third, the economic cost of R&D failure is not only high for business firms, but also adversely affects the human capital of CEOs. Failure can happen at any stage in the process, even before testing the commercial feasibility of the products. For example, in October 2010, Novartis AG decided to abandon the development of an anti-fungal drug that was to be named Mycograb, ending a four-year R&D effort.

\textsuperscript{2} In a recent article in \textit{The Wall Street Journal}, Stovall (3 February 2011) notes the direct involvement of CEOs in determining the level and type of R&D activities in three large pharmaceuticals. The first is Andrew Witty, the CEO of GlaxoSmithKline, who decided to exit high risk ‘research and development in diseases affecting the brain, nervous system and gastrointestinal disorders such as pain, anxiety and depression, while still actively seeking solutions for neurodegenerative diseases such as Alzheimer’s and Parkinson’s’. In the same article, it was noted that the CEO of Pfizer has taken a similar action by closing R&D facilities in Sandwich, United Kingdom, and the CEO of AstraZeneca decided to cease ‘discovery efforts in heart disease, acid reflux, ovarian and bladder cancers, inflammation, schizophrenia, bipolar disorder, depression and anxiety, hepatitis C and vaccines other than viral lung disease and influenza’. All are considered costly endeavours carrying high risk (http://blogs.wsj.com/source/2011/02/03/gsk-makes-savings-by-exiting-risky-rd-but-at-what-cost/)

\textsuperscript{3} Other Sources for R&D spending are: (a) ComputerWeekly.com (http://www.computerweekly.com/Articles/2009/10/08/238053/Microsoft-steps-up-Ramp-D-spending.htm) reports that ‘Microsoft R&D spending reached $8.5bn in fiscal 09 compared to $6.3bn from IBM, $5.2bn by Cisco and $2.8bn at Oracle and it had plans to increase it to $9.5bn next year. Microsoft said it would invest $4.2bn into PCs research, $7.2bn in communications and productivity, $2.2bn in servers, $1bn in phones, $1.6bn in TV and entertainment, $2.1bn in search and $2.7bn in enterprise infrastructure’; (b) in business year 2009, Siemens spent €3.9 billion on R&D, which is equivalent to 4.9% of their sales (see: http://aunz siemens.com/AboutUs/Sustainability/Pages/CC_8083_ResearchDevelopment.aspx); (c) the Wall Street Health Blog presents information for the top R&D pharmaceutical industries. R&D spending for the first three quarters of 2009 are (in billions): $5.6 (Pfizer); $4.8 (Johnson & Johnson); $3.9 (Merck); $3.1 (Eli Lilly); and $2.6 (Bristol-Myers Squibb). (http://blogs.wsj.com/health/2009/12/22/rd-spending-numbers-for-pfizer-jj-merck-lilly-and-bristol/).
that cost $595 million. Costly R&D failure can also happen after patents are obtained and the products reach the market. The class action lawsuit against Merck in connection with the drug VIOXX is estimated to have cost the company more than $5 billion (not including the negative spillover impact on reputation and demand for other drugs). In this case, the CEO, Raymond V. Gilmartin, was singled out as responsible for the company’s R&D failure, and was forced to resign in May 2005 just as Congress began to discuss the case. Furthermore, product liability cases extend far beyond the drug industry—they cover the automobile industry, including well-documented recalls, elevator safety, appliances, and any product that could cause harm.

As a combination of tangible and intangible elements, R&D projects are exposed to significantly higher risk than investing in tangible assets. There is always uncertainty about success in completing all the necessary stages required by an R&D project, as well as uncertainty about the ‘realizability’ of expected payoff or outcome while maintaining all property rights. For example, only 8 to 10% of pharmaceutical R&D projects reach the commercial development stage (CBO, p. 31).

More specifically, the adverse impact of uncertainty could happen at any of the five stages of R&D uncertainty: ‘market payoffs, project budgets, product performance, market requirements, and project schedules’ (Huchzermeier and Loch, 2001, p. 1). To manage uncertainty, some enterprises use real option pricing theory as a decision aid for continuation, abandonment, and flexibility (e.g., Nichols, 1994; Huchzermeier and Loch, 2001; Hartman and Hassan, 2006).

These factors give rise to the question: do CEOs allow their own risk preferences to influence their own entities’ plans and decisions on R&D? In the above-noted cases of CEOs at GlaxoSmithKlein, Pfizer, Novartis and Merck, we see examples of CEOs being directly involved in making choices to continue or abandon vital investment projects based on the risk exposure of a specific project. These examples became known to the public because of their public health externalities, but the general case of linking CEOs’ risk preference and the choice of risky investments remains to be established more methodically.

STATEMENT OF HYPOTHESES

Several studies have addressed the connection between R&D and CEOs’ characteristics. While not addressing CEOs’ risk aversion or preferences directly, Barker III and Mueller (2002) report that ‘R&D spending is greater at firms where CEOs are younger, have greater wealth invested in firm stock and significant career expe-

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5 For example, Gagg (2005) reports that in 2005, the United Kingdom alone had 50 fatalities and 40,000 visits to emergency rooms due to faulty step ladders. In 1981, R&D and engineering failure caused the collapse of the Hyatt Regency skywalk in Kansas City that killed 114 people. These examples point to the possible increase in litigation risk because of R&D quality, functioning of components, or design failure, all of which could be compounded by the management’s neglect to inform and warn consumers.
Coles et al. (2006) use the sensitivity of CEOs’ stock option prices to stock price volatility (vega) as a measure of CEOs’ risk appetite and to show significant positive associations between vega and three indicators of risk taking—namely, increased leverage, increased R&D spending, and reduced capital expenditures. Nam et al. (2003) report similar findings by using the ratio of the volatility of CEO options to the volatility of equity as a measure of CEO risk preference.

A shortcoming of these studies is the utilization of CEOs’ stock options to measure their risk preferences. CEOs have portfolios of incentive instruments extending beyond stock options, because they own equity shares, are granted both stock options and restricted stocks, and have cash bonuses based on outcomes of short and long-term performance. In combination, these factors create conflicting incentives, as first recognized in Lambert et al. (1991) and documented in two studies: Ryan and Wiggins III (2002) find that R&D expenditures are positively associated with executive stock options, but are negatively associated with restricted stock; and Parrino et al. (2005, p. 52) provide a model and supporting evidence from large publicly-held companies and note that:

[A] manager who holds stock and options in proportion to the median ownership of CEOs at large publicly traded corporations is likely to behave in an overly risk-averse manner in selecting projects. The manager will accept some safe, value reducing projects, and reject some risky, value-increasing projects.

Carpenter (2000) notes further that granting options does not necessarily motivate managers to take on more risk. Ross (2004) develops a more general model showing that the concavity of the manager’s utility function could overcompensate for the incentive effects of granting options (i.e., convexity), such that the manager may continue to exhibit risk-averse behaviour and pass on risky projects having positive NPV (2004, p. 224).

Approaching the relationship between CEOs and R&D differently, Griffith and Webster (2004, 2009) use management style as a proxy for risk tolerance. They collected data on CEOs’ management styles (using the Likert scale) and developed five types: bold, flexible, systematic, aggressive, and communication styles. In their 2004 study, the authors conclude that ‘the propensity to undertake R&D is related to both the managerial style of the firm (i.e., CEO)—more aggressive and intuitive managers have higher R&D ceteris paribus—and the extensive use of incentive schemes’ (p. 28). However, in their 2009 study, which also provides an extensive overview of the literature, they find that ‘the less aggressive firms are towards their competitors but the more they strive to become product leaders, the more R&D

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6 Reportedly, the Wallach and Kogan study (1961) is the first to show that risk taking declines with age—that is, risk aversion increases with age. Subsequently, Vroom and Pahl (1971) report on the results of a survey of 1,484 managers, showing a significant negative relationship between age and risk taking.

7 The two studies use different statistical methods for analysis.

8 Of the five styles, they define ‘bold’ as reflecting managers’ attitudes towards risk taking.
activity, *ceteris paribus* (2009, p.17 and Table 7, p. 19). Resorting to using different management styles generated from data collected by survey instruments is due to (1) the absence of an acceptable empirical measure of CEO risk preference, and (2) the absence of defensible empirical evidence that links the CEO risk preference and investment in R&D.

To address these issues, this study develops a measure of CEOs’ risk preferences using publicly available data and tests the following hypotheses:

H1: CEOs’ socioeconomic factors are predictors of CEO risk tolerance.

H2: R&D expenditures and intensity increase with the increase in the CEO’s risk tolerance.

**MEASUREMENT OF RISK PREFERENCE**

Researchers have examined risk-taking appetite from different perspectives for different subject domains of interest. For some behavioural scientists, for example, risk aversion is viewed as a function of impulsivity (Zuckerman and Kuhlman, 2000), cognitive ability (Dohmen et al., 2007), genetics (Zyphur et al., 2009), or the propensity to engage in risky behaviour in general (Barsky et al., 1997).

Unlike social psychologists, classical economics assumes rationality and looks to the behaviour of the individual’s utility function (assuming that utility is measurable) over wealth or income to identify the individual’s attitude toward risk taking. Since utility is not measurable, risk preference may be gauged from the size of the risk premium that one requires to earn by investing in risky assets (the investment tradition of Markowitz, 1952; Arrow, 1971), or the premium that one has to pay to transfer risk to others (the insurance tradition of Pratt, 1964). Both measures arrive at the same conclusion: a risk-averse person has a concave utility function, showing utility functions increasing at a decreasing rate as wealth (or income) increases.9 Different individuals’ attitudes toward risk could be reflected by the degree of concavity in the utility function. Risk tolerance is simply the inverse of the risk aversion parameter.

**Alternative Empirical Approaches to the Measurement of Risk Aversion**

Two approaches commonly employed in measuring risk aversion are outlined below, followed by the approach developed in this study.10

I. *The asset allocation approach* This approach makes two assumptions: (a) individuals allocate their investment portfolios between safe and risky assets in a

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9 One of the most commonly referenced functions is the Arrow-Pratt decreasing absolute risk aversion: \(-\partial^2(u)/\partial(u).\) See, for example, Hirshleifer and Riley (1992).

10 Accounting studies refer to CEO risk aversion but use simple proxies as measures such as ‘age’ or ‘cash compensation’. For example, ‘we attempt to explicitly control for inter-firm differences in potential CEO risk-aversion by including CEO’s cash compensation as an explanatory variable’. (Rajgopal and Shevlin, 2002, p. 154).
manner consistent with the individual’s own attitude toward risk taking, and (b) observable determinants can explain this behaviour.

It was not until the mid-1970s that empirical studies in the U.S. began validating the asset allocation method (Friend and Blume, 1975; Cohn et al., 1975; Riley and Chow, 1992; Bajtelsmit and Bernasek, 2001). Similar empirical studies took place in other countries—for example, Morin and Suárez (1983) in Canada, Pålsson (1996) in Sweden, Donkers and van Söst (1999), Hartog et al. (2000; 2002) in The Netherlands,11 and Guiso and Paiella (2005) in Italy. The collective findings of these studies are that risk-taking appetite decreases with age, but increases with income, wealth, and education, and that women are more risk-averse than men.12

The relationship between age and attitudes toward risk taking remains controversial, however. While the above noted studies show that risk aversion increases with age, other recent studies show the reverse (Grable, 2000; Gollier, and Zeckhauser, 2002; and by Hallahan et al., 2004).

2. The lottery payoff-to-cost ratio The second approach is the measurement of risk preference by the ratio of the expected lottery (i.e., project) prize, or payoff to the price or cost of entry (the lottery ticket). Work in this strand of the literature varies from the setting of controlled experiments (Loehman, 1998; Holt and Laury, 2002) to conducting experiments embedded in large-scale questionnaires (Barsky et al., 1997; Donkers et al., 2001; Dohmen et al., 2007).

Of particular interest is the study by Donkers et al. (2001) that introduces two lottery settings and analyzes responses from 3,458 Dutch respondents. In the first setting, participants are provided with five decision situations, with two possible outcomes for each; one outcome is more risky than the other. Participants were asked to choose one outcome for each decision situation. The analysis shows that the proportion of participants who chose the more risky outcome varies between 12% and 56%, suggesting a wide variance in their attitudes toward risk taking.

In the second setting, each respondent is asked to state the acceptable level of probability of winning a pre-specified amount of money from a lottery that would induce him or her to purchase a ticket. In this setting, the results show that the average probability the participants had required for winning varied between 0.34 and 0.62. Donkers et al. proceeded to examine the extent to which individual-specific socio-demographic characteristics explain the variation in the measurement of risk aversion. The results are consistent with the findings of the asset allocation method noted above.

3. The quasi-lottery approach The two approaches noted above require conducting either a survey of CEOs or having the CEOs participate in experiments. Neither

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11 Hartog et al. (2000; 2002) conducted three surveys: the Brabant Survey for households, the Newspaper Survey to which newspaper readers were invited to respond, and the Accountants Survey that covered only professional accountants.

12 For gender differences, see also Riley and Chow (1992); Borghans et al. (2009).
one of those approaches is feasible. Alternatively, this study provides an approach to the measurement of risk preference using archival data. This approach utilizes the relationship between CEO incentive compensation and salary, along with the socio-demographic characteristics of CEOs that emerged as determinants of risk preference in both the asset allocation and lottery prize-to-cost approaches noted above.

To develop this approach, we group executive compensation contracts into two types:\(^{13}\)

- Type I is a ‘pure-pay strategy’, in which compensation consists of straight salary only.\(^ {14}\)
- Type II is a ‘mixed-pay strategy’, in which the executive opts to receive a proportion of compensation as salary (assured pay) and the remainder as uncertain pay contingent on some pre-specified performance targets.\(^ {15}\)

A crucial prerequisite in the study of these contracts is the proposition that CEOs self-sort, so that each would have his or her employment contracts fit his or her own risk appetites (Rosen, 1986; Lazear, 1998). However, in the early stages of a job search, each one has a reservation wage, the required income level to match his or her skills. Assume that the perceived reservation wage is $RW_i$ for \(j\)th CEO. If the employer contracts to pay $RW_j$ as a fixed salary, the employer would be bearing all the risk of the labour contract. To share that risk, the employer could offer a mixed-pay strategy to pay only a proportion, ‘\(p_r\)’ of $RW_j$ as a salary (sure pay), and the promise of paying an uncertain amount of compensation that would be contingent on performance (pay at risk). The expected compensation of the CEO under this type of contract would take the form

$$E(pay_j) = p_jRW_j + E(C_j)$$  \hspace{1cm} (1)

where \(E(C)\) is the expected performance-contingent pay, \(p\) is proportion of the reservation wage \(RW\), which is the desired level of certain (sure) compensation if all compensation were to be fixed \textit{a priori}. The assumption made here is that \(p\) is the CEO’s risk preference parameter: a highly risk averse (tolerant) CEO would require high (low) value of \(p\) and \textit{vice versa}.

\(^{13}\) There is a third type, which is the group of CEOs having zero salary and all pay is contingent on performance. There are very few CEOs of this type.

\(^{14}\) Generally, the pure-strategy of contingent compensation only is rare, although it exists. In 1978, Lee Iacocca, the former CEO of the Chrysler Corporation, set a precedent by having contracted for an annual salary of one dollar, with greater compensation expected based on performance. Since then, Moira Herbst (2007) notes that prominent CEOs have followed suit: Richard Kinder (Kinder Morgan); Steve Jobs (Apple); Eric Schmidt (Google); James Rogers (Duke Energy); Richard Fairbank (Capital One Financial); Terry Semel (Yahoo); John Mackey (Whole Foods Market); Jerrold Perenchio (Univision Communications) and William Ford Jr. (Ford Motor).

\(^{15}\) Contracting in labour markets is a voluntary decision, and labour markets are characterized by self-sorting (Rosen, 1986; Lazear, 1998). A manager’s choice of employment contracts of mixed strategy (part fixed and remaining is performance-based) is in effect acceptance of having pay-at-risk, which is not different in concept from a lottery, as will be discussed below.
But neither $p$ nor $RW$ is observable, and we could estimate a proxy for $p$ by treating the mixed-pay strategy in (1) as a quasi-lottery. The cost or the price a CEO pays for the lottery is the sacrificed portion of the desired sure pay, which is $(1 - p_j)RW_j$, while the expected prize or reward of the lottery is the expected level of contingent pay, $E(C_j)$.

Under this assumption, the ratio $\lambda_j = E(C_j) / (1 - p_j)RW_j$ (ratio of prize to implicit cost) would be a proxy for the risk preference of the CEO. In this structure, risk tolerance (inverse of risk aversion) is the indicator of risk preference.

Empirically, the known information includes the actual salary and actual performance-contingent pay. The actual salary, $S_j$, should be identical to $p_jRW_j$ in the relationship (1) above. Having only the realized components of pay, the CEO risk indicator $\lambda_j$ is not observable and should be imputed from components of actual compensation and proxied by contingent pay per one dollar of salary. However, the components of the actual compensation ratio of $C_j / S_j$, not only capture CEOs’ risk preferences, they also reflect the impact of firm performance on pay. That is, relative pay-at-risk measured as

$$\frac{C_j}{S_j} = \pi_j$$

could be construed to consist of two components: (a) a CEO’s own risk preference denoted by $\lambda$, and (b) the impact of firm performance. Assuming a linear combination,

$$\pi_{ij} = \lambda_j + \text{impact of the firm } i \text{ performance, } + \text{ random shocks}_j. = \lambda_j + \theta_j + \text{ random shocks}_j$$

where $\lambda_j$ is the ex ante intrinsic risk tolerance of CEO $j$, $\pi_j$ is the realized relative pay-at-risk, $\theta$ is the contribution of the firm’s performance to relative pay-at-risk, and the indexes $i$ and $j$ are for the firm and the CEO, respectively.

To evaluate the extent to which $\pi$ captures individual CEO’s risk preference, I draw on the variables used in the literature and reviewed earlier in connection with the asset-allocation approach to the measurement of risk aversion. These variables are Age, Education, Income, Wealth, and Gender. Given that risk tolerance is the inverse of risk aversion, the signs on the coefficients of the determinants of risk tolerance should be the opposite of the signs of the coefficients when measuring risk aversion.

In particular, the sign on the coefficient of CEO Age should be negative, suggesting that risk tolerance (aversion) decreases (increases) with age. By the same token, the coefficients on Income and Wealth should be positive, but there is no reason a priori to expect a particular direction for the sign of the coefficient on the

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16 This is equivalent to saying that risk aversion increases with age. Similarly, Cadman et al. (2010) found that CEO Age and Tenure distinguish between CEOs on ExecuComp and others.
indicator variable for Gender. In addition, I use CEO Tenure as a proxy for Education because it is a measure of the CEO’s firm-specific knowledge.  

Equation (3) presents this linear model and shows the partitioning of the determinants of relative pay-at-risk into CEOs’ demographics and firm-specific exogenous components.

\[ \pi_{ij} = \alpha_{0j} + \alpha_1 Age_{ij} + \alpha_2 Tenure_{ij} + \alpha_3 Income_{ij} + \alpha_4 Wealth_{ij} + \alpha_5 Gender_{ij} + \theta + \text{error}_{ij} \]  

(3)

In this construction, \( \lambda \) is endogenously generated by instrumental variables (two-stage least squares). Since we do not know the extent to which \( \pi \) captures CEO intrinsic risk aversion, this study aims at answering two questions:

1) is relative pay-at-risk a good proxy for CEO risk tolerance?
2) what is the association between the estimated risk tolerance parameter and R&D expenditures?

**FIRM PERFORMANCE AND R&D FACTORS**

In this section, I describe the factors offered in the literature (and adopted here) as determinants of R&D. These factors include firm size and profitability and, as a result, provide measures of firm performance that impacts CEO pay. These variables are discussed below.

- **Firm size (Z).** The impetus for expecting association between firm size and R&D is the Schumpeterian concept that larger firms are better able to innovate and have greater commitment to R&D (Schumpeter, 1942; Cohen and Klepper, 1996; Griffith and Webster, 2004; Lee and Sung, 2005). Guay (1999) and Rajgopal and Shevlin (2002) also find a significant association between firm size and firm risk

\[ \pi_{ij} = \lambda + \theta \]

\[ \text{Determinants of CEO risk tolerance} \]

\[ \text{Firm-specific determinants} \]

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17 In some earlier studies, the variable education is measured as a nominal variable varying between 1 and 5. (see Donkers et al., 2001). If the number of years in formal education is used as a measure of this variable, high profile entrepreneurs like Bill Gates (Microsoft) and Steve Jobs (Apple), who dropped out of college, would be at the lowest scale.
measured by intensity of R&D investment and volatility of cash flow. The National Science Foundation (NSF, 2010, Ch. 4) uses two alternatives: total assets (a measure of scale) and the number of employees (a measure of complexity as suggested by Griffith and Webster, 2004).

- **Profitability (ROA).** More profitable firms increase their investment in R&D, and *vice versa.* However, because R&D expenditures are expensed as incurred, the higher the R&D, the lower the income; by construction, the association between R&D expenditures and reported net income is negative. This mechanical relationship appears to be the reason for the unreasonable conclusion offered by Wöhrl and Dowling (2009) in which they state ‘R&D leads to lower return on sales’. Therefore, not adjusting for the accounting method of charging R&D expenditures could lead to perverse empirical findings. In addition, management’s concern for reporting smooth earnings might lead to using R&D, a real activity, to manage reported profits (Baber *et al.*, 1991; Perry and Grinaker, 1994; Bushee, 1998; Roychowdhury, 2006).

In this study, I undo the accounting expensing of R&D and estimate return on assets (ROA) before R&D charges. Approximating this correction requires making assumptions about amortization and tax rates. The revised measure, \( AdjROA \), is estimated as follows:

\[
adjROA = \frac{[\text{Net Income} + \text{R&D} (1 - Am)(1 - txr)]}{(\text{Total Assets} + \text{Estimated R&D Asset})}
\]

\( adjROA \) is the return on assets adjusted for R&D accounting charges, for income tax rate (\( txr \)), and for the annual rate of amortization (\( Am \)).

- **Growth.** R&D spawns growth, but generally with lags, depending on the nature of the project and type of industry. Pindado *et al.* (2010) find firm growth to be a significant determinant of the impact of R&D on market valuation. However, a summary of the empirical evidence reveals mixed findings with respect to the relationship between growth and spending on R&D as, for example, noted in Del Monte and Papagni for Italian firms (2003). In this study, growth is measured in two ways: rolling five-year period growth in sales, and annual rate of increase in assets.

- **Leverage.** The uncertainty inherent in R&D projects increases the degree of information asymmetry between managers and investors such that equity market participants could demand higher cost of capital, because of what Leland and Pyle (1977) call the lemons’ premium. As a consequence, the higher cost of equity capital is assumed to drive firms to raise capital in debt markets, especially because

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18 Generally Accepted Accounting Principles (GAAP) in the U.S. and International Financial Reporting Standards (IFRS) require charging research expenditures as periodic cost to the profit and loss statement. However, IFRS allows capitalization of development costs, whereas U.S. GAAP requires, expensing them until reaching commercial feasibility.
creditors can demand (and often obtain) more information than equity market participants and have preference over the firm’s assets, while equity holders end up with the residual. However, Cumming and McIntosh (2000) do not find a positive association between leverage and R&D intensity.\(^{19}\)

- **Relative Volatility of Cash Flow.** In addition to leverage, and perhaps due to the lemons’ premium, Hall (2002) shows that firms seek to finance high-risk projects using internal sources of funds. R&D expenditures are sticky because projects often last for years, and the projects that use internal sources of funding must have a relatively stable cash-generating ability. The relative stability or volatility of operating cash flows can be gauged by the ratio of the standard deviation of operating cash flow to the standard deviation of earnings from continuing operations. This measure is expected to be greater than unity, because accruals have the added benefit of smoothing earnings—the higher the ratio, the more volatile are operating cash flows relative to earnings and the more that a firm relies on internal funds to finance R&D. Therefore, the correlation between relative cash flow volatility and R&D expenditures is expected to be negative. To measure this variable, we use 12 rolling quarters prior to the period of analysis for estimating the standard deviation of both cash flow and earnings.

- **Firm Age.** Firms go through stages of research cycles, and younger firms spend higher proportions of their sales on R&D (Cumming and McIntosh, 2000). In addition, Balasubramanian and Lee (2005) report ‘... using data on 180,500 U.S. patents of Compustat firms applied for during 1984–94, we find that firm age is significantly and negatively related to technical quality’ (p. 1). Wöhrl and Dowling (2009) report similar results for firms listed on the German Neuer Markt.\(^{20}\)

- **Industry.** The National Science Foundation (NSF, 2010) reports that four industry groups undertake about 80% of the R&D activity in the U.S. These groups are: chemicals (including pharmaceuticals), computer hardware and electronic products including software and related services, aerospace and defence manufacturing, and automotive industries. Industry analysis in this study will adopt the four-digit Global Industrial Classification System (GICS) that is likely to replace SIC.\(^{21}\)

A summary description of the measurement of these variables is in Exhibit 1.

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20 There is no information on Compustat for firm age, but an approximation is made based on the number of years a company has been listed on Compustat. Admittedly, this measure does not provide accurate information at the upper end, but it does provide accurate information for younger companies.

21 See a description at http://www2.standardandpoors.com/spf/pdf/index/GICSIndexDocument.PDF.
EXHIBIT 1

DEFINITION OF VARIABLES

- $i$: index for the firm.
- $j$: index for the CEO.
- $Pr$: Predicted.

**MSV** _manager-specific variables_

- $\pi_{ij}$: Relative pay-at-risk premium, which is measured as the ratio of realized incentive pay (bonus plus realized gains on exercising options and restricted stock plus annual awards) to salary.
- $\ln(\pi_{ij})$: The natural log of relative pay-at-risk premium.
- $\lambda_{ij}$: The estimated CEO risk tolerance metric, which is the predicted value of $\ln(\pi)$ conditional on firm-specific characteristics, either using instrumental variables (2SLS). It is the inverse of risk aversion. $\lambda_{ij}$ is low for a highly risk-averse person and high for individuals with high risk tolerance.
- $\text{Age}_{ij}$: CEO age in years.
- $\text{Tenure}_{ij}$: Tenure as the number of years on the job as a CEO ($\text{Tenure} \geq 1$).
- $\ln(\text{Income}_{ij})$: Natural log of income earned for the year, both realized and unrealized (salary, bonus, long-term incentive compensation, realized gain on exercised options, unrealized gains on awarded options and unrestricted stock, other compensation).

It is important to note that the analysis was carried out with and without the variable of CEO ‘Income’ due to collinearity with firm size.

- $\text{CEO Wealth}_{ij}$: Natural log of the market value of CEO equity holding as a proxy for wealth.
- $\text{Gender}_{ij}$: Gender (0 for male, 1 for female).

**FSV** = _firm-specific variables:

- Firm Size$_j$: Size measured by the natural log of sales, assets or number of employees.
- $\text{AdjROA}_i$: Return on assets, which is adjusted income to total assets. Adjusted income is measured as reported net income adjusted for expensing R&D by adding it back to earnings gross of the estimated tax and net of estimated amortization.
- $\text{Sales Growth}_i$: The rate of sales growth over the preceding five years.
• **Leverage**: Leverage measured by assets net of common equity divided by total assets

• **Cash Flow Volatility**: Cash flow volatility relative to income volatility as measured by the ratio of the standard deviation of operating cash flow to the standard deviation of income over the preceding 12 (rolling) quarters

• **Firm Age**: Firm age in years proxied by the number of years listed on Compustat

DATA

I obtained data from ExecuComp and Compustat for the period 1993–2009. I targeted for sampling only firms operating in industries that require investing in R&D activities. These firms exclude financial institutions and enterprises in retailing and utilities. I also excluded the firms that were seriously distressed to the point of having negative owners’ equity during the sampling period.22 Finally, I winsorized the observations at 2% off the tails. The final sample of usable data consists of 6,479 firm/year observations. I present descriptive statistics of key variables in Table 1 and Pearson correlation coefficients in Table 2.

ANALYSIS

A. Is Relative Pay-at-Risk a Valid Proxy for Risk Preference?

This question is the subject of Hypothesis 1. To test this hypothesis, I use the $F$ statistic for determining whether CEO-specific variables are superfluous or relevant determinants of $\pi$, relative pay-at-risk. Drawing on the findings of prior literature, the five variables used are CEO’s Age, Tenure, Income, Wealth, and Gender. The extent to which these variables are not superfluous is tested by comparing the fit of two regression models: one is the full *unrestricted* model that includes both firm-specific and CEO-specific variables, and the other is a *restricted* model in which the coefficients on the CEO-specific variables are restricted to be zero. After correcting for the degrees of freedom and number of restrictions, the difference between the explanatory powers is measured as:

$$FS_{(m,df)} = \frac{(R^2_U - R^2_R)}{m (1 - R^2_R)/df},$$

with $R^2_U$ being the ratio of explained variation of the augmented model, $R^2_R$ being the ratio of explained variation of the basic restricted model, $df$ being the number of

---

22 These types of firms exist in the database due to either coding errors or accumulating unusual losses. However, firms with negative owners’ equity will introduce bias, because these firms are essentially bankrupt and do not invest in R&D.
degrees of freedom of the unrestricted model, and \( m \) being the number of restrictions. The statistic \( FS_{(m, df)} \) follows the \( F \) distribution with \( m \) and \( df \) degrees of freedom.

The unrestricted and restricted models are specified as follows:

\[
\pi_{ij} = \beta_{0i} + \beta_{1i} CEO\ Age_{ij} + \beta_{2i} Tenure_{ij} + \beta_{3i} Income_{ij} + \beta_{4i} Wealth_{ij} + \beta_{5i} Gender_{ij} + \beta_{6i} Size_{ij} + \beta_{7i} ROA_{ij} + \beta_{8i} Sales\ Growth\ Rate_{ij} + \beta_{9i} Leverage_{ij} + \beta_{10i} Cash\ Flow\ Volatility_{ij} + \beta_{11i} Firm\ Age_{ij} + u_{ij} \tag{4U} \\
\]

\[
\pi_{ij} = \alpha_{0i} + \alpha_{1i} Size_{ij} + \alpha_{2i} adjROA_{ij} + \alpha_{3i} Sales\ Growth\ Rate_{ij} + \alpha_{4i} Leverage_{ij} + \alpha_{5i} Cash\ Flow\ Volatility_{ij} + \alpha_{6i} Firm\ Age_{ij} + v_{ij} \tag{4R} \\
\]

Table 1
DESCRIPTIVE STATISTICS

<table>
<thead>
<tr>
<th>A. Firm-specific Variables</th>
<th>Mean</th>
<th>Standard Deviation</th>
<th>Lowest Quartile</th>
<th>Median</th>
<th>Highest Quartile</th>
</tr>
</thead>
<tbody>
<tr>
<td>Research &amp; Development in $m</td>
<td>181.60</td>
<td>517</td>
<td>17.2</td>
<td>43</td>
<td>131</td>
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<tr>
<td>ln Research &amp; Development</td>
<td>3.90</td>
<td>1.52</td>
<td>2.84</td>
<td>3.77</td>
<td>4.87</td>
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<tr>
<td>First Difference in &amp;D</td>
<td>11.46</td>
<td>47.12</td>
<td>−0.80</td>
<td>2.11</td>
<td>10.53</td>
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<tr>
<td>Research Development/Sales</td>
<td>0.007</td>
<td>0.036</td>
<td>−0.0007</td>
<td>0.002</td>
<td>0.011</td>
</tr>
<tr>
<td>Research Development in $1000/Employees</td>
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<td>12.84</td>
<td>−0.14</td>
<td>0.43</td>
<td>2.58</td>
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<tr>
<td>Sales in $m</td>
<td>3962</td>
<td>11.066</td>
<td>335</td>
<td>948</td>
<td>3,027</td>
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<tr>
<td>Log Sales</td>
<td>6.96</td>
<td>1.57</td>
<td>5.61</td>
<td>6.85</td>
<td>8.01</td>
</tr>
<tr>
<td>Return on Assets</td>
<td>4.03</td>
<td>16.50</td>
<td>2.01</td>
<td>5.80</td>
<td>9.40</td>
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<tr>
<td>Adjusted Return on Assets*</td>
<td>8.7</td>
<td>16.60</td>
<td>4.8</td>
<td>9</td>
<td>15</td>
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<tr>
<td>Sales Growth (5-year Sales Growth)</td>
<td>15.17</td>
<td>46.30</td>
<td>2.85</td>
<td>9.07</td>
<td>10.70</td>
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<tr>
<td>Leverage</td>
<td>0.47</td>
<td>0.21</td>
<td>0.312</td>
<td>0.49</td>
<td>0.62</td>
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<tr>
<td>Relative cash flow volatility</td>
<td>2.58</td>
<td>2.70</td>
<td>1.10</td>
<td>1.93</td>
<td>3.26</td>
</tr>
</tbody>
</table>

| B. CEO Socio-demographic Variables | | | | | |
| CEO Age                | 55.3    | 6.70     | 51   | 56 | 60 |
| Tenure                 | 7       | 6.50     | 2    | 5  | 9  |
| ln pay                 | 7.84    | 1.01     | 7.14 | 7.82 | 8.53 |
| ln CEO Wealth          | 8.42    | 1.78     | 7.41 | 8.58 | 9.63 |
| Gender                 | 0.98    | 0.117    | 1    | 1  | 9  |
| Log relative incentive pay (incentives/salary) | 1.076 | 0.92 | 0.41 | 0.85 | 1.52 |
| Predicted CEO Risk Tolerance (full model) | 1.077 | 0.43 | 0.91 | 1.10 | 1.25 |
| Predicted CEO Risk Tolerance (using CEO-specific variables only) | 1.076 | 0.26 | 0.93 | 1.10 | 1.25 |

*AdjROA is corrected for the accounting impact of accruing R&D as an expense obtained from Execucomp.
### Table 2

PEARSON CORRELATION COEFFICIENTS

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<tr>
<th></th>
<th>1</th>
<th>2</th>
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<th>14</th>
<th>15</th>
<th>16</th>
<th>17</th>
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<tbody>
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<td>1  logR&amp;D</td>
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<td>2  R&amp;D Change</td>
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<td>3  R&amp;D Change/Sales</td>
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<tr>
<td>4  R&amp;D Change/No. Employees</td>
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<td>0.37</td>
<td>0.86</td>
<td>1.00</td>
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<tr>
<td>5  CEO Age</td>
<td>-0.02</td>
<td>-0.02</td>
<td>-0.06</td>
<td>-0.05</td>
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<td>6  CEO Tenure</td>
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<tr>
<td>7  Log CEO Compensation</td>
<td>0.60</td>
<td>0.25</td>
<td>0.04</td>
<td>0.08</td>
<td>0.02</td>
<td>-0.14</td>
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<tr>
<td>8  Log CEO Wealth</td>
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<td>0.20</td>
<td>0.08</td>
<td>0.07</td>
<td>0.15</td>
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<td>9  Gender</td>
<td>-0.03</td>
<td>0.01</td>
<td>0.01</td>
<td>0.08</td>
<td>0.05</td>
<td>-0.03</td>
<td>0.01</td>
<td>1.00</td>
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<tr>
<td>10 Log Sales</td>
<td>0.69</td>
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<td>11 AdjROA</td>
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<td>0.13</td>
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<td>-0.06</td>
<td>0.05</td>
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<tr>
<td>12 Assets Growth Rate</td>
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<td>0.15</td>
<td>0.29</td>
<td>0.24</td>
<td>-0.06</td>
<td>0.02</td>
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<td>1.00</td>
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<tr>
<td>13 Sales Growth Rate</td>
<td>-0.02</td>
<td>0.12</td>
<td>0.19</td>
<td>0.19</td>
<td>-0.13</td>
<td>0.12</td>
<td>0.01</td>
<td>0.17</td>
<td>0.01</td>
<td>0.020</td>
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<tr>
<td>14 Leverage</td>
<td>0.19</td>
<td>0.02</td>
<td>-0.10</td>
<td>-0.12</td>
<td>0.13</td>
<td>-0.17</td>
<td>0.24</td>
<td>0.01</td>
<td>0.02</td>
<td>0.006</td>
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<td>-0.07</td>
<td>-0.27</td>
<td>1.00</td>
<td></td>
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<tr>
<td>15 Cash Flow SD/Earnings SD</td>
<td>-0.10</td>
<td>-0.01</td>
<td>-0.01</td>
<td>-0.02</td>
<td>0.07</td>
<td>-0.02</td>
<td>0.00</td>
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<td>0.02</td>
<td>0.021</td>
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<td>0.02</td>
<td>-0.03</td>
<td>0.18</td>
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<td>16 Firm Age</td>
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<td>0.02</td>
<td>-0.08</td>
<td>-0.06</td>
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<td>0.12</td>
<td>0.05</td>
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<td></td>
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<tr>
<td>17 Relative Pay at Risk</td>
<td>0.25</td>
<td>0.22</td>
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<td>0.15</td>
<td>0.03</td>
<td>0.04</td>
<td>0.41</td>
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<td>0.03</td>
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<td>0.28</td>
<td>0.23</td>
<td>0.20</td>
<td>-0.04</td>
<td>0.01</td>
<td>-0.03</td>
<td>1.00</td>
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<tr>
<td>18 Risk Tolerance Metric</td>
<td>0.49</td>
<td>0.32</td>
<td>0.20</td>
<td>0.22</td>
<td>0.05</td>
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<td>0.39</td>
<td>-0.08</td>
<td>0.01</td>
<td>-0.06</td>
<td>0.53</td>
</tr>
</tbody>
</table>
In these regressions, $\pi$ is relative pay-at-risk, measured by the ratio of contingent compensation salary; the $\beta$ coefficients are the estimated parameters for the unrestricted model; the $\alpha$ are the estimated model parameters for the restricted model; $\nu$ and $\mu$ are error terms; the index $i$ is a firm designation; the index $j$ is a CEO designation; and other variables are measured as described in Exhibit 1.

Table 3 presents the results of estimating both the unrestricted model (4U) in Column A and the restricted model (4R) in Column B. For the purpose of this test, we are interested only in $R^2$ values. In the next segments, we will address the significance and relevance of the coefficients. As shown, the $R^2$ values are 27.7% and 18.3% for the unrestricted model and the restricted model, respectively. Using these values, the $F(m, df)$ statistic is calculated as

$$F(m, df) = \frac{(R_{2}^2 - R_{1}^2)/m}{(1 - R_{2}^2)/df} = \frac{(0.277 - 0.183) \times 5.398}{0.723 \times 5} \approx 140$$

(5)

An $F(m, df)$ value of 140 is statistically significant at $p < 0.01$, suggesting that the dependent variable, relative pay at risk, is a proxy for risk preference, because an incrementally significant proportion of variation is explained by CEO-specific variables. Since relative pay-at-risk is a measure of contingent compensation per one dollar of salary, the risk preference indicator in this case is the degree of risk tolerance. This finding is consistent with hypothesis 1.

B. Does a CEO’s Risk Tolerance Relate to R&D?

B.1 Preliminary analysis of CEO age and R&D intensity The coefficient on CEO Age in regression (4R, reported in Column C of Table 3) is negative and significant (at $p < 0.01$), suggesting that conditional on firm performance, older CEOs have less tolerance for risk taking. A preliminary graphical presentation of the behaviour of R&D intensity, $RDIS$ (R&D expenditure per a dollar of sales) in relationship to CEO Age is in Figure 1. The figure is for the full sample and three industry classification groups:

a. The full sample: Average $RDIS$ decreases from a high of 11% for the top decile of CEO Age to a low of 5.3% for the lowest decile.

b. Firms in Life Sciences (GICS 3520): Average $RDIS$ range between 18% and 12%.

c. For firms in Software Services (GICS 4510): average $RDIS$ is declining with Age deciles and varies between 17% and 9%.

d. The relationship for firms in Telecommunication & Equipment (GICS 4520): $RDIS$ remains steady at around 13%. For the Software industry, $RDIS$ declines from 19% for the top decile to 11% for the lowest decile.

In general, these patterns show a negative relationship between $RDIS$ and CEO Age. A more detailed analysis of industry differences is presented in the out-of-sample robustness test.
B.2 Multivariate analysis

B2.1 First-stage regression analysis

i. Estimation Results

The first stage in a two-stage least-squares (2SLS) method provides an OLS estimation of regressing the instrumented dependent variable, which is relative pay-at-risk, on all exogenous variables in the system that are used as instruments. The result of this stage is identical to the result of estimating the unrestricted model in (4U), presented in Table 3, Column A. These results report a good fit ($\text{Adj } R^2 = 27.7\%$) and statistically significant coefficients on most variables with the exception being the coefficients on $\text{Tenure}$, $\ln \text{Sales}$, and $\text{Relative Cash Flow Volatility}$. The lack of significance on firm size is likely due to the high colinearity between $\ln \text{Sales}$ and $\ln \text{Income}$; when the latter variable is dropped, the coefficient on $\ln \text{Sales}$ becomes significant and positive.

Of the CEO-specific variables, $\text{Age}$, $\text{Income}$, $\text{Wealth}$, and $\text{Gender}$ are statistically significant at $p < 0.01$ and have positive signs.\(^{23}\) The coefficient on $\text{Gender}$ is perhaps not meaningful in this study, given that only 2% of sample firms have

\(^{23}\) Obtaining a negative relationship between CEO $\text{Age}$ and risk tolerance when using CEO-specific variables only is consistent with prior literature on risk aversion.
HISTOGRAMS OF RELATIVE PAY AT RISK AND CEO RISK TOLERANCE METRICS
### Table 3

THE TWO-STAGE LEAST SQUARES RESULTS USING SCALED AND UNSCALED FIRST DIFFERENCE IN R&D EXPENDITURES

<table>
<thead>
<tr>
<th>Dependent Variable is Relative Pay at Risk (π)</th>
<th>Restricted Models</th>
<th>Second Stage Estimation of 2SLS</th>
<th>Dependent Variable is the First Difference in R&amp;D</th>
<th>Second Stage Estimation of 2SLS. Dep. Variable Scaled by Sales</th>
<th>Second Stage Estimation of 2SLS. Dep. Variable Scaled by Number of Employees</th>
</tr>
</thead>
<tbody>
<tr>
<td>First Stage OLS Estimation (the Unrestricted Model)</td>
<td>First Stage (Column A): $\pi_{ij} = \beta_0 + \beta_1 \text{CEO Age}<em>{ij} + \beta_2 \text{Tenure}</em>{ij} + \beta_3 \text{Income}<em>{ij} + \beta_4 \text{Wealth}</em>{ij} + \beta_5 \text{Gender}<em>{ij} + \beta_6 \text{Size}</em>{ij} + \beta_7 \text{ROA}<em>{ij}$ + $\beta_8 \text{Sales Growth Rate}</em>{ij} + \beta_9 \text{Leverage}<em>{ij} + \beta</em>{10} \text{Cash Flow Volatility}<em>{ij} + \beta</em>{11} \text{Firm Age}<em>{ij} + u</em>{ij}$</td>
<td>Second Stage (Column D): $d\text{R}<em>{ij} = \alpha_0 + \alpha_1 \lambda + \alpha_2 \text{Size}</em>{ij} + \alpha_3 \text{AdjROA}<em>{ij} + \alpha_4 \text{Sales Growth Rate}</em>{ij}$ + $\alpha_5 \text{Leverage}<em>{ij} + \alpha_6 \text{Cash Flow Volatility}</em>{ij} + \alpha_7 \text{Firm Age}<em>{ij} + v</em>{ij}$</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>A</td>
<td>B</td>
<td>C</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Intercept</strong></td>
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<td>$-0.28$</td>
<td>$-2.59$</td>
<td>$-40.60$</td>
<td>$-0.06$</td>
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<tr>
<td></td>
<td>($-17.27)^a$</td>
<td>($-4.50)^a$</td>
<td>($-13.55)^a$</td>
<td>($-5.28)^a$</td>
<td>($2.30)^a$</td>
</tr>
<tr>
<td><strong>CEO Age</strong></td>
<td>$0.005$</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>($2.81)^a$</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>CEO Tenure</strong></td>
<td>$0.0001$</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>(0.07)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Log CEO Realized Income</strong></td>
<td>$0.38$</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>(25.00)^a</td>
<td></td>
<td></td>
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</tr>
<tr>
<td><strong>Log CEO Wealth</strong></td>
<td>$0.043$</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>(6.00)^a</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Gender</strong></td>
<td>$0.26$</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>(2.72)^a</td>
<td></td>
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</tr>
<tr>
<td><strong>CEO Risk Tolerance Variable</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
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</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>logSales</strong></td>
<td>$-0.002$</td>
<td>$0.19$</td>
<td></td>
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</tr>
<tr>
<td></td>
<td>($-0.16)$</td>
<td>($17.58)^a</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>AdjROA</strong></td>
<td>$1.55$</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>(14.63)^a</td>
<td>($5.87)^a</td>
<td></td>
<td></td>
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</tr>
<tr>
<td><strong>Sales 5-year Growth Rate</strong></td>
<td>$0.008$</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>(9.91)^a</td>
<td>($13.16)^a</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Leverage (Debt to Assets)</strong></td>
<td>$-0.24$</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>($-3.25)^a</td>
<td>($-4.85)^a</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Relative Cash Flow Volatility</strong></td>
<td>$0.0015$</td>
<td></td>
<td></td>
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<td></td>
</tr>
<tr>
<td></td>
<td>($-6.79)^a</td>
<td>($-2.39)^a</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Firm Age</strong></td>
<td>$0.005$</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>($2.81)^a</td>
<td>($-3.97)^a</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>R²</strong></td>
<td>26.4%</td>
<td>16.29%</td>
<td>18.82%</td>
<td>10%</td>
<td>8.3%</td>
</tr>
<tr>
<td><strong>F statistic</strong></td>
<td>176.07</td>
<td></td>
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</tr>
<tr>
<td><strong>Number of Observations</strong></td>
<td>5,404</td>
<td>6,479</td>
<td>5,509</td>
<td>5,404</td>
<td>5,404</td>
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<tr>
<td>Notes:</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>$^a$ = significance at $p &lt; 0.01$; $^b$ = significant at $p &lt; 0.05$; and $^c$ = significant at $p &lt; 0.10$.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>The models estimated are:</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>The two-stage least squares using instrumental variables in which all exogenous variables are employed to predict the risk preference metric, $\lambda_{2sls}$ for use in the second stage of the R&amp;D function.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>First Stage (Column A): $\pi_{ij} = \beta_0 + \beta_1 \text{CEO Age}<em>{ij} + \beta_2 \text{Tenure}</em>{ij} + \beta_3 \text{Income}<em>{ij} + \beta_4 \text{Wealth}</em>{ij} + \beta_5 \text{Gender}<em>{ij} + \beta_6 \text{Size}</em>{ij} + \beta_7 \text{ROA}<em>{ij}$ + $\beta_8 \text{Sales Growth Rate}</em>{ij} + \beta_9 \text{Leverage}<em>{ij} + \beta</em>{10} \text{Cash Flow Volatility}<em>{ij} + \beta</em>{11} \text{Firm Age}<em>{ij} + u</em>{ij}$</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Second Stage (Column D): $d\text{R}<em>{ij} = \alpha_0 + \alpha_1 \lambda + \alpha_2 \text{Size}</em>{ij} + \alpha_3 \text{AdjROA}<em>{ij} + \alpha_4 \text{Sales Growth Rate}</em>{ij}$ + $\alpha_5 \text{Leverage}<em>{ij} + \alpha_6 \text{Cash Flow Volatility}</em>{ij} + \alpha_7 \text{Firm Age}<em>{ij} + v</em>{ij}$</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>All regressions are based on Robust Regression estimation.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Description of the measurement of all variables is in Exhibit 1.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>The number of observations varies and is lower than the full sample when using first difference and winsorizing outliers at the 2% tail.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
female CEOs. These results are generally consistent with expectations and validate relative pay-at-risk as a proxy for risk tolerance.

ii. Prediction

I use the estimated coefficients of the first stage OLS regression (Column A in Table 3) to predict CEO risk tolerance metrics, $\lambda_{j}^{2SLS}$ for use in the second stage. $\lambda_{j}^{2SLS}$ is the predicted value of relative pay-at-risk attributable to CEO-specific variables. These predicted values form the measures of risk tolerance used as an explanatory variable in the second stage regression.

I present the descriptive statistics of $\lambda_{j}^{2SLS}$ in Table 1, and Pearson correlation coefficients between $\lambda_{j}^{2SLS}$ and other explanatory variables in Table 2. These tables include descriptive statistics of both the estimated CEO risk metrics predicted from the first stage for use in the second stage, $\lambda_{j}^{2SLS}$, and the raw data of relative pay-at-risk in a log form, $ln\pi$.24

As these descriptive data and the distributions in Figure 2 show, the two measures $\lambda_{j}^{2SLS}$ and $ln\pi$ have similar averages, but different volatility. The volatility of $ln\pi$ is more than twice as much as the volatility of $\lambda_{j}^{2SLS}$. In addition, the raw data of log relative pay-at-risk ($ln\pi$) are positively skewed with skewness coefficient of 1.27 compared to skewness coefficient of 0.10 for the predicted risk metrics, $\lambda_{j}^{2SLS}$. This skewness may also be detected in comparing the median and the mean. For $ln\pi$, the mean is 0.755, while the median is 1.01. In contrast, the median and mean values are close to 1.01 and 1.02 for the predicted metrics $\lambda_{j}^{2SLS}$. In addition, as shown in Table 2, the correlation coefficient between $\lambda_{j}^{2SLS}$ and $lnR&D$ is 49%, but only 25% for the correlation between $ln\pi$ and $lnR&D$.

**B.2.2 Second-stage regression results**  The second stage of the 2SLS uses the predicted CEO risk preference estimates, $\lambda_{j}^{2SLS}$—as an (endogenous) explanatory variable of the variation in R&D over time and across firms. In this analysis, I use the first difference in R&D as the dependent variable, because R&D expenditures are sticky and have high serial correlation. However, in order to validate these assertions, the second stage regression is repeated, using $lnR&D$ as the dependent variable. The results of this additional analysis are in Appendix B.25 As shown, using R&D levels ad dependent variable, $R^2$ value in the second stage is 42%, and the coefficient on $\lambda$ has a t-statistic of 11.92.

For these reasons, I use first difference in annual R&D expenditures to generate three measures for the dependent variable in testing hypothesis 2. These measures are

24 All data are winsorized by 2%.

25 Any given project takes several years to complete (an average of 12 years for pharmaceuticals). As a result, R&D expenditures have high serial correlation and pooling time-series and cross section data would create econometric problems—inflate $R^2$ values and the significance of the estimated coefficients. In addition, the collected data have unbalanced panel because different years have different number of observations for different industries. In this case, the first stage estimation does not change for the unrestricted model (4UR).
a) $dR&D$, first measure is for unscaled first difference

b) $dRDIS$, first difference of R&D intensity equals to R&D expenditures expenditures scaled by sales

c) $dRDIE$, first difference of R&D intensity equals to R&D expenditures expenditures scaled by the number of employees

The second stage regression model takes the following form for each of the three measures:

$$A \text{ Measure of } R&D \text{ Difference} = \beta_0 + \beta_i \lambda_i^{SLS} + \beta_{ii} Size_i + \beta_{ii} \text{ adjROA}_i$$
$$+ \beta_{iii} Sales \text{ Growth}_i + \beta_{iii} Assets \text{ Growth Rate}_i$$
$$+ \beta_{iii} \text{ leverage}_i + \beta_{iii} \text{ Cash Flow Volatility}_i$$
$$+ \beta_{iii} \text{ Firm Age}_i + u_{rdDiff}$$ (6)

The variable $\lambda_i^{SLS}$ is the CEO risk-tolerance metric as the predicted values from the first-stage regression; the indexes $i$ and $j$ are for the firm and the CEO, respectively; $u_{rdDiff}$ is the error term; and all other variables are defined in Exhibit 1.

The second stage results are presented in Table 3—in Column D for $dR&D$, the unscaled first difference; in Column E is for $dRDIS$, the first differences scaled by sales; and in Column F for $dRDIE$, first differences scaled by the number of employees.

A summary of these results is captured in the following outline:

1) **Model Goodness of Fit**: The second stage $R^2$ values are 11.20% for $dR&D$, 12.30% for $dRDIS$, and 10% for $dRDIE$. The $F$ statistics associated with these values are statistically significant at $p < 0.01$.27

2) **The Coefficients on Predicted CEO Risk Tolerance**: The second stage results show positive and statistically significant coefficients on CEOs risk tolerance metrics $\lambda_i^{SLS}$. The values of the coefficients (t-statistics) are 9.86 (4.6) for the unscaled $dR&D$ presented in Column D; 0.0045 (2.63) for $dRDIS$ presented in Column E, and 2.0 (3.64) for $dRDIE$ presented in Column F. These values of t-statistics are significant at $p < 0.01$. Collectively, these results reflect the significant positive association between CEOs’ risk tolerance and investment in research and development; that is, R&D expenditures are higher for firms having CEOs with higher risk tolerance. These findings are consistent with hypothesis 2.

3) **Validity of Estimated Models**: Validating the model requires examining the coefficients on all variables in the results of the second stage regression to check their consistency with expectation. For example, the coefficient on firm size (lnSales) is positive and statistically significant at $p < 0.01$.28 The coefficients on growth rates

26 These are two of the measures of R&D intensity indicators used by the National Science Foundation.

27 Notice that if lnR&D values are used as the dependent variable instead of first differences, $R^2$ would be about 43%. See Appendix B.

28 Using sales or any firm size indicator as an explanatory variable is valid only for the unscaled first differences in R&D. For the scaled differences, either sales or number of employees are used as scalars.
of both sales and total assets are positive and statistically significant at $p < 0.01$ in all three models. However, profitability as measured by $AdjROA$ is positive and statistically significant only in the unscaled model. The coefficients on leverage are negative and statistically significant for the unscaled model and for the model scaling first differences by the number of employees. While the coefficients on growth and profitability are consistent with expectations, the negative coefficient on leverage is inconsistent with the Lemons’ Premium of Leland and Pyle (1977), discussed earlier.

C. Robustness Tests
Model (3) posits that CEO’s intrinsic risk tolerance is a function of the CEO-specific variables only. However, in the $2SLS$ estimation, $\lambda_{j}^{2sls}$ is estimated using all exogenous variables of both CEO-specific and firm-specific. The question then arises as to whether estimating the risk tolerance metric using CEO-specific variables only, $\lambda_{j,ceov}$, would lead to different results from those obtained using $\lambda_{j}^{2sls}$. This query is answered by estimating $\lambda_{j,ceov}$ and using the predicted values as an endogenous variable in a second-step regression similar to the second stage in $2SLS$.

To perform this test, the following regression models are estimated.

$$\pi_{ij} = \beta_{0i} + \beta_{1i} CEO Age_{ij} + \beta_{2i} Tenure_{ij} + \beta_{3i} Income_{ij} + \beta_{4i} Wealth_{ij} + \beta_{5i} Gender_{ij} + u_{i}$$

A Measure of $dR&D_{i} = \beta_{0} + \beta_{1} \lambda_{CEOV} + \beta_{2} Size_{i} + \beta_{3i} ROA_{i} + \beta_{4i} Sales Growth Rate_{i} + \beta_{5i} leverage_{i} + \beta_{6i} Cash Flow Volatility_{ij} + \beta_{7i} Firm Age_{i} + u_{w&D,j}$

The measures of $dR&D$ are as noted above—unscaled, scaled by sales, or scaled by the number of employees. The results of estimating (8) are in Table 4.

D. Out of Sample Tests and a Comparison of Industry Differences
D.1 Predicted R&D and predicted risk preferences  The results reported above are based on using in-sample data, but using out-of-sample (hold-out) sample data should provide a stronger test (White, 2000). For this test, I estimated the first stage model (model 4U) as before, but the second stage regression has $lnR&D$ as the dependent variable. This estimation is done year-by-year for the period 1993–2007 for use as bases for predictions in other periods. The estimated coefficients for any year are used to predict both CEO risk tolerance metric $Pr(\lambda_{T+1})$ based on first stage estimation, and $Pr(lnR&D_{T+1})$ based on second stage estimation, where ‘T’ is for the year of estimation and ‘h’ is for the prediction horizon. These predicted values are used as forecasts of CEO risk tolerance metric and for $lnR&D$.

Figure 3 presents the scatter plots of $Pr(lnR&D_{1999+1})$ on the x-axis and predicted CEO risk tolerance, $Pr(\lambda_{1999+1})$, on the y-axis. These scatter plots show that the and should not be also used as explanatory variables. Furthermore, sales and the number of employees as highly correlated such that once is a substitute for the other.

The results of using other years for estimation are very similar and are not reported here.
correlation coefficients between predicted values of R&D and risk tolerance metrics are 30% for the full sample, 44% for the chemical and pharmaceutical industry, and 26% for the computer and software industry.

To formalize this analysis, the R&D forecast error, \( U_{lnR&D}^{T+h} \), is measured as

\[
U_{lnR&D}^{T+h} = lnR&D_{T+h} - Pr(lnR&D_{T+h})
\]

In this formulation, \( Pr(\lambda_{T+h}) \), \( Pr(lnR&D_{T+h}) \) and \( U_{lnR&D}^{T+h} \) are generated for out-of-sample observations that allowed testing the direction and significance of

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### RESULTS OF REGRESSING LEVELS AND FIRST DIFFERENCE IN R&D ON CEO’S RISK TOLERANCE METRICS & OTHER DETERMINANTS USING THE CEO VARIABLES ONLY IN PREDICTING RISK TOLERANCE METRICS

<table>
<thead>
<tr>
<th>R &amp; D Measures</th>
<th>Unscaled</th>
<th>Scaled First Difference of R&amp;D Expenditures</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>InR&amp;D</td>
<td>First Difference in R&amp;D</td>
</tr>
<tr>
<td>Intercept</td>
<td>-0.82</td>
<td>-38.42</td>
</tr>
<tr>
<td></td>
<td>(-9.0)a</td>
<td>(-10.00)a</td>
</tr>
<tr>
<td>CEO Risk Tolerance&lt;sub&gt;(λ&lt;sub&gt;ceov&lt;/sub&gt;)&lt;/sub&gt;</td>
<td>0.70</td>
<td>12.43</td>
</tr>
<tr>
<td></td>
<td>(15.08)a</td>
<td>(6.37)a</td>
</tr>
<tr>
<td>InSales</td>
<td>0.69</td>
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<tr>
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<td>(44.80)a</td>
<td>(7.67)a</td>
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<tr>
<td>AdjROAD&lt;sup&gt;(e)&lt;/sup&gt;</td>
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<td>32.52</td>
</tr>
<tr>
<td></td>
<td>(2.95)a</td>
<td>(2.74)a</td>
</tr>
<tr>
<td>Sales 5-year Growth Rate</td>
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<td>0.34</td>
</tr>
<tr>
<td></td>
<td>(1.64)c</td>
<td>(8.68)a</td>
</tr>
<tr>
<td>Leverage (Debt to Assets)</td>
<td>-1.38</td>
<td>-18.60</td>
</tr>
<tr>
<td></td>
<td>(-12.35)a</td>
<td>(-4.28)a</td>
</tr>
<tr>
<td>Relative Cash Flow Volatility&lt;sup&gt;(f)&lt;/sup&gt;</td>
<td>-0.12</td>
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</tr>
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<td></td>
<td>(-15.95)a</td>
<td>(-1.00)</td>
</tr>
<tr>
<td>Firm Age</td>
<td>-0.004</td>
<td>-0.37</td>
</tr>
<tr>
<td></td>
<td>(-1.53)</td>
<td>(-3.40)a</td>
</tr>
<tr>
<td>( R^2 )</td>
<td>58%</td>
<td>11.70%</td>
</tr>
<tr>
<td>( F ) Statistics</td>
<td>915.83a</td>
<td>52.14a</td>
</tr>
<tr>
<td>Number of Observations&lt;sup&gt;(g)&lt;/sup&gt;</td>
<td>5,404</td>
<td>5,404</td>
</tr>
</tbody>
</table>

Notes:
- \( a = \) significance at \( p < 0.01; b = \) significant at \( p < 0.05; \) and \( c = \) significant at \( p < 0.10. \)
- Describing measurements of all variables is in Exhibit 1.
- All regressions are based on Robust Regression models, which corrects for heteroscedasticity.
- The two-stage least squares method employs the instrumental variables approach in which all exogenous variables are employed to predict the risk preference metric, \( \lambda_{ceov} \) for use in the second stage of the R&D function.
- The number of observations is lower than the full sample because of using first difference and winsorizing outliers 2% at the tails.

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268

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Figure 3

THE RELATIONSHIP BETWEEN PREDICTED R&D (BASED ON FIRM-SPECIFIC VARIABLES) AND PREDICTED CEO RISK PREFERENCE (BASED ON MANAGER-SPECIFIC VARIABLES ONLY)

ONE YEAR AHEAD PREDICTION
FULL SAMPLE

ONE YEAR AHEAD PREDICTION
CHEMICALS AND PHARMACEUTICALS

ONE-YEAR AHEAD PREDICTION
COMPUTER AND SOFTWARE INDUSTRIES

CEO RISK PREFERENCE AND INVESTING IN R&D

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relationship between unexpected R&D and predicted CEO risk tolerance using the regression in (10):

\[ UlnR&D_{T+h} = \delta_{I_{ij},T+h} + \delta_{I_{ij},T+h}Pr(\lambda_{T+h}) + u_p \]  

(10)

D.2 Industry analysis

This analysis was carried out for eleven different industries and several prediction horizons. The estimated coefficients in year 2001 are used for prediction and estimation of the forecast error \( UlnR&D \) for two horizons: for the period 2002–2009 for forward prediction, and the period 1993–2000 for backward prediction.\(^{30}\) The regression in (10) is estimated for each period for each of 11 industries. The amounts of R&D expenditures vary in size by industry and, as a result, Table 5 shows the standardized Beta coefficients for \( \delta_{I_{ij}} \) and \( R^2 \) values.

The Beta coefficients (standardized \( \delta_{I_{ij},T+1} \)) are statistically significant for nine of the 11 industries, the exceptions being the Energy and Components (GICS 1010) and Consumer Durables (GICS 2510) industries. The standardized Beta coefficients of \( \delta_{I_{ij},T+1} \) range between 0.20 and 0.70 for Prediction Period I and between 0.11 and 0.49 for Prediction Period II. The high Beta coefficients are obtained for Life Sciences (GOCS 3520) and Commercial Services and Products (GICS 2020). R&D results for these same two industry groups have the highest \( R^2 \) values. The Electronic Equipment & Semiconductors have relatively large Beta coefficients (0.39 and 0.30) but relatively lower \( R^2 \) values (14% and 9%).

In summary, analysis of forecast errors of \( lnR&D \) and predicted CEO risk preference show statistically significant (at \( p < 0.01 \)) positive relationships between predicted CEO risk metrics and unexpected changes in R&D. Significant relationship exists in nine out of 11 industries, but with varying strength. The positive coefficients provide further evidence consistent with hypothesis 2—the higher the CEO’s risk tolerance, the higher the investment in R&D.

SUMMARY AND CONCLUSION

This study provides a test of two hypotheses: the first posits that relative pay at risk is a valid proxy for CEOs’ risk preferences, and the second asserts that these risk preference measures are positively correlated with R&D expenditures. To test the first hypothesis, I provide an overview of the two commonly used methods for measurement of individuals’ risk aversion (the inverse of risk tolerance). These are offered under the labels of ‘Resource Allocation Method’ and the ‘Lottery Approach’. A consensus of the literature of both methods shows that socio-demographic factors such as age, education, income, wealth, and gender are major determinants of individuals’ attitudes toward risk taking. These variables are adopted in this study to test the first hypothesis.

The data used are for the firms listed on the ExecuComp database and are restricted to business enterprises with any R&D activity as reported in Compustat.

\(^{30}\) Notice that firm/year observations are almost one half of the total sample, because the entire period is split into two prediction periods.
The results show that these variables explain a significant proportion of CEOs’ relative pay-at-risk, which is measured as contingent compensation per a dollar of salary. Relative pay-at-risk is a measure of the propensity to take risk, or risk tolerance, which is the inverse of risk aversion. Therefore, the signs of the coefficients on these variables are opposite to the signs obtained in the literature for the measurement of risk aversion.

The results of this test are consistent with the hypothesis that CEOs’ relative pay-at-risk is a measure of risk tolerance. This finding allowed me to proceed to examine the relationship between the predicted measures of risk tolerance and investment in R&D.

Table 5

INDUSTRY INFORMATION FOR R&D INTENSITY AND PREDICTION OF ULNR&D BASED ON PREDICTED CEO RISK PREFERENCE

<table>
<thead>
<tr>
<th>C1</th>
<th>C2</th>
<th>C3: Results of Estimating</th>
</tr>
</thead>
<tbody>
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<td></td>
<td>Industry (GICS)</td>
<td>(Prediction Horizon I)</td>
</tr>
<tr>
<td></td>
<td>Standardized δ (Beta)</td>
<td>( R^2 )</td>
</tr>
<tr>
<td>Name</td>
<td>Energy</td>
<td>1010</td>
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<tr>
<td></td>
<td>Materials</td>
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<td></td>
<td>Capital Goods</td>
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<td>Commercial Services &amp; Supplies</td>
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<td>Components &amp; Cons. Durables</td>
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<tr>
<td></td>
<td>Personal Products &amp; Health Care</td>
<td>3030</td>
</tr>
<tr>
<td></td>
<td>Pharmaceuticals &amp; Biotech</td>
<td>3510</td>
</tr>
<tr>
<td></td>
<td>Life Sciences</td>
<td>3520</td>
</tr>
<tr>
<td></td>
<td>Software, Tech &amp; Hardware</td>
<td>4510</td>
</tr>
<tr>
<td></td>
<td>Electronic Eq. &amp; Semiconductors</td>
<td>4520</td>
</tr>
<tr>
<td></td>
<td>Telecommunication &amp; Equipment</td>
<td>4530</td>
</tr>
<tr>
<td>Total</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

C1: Global industrial classification index; C2: Industry sector.

C3: \( UlNRI&D \) = \( \delta_{0i,Y+h} + \delta_{1i,Y+h} \Pr(\lambda_{Y+h}) + u_{pr} \).

C4: \( RDIS = R & D/Sales \) ; C5: \( RDIE = R & D/Number of Employee \).

The results show that these variables explain a significant proportion of CEOs’ relative pay-at-risk, which is measured as contingent compensation per a dollar of salary. Relative pay-at-risk is a measure of the propensity to take risk, or risk tolerance, which is the inverse of risk aversion. Therefore, the signs of the coefficients on these variables are opposite to the signs obtained in the literature for the measurement of risk aversion.

The results of this test are consistent with the hypothesis that CEOs’ relative pay-at-risk is a measure of risk tolerance. This finding allowed me to proceed to examine the relationship between the predicted measures of risk tolerance and investment in R&D.
I collected annual R&D expenditures from *Compustat* for the period 1993–2009. Testing the hypothesis that CEOs’ risk tolerance is positively associated with R&D expenditures is made conditional on other firm-specific determinants of R&D. These determinants consist of firm size, profitability, growth, and leverage.

In looking at the nature of R&D in some major industries, it was evident that many R&D projects have periods of gestation longer than a single accounting period. This observation is more evident in the chemical and pharmaceutical industries and resulted in a highly serial correlation of R&D expenditures. For this reason, I use first difference in R&D, both unscaled and scaled, as a dependent variable. Scaling R&D shows R&D intensity per one dollar of sales or per employee.

The main test method is the instrumental variables regression (2SLS) using all exogenous variables as instruments to predict risk tolerance indexes. The results show that the coefficients on predicted risk tolerance are positive and statistically significant at $p < 0$ for each of three R&D difference measures: the unscaled, intensity of R&D differences per dollar of sales, and intensity of R&D differences per employee. The results of the analysis are consistent with hypothesis 2—R&D expenditures are positively (negatively) related to CEOs’ risk tolerance (aversion).

Robustness of these results is ascertained in several ways. First, the analysis is repeated using R&D levels instead of differences. Second, the variables used in the regression model to estimate and predict risk tolerance are reduced to include only CEO-specific variables to estimate the risk tolerance metric that is close to being intrinsic. The association between the predicted measures and R&D expenditures is consistent with the results of the 2SLS.

A final robustness check is a test of the association between predicted CEO risk tolerance metrics and unexpected R&D expenditures. The results continue to show significant positive association for total sample observations and nine of 11 industry groups.

Using relative pay-at-risk an indicator of risk preference is new, and draws empirical support from the evidence reported in this study. Furthermore, the findings in this study should be useful in two respects: (1) considerations related to the design of CEOs’ compensation contracts by providing incentives to neutralize the negative impact of risk aversion on investing in R&D projects; and (2) disentangling the incentives to use R&D expenditure to manage earnings from changes in R&D arising from CEOs’ own aversion to risk taking.

While the empirical results are statistically significant in the predicted directions, these results establish association between CEOs’ risk preference and R&D expenditure. Making inferences about causality requires repeated studies under different experimental controls. Additionally, using ownership in company stock as a measure of CEO’s wealth stands as a limitation that calls for more inclusive measures of wealth in future research. Finally, including the impact of different macroeconomic factors should offer an improvement to this research, because different industries are impacted by changes in macroeconomic facts differently.
REFERENCES


Balasubramanian, N. and J. Lee (2005), *Firm Age and Innovation*, Working Paper, UCLA.


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CEO RISK PREFERENCE AND INVESTING IN R&D

NSF (National Science Foundation) (2004), Science and Engineering Indicators 2004, National Science Board (NSB 04–01), Arlington, VA.

—— (2010), Science and Engineering Indicators 2010, National Science Board (NSB 10–01), Arlington, VA.


**APPENDIX A**

**Measuring Risk Tolerance using Publicly Available Information**

An enterprise compensation policy might be categorized into three types:

i. Pure strategy I: all fixed salary and no contingent compensation

ii. Pure strategy II: performance-contingent compensation only and no fixed salary component

iii. Mixed strategy that consisting of a combination of proportions of Pure strategy I and Pure strategy II

To formulate the relationship that captures the employee (the CEO) risk preference, let

- \( p \) = the proportion of the maximum pay as a fixed salary that the CEO is willing to accept as an unconditional compensation, not contingent on performance
- \( RW \) = the reservation pay (the income that the labour market would pay to a person of this talent). It is also the maximum compensation an employer would pay if all pay is fixed (Pure strategy I).
- \( E(C) \) = the expected incentive pay that the agent expects to earn
- \( E(x) \) = the risk premium the agent (CEO) expects to earn for taking risk by accepting a proportion of compensation to be pay-at-risk

By agreeing to a mixed-strategy contract, the employer anticipates the following relationship:

\[
E(\text{pay}) = p(RW) + E(C) \quad (1)
\]

\[
E(C) = (1 - p)RW + E(x) \quad (2)
\]

\[
p(RW) \leq [p(RW) + E(C)] \geq RW \quad (3)
\]

In this formulation, the parameter \( p \) is a measure of risk aversion; a high risk averse employee will require higher \( p \) as compared to a lower risk-averse employee. However, neither \( p \) nor \( RW \) are observable. While the employer anticipates that, in a mixed strategy, the agent or employee will receive higher income than the reservation wage, the mixed strategy is optimal from the employer’s standpoint, because of (a) transferring the risk of achieving performance targets to the agent, and (b) expecting to pay higher compensation (\( E(C) \)) only as a result of higher performance. In this construction, \( E(C) > (1 - p)RW \). That is, the expected contingent pay is strictly greater than the scarified portion of the reservation wage that could

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31 In 1978, Lee Iacocca, the former CEO of the Chrysler Corporation, set a precedent by having contracted for an annual salary of one dollar with greater compensation expected, based on performance. Since then, Moira Herbst (2007) notes that prominent CEOs have followed suit: Richard Kinder, (Kinder Morgan); Steve Jobs (Apple); Eric Schmidt (Google); James Rogers (Duke Energy); Richard Fairbank (Capital One Financial); Terry Semel (Yahoo); John Mackey (Whole Foods Market); Jerrold Perenchio (Univision Communications); and William Ford, Jr. (Ford Motor).
have been attained for certain. \(E(x)\) is the excess of expected contingent compensation over the sacrificed fixed component, and is the premium for taking risk by sacrificing an assured pay for performance-contingent compensation.

By analogy to the lottery experiment for the measurement of risk aversion, the mixed strategy compensation contract may be construed as a quasi-lottery with the following structure:

\[
(1 - p)RW \approx \text{the price of entering the lottery (the opportunity cost)}
\]

\[
E(C) \approx \text{the prize of winning the lottery}
\]

In realization, actual total compensation \(\hat{y}_j\) consists of an actual salary \(S_j\), which is exactly the amount specified in the contract \((S_j = p_j(RW_j))\) plus actual pay-at-risk \(C_j\). While observed \(S_j\) does not deviate from the contract, actual contingent pay deviates from expectation as follows:

\[
\hat{y}_j = S_j + C_j + \varepsilon_j \quad (4)
\]

where \(S_j\) and \(C_j\) refer to actual salary and actual pay-at-risk (i.e., performance-contingent pay). The error \(\varepsilon_j\) is a random component with an expected value of zero and a standard deviation of \(\sigma\). Therefore, \(C_j\) has a truncated distribution with a lower limit of zero—that is, the maximum income a manager could lose is the sacrificed amount of salary. By analogy to the lottery approach of determining risk preference from (2), we have \(E(C) = (1 - p)RW + E(x)\). Dividing both sides by the cost of the quasi-lottery, we have

\[
\frac{E(C)}{(1 - p)RW} = 1 + \frac{E(x)}{(1 - p)RW}
\]

\[
\frac{E(C)}{(1 - p)RW} - 1 = \frac{E(x)}{(1 - p)RW} = \frac{\text{Risk Premium}}{\text{The Opportunity Cost or sacrificed fixed pay}}
\]

which would be a proxy for the risk tolerance (inverse of risk aversion) of the employee. The more the risk tolerant an employee is, the higher the ratio of risk premium to the sacrificed fixed pay.

Empirically, \((1 - p)RW\) is not observable. For empirical analysis, I invoke the Bayes’ Principle of Indifference\(^{32}\) such that \(p = 0.50\) resulting in \((1 - p)RW = p \cdot (RW) = S\) and (5) will be approximated by

---

representing actual relative pay-at-risk.

**APPENDIX B**

In this Appendix, I report the results of the second-stage regression using the levels of R&D in the log form \((\ln R&D)\) as the dependent variables. This result should be compared with the result for first difference reported in Table 3, Column D.

*Second Stage Regression of \(\ln R&D\) on CEO Risk Metrics and other Determinants of R&D*

<table>
<thead>
<tr>
<th>Dependent variable is (\ln R&amp;D)</th>
<th>Coefficient</th>
<th>t-statistic</th>
<th>Probability of Significance</th>
</tr>
</thead>
<tbody>
<tr>
<td>Intercept</td>
<td>-0.89</td>
<td>-9.79</td>
<td>&lt;0.01</td>
</tr>
<tr>
<td>CEO Risk Tolerance Endogenous Variable</td>
<td>0.687</td>
<td>12.10</td>
<td>&lt;0.01</td>
</tr>
<tr>
<td>(\log \text{Sales})</td>
<td>0.69</td>
<td>38.61</td>
<td>&lt;0.01</td>
</tr>
<tr>
<td>(\text{AdjROA})</td>
<td>0.09</td>
<td>0.40</td>
<td>0.694</td>
</tr>
<tr>
<td>Sales 5-year Growth Rate</td>
<td>-0.003</td>
<td>-2.22</td>
<td>&lt;0.026</td>
</tr>
<tr>
<td>Leverage (Debt to Assets)</td>
<td>-1.26</td>
<td>-11.57</td>
<td>&lt;0.01</td>
</tr>
<tr>
<td>Relative Cash Flow Volatility</td>
<td>-0.12</td>
<td>-14.50</td>
<td>&lt;0.01</td>
</tr>
<tr>
<td>Firm Age</td>
<td>0.006</td>
<td>1.96</td>
<td>≤ 0.05</td>
</tr>
<tr>
<td>(R^2)</td>
<td>43%</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td>(F) statistic</td>
<td>720(^a)</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td>Number of Observations</td>
<td>5,404</td>
<td>—</td>
<td>—</td>
</tr>
</tbody>
</table>

- This is the second stage in the Two-Stage-Least-Squares method. The first stage is the same as in Table 3.
- The dependent variable is \(\ln R&D\)—the log of R&D expenditures
- The model is \(\ln R&D = a_{\text{Intercept}} + a_{1i} \pi_j + a_{2i} \log \text{Sales}_i + a_{3i} \text{AdjROA}_i + a_{4i} \text{Sales Growth Rate}_i + a_{5i} \text{Asset Growth Rate}_i + a_{6i} \text{Leverage}_i + a_{7i} \text{Cash Flow Volatility}_i + a_{8i} \text{Firm Age}_i + \epsilon_{ij}\)
- All regressions are based on Robust Regression models, which corrects for heteroscedasticity.
- Measurements of all variables are described in Exhibit 1.
- The number of observations varies and is lower than the full sample when using first difference and winsorizing outliers by 2% at the tails.