CEO RISK PREFERENCE AND MAKING RISKY INVESTMENTS

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January 12, 2012

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Key words:  
Real Earnings Management; Determinants of R&D; Risk Aversion; Risk Tolerance; Risky Investments

Acknowledgement: I benefitted by comments from the participants at the Hebrew University of Jerusalem, Accounting & Finance Research Conference of workshops at National Taiwan University and at the University of Illinois, Kuwait University, and Southern Illinois University, especially those provided by Salvadore Carmona, Po-chang Chen, Michael Donoheo, Adel Ibrahim, and Jeff Wang. I also wish to thank Po-chang Chen for his research assistance in preparing the data set.
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Abstract

This study tests the significance of association between CEO risk tolerance and investment in risky projects. CEO risk tolerance metrics are developed using (a) the structure of compensation contracts, and (b) the socio-demographic factors that have been documented in the literature as determinants of risk aversion. Risky projects are measured by R&D expenditures, intensity and growth. The empirical tests are carried out for in-sample, out-of-sample predictions, growth rates, and for different industries. The findings show significant positive associations between various R&D measures and CEO risk tolerance whether using the developed risk metrics or the determinants of risk aversion, but with varying sensitivities across industries.

The extant literature on organization theory and behavior suggests that the strategies and decisions taken 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; Finkelstein and Hambrick, 1996; Hambrick, 2007). This assertion is highlighted in a recent study by Boivie et al. (2011) stating that “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). One of the major policies expected of a CEO is the level and extent of investing in research and development risky projects of research and development (R&D). This aspect of the CEO’s task is critically significant to the organization for several reasons.

First, agency theory assumes that CEOs (the agents) are risk averse because of their being contractually locked in specific job contracts and are therefore unable to diversify their human capital. Shareholders, the principals, on the other hand, could be considered risk neutral in their role as investors because they could diversify their exposure to idiosyncratic (enterprise-specific) risk. This stipulated difference in the risk-taking
disposition between the owners and agents gives rise to different investment preferences: owners prefer that the firm invests in all positive net present value (NPV) projects, whereas managers ration their taking on risky projects in a manner consistent with their risk appetite. Thus, in the absence of appropriately designed incentives, managerial actions could entail sacrificing some investments that are otherwise profitable. This behavior may be manifested by requiring higher hurdle rates for high risk projects (Stein, 1996), or by redesigning and redirecting R&D strategy as is currently being observed at large pharmaceutical companies in an effort to improve (near term) profits. It is also of import to note that the implied myopia is not mitigated by incentive contracts as they are currently designed because the instruments used have conflicting incentive impact. For example, increasing enterprise risk taking leads to increase in the value of executive stock options and to decrease in the values of owned stocks and restricted stocks granted as incentive compensation (Ryan and Wiggins, III, 2002; Ross, 2004; Parrino, Poteshman, and Weisbach, 2005).

Second, while R&D is a discretionary activity (NSF, 2004, p. 4-14), it is highly costly. The latest comprehensive statistics published by the National Science Foundation show that the business sector has invested approximately 270 billion dollars in R&D in 2007.

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1 In a recent article in Wall Street Journal, Stovall (February 3, 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 CEO of Pfizer has taken a similar action by closing R&D facilities in Sandwich, United Kingdom, and the decision of AstraZeneca 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 endeavors carrying high risk.

(NSF, 2010, p. 4-19), reflecting a significant increase from the $197 billion spent in 2002 (NSF, 2004, p. 4-12). The chemical industry (including pharmaceuticals) is the business sector with largest R&D in the NSF industry classification. The 2007 R&D expenditures in this industry alone were about $56 billion, a level that was approached only by the computer and software industries. At the micro level, the Congressional Budget Office reported on the analysis that puts “the average cost of developing an innovative new drug at more than $800 million, including expenditures on failed projects and the value of forgone alternative investments” (CBO 2006, p. 19).²

Third, the financial cost of R & D failure is very high to the business firm and to the human capital of CEOs. Failure could happen at any stage in the process, even before testing commercial feasibility. For example, in October 2010 Novartis AG decided to abandon the development of an antifungal drug that was to be named Mycograb ending a four-year R&D effort that cost $595 million.³

² According to the US Congressional Budget Office CBO), “A recent, widely circulated estimate put the average cost of developing an innovative new drug at more than $800 million, including expenditures on failed projects and the value of forgone alternative investments.” CBO (2006, p. 19). Other Sources for R&D spending are: (a) The ComputerWeekly.com at http://www.computerweekly.com/Articles/2009/10/08/238053/Microsoft-steps-up-RampD-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 percent of our 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 billion): $5.6 (Pfizer); $4.8 (Johnson & Johnson); $3.9 (Merck); $3.1 (Eli Lilly); and $2.6 (Bristol-Myers Squibb). Source URL: http://blogs.wsj.com/health/2009/12/22/rd-spending-numbers-for-pfizer-ji-merck-lilly-and-bristol/  

Costly failure could also happen after patents are obtained and the products reach the market. The class action suit against Merck in connection with the drug VIOXX is estimated to have cost the company more than five billion dollars (not including the spillover negative impact on reputation and demand for other drugs). In this case, the CEO, Raymond V. Gilmartin, was singled out for the company's R&D failure and was forced to resign in May 2005 just as Congress discussing the case. Furthermore, product liability cases extend far beyond the drug industry—it covers the automobile industry including the well documented recalls, elevators safety, appliances and any product that could cause harm.\textsuperscript{4}

There is always uncertainty about success in completing all necessary stages that an R&D project requires as well as about the realizability of expected payoff or outcome while maintaining all property rights. More specifically, Huchzermeier and Loch (2001) identify five types of R&D uncertainty: “market payoffs, project budgets, product performance, market requirements, and project schedules” (p. 1). As a mix of tangible and intangible elements, R&D projects are exposed to significantly higher risk than the risk exposure of investing in tangible assets. For example, only eight to ten percent of pharmaceutical R&D projects reach the commercial development stage (CBO, P. 31). Even within the portfolio of R&D, different projects face different degrees of uncertainty, a fact that gave way to the use of real option pricing theory in the valuation of different aspects of R&D projects—e.g.,

\textsuperscript{4} 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.\textsuperscript{7} These are examples that points to the possible increase in litigation risk because of R&D, quality and functioning of components, or design failure, all of which could be compounded by the management’s neglect to inform and warn consumers.
continuation, abandonment, and flexibility (e.g., Nichols, 1994; Huchzermeier and Loch, 2001; Hartman and Hassan, 2006).

These factors are elements of complex processes that are fraught with uncertainty and the question arises as to whether the CEOs unintentionally allow their risk preferences to influence plans and decisions on R&D. The above noted cases of the CEOs at GlaxoSmithKlein, Pfizer, and Novartis who abandoned risky projects are anecdotal examples of CEOs’ direct involvement by making choices to continue or abandon vital investment projects based on the project risk exposure. These examples became known to the public because the public health externalities, but the general case of linking CEO risk preference and choice of risky investment in different R&D projects remains to be established more methodically.

Three studies come close to explicitly examining managerial risk preference in connection with R&D efforts. These are the study by Barker, III and Mueller (2002) and the two studies by Griffith and Webster (2004; 2009). Barker, III and Mueller searched for association between R&D and personal characteristics of CEOs such as age and stock ownership in the firm, but shied away from discussing risk. In the latter two studies, Griffith and Webster collected data on CEOs’ management styles (using Likert scale) and developed five types: bold, flexible, systematic, aggressive, and communication style.5 In the 2004 study, they 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 the 2009 study, which additionally provides extensive overview of the literature, they

5 Of the five styles, they define “bold” as reflecting managers’ attitudes towards risk taking.

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find that "the less aggressive firms are towards their competitors but the more they strive to become product leaders, the more R&D activity, *ceteris paribus* (2009, p.17 and Table 7, p. 19). However, the measure of CEO boldness (willingness to take risk) is not statistically significant. These studies have two implications: (i) management style is used as a proxy for risk tolerance because of the absence of an acceptable empirical measure of CEO risk preference, and (ii) the absence of defensible empirical evidence that links the CEO risk preference and investment in R&D.

Accordingly, the first part of the present study is the development of a method by which publicly available information could be used to measure CEO’s tolerance (or aversion) for taking risk. The data employed for this purpose consist of socio-demographic attributes and incentive pay. In particular, a model is developed based on two assumptions: (i) the labor market for CEOs is characterized by self-sorting that matches available jobs and skills (Rosen, 1986; Lazear, 1998), and (ii) as developed by the risk measurement model below, accepting compensation contracts with performance contingent component is tantamount to buying a lottery ticket.

The model developed in this study to measure risk preference has benefited by the related experimental literature (e.g., Barsky et al, 1997; Loehman, 2001; Holt and Laurey, 2002) and other studies about the demographic factors associated with risk aversion (Friend and Blume, 1975; Cohn et al., 1975; Pålsson, 1996; Donkers et al, 2001; Guiso and Paiella, 2002; Bajtelsmit and Bernasek, 2001). These factors are CEO’s age, education, level of expected income, wealth and gender.

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6 The two studies use different statistical methods for analysis.
7 There is some evidence that ethnicity could be a factor; Colman (2003) find Hispanic heads of households to be more risk averse than others and hold smaller proportions of their portfolios in risky assets.

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After obtaining measures for CEO risk tolerance, the empirical analysis is carried out to test the hypotheses of significant association between these metrics and R&D expenditures, intensity and growth. These tests are conditioned on other enterprise-specific determinants of R&D—firm size, profitability and growth rates, leverage, cash flow volatility, and firm age. A sample of 7,083 firm/year observations is used for empirical analysis. It consists of all firms on the Execucomp database that have spent between 0.0005 and 0.60 of sales on R&D, and that also satisfy other data requirements for the period 1993 to 2009. Because R&D projects often take longer than one year, the research method must take into consideration the fact that R&D data in any given year are not independent from the preceding years. The problems that emanate from the inherent cost stickiness from one year to the next depend on the duration of the research project which varies by the domain of research and the type of industry. Whether the duration is two years (as in the development of some software projects) or twelve years (as the average in pharmaceutical industry) the cost stickiness makes pooling of data problematic in some specification of parametric statistical analysis.\(^8\) As a result, the regression analysis is carried out on a year by year basis, except when the data are differenced or when they consist of prediction errors because neither type is serially correlated. Testing these hypotheses is based on (a) in-sample estimation; (b) out-of-sample (hold-out) predictions; (c) Chow F-test of weak causality; and (d) an assessment of the variation among different industries. The results are validated by a number of robustness checks.

\(^8\) Pooling the data actually provides much higher \(R^2\) and more significance tests as compared to the year-by-year analysis, but some of that is spurious because of the overlapping generations of R&D projects.

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The evidence shows that investment in R&D is, on the margin, 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, three observations summarize the findings:

1. Both the level and intensity of investment in R&D are significantly positively associated with the composite estimates of CEOs’ tolerance for taking risk (negatively associated with risk aversion).

2. CEO’s age, tenure (firm-specific knowledge which is used as a proxy for education), income and equity ownership in the firm (wealth) are significant determinants of CEO’s risk tolerance.

3. R&D intensity (with respect to sales) declines significantly in CEOs’ ages.

The remainder of this paper consists of the following sections. Section one presents the research problem and statement of hypotheses. In the second section, two commonly known approaches to the development of empirical measures of risk aversion are summarized, which are then followed by the method developed in this study to measure CEO risk preference. The third segment provides the linear models relating R&D and CEO risk tolerance. Data description and empirical method of estimation and testing hypotheses are in section four. Robustness checks are provided in section five. A final section consists of summary and concluding remarks.

**Development of Hypotheses**

The extant literature report the Wallach and Kogan study (1961) as one of the first to analyze the relationship between age and risk disposition. They find that risk taking
declines with age—i.e., risk aversion increases with age. In a 1971 study, Vroom and Pahl report the results of a survey of 1,484 managers showing a significant negative relationship between age and risk taking. Almost three decades later and without specific measure of risk preference, 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 experience in marketing and/or engineering/R&D” (p. 82). More recently, Coles (2006) used vega (executive stock option price convexity, or the sensitivity of option values to equity risk) as a measure of CEO risk preference and find a positive association between vega and three indicators of risk taking: increased leverage, increased R&D spending, or reduced capital expenditures. Nam, Ottoo and Thornton (2003) used the ratio of the volatility of CEO options to the volatility of equity as a measure of CEO risk preference and find similar relationships between the volatility ratio and increase in both the investment in R&D and leverage.

In their 2009 study, Griffith and Webster review two strands of research on R&D from the economics and the management perspectives. Their study, however, does not find a significant relationship between R&D and CEOs’ propensities to take risk (measured by the management style which they classified as “bold”). Furthermore, the Griffith and Webster studies of 2004 and 2009 reach different findings with respect to the managerial style classified as aggressive or bold.

Analytical studies have also examined the association between risk aversion and investment in R&D. It is argued that risk aversion distorts investing in R&D by passing on projects with expected positive NPV either because of requiring higher hurdle rates (Stein, 1996) or because of the conflicting incentives for top executives who own equity shares in
the firms they manage and are also granted stock options. For example, Ryan and Wiggins, III (2002) find that R&D expenditures are positively associated with executive stock options, but are negatively associated with restricted stock. Lambert et al. (1991) also examine the conflicting incentive consequences of the different incentive plans and suggest that managerial behavior may be governed by the combination of different incentive instruments that should be viewed as a portfolio. Because of the contingencies involved, Lambert et al. (1991) and Carpenter (2002) note 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 behavior and pass on risky projects having positive NPV. In particular, he states that the impact of compensation

“schedule on an agent’s attitudes toward risk depends not only on the convexity of the fee schedule, but also on how it translates the domain of the utility function into more or less risk-averse portions and to the extent to which it magnifies (or contracts) any gamble at the margin. These latter two effects are as important as convexity and they can quite commonly undo the intuitive impact of convex or concave fee schedules” (2004, p. 224).

In similar vein, Parrino et al. (2005) 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” (p. 52).
Finally, Whalley (2008) develops a real options model showing that introducing risk aversion reduces the level of investment in R&D even when the expected NPV is still positive (p. 7).

These studies raise four issues: (i) there is no direct evidence documenting the relationship between CEOs personal preference for risk taking and investment in risky projects for the firms they manage; (ii) in a portfolio of instruments granted for CEOs’ compensation contracts, the characteristics and behavior of any single instrument is not an adequate indicator of the CEOs’ risk appetites because the mix of instruments and their incentive effects differ; (iii) a measure of risk aversion other than the convexity (vega) of CEO options must be developed in order to test the relationship between CEOs risk preference and investment in risky projects such as R&D; and (iv) the structures of incentive contracts are not designed to take into effect the CEO’s risk preference.

This study addresses the first two issues and leaves the third issue as another research project. However, validation of the risk preference metric developed in this study rests on the significance of its association with R&D as the risky ventures that constantly confront CEOs. Therefore, the two hypotheses being tested are as follows:

**Hypothesis 1:** R&D expenditures increase with the increase in the CEO’s propensity to take risk.

**Hypothesis 2:** R&D intensity (with respect to sales) increases with the increase in the CEO’s propensity to take risk.
MEASUREMENT OF RISK TOLERANCE (AVERSION)

Risk-taking appetite emanates from several factors that differ by the domain of interest. For behavioral scientists, risk aversion (inverse of risk tolerance) is viewed as a function of personality traits such as impulsivity (Zuckerman and Kuhlman, 2000), cognitive ability (Dohmen et al., 2007), genetics (Zyphur et al., 2009), or risky behavior in general (Barsky et al., 1997). As an element of rational behavior, economists look at the behavior of the individual’s utility function over wealth or income to identify that individual’s risk preference. Alternatively, risk preference may be gauged from the size of the risk premium that one requires to invest in risky assets (the investment tradition of Markowitz, 1952; Arrow, 1971) or one has to pay to transfer risk to others (the insurance tradition of Pratt, 1964). Both traditions arrive at the same conclusion that a risk-averse person has a concave utility function showing increasing aversion to risk at a decreasing rate as wealth (or income) increases. Different individuals might have different utility functions that could be reflected in different degrees of concavity. Risk tolerance is simply the inverse of the risk aversion parameter.

Two Approaches in the Empirical Literature

The empirical literature offers two main streams to measure risk aversion: the asset allocation method and the lottery payoff/cost ratio.

A. The Asset Allocation Method: Under this approach, it is assumed that individuals allocate their investment portfolio between safe and risky assets in a manner

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9 One of the most commonly referenced functions is the Arrow-Pratt decreasing absolute risk aversion: $-\frac{\partial^2 u}{\partial u^2}$.

See, for example, Hirshleifer and Riley (1992).

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consistent with the individual’s own risk. It was not until the mid-1970s when empirical studies in USA aimed at validating the asset allocation hypothesis (Friend and Blume, 1975; Cohn et al., 1975; Riley and Chow, 1992; Bajtelsmit and Bernasek, 2001). Similar empirical studies took place in other countries. Morin and Suarez (1983) in Canada; Pälsson (1996) in Sweden; Donkers and van Soëst (1999) and Hartog, Ferreri-Carbonell and Jonker (2000; 2002) in The Netherlands; and Guiso and Paiella (2002) in Italy. These studies took the allocation of households’ investment portfolios between risky and safe assets an indicators of risk preferences and conducted systematic evaluation of the factors that explain this behavior. The collective findings of these studies are that risk taking appetite decreases in age, increases in income, wealth and education and that women are more risk averse than men.

The relationship between age and risk taking remains controversial, however. While the above noted studies show that risk aversion increases with age (i.e., risk tolerance decreases with age), recent studies by Grable (2000), Gollier and Zeckhauzer (2002) and Hallahan et al. (2004) show the opposite relationship.

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

11 For gender differences, see also Riley and Chow (1992); Borghans et al. (2009).

12 Some empirical studies use the convexity (vega) of CEO stock options (Coles et al., 2006) or other volatility measures (e.g., Nam et al., 2002) as indicators of CEOs’ attitudes toward risk taking. High values of vega (or volatility) indicate high risk-taking appetite (low risk aversion), and vice versa. While informative, executive stock options vega is an incomplete description of risk preference for two reasons: (a) stock options are not the only incentive mechanism in a portfolio of several incentive schemes in a compensation contract (Lambert, et al. 1991); and (b) stock options and ownership in the firm (as well as restricted stocks) induce different and opposing incentive (Ross, 2004; Parrino et al., 2005).
B. The Lottery Payoff/cost Ratio: An alternative approach to asset allocation is measurement of risk preference by the relationship of the expected lottery payoff to the price or cost of the lottery ticket. Work in this strand of the literature varies from the setting of controlled experiments (Loehman, 1998; Holt and Laurey, 2002) to conducting experiments embedded in large-scale questionnaires (Barsky et al, 2001; Donkers et al, 2001; Dohmann et al., 2007). Of particular interest is the study by Donkers, Melenberg and van Söest (2001) that introduces two lottery settings and analyzes responses from 3,458 Dutch households. In the first setting, the respondent chooses between two lotteries with different outcomes reflecting various degrees of risk (varying between 12% and 56%). In the second setting, each respondent was 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 lottery ticket. In this setting, the results show that the average probability participants required for winning varied between 34% and 62%. Donkers et al. then proceeded to examine the extent to which individual-specific socio-demographic characteristics explain the variation in this behavior. The results are consistent with the findings of the other empirical studies using the asset allocation method.

A Model for the Development of a Risk Tolerance Metric

Executive compensation contracts may be grouped into two types: (i) Type I is what might be called "pure-pay strategy" in which compensation consists of either a straight salary only, or performance-contingent pay only. (ii) Type II is a "mixed-pay strategy" in
which the executive opts\textsuperscript{13} and contracts for a proportion of the compensation as assured pay (salary) and another as being contingent on some pre-specified performance targets. The amounts of contingent pay are unknown \textit{a priori}. Performance targets are typically some measures of success indicators that are selected to reflect the executive’s effort as well as the ability to manage exogenous factors to achieve the target goals. If the collective impact of these other factors is considered equivalent to “chance” or states of nature, a CEO’s acceptance of a mixed-strategy compensation contract would be analogous to purchasing a lottery ticket. But unlike a true lottery, the payoff of this \textit{pseudo} lottery is not solely contingent on chance because of the impact of CEO’s effort and the nature of the decisions made.

To show, and use the similarity between a mixed-strategy compensation contract and the setting of a lottery, assume that a CEO seeking employment believes that the reservation wage of level $Y$ is consistent with her his/her skills and ability. But no employer would be willing to guarantee all of $Y$ as a fixed salary. Instead, the employer would offer one of two packages:

\begin{itemize}
\item[a)] Only a straight salary of level $S$, where $S < Y$.\textsuperscript{14}
\end{itemize}

\textsuperscript{13} I assume that contracting in labor markets is a voluntary decision and that labor markets are characterized by self sorting (Rosen, 1986; Lazear, 1998). Managers’ choice of employment contracts of mixed strategy is in effect their acceptance of having pay-at-risk contract, which is not different in concept from a lottery as will be detailed below.

\textsuperscript{14} Practically speaking, the pure-strategy of contingent compensation only is rare although it exists. In 1978, Lee Iacoca, the former CEO of the Chrysler Corporation, set a precedent by having contracted for an annual salary of one dollar and expected to capture a higher level of compensation based on performance. Since then, Moira Herbst (2007) notes that prominent CEOs have followed suite: 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).
b) A proportion of the straight salary, $pS$, plus an expected incentive pay, $E(C)$, which is contingent on achieving the success indicators stipulated in the contract, where $p$ is the percentage ($0 < p < 1$) of the maximum amount that could guaranteed as a straight salary. In this case, three things take place:

i. The *expected* total compensation is greater than the maximum amount that could be guaranteed as a straight salary; that is, $pS + E(C) > S$.

ii. The expected incentive pay $E(C)$ is contingent on performance and on achieving specific targets; the amount is uncertain and $E(C)$ could be as low as zero. Therefore, $E(C)$ is essentially compensation or pay-at-risk. To accept this pay at risk award, the CEO sacrifices a proportion of what could have been a salary under pure-pay strategy. This proportion is $1 - pS$, which is an opportunity cost the CEO is willing to incur in order to receive higher compensation in terms of the expectation of $E(C)$.

As an analogy with the lottery setting, $E(C)$ is the expected lottery payoff and $1 - pS$ is the cost of the lottery ticket. The *pseudo lottery expected* payoff, $E(C)$, should be higher than the sacrificed price by a risk premium the CEO is expecting to compensate him/her for the risk taken. The expected pay at risk, therefore, is set such that $E(C) = (1 - pS) + E(x)$, where $1 - pS$ is the sacrificed salary (cost of the lottery) and $E(x)$ is the expected risk premium.

Using this structure, the model developed in the Appendix utilizes CEO attributes (age, tenure (a substitute for education), earned income, wealth and gender) to arrive at CEO risk preference measured as the ratio of $\pi = \frac{E(C)}{(1 - p)S}$ captures the CEO’s risk preference and compensation for risk taking. This measure could be viewed in one of three ways:
(i) It is the relative pay-at-risk-premium that the CEO actually receives per dollar of salary and, as a standardized measure, it is comparable across time and people.

(ii) An approximation of the ratio of the pseudo lottery's payoff to the price of the lottery.

(iii) The ratio of (expected) return on risky assets to (expected) return on safe assets under the assumption that both of the amounts of pay-at-risk and actual salary are two draws from the distribution of expected return on two different components of human capital.

Under any of these three scenarios, \( \pi \) should reflect the variation in two components: (a) CEOs' own relative risk preferences, and (b) what their employer firms pay them for performance. disentangle these two components. The risk preference component could be estimated by employing the same socio-demographic variables discussed above in the literature on asset-allocation and the lottery-payoff tests. These determinants are the manager's age (\( MA \)); education which is replaced by firm-specific knowledge as connoted by tenure on the job (\( T \));\(^{15}\) CEO earned income (\( I \)) as measured by the natural log of all realized income for the period;\(^{16}\) CEO wealth (\( W \)) which is proxied by the natural log of the market value of CEO equity holding; and gender (\( G \)).\(^{17}\)

The resulting linear model is as follows:

\[
\pi = \alpha_0 + \alpha_1 MA + \alpha_2 T + \alpha_3 I + \alpha_4 W + \alpha_5 G + \theta + \epsilon
\]

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\(^{15}\) The factor “education” is found to be important for studies with the general public. It is debatable, however, whether the formal schooling or the “industry” knowledge would be more relevant for CEOs. For example, CEOs like Bill Gates (Microsoft) and Steve Jobs (Apple) have formal education only to the high-school level.

\(^{16}\) The explanatory variable income includes both realized which includes salary, bonus, realized gain on exercising stock options and restricted stocks plus unrealized income which includes the change in values of held and granted options and stock appreciation rights as well as granted restricted stocks.

\(^{17}\) The variable for Gender is used for consistency with the literature, but it is problematic when the subject pool consists of CEOs because of the lack of variability; women are only slightly over two percent of the sample.

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\textit{predicted sign} \quad - \quad + \quad + \quad + \quad ?

\[ = \alpha_{0j} + \sum_{k=1}^{5} \alpha_{k} MSV_{k} + \theta + \varepsilon_{\pi} \quad (6a) \]

\[ E(\pi) = \lambda = \lambda_{M} + \theta \quad (6b) \]

where $MSV_{k}$ are manager-specific variables (age, tenure, income, wealth and gender) resulting in an expected risk preference metric $\lambda_{M}$, which is independent of other firm-specific exogenous variables ($FSV$) such as firm size, profitability and growth that are summarized (for now) by the variable $\theta_{ij}$; $\lambda$ is the combined impact of $MSV$ and $FSV$ that shape a CEO’s risk reference; and $\varepsilon_{\pi}$ is a residual term distributed as $[0; \sigma_{\varepsilon_{\pi}}^{2}]$. In this construction, $\lambda$ is endogenous and is employed as such in the models estimating R&D functions discussed next.

\textbf{Relating Risk Tolerance and R&D Spending}

Estimating the impact of CEO risk preference on R&D spending should be conditioned on other firm-specific determinants ($FSV$) that have been studied and documented in the literature. These factors are:

1. \textit{Firm size ($Z$):} The Schumpeterian concept of larger firms are more able to innovate is the cornerstone for the relationship between firm size and innovation has been further documented to show that larger firms have greater commitment to R&D (Schumpeter, 1942; Cohen and Klepper, 1996; Griffith and Webster, 2004; Lee and Sung, 2005). Guay (1999) also finds a significant association between firm size and firm risk. Sales revenue is an operational measure of firm size typically used as a basis for identifying commitment to, and
intensity of R&D investment.\textsuperscript{18} Total assets (a measure of scale) and the number of employees (a measure of complexity as in Griffith and Webster, 2004) are alternative measures and are employed for robustness checks. The National Science Foundation Report (2010) recognize these three bases (sales, employees and assets) as reference indicators for gauging the business firm's commitment to innovation (NSF, 2010, Ch. 4).

2. \textit{Profitability (ROA):} More profitable firms invest more in R&D, and vice versa. However, the method of accounting for R&D could lead to perverse empirical findings. In particular, current accounting standards\textsuperscript{19} require expensing R&D as incurred, which results in reporting lower profits as R&D expenditures increase. Franzen, et al. (2007) argue that the accounting for R&D distorts the reported income and could in some instances lead to predicting insolvency for solvent firms. In addition, concern for reporting smooth earnings might induce managers to use R&D to manage reported profits (Baber, Fairfield and Haggard, 1991; Perry and Grinaker, 1994; Bushee, 1998; Rychodhory, 2006 ). The impact of these two issues could also be the reason that led some authors to make the unreasonable conclusion that “R&D leads to lower return on sales” (Wöhrl, Hüsig, and Dowling, 2009).

To examine the extent to which the negative association between R&D expenditures and profitability is an artifact of the accounting treatment, \textit{ROA} is

\textsuperscript{18} See, for example, National Science Foundation (2010) \textit{ibid}.

\textsuperscript{19} Generally Accepted Accounting Principles (GAAP) in the USA and International Financial Reporting Standards (IFRS) internationally requiring charging Research expenditures as periodic cost to the profit and loss statement. However, IFRS allows capitalization of Development costs, which U. S. GAAP requires expensing them.

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recalculated by assuming capitalization and amortization of R&D using the following approximation:

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

with \(txr\) being the income tax rate and \(Am\) is the annual rate of amortization. Not knowing the duration of the R&D asset if it were to be capitalized, different rates are assumed for sensitivity analysis. The empirical work is repeated with \(\text{adjROA}\) instead of \(\text{ROA}\). Changing sign or significance would be an indication of the impact of the distortion emanating from expensing R&D under accounting standards.

3. **Growth (sg):** R&D spawns growth with a lag depending on the nature of the project and type of industry. However, a summary of the empirical evidence reveals mixed findings with respect to the relationship between growth and spending on R&D in Italian firms (Del Monte and Papagni, 2003). More recently, Pindado et al. (2010) find firm growth to be a significant determinant of the impact of R&D on market valuation.

4. **Leverage (lev):** The uncertainty inherent in R&D projects increases the degree of information asymmetry between managers and investors such that results the equity market could demand higher cost of capital because of what Leland and Pyle (1977) calls the lemons’ premium. As a consequence, the higher cost of equity capital is assumed to drive firms to debt markets, especially since creditors could demand and often receive more information than equity market participants. However, the implied positive association between leverage and
R&D intensity is not observed empirically; Cummings and McIntosh (2000) find a negative association between leverage and R&D expenditures.\(^\text{20}\)

5. *Stability of Cash Flow (cfrisk)*: 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. Since R&D projects often last for durations of multiple years and their costs are sticky, making commitments to projects using internal sources hinges upon anticipating stable cash-generating ability. Since the difference between operating cash flow and income from continuing operations is the non-cash accruals, the relative stability or volatility of operating cash flows could be gauged by the ratio of the standard deviation of operating cash flow to the standard deviation of earnings from continuing operations, \(cfrisk\). Because accounting accruals smooth the variation in reported earnings, \(cfrisk\), is expected to be greater than unity—the higher the ratio, the more volatile are operating cash flows relative to earnings and the less reliance on internal funds to finance R&D. Therefore, like the variable for leverage, a negative correlation between \(cfrisk\) and R&D is expected. Periods of twelve rolling quarters each are used to estimate the standard deviation of each variable.

6. *Firm Age (FA)*: Firms appear to go through stages of research cycles and younger firms spend higher proportion of sales on R&D (Cumming and McIntosh, 2000). In addition, Balasubramanian and Lee (2005) report that “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). Wöhrle, R.,


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S. Hüsig, and M. Dowling (2009) report similar results for firms listed on the German Neuer Markt. 21

7. **Industry**: The National Science Foundation (NSF, 2010) reports that four industry groups undertake about 80 percent of the R&D activity in the USA. These groups are: chemicals (including pharmaceuticals); computer hardware and electronic products; software and related services; aerospace and defense manufacturing; and automotive industries. Industry analysis in this study will adopt the four-digit NAIC, the classification replacing SIC22.

**The Linear Model for R&D Levels**

The impact of CEO risk tolerance on the level of investment in R&D is first examined in this study using two linear models estimated by 2SLS, with the estimated CEO risk preference parameter being endogenously determined from the first stage based on model (6) specified above. The second model employs the estimated risk tolerance parameter \( \lambda_{ij} \) obtained from the first stage as an endogenous variable, while the firm-specific variables (FSV) presented above are exogenous determinants of R&D expenditures. Thus, the R&D model takes the following form

\[
\ln R&D_i = \beta_0 + \beta_1 \lambda_{ij} + \beta_2 \ln Z_i + \beta_3 \text{ROA}_i + \beta_4 \text{lev}_i + \beta_5 \text{cfrisk}_i + \beta_6 \text{FA}_i + u_{R&D,j} \tag{7}
\]

Predicted signs: \( + \quad + \quad + \quad - \quad - \quad - \quad - \)

where \( \lambda_{ij} \) is an instrumented prediction from Model (6) as

\[
\lambda_{ij} = E[\alpha_0 + \sum_{k=1}^5 \alpha_{jk} \text{MSV}_{kj} + \sum_{n=6}^{11} \alpha_{jn} \text{FSV}_{nj}]
\]

21 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 the Compustat. Admittedly this measure does not provide accurate information at the upper end, but does so for younger companies.

Instruments = \{ MA_{ij}, T_{ij}, I_{ij}, W_{ij}, G_{ij}, \ln Z_i, ROA_i, sg_i, lev_i, cfrisk_i, FA_i \}

These variables are defined as follows:

\[ \lambda_{ij} \] = the estimated CEO risk tolerance metric, which is low for highly risk averse person and high for individuals with high risk tolerance. This variable is the predicted value from the first stage estimation of applying model (6) using all exogenous variables.

\[ MSV = \text{manager-specific variables (obtained and developed from Execucomp)}: \]

\[ MA_{j} \] = manager’s age.

\[ T_{j} \] = tenure on the job as a CEO.

\[ I_{j} \] = natural log 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).

\[ W_{j} \] = natural log of the market value of CEO equity holding as a proxy for wealth.

\[ G_{j} \] = gender (0 for male, 1 for female).

\[ FSV = \text{firm-specific variables: (Obtained from Compustat)} \]

\[ \ln Z_i \] = firm size measured by natural log of sales (and alternatively, the natural log of total assets or natural log of the number of employees).

\[ ROA \] = return on assets measured as reported net income to total assets, as noted above, an estimated alternative measure is \( \text{adjROA} \), which is corrected for the accounting Impact of accruing R&D as an expense).

\[ \text{adjROA} \]

\[ \text{adjROA} \] = return on assets measured as reported net income to total assets, as noted above, an estimated alternative measure is \( \text{adjROA} \), which is corrected for the accounting Impact of accruing R&D as an expense).

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\[ ^{23} \text{The predicted sign for the coefficient on } ROA \text{ is negative because under the prevailing generally accepted accounting principles (GAAP) reported income is measured after deducting R&D expenditures for the year. Therefore, higher R&D levels would lead to lowering reported earnings, and vice versa. The impact of accounting distortion on income could be reduced if R&D were to be capitalized and amortized over the productive lives of the related projects. The alternative is } \text{adjROA} \text{ and will be approximated in the empirical analysis below.} \]
$sg_i = \text{sales growth rate over the preceding five years.}$

$lev_i = \text{leverage measured by assets net of common equity divided by total assets.}$

$cfrisk_i = \text{cash flow volatility relative to income volatility as measured by the ratio of the standard deviation of operating cash flow to the standard deviation of income over the preceding twelve (rolling) quarters.}$

$FA_i = \text{firm age in years}.$

The indices $i$ and $j$ are for the firm and the CEO, respectively; and the error term $u_{R&D,i}$ has an expected values of zero and variance $\sigma^2_{R&D,i}$.

The Linear Model for R&D Intensity:

Another measure of a firm’s commitment to invest in research and development is R&D intensity which is measured differently for different purposes (NSF, 2004; 2010). The indicators commonly used in microstructure analysis are intensity measures with respect to sales, $RDIS$, or in relationship to the employed labor force (R&D dollars spent per employee), $RDIE$. Therefore, unlike model (7), firm size is not an exogenous variable for explaining the variation in either measure of R&D intensity—$RDIS$ or $RDIE$. For this reason, the linear model for R&D intensity (will be referred to as model 8) is similar to model (7), except for three issues: (a) the dependent variable is a ratio, either $RDIS$ or $RDIE$; (b) firm size is not an exogenous variable but is a scalar of the dependent variable’ and (c) the

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24 Proxied by the number of years listed on Compustat.

25 The National Science Foundation states that R&D intensity could be measured as “R&D expenditures relative to size, production, financial, or other characteristic for a given R&D-performing unit (e.g., country, sector, company). Examples include R&D to GDP ratio, company-funded R&D to net sales ratio, and R&D per employee.” (National Science Foundation, 2010, p. 4-62. The ratio of R&D to GDP is used in comparing the commitment of different nations or regions (such as EU) to investing in innovation. The other measures of intensity are more useful for micro level analysis.)
intensity model (8) is not in a log linear format as is the case with model (7). As a dependent variable, the indices $RDIS$ and $RDIE$ are employed as substitutes.

**METHOD**

**Data**

The data used in this study consist of the firms included on *ExecuComp* with the data being supplemented from *Compustat* for the period 1993 – 2009 that satisfy certain data selection constraints. The first relates to target firms; to test hypotheses about R&D, the business firms of interest should be in industries having some degree of R&D expenditures. This restriction resulted in excluding firms in retailing, utilities and financial institutions as well as firms for which data on R&D is missing. Second, firms with negative owners’ equity$^{26}$ and the very small firms (sales below $30$ million) are also excluded. Finally, only firm/year observations without missing data are included in the analysis resulting in different numbers of sample observations in different years. The final sample consists of $7,083$ firm/year observations. Descriptive statistics of key variables are in Table I and Pearson correlation coefficients are in Table II.

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*Insert Table I and Table II about here*

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**Estimation Results and Hypotheses Testing**

**A. In-Sample Explanation and Test**

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$^{26}$ These types of firms exist in the database due to either coding errors or accumulating unusual losses.

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Instrumental variables (IV) regression models are estimated for each year from 1993 to 2009 separately\textsuperscript{27} for three different predicted variables:

(a) R&D expenditures using natural log R&D; and

(b) R&D intensity which measures the R&D expenditures per a dollar of sales ($RDIS$) or per employee ($RDIE$).

\textit{Estimation for R&D Level:}

The results of estimating model (7) for R&D levels are reported in Table III. Model $F$-statistics are significant (at $p < 0.01$) in each of the seventeen years reflecting adjusted $R^2$ values ranging between 30\% and 57\%. Although not specifically subject to hypothesis testing, validating the R&D model requires that the obtained results for firm-specific exogenous variables ($FSV$) are consistent with expectations. Taking one variable at a time for the models estimated for each of the seventeen years, the coefficients $\beta_1$ on \textit{Firm Size} are positive and statistically significant (at $p < 0.01$) in every year. This is consistent with the expectation that larger firms invest more in research and development (Cohen and Klepper, 1996). The coefficients of $\beta_2$ on \textit{ROA} (profitability measure calculated on the basis of reported accounting numbers) are negative and significantly different from zero in fifteen of the seventeen years. However, as noted earlier, this result must not be taken at face value because the accounting method under GAAP requires that R&D expenditures be accrued as an expense when incurred. Higher R&D expenditures will therefore reduce contemporaneous accounting earnings and the calculated \textit{ROA}. To validate the assertion

\textsuperscript{27} When pooled data are used, each and every variable has a significant coefficient at $p < 0.001$. However, we know that the data are not independent over the years, especially since typical R&D projects could cover multiple accounting periods. The statistical methods that are used to control for serial correlation do not alter this type of structural dependence. To avoid this problem, I conduct the analysis on each year separately or on randomly selected sub-samples. Data are pooled only when the dependent variable of R&D is differenced.

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that the negative sign of the coefficients on \( \text{ROA} \) is a result of the distortion caused by accounting methods, the analysis is repeated with an alternative measure for profitability, \( \text{adjROA} \), which is substituted for \( \text{ROA} \). As noted earlier, \( \text{adjROA} \) is accounting income divided by assets as if R&D expenditures were capitalized and amortized according to some estimated life span. Unlike the negative sign obtained under \( \text{ROA} \), the coefficients \( \beta_2 \) on \( \text{adjROA} \) are significantly positive in eleven of the seventeen years and not different from zero in six years.

*Insert Table III about here*

The coefficients \( \beta_4 \) on \( \text{lev} \) (Leverage) and \( \beta_5 \) on \( \text{cfrisk} \) (Volatility of Cash Flow relative to the volatility of earnings) are consistently negative and statistically significant at \( p < 0.01 \), which is consistent with the extant literature that R&D financing is generated more by equity from external and internal sources. Finally, the coefficients on \( \text{sg} \) (Sales Growth) and on \( \text{FA} \) (Firm Age) are not significantly different from zero (at conventional levels of significance) for most periods. These results of estimating model (7) are generally in line with the expectations drawn from the extant literature with respect to the effects of \( \text{FSV} \) (firm-specific variables) on R&D expenditures.

With respect to the coefficients of interest for hypothesis testing, \( \beta_{ri} \) on the estimated metric for CEO risk tolerance, \( \lambda_{ij} \). As in Table III shows, estimated \( \beta_{ri} \) coefficients are consistently positive and statistically significant (at \( p < 0.01 \)) in every year over the period 1993 – 2009. Since \( \lambda_{ij} \) measures CEO risk tolerance (i.e., the inverse of risk
aversion), this finding suggests that the greater the relative CEO tolerance for risk taking (i.e., lower risk aversion), the more they invest in R&D.\textsuperscript{28}

\textit{Results for R&D Intensity:}

In estimating regression models for R&D intensity, firm size is used as a scalar because intensity is measured in relationship to sales (\textit{RDIS}), or in relationship to the size of labor force (\textit{RDIE}).\textsuperscript{29} Model (8) is used for estimation and assessing the in-sample impact of CEO risk preference on either \textit{RDIS} or \textit{RDIE}.\textsuperscript{30} For each calendar year, this model is estimated alternatively by using \textit{RDIS} or \textit{RDIE} as the predicted variable. To reduce the number of tables reported here without loss of information, Table IV presents the results of estimation for \textit{RDIS} in odd-numbered years, while Table V presents the results of \textit{RDIE} for even-numbered years. In each case, the results of the periods not reported are consistent with those presented. For \textit{RDIS}, adjusted $R^2$ values range between 10\% and 34\% and model \textit{F-statistics} range between 14 and 34 (statistically significant at p < 0.01). Similar results are obtained for \textit{RDIE}: adjusted $R^2$ values range between 13\% and 24\% and model \textit{F-statistics} range between 13 and 24 (statistically significant at p < 0.01).

\textsuperscript{28}The variables used are trimmed by 1\% at each tail. When these outliers of the eight models estimated, the data used ended up having the following boundaries: R&D/Sales > 0.005 and < 0.60; liabilities/assets (leverage) <0.90; sales > $50 million; total income (realized and expected from granted options) >$ 10,000 and < $20 million, and realized incentive pay >0.

\textsuperscript{29}The size of total assets is the third size measure, but all these three variables are highly correlated and the results of using total assets as a scalar for R&D are not different from using sales.

\textsuperscript{30}There is no explicit presentation of model 8 here for parsimony in presentation since it is same as model 7 except for using firm size \textit{Z} to scale R&D instead of being an exogenous predictor.
Estimation results of both R&D intensity models are generally consistent with the results reported above for the analysis of R&D spending levels. In particular, when ROA is based on reported accounting numbers, a negative and statistically significant (at \( p < 0.01 \)) coefficient is obtained. The implication that more profitable companies spend less on R&D is, as noted earlier, unintuitive. For the year-by-year analysis in this paper, the sign on this coefficient changes from year to year to either positive or not significantly different from zero when earnings numbers are corrected for the accounting charges of R&D as an expense—that is, when adjROA is used instead of the ROA numbers based on reported numbers. The coefficients on leverage (\( lev \)) and cash flow volatility (\( cfrisk \)) are negative and statistically significant (at \( p < 0.01 \)). The coefficients on sales growth (\( sg \)) and firm age (\( FA \)) do not have a consistent pattern in terms of either significance or direction. Finally, the coefficients on the test variable of CEO risk preference, \( \lambda \), are positive and significant (at \( p < 0.01 \)) in sixteen of the seventeen-year period; only the coefficients in year 2009 are not statistically significant for both measures of intensity.

**B. Out-of-Sample Predictions**

The above-reported results are based on tests using the estimation sample, but a more powerful test could be obtained by using out-of-sample observations. The design of this test has four components:

a. A reduced form version of the R&D model in (7) is estimated for each year separately using \( FSV \) only (size, profitability, growth, cash flow volatility, leverage, and firm age) and ignoring manager-specific variables.
b. The obtained coefficients from this reduced form estimation are then applied to data of other periods to predict R&D expenditures one-to-three years ahead, obtaining $Predicted \ R&D_{T+\tau}$, where the subscript $T$ connotes the year of estimation and $\tau$ is a subscript connotes the forecast horizon or distance from $T$.

c. Unexpected R&D is then measured as the difference between actual and predicted R&D for the year of prediction as follows:

$$\text{Unexpected R&D}_{T+\tau} = (\log R&D_{T+\tau} - Predicted R&D_{T+\tau}),$$  \hspace{1cm} (9)

where the forecast horizon $T-\tau$ is 1, 2, or 3.

d. Finally, the extent to which the determinants of CEO’s risk preference explain the variation in unexpected R&D using the following regression:

$$\text{Unexpected R&D}_{T+\tau} = \delta_0 + \delta_1 \text{Manger Age}_{j,T+\tau} + \delta_2 \text{CEO Tenure}_{j,T+\tau}$$

$$+ \delta_3 \text{CEO Income}_{j,T+\tau} + \delta_4 \text{CEO Wealth}_{j,T+\tau} + \delta_5 \text{Gender}_{j,T+\tau} + \epsilon_{j,T+\tau}$$  \hspace{1cm} (10)

with these variables are as defined earlier. If the obtained results are not due to the in-sample estimation bias, then the expectations would be as follows: $\delta_1$ would have a negative sign (older CEOs spend on R&D less than expected), while $\delta_2, \delta_3, \text{ and } \delta_4$ have positive signs (higher income, wealth and knowledge of the firm will lead to spending more on R&D than expected). The sign of the coefficient on Gender is unpredictable.

The results of these regression models show that (a) CEO Age and (b) Income are the only two variables that consistently have significant coefficients explaining the unexpected investment in R&D. The average $t$-statistics for the coefficient on CEO Age and Income over the three year horizons are as follows:
<table>
<thead>
<tr>
<th>t-statistics on CEO Age:</th>
<th>Average</th>
<th>-3.0</th>
</tr>
</thead>
<tbody>
<tr>
<td>Range</td>
<td>-1.8 to -4.5</td>
<td></td>
</tr>
<tr>
<td>t-statistics on CEO Income</td>
<td>Average</td>
<td>3.5</td>
</tr>
<tr>
<td>Range</td>
<td>1.8 to 4.5</td>
<td></td>
</tr>
</tbody>
</table>

This analysis is repeated for the firms having different degrees of R&D intensity with respect to sales, *RDIS*, and with respect to labor force, *RDIE*. For the prediction of these variables, adjusted $R^2$ values for estimating model (10) range between 13% and 34% for *RDIS* and between 13% and 24% for *RDIE*. Additionally, as with the analysis of R&D levels, the coefficients on *CEO Age* are significantly negative and the coefficients on CEO *Income* are significantly positive.

These results indicate that the variables capturing CEO’s risk tolerance (aversion) are relevant in determining unexpected R&D expenditure one-to-three years ahead; unexpected R&D expenditures declines with CEO *Age* and increases with CEO *Income*. Except for 2008 and 2009, adjusted $R^2$ values for explaining unpredicted R&D vary between 1.1% and 5.6% for which the related *F-statistics* are statistically significant. While these statistics appear low, they are quite significant economically because the dependent variable is a forecast error and, for these unexpected R&D intensity ratios, CEO risk tolerance appears to be only on the margin.

**C. Incremental Impact of CEOs’ Risk Preference Variables: A Weak Test of Causality**

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While the above-stated results are based on comparing the in-sample and out-of-sample empirical tests, they are consistent in showing a strong positive association between CEO risk tolerance and each of R&D spending levels and R&D intensity: \( RDIS \), and \( RDIE \). However, obtaining association is a necessary but not a sufficient condition for making causal inferences. To provide a further step in that direction, the method of Chow F-statistics is adopted to provide a test, albeit weak, of causality. This test bypasses the instrumentation process and uses manager-specific variables (MSV) directly. Two linear models are estimated: (a) the first is for an unrestricted regression (denoted \( U \)) using all exogenous variables to explain the variation in R&D, and (b) the other is a restricted model (R) that employs the Firm-specific-variables (FSV) only. The obtained \( R^2 \) values are used to estimate the F-statistics. This estimation is as follows:

**The Unrestricted (U) Model:**

\[
RD_i = \gamma_0 + \gamma_1 M A_{ij} + \gamma_2 T_{ij} + \gamma_3 I_{ij} + \gamma_4 W_{ij} + \gamma_5 G_{ij} + \gamma_6 Z_i + \gamma_7 ROAi + \gamma_8 sgi
+ \gamma_9 lev_i + \gamma_9 cfrisk_i + \gamma_9 FA_i + \epsilon_{gi}
\]  

(11)

**The Restricted (R) Model:**

\[
RD_i = R\gamma_0 + R\gamma_1 ROAi + R\gamma_2 sgi + R\gamma_3 lev_i + R\gamma_4 cfrisk_i + R\gamma_5 FA_i + \epsilon_{gi}
\]  

(12)

The explanatory power values of these two models are then used to estimate Chow F-statistic:

\[
F = \frac{(R^2_U - R^2_R)}{(V_U - V_R) / df_U}
\]

(13)

where \( R^2_U \) is the explanatory power for the unrestricted model using both FSV and MSV variables; \( R^2_R \) is the explanatory power for the restricted model using only FSV variables; \( V_U \)
is the number of exogenous variables in the unrestricted model; $V_R$ is the number of exogenous variables in the partial model; $df_{U}$ is the number of degrees of freedom for the unrestricted model; and $RD$ is one of three R&D measures: $lnR&D$ for expenditures levels; $RDIS$ for intensity with respect to sales; and $RDIE$ for intensity with respect to labor force.$^{31}$

These models and the related $F$-statistics (in 13) are estimated for the period 1993 – 2009 for each year separately (during) and for each of the three endogenous variables, R&D level, ($lnR&D$), R&D intensity with respect to sales ($RDIS$), and R&D intensity with respect to labor force ($RDIE$) resulting in fifty one $F$-statistics. The resulting Chow $F$-statistics average 6.67 and range between 2.02 and 11.5 for $RD = lnR&D$; average 5.73 and range between 3.0 and 11.1 for $RD = RDIS$; and average 8.3 and range between 5.0 and 12.1 for $RD = RDIE$. These results show that fifty of the fifty one Chow $F$-statistics are statistically significant at $p < 0.01$. These findings provide strong evidence that CEOs’ socio-demographic factors that determine their attitudes toward risk have an incremental impact on determining the level and intensity of R&D spending.

**D. Industry Differences**

Does the impact of CEO risk tolerance on R&D differ by industry? To examine this question, the analysis is carried out separately for firms in different industries. The industrial classification used in this study is the new Global Industrial Classification System (GICS) based on NAICS that is replacing SIC codes.$^{32}$ There are 23 industry groups in the 4-digit classification of which eleven industry groups have R&D expenditures and are well

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$^{31}$ As before, when the dependent variable is either $RDIS$ or $RDIE$, the size variable, $Z$, is not used as an exogenous variable since intensity is the ratio of R&D to a measure of size, sales or labor force, and the two size measures are highly correlated.

$^{32}$ http://www2.standardandpoors.com/spf/pdf/index/GICSIndexDocument.PDF

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represented in the sample. The names of these groups and related statistics are presented in Table VI. The third column (C3) shows that the average research and development by industry varying between 2% of sales for Personal Products & Health Care Equipment and 13% for Telecommunication & Equipment.\(^{33}\)

To highlight the differences in R&D intensity among industries, Figure One shows plots of average ratio of R&D to sales on the y-axis for CEO Age deciles on the x-axis for four sets of sample firms: (a) all firms in the sample, (b) firms in Life Sciences (GICS 3520); (c) firms in Software Services (GICS 4510); and (d) firms in Telecommunication & Equipment (GICS 4520). For the full sample, the ratio of R&D expenditures per one dollar of sales (RDIS) decreases from a high of 11% for the top decile of CEO Age to a low of 5.3% for the lowest decile. For the Software industry, RDIS declines from 19% for top decile to 11% for the lowest decile, but RDIS remains almost steady around the 7% level for Life Sciences.

The differences between industries with respect to the sensitivity of investment in R&D to CEO risk preference are examined further using two approaches:

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**Insert Figure One Here**

**Insert Table VI about Here**

a) Predicting CEO risk preference using the models developed in one year to predict the following years, and evaluating the extent to which the predicted risk preference measures are associated with predicted R&D for each industry group. To obtain out-of-sample predictions for CEO risk tolerance for any period, a version of model (6) is estimated using the manager-specific variables only and the obtained coefficients are projected to data in other periods to forecast predicted risk preference. Predictions of R&D are obtained in a

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\(^{33}\) It should be noted that outliers—i.e., RDIS >0.6—are excluded from the average.
similar way: using firm-specific variables only as in model (12) and then apply the obtained coefficients to data of future period. As a result, the predictions generated for R&D and for CEO risk tolerance are generated from two non-overlapping sets of exogenous variables: the former is based on manager-specific variables only (CEO Age, Tenure, Income, Wealth, and Gender), while the latter is based on firms specific variables only (firm size, profitability, sales growth, leverage, cash flow volatility, and firm age). Therefore, unless CEO risk preference impacts R&D, there is no a priori reason to expect predicted risk preference and predicted R&D to be significantly correlated.

To illustrate the relationship between these two predictions, Figures Two, Three, and Four present the scatter graphs for the full sample, for the Chemical and Pharmaceuticals sector (two-digit GICIS 35), and for the Computer and Software Industry sector (two-digit GICS 45). These graphs are for one-year-ahead forecasts for the year 2000 using 1999 as an estimation year. Other periods provided very similar results in showing a positive association between predicted R&D and predicted CEO risk preference one-year ahead reflecting relatively high sensitivity for the Chemicals and Pharmaceuticals ($R^2$ is 0.44), and relatively lower sensitivity for the Computer and Software industry group ($R^2$ is 0.26) as well as for all sample firms combined ($R^2$ is 0.30). Positive industries have also shown positive association, although these results might not be surprising because the predictions are for R&D levels, which lead to the second approach.

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b) The second approach is based on using the forecast errors of R&D as the dependent variable. The forecast error is the difference between actual R&D in any given year and the
predicted R&D for that year. The model used for evaluating the sensitivity of R&D to CEO risk tolerance is then estimated using the following relationship:

\[ \text{Unpredicted R&D} = q_1 + q_2 \text{Predicted Risk Preference} + \epsilon_{ur} \] (14)

where the coefficient \( q_2 \) is a measure of the sensitivity of unexpected R&D to predicted CEO risk preference for the prediction horizon \( T+\tau \). Because \text{Unpredicted R&D} measures are prediction errors, they are not serially correlated. As a result, data for all years are pooled to estimate one regression of the form in (14).

Table VI presents the results for each industry group and for the total sample using \( T = 2001 \) as an example. Evaluating the sensitivity of R&D to risk preference is examined using two normalized statistics: (i) the standardized (Beta) coefficients instead of the unscaled \( q_2 \) coefficients, and (ii) \( R^2 \) values.\(^{34}\) As the results in Table VI show, the impact of predicted CEO risk tolerance on R&D spending differs by industry: a relatively high association is obtained for the firms in the Commercial Services & Supplies \( (R^2 = 0.48 \text{ and Beta } = 0.70) \); for the firms in Personal Products & Health Care Equipment \( (R^2 = 0.43 \text{ and Beta } = 0.66) \), and for Life Sciences \( (R^2 = 0.28 \text{ and Beta } = 0.53) \). In contrast, no significant relationship is obtained for firms in Energy (GICS 1010) and Components and Consumer Durables (GICS 251). For the backward predictions (using estimated coefficients in a given year to predict R&D in prior years), firms in Life Sciences (GICS 3520) have the highest correlation \( (R^2 = 0.24 \text{ and Beta } 0.49) \) and firms in the Energy sector continue to show no significant relationship between predicted CEO risk preference and unexpected R&D. In general, however, both of Beta and \( R^2 \) statistics show that R&D forecast errors are

\(^{34}\) Beta coefficients are the estimated regression parameters obtained after standardizing the data of each variable before estimation.
significantly (at p < 0.01) associated in nine of the eleven industry groups for both the forward and backward predictions.

E. Summary of Test Results

(a) Statistically significant, positive coefficients on estimated CEO risk tolerance are obtained for the level and intensity of R&D in each of the seventeen-year period using instrumental-variables-regressions.

(b) R&D forecast errors generated for out-of-sample predictions for one-, two-, and three-year-ahead have significant negative association with CEO Age and significant positive association with CEO income, both of which are consistent with the hypotheses stating that high risk tolerance (aversion) leads to high (low) investment in risky assets.

(c) Tests of the impact of the incremental contribution of the determinants of CEO risk aversion in explaining variation in R&D have statistically significant Chow F statistics.

(d) Industry differences exist showing different sensitivities to CEO risk tolerance, but these differences do not alter the conclusions noted above.

(e) These results are obtained for the level of expenditures on R&D and for R&D intensity with respect to sales and with respect to employed labor force.

Robustness Tests

Tests of robustness and sensitivity of the results include: (1) evaluating the association between CEO risk preference and growth (changes) in R&D; and (2) comparing
the difference in R&D expenditures between the high and low quintiles of CEO risk preference.

1. **Growth (Change) in R&D**

R&D projects vary in duration, depending on the nature of the projects undertaken and the type of industry, but all have first-order stochastic relationship resulting in serially correlated errors if cross-section raw data are pooled across time. With serially correlated errors, the coefficients of estimated regressions would not be efficient estimators. An acceptable method of mitigating this impact is the use of first-order differencing of the dependent variable. In the above analysis, using R&D prediction errors allowed controlling for this serial dependence. In this section, the robustness check utilizes first-order differencing of R&D expressed as the continuous growth rate $igrRD$ measured by $\ln(R&D_t / R&D_{t-1})$. For this analysis, the change variable, *RD growth*, becomes the endogenous variable in a linear model that combines manager-specific and firm-specific variables as explanatory variables in one-step regression:

$$igrRD_i = \delta_0 + \delta_{1i} MA_{ij} + \delta_{2i} T_{ij} + \delta_{3i} L_{ij} + \delta_{4i} W_{ij} + \delta_{5i} G_{ij} + \delta_{6i} igrZ_i + \delta_{7i} ROAi + b_{8i} sg_i + b_{9i} lev_i + b_{10i} cfrisk_i + b_{11i} FA_i + e_{gi}$$

(15)

where $igrRD_i$ is the continuous rate of growth in R&D measured by $\ln(R&D_t / R&D_{t-1})$; $igrZ_i$ is the rate of growth in firm size and is measured as $\ln(Z_t / Z_{t-1})$ with $Z$ being either total assets or sales revenue, and all other variables are as defined earlier.
Model (15) is estimated for the full (differenced) sample of 6,403 observations using quantile regression (minimizing weighted squared deviations from the median)\(^{35}\) and robust OLS regression. The diagnostics of estimated models are reported in Table VII. These results are consistent with expectations: (i) *pseudo R*\(^2\) of 11% for the quantile regression, and *F-statistic* of 215 for the robust regression—both are significant at *p* < 0.01; (ii) significant (at *p* < 0.01) positive coefficients on *Asset Growth* (rate of growth in assets), on *ROA*; (profitability), and on; and on *Sales Growth*; (iii) significant negative coefficients on *Leverage, Cash Flow volatility, Leverage* and on *Firm Age*. With respect to determinants of CEO risk preference, the coefficient on *CEO Age* is significantly negative (at *p* < 0.025) and the coefficient on *Wealth* is significantly positive (at *p* < 0.01).

To assess the robustness of these findings further, manager-specific variables in (15) are replaced by the predicted (restricted) risk preference metrics, for various estimation and prediction periods. An example of the results is in Table VII, last column (as second-stage regression) showing a positive and significant (at *p* < 0.01) coefficient on the predicted risk tolerance variable. Thus, the higher the degree of risk tolerance, the greater the growth rate in R&D. These findings hold for various partitions of prediction periods and for one-year and two-year prediction horizons.

Insert Table VII about here

2. **R&D Growth for High vs. Low Risk Tolerance**

\(^{35}\) Quantile regression estimated parameters of a linear function by minimizing the weighted sum of the squared deviations from the median, which is an effective model for dealing with heteroscedastic errors. See Koenker and Hallock (2001). September 14, 2011
The final robustness check attempts to respond to the following question: Does the impact on R&D vary by the intensity of CEO risk preference? The one-year-ahead and two-year-ahead predictions of CEO risk tolerance, \( \text{preriskpref} \), are used separately as dependent variables in the following reverse regression:

\[
\text{preriskpref}_{ij} = \omega_0 + \omega_{r\&d_i} \ln R&D_i + \omega_{igrA_i} + \omega_{ROA_i} + \omega_{sg_i} + \omega_{lev_i} + \omega_{cfrisk_i} + \omega_{CA_i} + e_{pi}
\]  

(16)

with all variables are as defined above; \( \omega_s \) are estimated coefficients and \( e_{pi} \) is an error term. Table VIII presents a sample of the results for two predictions based on model estimation that uses data of 1995, and two predictions using data of 2001. The regression results obtain model \( R^2 \) values ranging between 37% and 45%, and the coefficients \( \omega_{r\&d} \) on the R&D variable are positive and have \( t \)-statistics ranging between 11.0 and 14.6 (significant at \( p < 0.01 \)), depending on the year. Other periods and predictions provide very similar results. This result is therefore a further confirmation of the earlier analysis.

**Insert Table VIII about Here**

**SUMMARY AND CONCLUSION**

This study examines the relationship between the estimated CEO risk preference and R&D expenditures with the expectation of finding support for the hypothesis that greater risk tolerance (lower risk aversion) leads to higher expenditures on R&D and higher R&D intensity. In line with the literature in organization behavior and management, CEOs are taken as the decision-making agents whose goals and cognitive

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36 It should be noted that \( \text{preriskpref}_{ij} \) is generated from models that use manager-specific variables only; thus, there are no exogenous variables used in (16) that have been used in estimating the coefficients used to generate \( \text{preriskpref}_{ij} \).
processes shape the strategies of the firms they manage. An empirical measure of risk tolerance is derived from the CEOs' relative pay-at-risk premium based on the assumption that—in a labor market characterized by self-sorting—accepting compensation contracts that entail performance-contingent pay are pseudo lotteries for which the ratio of expected payoff to cost is an indication of risk taking preference. A simple empirical model is developed to show that the ratio of realized pay-at-risk to salary is the rate of risk premium that the CEO receives for accepting the mixed-pay strategy (part assured and part contingent) type of contract. As posited in the economics literature on risk aversion, and accepting the theories of self-sorting in labor markets, this rate of risk premium is assumed to reflect the decision maker's own risk tolerance (or aversion) that could be explained by the individual-specific socio-demographic factors. These factors are CEO age, education (proxied here by tenure), earned income (both realized and unrealized), wealth and gender. While these factors have been shown to explain risk taking appetite in numerous contexts related to private investments with similar results being obtained in different countries, they have not been studied in the context of risk taking when the investor is an agent making risky investment decisions on behalf of absentee owners such as the case in business firms decisions on R&D.

In addition to the agent's own intrinsic disposition toward risk taking, firm-specific variables affect CEOs' willingness to accept pay-at-risk and therefore impact the risk tolerance metric estimated from the structure of compensation contracts. These variables are firm size, profitability, growth, leverage, cash flow volatility and firm age. The estimated metrics of risk tolerance (endogenous) and the firm specific (exogenous) variables are then used as explanatory variables in instrumental variables regressions.
using the two-stage-least squares method. The firm’s commitment to R&D is measured by (a) R&D expenditures; (b) R&D intensity with respect to sales, and (c) R&D intensity with respect to the employed labor force. Because R&D expenditures are sticky with varying durations depending on the nature of the projects undertaken, the instrumental variable regressions are estimated for each year separately during the period 1993-2009, except when the dependent variable is differenced or consists of prediction errors.

The data used are for the firms listed on the Execucomp database and are restricted to business enterprises with any R&D activity as obtained from Compustat. The instrumental-variables models estimated for R&D levels and intensity are shown to behave consistent with expectations in terms of model fit, direction and significance of coefficients. The analysis is further extended to include out-of-sample predictions, to examine the relationship between unexpected R&D spending and predicted CEO risk tolerance, and to examine the effect of the raw determinants of CEO risk preference on unexpected R&D. To establish conditions for weak causality, Chow F-statistics are estimated to test for the significance of the incremental effect of CEOs’ risk factors in explaining R&D and R&D intensity. Robustness tests further evaluate the association between CEO risk tolerance and change (growth) in R&D.

All test results consistently fail to reject (at conventional levels of significance) the hypotheses of significant positive (negative) relationships between CEO risk tolerance (aversion) and each of the variables measuring R&D spending, rate of growth in R&D, and R&D intensity. It must be emphasized, however, that effects of CEOs’ risk preferences on R&D are material and significant in statistical sense but only on the margin since the main drivers of R&D expenditures are other managerial strategic factors.

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This study makes two contributions: (i) the first is the development of a methodology to estimate risk tolerance using publicly available data, and (ii) the second is providing direct empirical evidence on the relationship between CEO risk tolerance and investment in R&D.

One could argue that this finding should not exist. In other words, CEOs’ own risk preferences should not be allowed to impact the decisions made. However, we know this to be the cases in situations where the decisions made have serious externalities (e.g., GlaxoSmithKlein, Pfizer and AztraZeneca). Is it possible to design incentive compensation schemes that would avoid having this impact? This would be a useful implication of this study that could the subject of future research.

While the findings of this study have implications to the design of incentive contracts and managerial behavior, the contribution to the literature lies along two dimensions:

(a) This is the first study that explicates and documents the connection between managerial risk preference (tolerance or aversion) and R&D spending.

(b) The results and findings clearly show that changes in R&D accruals arise from fundamental changes in managerial attitudes toward risk taking. Such changes take place overtime as CEOs age and firms grow or as CEOs change or retire. Changing R&D accruals may therefore not necessarily be willfully or opportunistically undertaken to manipulate earnings. More specifically, the accounting research claiming that managers undertake

37 These are well publicized because of their obvious public interest.
real earnings manipulation by changing R&D to achieve some targets could perhaps be missing the mark by failing to control for changes in R&D arising from fundamental changes in CEOs' risk preferences or, as Hambrick and Fukutomi (1991) calls it “the seasons of a CEO tenure.”
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Figure One: R&D intensity per dollar of sales (RDIS) per decile of CEO Age for total sample, Life Sciences (GCIS 3510); Software (GCIS 4510), and Telecommunication & Equipment (GCIS 4530).
Figure Two: The relationship between predicted R&D (based on firm-specific variables) and predicted CEO risk preference (based on manager-specific variables) for the year 2000 using the coefficients estimated for the year 1999. For the full sample, $R^2$ is 0.30.
Figure Three: The relationship between predicted R&D (based on firm-specific variables) and predicted CEO risk preference (based on manager-specific variables) for the year 2000 using the coefficients estimated for the year 1999. For the Chemicals and Pharmaceuticals industry group sector (GCIS 35), $R^2$ is 0.44.
**Figure Four:** The relationship between predicted R&D (based on firm-specific variables) and predicted CEO risk preference (based on manager-specific variables) for the year 2000 using the coefficients estimated for the year 1999. For the Computers and Software industry group (GCIS 45), $R^2$ is 0.26.
Exhibit 1
Definition of Variables

\(i\) : index for the firm.

\(j\) : index for the CEO.

**MSV** manager-specific variables

\(\pi_{ij}\) : 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) divided by salary.

\(\ln \pi\) : the natural log of relative pay-at-risk premium

\(\lambda_{ij}\) : the estimated CEO risk tolerance metric, which is the predicted value of \(\ln \pi\) and is the inverse of risk aversion. \(\lambda_{ij}\) low for highly risk averse person and high for individuals with high risk tolerance.

\(MA_{ij}\) : manager’s age.

\(T_{ij}\) : tenure as the number of years on the job as a CEO (\(T \geq 1\)).

\(l_{ij}\) : natural log 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).

\(W_{ij}\) : natural log of the market value of CEO equity holding as a proxy for wealth.

\(G_{ij}\) : gender (0 for male, 1 for female).

**FSV** firm-specific variables:

\(Z_{i}\) : Size measured by sales, assets or number of employees.

\(\ln Z_{i}\) : firm size measured by natural log of sales (and alternatively, the natural log of total assets or natural log of the number of employees).

\(ROA_{i}\) : return on assets measured as reported net income to total assets. (as noted above, an estimated alternative measure is \(adjROA\), which is corrected for the accounting Impact of accruing R&D as an expense obtained from Execucomp.

\(sg_{i}\) : sales growth rate over the preceding five years.

\(lev_{i}\) : leverage measured by assets net of common equity divided by total assets.

\(cfrisk_{i}\) : relative 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 twelve (rolling) quarters.

\(FA_{i}\) = firm age in years proxied by the number of years listed on Compustat.
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<th>Mean</th>
<th>S.D.</th>
<th>1st Qtr.</th>
<th>Median</th>
<th>75%</th>
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<td>690</td>
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<td>2.87</td>
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<td>4.9</td>
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<td>3.9</td>
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<td>Rate of Growth in Research &amp; Development</td>
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<td>0.32</td>
<td>-0.02</td>
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<td>0.2</td>
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<td>Total Assets in $m</td>
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<td>3330</td>
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<td>Log Total Assets</td>
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Log is the natural log to base \( e \).
### Table II: Pearson Correlation Coefficients

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<td>2 Rate of Growth in Research &amp; Development</td>
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<td>4 log Assets</td>
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<tr>
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<tr>
<td>13 log CEO Wealth</td>
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<td>0.27</td>
<td>0.09</td>
<td>0.21</td>
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<td>0.16</td>
<td>0.36</td>
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</table>

Log is the natural log to base $e$. 
Table III: Second Stage Regression of R & D on CEO Risk Preference and Firm Specific Determinants

<table>
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<tbody>
<tr>
<td>Constant (t)</td>
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<td>-1.57</td>
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<td></td>
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<td>CEO Risk Tolerance (λ)</td>
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<td>0.72</td>
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<td>(3.4)^a</td>
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<td>(5.4)^a</td>
<td>(2.66)^a</td>
<td>(4.1)^a</td>
<td>(4.7)^a</td>
<td>(4.7)^a</td>
<td>(4.1)^a</td>
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<tr>
<td>Log Sales (t)</td>
<td>+</td>
<td>0.86</td>
<td>0.83</td>
<td>0.74</td>
<td>0.77</td>
<td>0.77</td>
<td>0.79</td>
<td>0.71</td>
<td>0.75</td>
</tr>
<tr>
<td></td>
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<td>(11.6)^a</td>
<td>(3.6)^a</td>
<td>(11.7)^a</td>
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<tr>
<td>Return on assets: Profitability (t)</td>
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<td>-0.037</td>
<td>-0.01</td>
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<td>(-2.8)^a</td>
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<td>Sales Growth (t)</td>
<td>+</td>
<td>0.012</td>
<td>0.13</td>
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<td>0.008</td>
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<td>0.009</td>
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<tr>
<td></td>
<td></td>
<td>(1.99)^b</td>
<td>(2.8)^a</td>
<td>(-0.9)</td>
<td>(1.76)^c</td>
<td>(1.4)</td>
<td>(2.31)^a</td>
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<tr>
<td>Leverage (t)</td>
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<td>-2.38</td>
<td>-1.3</td>
<td>-1.77</td>
<td>-1.4</td>
<td>-1.93</td>
<td>-1.68</td>
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<tr>
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<tr>
<td>Voluntary of cash flow to earnings (t)</td>
<td>-</td>
<td>-0.09</td>
<td>-0.07</td>
<td>-0.08</td>
<td>-0.05</td>
<td>-0.07</td>
<td>-0.11</td>
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<td>(-1.9)^b</td>
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<td>(-3.8)^b</td>
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<td>(-4.1)^a</td>
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<tr>
<td>Firm Age (t)</td>
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<td>0.06</td>
<td>-0.03</td>
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<td>(1.5)</td>
<td>(-.8)</td>
<td>(0.9)</td>
<td>(-0.3)</td>
<td>(0.61)</td>
<td>(0.2)</td>
<td>(-0.9)</td>
</tr>
<tr>
<td>Adjusted R^2</td>
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<td>0.44</td>
<td>0.55</td>
<td>0.42</td>
<td>0.57</td>
<td>0.48</td>
<td>0.50</td>
<td>0.45</td>
<td>0.46</td>
</tr>
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<td>F-statistics</td>
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<td>49</td>
<td>63</td>
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<td>342</td>
<td>347</td>
<td>361</td>
<td>331</td>
</tr>
</tbody>
</table>

The model estimated in this model is In Research & Development = β_0 + β_1 CEO Risk Tolerance_0 + β_2i log Sales_i + β_3i Return on Assets_i + β_4i sales growth_i + β_5i leverage_i + β_6i Cash flow volatility_i + β_7i Firm Age_i + u_{i,m} where all variables are exogenous (as shown in the table) except for and the CEO Risk Tolerance (λ).
Table III (continued): Second Stage Regression of R & D on Risk Preference and Other Firm Specific Determinants

<table>
<thead>
<tr>
<th>Variable Name</th>
<th>Year</th>
<th>Pred. sign</th>
<th>2001</th>
<th>2002</th>
<th>2003</th>
<th>2004</th>
<th>2005</th>
<th>2006</th>
<th>2007</th>
<th>2008</th>
<th>2009</th>
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<td>Constant (t)</td>
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<td>-0.80</td>
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<td>-0.55</td>
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<td>CEO Risk Tolerance (λij).</td>
<td></td>
<td></td>
<td>+</td>
<td>0.75</td>
<td>0.90</td>
<td>1.08</td>
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<td>0.92</td>
<td>0.63</td>
<td>0.88</td>
<td>1.03</td>
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<tr>
<td>InSales (t)</td>
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<td></td>
<td>+</td>
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<td>0.70</td>
<td>0.67</td>
<td>0.69</td>
<td>0.74</td>
<td>0.79</td>
<td>0.76</td>
<td>0.67</td>
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<tr>
<td>Return on assets: Profitability (t)</td>
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<td></td>
<td>+</td>
<td>-0.01</td>
<td>-0.026</td>
<td>-0.04</td>
<td>-0.03</td>
<td>-0.03</td>
<td>-0.04</td>
<td>-0.04</td>
<td>-0.04</td>
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<td>Sales Growth (t)</td>
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<td>-0.007</td>
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<tr>
<td>Leverage (t)</td>
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<td>-1.44</td>
<td>-2.3</td>
<td>-2.9</td>
<td>-2.86</td>
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<tr>
<td>Cash Flow Volatility (t)</td>
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<td>-0.18</td>
<td>-0.19</td>
<td>-0.2</td>
<td>-0.08</td>
<td>-0.08</td>
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<tr>
<td>Firm Age (t)</td>
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<td>-0.01</td>
<td>0.009</td>
<td>0.016</td>
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<td>-0.001</td>
<td>-0.01</td>
<td>-0.005</td>
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<td>0.39</td>
<td>0.35</td>
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<td>0.42</td>
<td>0.41</td>
<td>0.34</td>
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<td>439</td>
<td>453</td>
<td>486</td>
<td>452</td>
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</tr>
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</table>

The model estimated in this model is \( \ln \text{Research \\&Development} = \beta_0 + \beta_1 \text{CEO Risk Tolerance} + \beta_2 \log \text{Sales} + \beta_3 \text{Return on Assets} + \beta_4 \text{sales growth} + \beta_5 \text{leverage} + \beta_6 \text{Cash flow volatility} + \beta_7 \text{Firm Age} + u_{R&D,j} \), where all variables are exogenous (as shown in the table) except for and the CEO Risk Tolerance (\( \lambda_{ij} \)).
Table IV: Second Stage Regression of R & D Intensity (RDIS) Risk Preference and Other Firm Specific Determinants (Odd-numbered Years)

<table>
<thead>
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<th>Variable Name</th>
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<th>1997</th>
<th>1999</th>
<th>2001</th>
<th>2003</th>
<th>2005</th>
<th>2007</th>
<th>2009</th>
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<tbody>
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<td>Constant (t)</td>
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<td>0.14</td>
<td>0.15</td>
<td>0.15</td>
<td>0.16</td>
<td>0.17</td>
<td>0.19</td>
<td>0.18</td>
<td>0.18</td>
</tr>
<tr>
<td>(t)</td>
<td>(4.9)^a</td>
<td>(6.1)^a</td>
<td>(6.9)^a</td>
<td>(8.2)^a</td>
<td>(8.6)^a</td>
<td>(9.6)^a</td>
<td>(10.9)^a</td>
<td>(10.9)^a</td>
<td>(9.7)^a</td>
</tr>
<tr>
<td>Risk Preference (t)</td>
<td>0.04</td>
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<td>0.026</td>
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<td>0.044</td>
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<td>0.036</td>
<td>0.008</td>
</tr>
<tr>
<td>(t)</td>
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<td>(4.1)^a</td>
<td>(2.7)^a</td>
<td>(4.6)^a</td>
<td>(2.9)^a</td>
<td>(3.6)^a</td>
<td>(2.9)^a</td>
<td>(2.7)^a</td>
<td>(0.55)</td>
</tr>
<tr>
<td>Return on assets: Profitability (t)</td>
<td>-0.002</td>
<td>-0.004</td>
<td>-0.003</td>
<td>-0.002</td>
<td>-0.0015</td>
<td>-0.004</td>
<td>-0.003</td>
<td>-0.004</td>
<td>-0.003</td>
</tr>
<tr>
<td>(t)</td>
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<td>(-7.2)^a</td>
<td>(-6.6)^a</td>
<td>(-5.2)^a</td>
<td>(-5.3)^a</td>
<td>(-6.2)^a</td>
<td>(-5.6)^a</td>
<td>(-5.1)^a</td>
<td>(-6.5)^a</td>
</tr>
<tr>
<td>Sales Growth (t)</td>
<td>0.0006</td>
<td>0.0006</td>
<td>0.0007</td>
<td>0.0002</td>
<td>-0.0015</td>
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<td>-0.008</td>
<td>0.0004</td>
<td>0.0008</td>
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<td>(t)</td>
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<td>(2.6)^a</td>
<td>(3.1)^a</td>
<td>(1.0)^a</td>
<td>(5.4)^a</td>
<td>(1.3)^a</td>
<td>(2.3)^a</td>
<td>(1.5)^a</td>
<td>(2.2)^a</td>
</tr>
<tr>
<td>Leverage (t)</td>
<td>-0.15</td>
<td>-0.13</td>
<td>-0.16</td>
<td>-0.15</td>
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<td>-0.18</td>
<td>-0.2</td>
<td>-0.16</td>
<td>-0.14</td>
</tr>
<tr>
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<td>(-7.2)^a</td>
<td>(-7.9)^a</td>
<td>(-0.4)^a</td>
<td>(-9.2)^a</td>
<td>(-8.5)^a</td>
<td>(-7.0)^a</td>
<td>(-6.2)^a</td>
</tr>
<tr>
<td>Cash Flow Volatility (t)</td>
<td>-0.003</td>
<td>-0.006</td>
<td>-0.006</td>
<td>-0.007</td>
<td>-0.17</td>
<td>-0.009</td>
<td>-0.007</td>
<td>-0.009</td>
<td>-0.006</td>
</tr>
<tr>
<td>(t)</td>
<td>(-2.6)^a</td>
<td>(-3.8)^a</td>
<td>(-3.9)^a</td>
<td>(-5.3)^a</td>
<td>(-8.7)^a</td>
<td>(-4.2)^a</td>
<td>(-3.4)^a</td>
<td>(-4.9)^a</td>
<td>(-2.6)^a</td>
</tr>
<tr>
<td>Firm Age (t)</td>
<td>-0.004</td>
<td>-0.003</td>
<td>-0.001</td>
<td>-0.001</td>
<td>-0.009</td>
<td>-0.001</td>
<td>-0.001</td>
<td>-0.001</td>
<td>-0.001</td>
</tr>
<tr>
<td>(t)</td>
<td>0.2</td>
<td>1.54</td>
<td>0.9</td>
<td>1.6</td>
<td>(-4.3)^a</td>
<td>(-0.8)^a</td>
<td>(-1.8)^a</td>
<td>(-2.5)^a</td>
<td>(-2.2)^a</td>
</tr>
<tr>
<td>Adjusted R^2</td>
<td>0.10</td>
<td>0.27</td>
<td>0.26</td>
<td>0.26</td>
<td>0.34</td>
<td>0.24</td>
<td>0.15</td>
<td>0.15</td>
<td>0.25</td>
</tr>
<tr>
<td>F-statistics</td>
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<td>34</td>
<td>28</td>
<td>26</td>
<td>22</td>
<td>24</td>
</tr>
<tr>
<td>Number of Observations</td>
<td>229</td>
<td>321</td>
<td>342</td>
<td>361</td>
<td>357</td>
<td>424</td>
<td>439</td>
<td>486</td>
<td>400</td>
</tr>
</tbody>
</table>

The model estimated in this model is \( \text{Research and Development Intensity (Sales)} = \beta_0 + \beta_1 \text{CEO Risk Tolerance}_{ij} + \beta_2 \log \text{Sales} + \beta_3 \text{Return on Assets} + \beta_4 \text{sales growth} + \beta_5 \text{leverage} + \beta_6 \text{Cash flow volatility} + \beta_7 \text{Firm Age}_{i} + u_{RDIS_{ij}} \) where all variables are exogenous (as shown in the table) except for and the CEO Risk Tolerance (\( \lambda_{ij} \)).
Table V: Second Stage Regression of R & D Intensity (RDIE) Risk Preference and Other Firm Specific Determinants (Even-numbered Years)

<table>
<thead>
<tr>
<th></th>
<th></th>
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<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Constant (t)</td>
<td>17 (2.8)</td>
<td>24 (4.0)</td>
<td>26 (4.1)</td>
<td>35 (5.6)</td>
<td>41.3 (7.6)</td>
<td>47 (8.1)</td>
<td>63 (8.1)</td>
<td>48 (5.6)</td>
</tr>
<tr>
<td>Risk Preference (t)</td>
<td>8.7 (3.7)</td>
<td>4.6 (2.8)</td>
<td>9.7 (3.6)</td>
<td>10.7 (3.5)</td>
<td>13.12 (3.7)</td>
<td>16.4 (4.0)</td>
<td>14 (2.9)</td>
<td>15 (2.7)</td>
</tr>
<tr>
<td>Return on assets: Profitability (t)</td>
<td>-0.26 (-1.7)</td>
<td>-0.12 (-1.3)</td>
<td>-0.7 (-4.0)</td>
<td>-0.2 (-4.0)</td>
<td>-0.46 (-4.6)</td>
<td>-1.1 (-4.6)</td>
<td>-1.0 (-4.8)</td>
<td>-0.42 (-2.8)</td>
</tr>
<tr>
<td>Sales Growth (t)</td>
<td>0.22 (3.8)</td>
<td>0.113 (1.5)</td>
<td>0.36 (5.3)</td>
<td>0.003 (0.0)</td>
<td>0.02 (0.27)</td>
<td>0.38 (3.1)</td>
<td>0.26 (1.74)</td>
<td>0.44 (2.9)</td>
</tr>
<tr>
<td>Leverage (t)</td>
<td>-25 (-4.6)</td>
<td>-35 (-6)</td>
<td>-40 (-6.1)</td>
<td>-31.1 (-5.1)</td>
<td>-45 (-7.5)</td>
<td>-63 (-7.7)</td>
<td>-71 (-7.1)</td>
<td>-50 (-5.6)</td>
</tr>
<tr>
<td>Cash Flow Volatility (t)</td>
<td>-1.1 (-3.4)</td>
<td>-1.3 (-3.2)</td>
<td>-1.7 (-3.5)</td>
<td>-2.0 (-3.3)</td>
<td>-3.1 (-5.1)</td>
<td>-4.4 (-4.6)</td>
<td>-3.5 (-3.8)</td>
<td>-2.9 (-3.3)</td>
</tr>
<tr>
<td>Firm Age (t)</td>
<td>0.10 (0.2)</td>
<td>0.4 (1.0)</td>
<td>0.16 (0.4)</td>
<td>-0.7 (-2.1)</td>
<td>-0.4 (-1.4)</td>
<td>-0.3 (-0.9)</td>
<td>-0.48 (-1.5)</td>
<td>-0.52 (-1.7)</td>
</tr>
<tr>
<td>Adjusted R²</td>
<td>0.13</td>
<td>0.2</td>
<td>0.24</td>
<td>0.23</td>
<td>0.18</td>
<td>0.15</td>
<td>0.16</td>
<td>0.08</td>
</tr>
<tr>
<td>F-statistics</td>
<td>15</td>
<td>13</td>
<td>24</td>
<td>20</td>
<td>23</td>
<td>24</td>
<td>21</td>
<td>15</td>
</tr>
<tr>
<td>Number of Observations</td>
<td>293</td>
<td>318</td>
<td>345</td>
<td>327</td>
<td>393</td>
<td>445</td>
<td>451</td>
<td>451</td>
</tr>
</tbody>
</table>

The model estimated in this model is Research and Development Intensity ($100 per employees) = $\beta_0 + \beta_1 \text{CEO Risk Tolerance}_{ij} + \beta_2 \text{log Sales}_i + \beta_3 \text{Return on Assets}_i + \beta_4 \text{sales growth}_i + \beta_5 \text{leverage}_i + \beta_6 \text{cash flow volatility}_i + \beta_7 \text{Firm Age}_i + u_{R&D,ij}$ where all variables are exogenous (as shown in the table) except for and the CEO Risk Tolerance (\lambda_{ij}).

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### Table VI: Industry Information Regarding R&D Intensity

<table>
<thead>
<tr>
<th>Industry (GICS)</th>
<th>Name</th>
<th>C3</th>
<th>C4</th>
<th>Year &gt; 2001</th>
<th>Years &lt; 2001</th>
</tr>
</thead>
<tbody>
<tr>
<td>1010</td>
<td>Energy</td>
<td>0.025</td>
<td>6.0</td>
<td>0 0 63</td>
<td>0 0 69</td>
</tr>
<tr>
<td>1510</td>
<td>Materials</td>
<td>0.024</td>
<td>8.3</td>
<td>0.20 0.04 299</td>
<td>0.11 0.06 322</td>
</tr>
<tr>
<td>2010</td>
<td>Capital Goods</td>
<td>0.026</td>
<td>5.3</td>
<td>0.27 0.07 578</td>
<td>0.27 0.07 480</td>
</tr>
<tr>
<td>2020</td>
<td>Commercial Services &amp; Supplies</td>
<td>0.026</td>
<td>4</td>
<td>0.70 0.48 53</td>
<td>0.36 0.13 74</td>
</tr>
<tr>
<td>2510</td>
<td>Components &amp; Consumer Durables</td>
<td>0.022</td>
<td>5</td>
<td>0 0 45</td>
<td>0.24 0.06 74</td>
</tr>
<tr>
<td>3030</td>
<td>Personal Products &amp; Health Care</td>
<td>0.019</td>
<td>6.6</td>
<td>0.66 0.43 52</td>
<td>0.29 0.08 62</td>
</tr>
<tr>
<td>3510</td>
<td>Equipment</td>
<td>0.075</td>
<td>16.4</td>
<td>0.36 0.13 288</td>
<td>0.29 0.09 183</td>
</tr>
<tr>
<td>3520</td>
<td>Pharmaceuticals &amp; Biotech Services</td>
<td>0.10</td>
<td>35</td>
<td>0.53 0.28 199</td>
<td>0.49 0.24 152</td>
</tr>
<tr>
<td>4510</td>
<td>Life Sciences</td>
<td>0.11</td>
<td>28</td>
<td>0.22 0.05 332</td>
<td>0.12 0.01 193</td>
</tr>
<tr>
<td>4520</td>
<td>Software Services, Tech &amp; Hardware</td>
<td>0.09</td>
<td>27</td>
<td>0.39 0.14 429</td>
<td>0.28 0.08 283</td>
</tr>
<tr>
<td>4530</td>
<td>Electronic Equipment &amp; Semiconductors</td>
<td>0.13</td>
<td>41</td>
<td>0.30 0.09 222</td>
<td>0.21 0.04 146</td>
</tr>
<tr>
<td></td>
<td>Telecommunication &amp; Equipment</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Total Sample</td>
<td>0.061</td>
<td>17</td>
<td>0.25 0.06 2,806</td>
<td>0.24 0.06 2,271</td>
</tr>
</tbody>
</table>

**Explanation of content of different columns:**
- C1: Global industrial classification index
- C2: Industry sector
- C3: $RDIS = R & D/Sales$
- C4: $RDIE = R & D/Number of Employee$
- C5: Results of the regression

$UR&D = q1 + q2 \cdot priskpref + \epsilon_{urd}$

for predictions of risk tolerance, $priskpref$, and unexpected R&D based on data of 2001. The first three columns show the forward predictions, and the last three columns show predictions for prior years.
Table VII: Regression results for rate of growth in R&D (dependent variable): one-stage OLS using risk preference determinants and second-stage regression for instrumented risk tolerance metric.

<table>
<thead>
<tr>
<th></th>
<th>Full Regressions—no Instrumentation</th>
<th>Second Stage Regression</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Quantile Regression</td>
<td>Robust Regression</td>
</tr>
<tr>
<td></td>
<td>Coeff.</td>
<td>T</td>
</tr>
<tr>
<td>Predicted CEO Risk Preference</td>
<td>---</td>
<td>----</td>
</tr>
<tr>
<td>CEO Age</td>
<td>-0.001</td>
<td>-3.11*</td>
</tr>
<tr>
<td>Tenure</td>
<td>0.007</td>
<td>1.97*</td>
</tr>
<tr>
<td>ln CEO Income</td>
<td>0.0025</td>
<td>1.09</td>
</tr>
<tr>
<td>ln CEO Wealth</td>
<td>0.0025</td>
<td>2.22*</td>
</tr>
<tr>
<td>Gender</td>
<td>0.005</td>
<td>0.05</td>
</tr>
<tr>
<td>Total assets growth</td>
<td>0.33</td>
<td>32.0*</td>
</tr>
<tr>
<td>Return on assets: profitability</td>
<td>0.006</td>
<td>3.32*</td>
</tr>
<tr>
<td>sales growth</td>
<td>0.0026</td>
<td>18.5*</td>
</tr>
<tr>
<td>leverage</td>
<td>-0.033</td>
<td>-2.8***</td>
</tr>
<tr>
<td>Cash flow risk</td>
<td>-0.005</td>
<td>-5.13*</td>
</tr>
<tr>
<td>Firm Age</td>
<td>-0.002</td>
<td>-2.5*</td>
</tr>
<tr>
<td>Intercept</td>
<td>0.03</td>
<td>1.07</td>
</tr>
</tbody>
</table>

N = 6,403

Pseudo $R^2 = 0.11$

\( F\text{-Statistic} = 215.4 \)

* significant at p < 0.01
** significant at p < 0.05
*** significant at p < 0.10

(Variable definitions are in Exhibit 1)
Table VIII: Examples of Reverse Regression for One-year and Two-year-ahead Predictions of CEO Risk Tolerance

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Intercept</td>
<td>0.32</td>
<td>0.33</td>
</tr>
<tr>
<td></td>
<td>(3.40)*</td>
<td>(3.78)*</td>
</tr>
<tr>
<td>ln Research &amp; Development</td>
<td>0.11</td>
<td>0.17</td>
</tr>
<tr>
<td></td>
<td>(11.04)*</td>
<td>(13.70)*</td>
</tr>
<tr>
<td>Total Assets Growth</td>
<td>-0.011</td>
<td>-0.03</td>
</tr>
<tr>
<td></td>
<td>(-0.02)</td>
<td>(-0.3)</td>
</tr>
<tr>
<td>Return on assets profitability</td>
<td>0.003</td>
<td>0.003</td>
</tr>
<tr>
<td></td>
<td>(1.90)**</td>
<td>(2.90)*</td>
</tr>
<tr>
<td>Sales growth</td>
<td>0.001</td>
<td>0.001</td>
</tr>
<tr>
<td></td>
<td>(1.07)</td>
<td>(1.03)</td>
</tr>
<tr>
<td>Leverage</td>
<td>0.25</td>
<td>0.22</td>
</tr>
<tr>
<td></td>
<td>(2.54)*</td>
<td>(2.70)*</td>
</tr>
<tr>
<td>Cash flow volatility</td>
<td>-0.005</td>
<td>-0.004</td>
</tr>
<tr>
<td></td>
<td>(-0.77)</td>
<td>(-0.75)</td>
</tr>
<tr>
<td>Firm Age</td>
<td>0.007</td>
<td>0.005</td>
</tr>
<tr>
<td></td>
<td>(1.00)</td>
<td>(1.05)</td>
</tr>
<tr>
<td>Adjusted $R^2$</td>
<td>0.39</td>
<td>0.42</td>
</tr>
<tr>
<td>$F$-Statistic</td>
<td>30.0</td>
<td>26.0</td>
</tr>
<tr>
<td>Average VIF</td>
<td>1.16</td>
<td>1.15</td>
</tr>
<tr>
<td>Number of Observations</td>
<td>327</td>
<td>338</td>
</tr>
</tbody>
</table>

*Significant at p < 0.01   ** significant at p < 0.05   *** significant at p < 0.10

(Variable definitions are in Exhibit 1)
APPENDIX

i. In agreeing to a mixed-strategy contract, the employer anticipated the following relationship,

\[ p(S) \leq pS + E(C) \geq Y \]
\[ [pS + E(C)] - Y = E(R) \]

where \( E(R) \) is the expected value of excess total pay over what the CEO had initially required. \( E(R) \) is essentially a premium that the employer would be willing to pay in order to transfer the risk of achieving certain performance to the agent. The employer is not setting an upper bound on the CEO’s pay-at-risk and is prepared to pay higher than \( Y \), the initial high wage sought by the CEO.

ii. In this construction,

\[ E(C) = f_1 \text{(performance factors)} \]
\[ \text{Also, } E(R) = f_2 \text{(performance factors)} \]

Where \( f_1 \) is the set of parameters stipulated in the compensation contract to generate amounts of incentive pay—i.e., the premium that the agent is willing to accept for taking pay-at-risk. Similarly, \( f_2 \) is a function representing the owners own assessment of the maximum amount they could pay to transfer the risk of performance to the agent.

iii. In this construction, the functions \( f_1 \) and \( f_2 \) are incentive compatible: the owners wish to enhance performance \( E(R) \) and do not set an upper limit on \( E(R) \), while the agent aims at enhancing performance in order to maximize the payoff \( E(C) \). Given this incentive compatibility, in
equilibrium \( E(R) = E(C) = (1-pS) + E(x) \). It follows then that \( E(C) \) is a sufficient statistic for the expectations of the owners and the agent in a mixed strategy compensation scheme.

iv. Since \( E(C) \) is the payoff of the pseudo lottery, the ratio \( \pi = [E(C) / (1-pS)] = [1+ E(x) / (1-pS)] \) is a measure of the agent’s risk appetite: as \( \pi \) increases, indicates high payoff to the cost of the pseudo lottery and the more the agent would be willing to take risk.

Let \( p_j \) be the manager’s subjective probability of accepting the proportion of the salary, \( p_j S_j \), and sacrificing the assurance of the remainder, \( (1-p_j) S_j \), in favor of taking performance-contingent compensation \( C_j \) such that \( E(pS_j + C_j) \geq Y \). While the amount of assured fixed income to be received \( p_j S_j \) (which should also the actual, \( s_j \)) is contractually determined, the pay-at-risk \( C_j \) is a random variable with an expected value of \( \hat{C}_j \) and a variance \( \sigma^2_C \). Because of accepting pay-at-risk, the manager (CEO) expects to receive a risk premium \( x_j \) having an expected value \( \mu_x \) and a standard deviation of \( \sigma_x \). The ex-ante distribution of \( x_j \) is lower-tail truncated at \(( p_j - 1)S_j \). That is,

\[
\hat{C}_j = (1-p_j)S_j + \mu_x \\
\mu_x \geq (1-p_j)S_j \\
\hat{C}_j \geq 0
\] (1)

The subjective probability \( p_j \) could then be obtained from the structure of compensation:

\[
Y_j = p_j(S_j) + C_j,
\]
and

\[
p_j \approx [Y_j - C_j] / S_j. \] (2)
This measure suggests two boundaries reflecting the two possible pure compensation strategies: (a) for a highly risk-averse person, \( p_j = 1 \) and all compensation derive from salary; and (b) for a CEO with proclivity for taking risk, \( p_j = 0 \) when the contract specifies that all compensation is contingent on some future events. Other than some known exceptions,\(^{38}\) most of CEO compensation contracts consist of a mixed strategy with varying \( p_j \) depending of the degree of risk tolerance (aversion). In realization, actual total compensation \( \hat{y}_j \) consists of an actual salary \( s_j = p_j(S_j) \) plus actual pay-at-risk \( c_j \), which deviates from expectation as follows:

\[
\hat{y}_j = s_j + c_j \\
\hat{y}_j = s_j + (1 - p_j)S_j + x_j
\]

and

\[
x_j = \mu_x + \varepsilon_j \tag{3}
\]

The random error \( \varepsilon_j \) is assumed to have a normal distribution with an expected value of zero and a standard deviation of \( \sigma_\varepsilon \). Following on prior assumptions, \( c_j \) has a truncated distribution with a lower limit of zero—i.e., the maximum income a manager could lose is the sacrificed amount of salary.

To compare compensation across agents and over time, a measure of relative premium for pay-at-risk, \( \pi_j \), must be developed relative to the opportunity cost \( (1 - p)S_j \) by standardizing the pay expression in (3):

\[\text{December 24, 2010}\]

---

\(^{38}\) In 1978, Lee Iacoca, the former CEO of the Chrysler Corporation, set a precedent by having contracted for an annual salary of one dollar and expected to capture a higher level of compensation based on performance. Since then, Moira Herbst (2007) notes that prominent CEOs have followed suite: 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).
\[ \frac{\hat{y}_j}{(1-p_j)S_j} = \left[ s_j + (1-p_j)S_j + x_j \right] / (1-p_j)S_j \]

Since the actual fixed salary is the contracted amount, substituting and rearranging,

\[ \frac{c_j}{(1-p_j)S_j} = \frac{[(1-p_j)S_j + x_j]}{(1-p_j)S_j} = 1 + x_j / (1-p_j)S_j \]

So that the relative risk premium

\[ x_j / (1-p_j)S_j = \frac{c_j}{(1-p_j)S_j} - 1 = \pi_j \quad (4) \]

Since neither \( p_j \) nor \( S_j \) are known, the empirical analysis will adopt the Bayesian concept of maximum ignorance\(^{39}\) and assign equal probability to each state of \( S_j \) so that \( (1-p_j)S_j = p_jS_j = s_j \) and the relative premium for pay-at-risk in (4) reduces to

\[ \pi_j = \left( \frac{c_j}{s_j} \right) - 1 \quad (5) \]