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Innovation and Incentives: Evidence from Corporate R&D

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Abstract:

Beginning in the late 1980s, American corporations began increasingly linking the compensation of central research personnel to the economic objectives of the corporation. This paper examines the impact of the shifting compensation of the directors of corporate research laboratories. Among firms with high stock volatility, a clear relationship emerges: more long-term incentives (e.g. stock options and restricted stock) are associated with more heavily cited patents. These incentives also appear to be somewhat associated with patents of greater generality. When controls for CEO compensation are added to the specification, more long-term incentives for the CEO are associated with fewer, less heavily cited awards.

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1. Introduction

Research and development expenditures have long been understood to be a key driver of economic growth. Yet profound changes in the U.S. corporate R&D sectors over the past two decades have attracted remarkably little attention by economists. This paper seeks to address this gap, by seeking to understand whether the increasingly high-powered incentives of central corporate research leaders are related to the innovation process.

The central corporate R&D laboratory was a dominant feature of the innovation landscape in the U.S. for most of the 20th century. While the concept of the centralized laboratory originated in the German chemical industry, U.S. corporations adopted it with enthusiasm by mid century. These campus-like facilities employed many thousands of researchers, many of whom were free to pursue fundamental science with little direct commercial applicability, most notably Bell Laboratories (with 11 Nobel Laureates) and IBM Central Research (with 5).

Beginning in the late 1980s, however, American corporations began fundamentally rethinking the role of these centralized research facilities (see, for example, the discussions in Rosenbloom and Spencer [1996]). Reflecting both a perception of disappointing commercial returns and intensified competitive pressures, firms undertook a variety of changes to these facilities. These included both paring the size of central research facilities in favor of divisional laboratories and more tightly

linking the compensation of central research personnel to the economic objectives of the corporation.[1]

Numerous observers within the scientific establishment have expressed concern about the long-run implications of these changes. For instance, the National Science Board in 1992 attributed the decline of centralized research facilities to "risk minimization" on the part of corporations and an inappropriate emphasis on "the needs of today's customers" instead of longer-run objectives. Concerns about these patterns have frequently been expressed as well by organizations such as the National Academies of Science and the Council on Competitiveness.

To economists, however, the issue is not so clear-cut. On the one hand, observers such as Jensen [1993] have contrasted the incentives within corporate research facilities unfavorably with those offered by venture capitalists. He suggests that had higher-powered incentives been offered, some of the poor performance of research-intensive firms would have been avoided. In a similar vein, Kortum and Lerner [2000] find that venture-backed firms are approximately three times as efficient in generating innovations than corporate research.

On the other hand, the addition of high-powered incentives could plausibly have deleterious consequences as well. A critical problem, highlighted by the line of work beginning with Holmstrom and Milgrom [1991], is "multi-tasking." In particular, when an agent has multiple tasks to perform, only some of which can be measured with precision, it may make sense to offer compensation schemes with flat or very limited

[1]These changes were frequently dramatic in magnitude. For instance, the head count of Bell Laboratories (now operated by Lucent Technologies) dropped from 35,000 in 1997 to 9,500 in 2005. Microsoft's $8 billion in R&D expenditures in 2003 included $1.3 billion in equity (http://www.spectrum.ieee.org/WEBONLY/publicfeature/nov04/1104rd.html, accessed March 12, 2005).

sensitivity to performance. Otherwise, the agent may neglect the activities that cannot be precisely measured.

Scientists and engineers in research facilities are likely to have a portfolio of projects that they can work on, with varying degree of observability. As the incentives offered by the corporation increase, researchers may be led to spurn riskier but important long-run projects in favor of straightforward efforts (Holmstrom [1989]). As a result, it may make sense to offer weaker incentives in these settings (see also Lazear [1989]).

Moreover, the effect of different types of performance pay may not be uniform. In particular, a series of papers have suggested that compensation in the form of option holdings will lead managers to riskier behavior, because the increased volatility of the firm will translate into option value. Meanwhile, risk-averse managers who receive extensive stock-based compensation and whose human and financial capital is poorly diversified will prefer that their firms make less risky choices. Example of literature where this idea has been developed are Smith and Stulz [1985], Hirshleifer and Suh [1992], and many others.

This question is also related to research on the relationship between authority and incentives in uncertain environments. Recent work suggests that for complex jobs it may be optimal to delegate decision-making to better-informed agents and keep them in check with high-powered incentives (Prendergast [2002]). Also, firms may link pay to global or firm performance measures for specific positions in order to encourage better decisions over project selection that have firm-wide implications (Athey and Roberts [2001]). While corporate research director positions vary across firms, the responsibilities can be

generally characterized as making decisions about research project selection in highly uncertain environments.

This paper examines the relationship between innovation and the shifting compensation of the directors of corporate research laboratories. We find that the compensation of corporate R&D heads changed dramatically over the course of the 1990s, with much greater use of long-term incentives (e.g., restricted stock and stock options). These shifts have mirrored those among other senior managers' compensation.

We then turn to understanding the relationship between these changes and shifts in innovation. We are unable to find consistent patterns among firms whose share price volatility is below the median, but among high volatility firms, a clear relationship emerges: more long-term incentives are associated with more frequent and more heavily cited patents. These incentives also appear to be associated with patents of greater generality. There is little evidence that high-powered incentives lead to the neglect of more tangential research or to a substitution of patents for publications in scientific journals: greater incentives generally are not associated with any drop-off in the volume of scientific publication. When controls for the compensation of the chief executive officer (CEO) are added to the specification, more high-powered incentives for the CEO lead to fewer, less heavily cited awards.

Finally, we examine the question of whether there is a causal relationship between the innovation measures and the long-term incentives of corporate research directors: specifically, whether we find support for the hypothesis that long-term incentives lead to better R&D decisions and more-heavily cited patents. While we must be careful in the interpretation of our analysis, we present one analysis that supports the incentives-

interpretation of the result. Using the methodology of Aggarwal and Samwick [1999], we show that the sensitivity of performance is positively related to performance, but declines with the volatility of performance. The negative risk-incentive relationship holds in firms with centralized R&D and R&D-intensive firms, which are precisely the firms where we anticipate that corporate R&D decisions will have the greatest effect on firm value, but not elsewhere. Furthermore, we find no relationship between patent citations and three other senior staff positions: General Counsel, Human Resources and Chief Financial Officer.

This paper is related to two sets of work. First, a number of articles, particularly in the accounting literature, have sought to relate R&D choices to the incentives of top management. Three pieces deserve special mention. Dechow and Sloan [1991] examines R&D expenditures of firms with CEOs in their final years of office, to determine whether they cut spending to improve short-term earnings performance. They find that these firms spend less on R&D during the CEOs' final years, unless the head has significant equity holdings in the firm. Holthausen, Larcker, and Sloan [1995] examine whether the compensation for the divisional CEO is related to subsequent innovative activity within the division. They find at least weak evidence that when divisional CEOs have a higher proportion of total compensation tied to long-term components, the ratio of patent awards to sales in the division rises. Finally, Eng and Shackell [2001] find no evidence that the adoption of long-term performance plans for senior management has implications for R&D spending, once the presence of holdings by institutional investors are controlled for. Because the compensation of officials directly responsible for managing R&D are typically not included in filings with the U.S. Securities and

Exchange Commission, these works focus on the compensation of senior managers (Holthausen, et al, being an exception).

The second, smaller body of work more explicitly seeks to relate the organizational structure of R&D to innovation. Cockburn, Henderson, and Stern [1999] examine the intensity of research workers' incentives for the distinct tasks of basic and applied research. Motivated by the multi-tasking framework, they suggest that when incentives are strong along one dimension, firms will set high-powered incentives for effort along other dimensions that compete for the worker's effort and attention. They find that firms who promote individuals based on scientific publications (which are likely to reflect basic research) also provide more intense incentives for success in applied research, by increasing programs budgets in response to patent filings. Argyres and Silverman [2004] examine how the centralization of a firm's R&D organizational structure and R&D funding authority affects its innovations. They find that in particular, firms with centralized R&D organizations generate innovations that are more cited, and are cited across a broader range of technological areas, than do firms with decentralized R&D organizations.[2]

The plan of this paper is as follows. Section 2 describes the data employed in the study. In Section 3, we present the key regression analyses and robustness tests. The final section concludes the paper.

2. Data Description

[2]This paper is also related to Guedj and Scharfstein [2004], who compare 235 cancer drugs developed by early-stage biotechnology companies and established pharmaceutical corporations. They find that early-stage firms are much more likely to advance drugs from Phase I to Phase II of clinical trials, but that these drugs are much less likely to reach later stages of trials or to be approved. This pattern is particularly pronounced in biotechnology companies with large cash reserves. They attribute this pattern to agency problems between managers of single-product firms and their investors.

2.1 Compensation Data

The primary dataset from which we draw our sample is an unbalanced panel of more than 300 publicly traded U.S. firms over the years 1987 to 1998, spanning a number of industries. This has a rich array of compensation data for senior and middle corporate management.

The data are collected from a confidential compensation survey conducted by Hewitt Associates, a leading human resources consulting firm specializing in executive compensation and benefits. The survey is the largest private compensation survey (as measured by the number of participating firms). The survey participants are typically the leaders in their sectors. More than 75% of the firms in the dataset are listed as Fortune 500 firms in at least one year and more than 85% are listed as Fortune 1000 firms. In general, Hewitt survey participants also participate in other compensation consulting firm surveys (e.g., Hay Associates, Mercer, Towers Perrin, to name a few) and do so primarily to receive information about pay practices to use as a competitive benchmark in evaluating their own compensation programs. It is important to note that the sample includes many more firms than Hewitt's consulting client base, with at least 50% of the survey participants having no other relationship to Hewitt. Based on several analyses described in Appendix A, we conclude that the survey sample is probably most representative of Fortune 500 firms.

The survey is comprehensive in that it collects detailed compensation data on many senior and middle management positions, including both operational positions (e.g., Chief Operations Officer and Divisional CEO) and staff positions (e.g., Chief

Financial Officer and Head of Human Resources). The survey typically covers all the positions at the top of the hierarchy and a sample of positions lower down.[3]

The data for each position include all components of compensation including salary, bonus, restricted stock, stock options, and other forms of long-term incentives (e.g., performance units). An observation in the dataset is a managerial position within a firm in a year. To ensure consistency in matching these positions across firms, the survey provides benchmark position descriptions and collects additional data for each position leading to a rich dataset. Hence, in addition to data on all aspects of compensation, the dataset includes position-specific characteristics such as job title, the title of the position that the job reports to (i.e., the position's boss), number of positions between the position and the CEO in the organizational hierarchy, and both the incumbent's status as a corporate officer and tenure in position.

In this paper, we focus on the subset of firms that report compensation data for the most senior executive responsible for corporate level R&D in the Hewitt survey and that report R&D expenditures in Compustat. This leads to a sample of approximately 800 firm-years and 140 firms. In some cases, the firms also have divisional R&D managers. As a basis of comparison, we also document compensation for Chief Executive Officers (CEOs) and for the General Counsel position. The definitions for each of these positions, and additional R&D positions included in the survey, are described in Appendix B.

We believe the survey data are accurate for several reasons. First, Hewitt personnel are knowledgeable about survey participants because they are assigned to specific participants for several years. Furthermore, while the participating firms initially

[3]The Hewitt database is thus far more comprehensive than the SEC filings which form the basis for the ExecuComp database. Because firms are required to only file information on the top five executive officers, information on R&D executives is rarely included in these sources.

match their positions to the benchmark positions in the survey, Hewitt personnel follow up to verify accuracy and spend additional 8 to 10 hours on each questionnaire, evaluating the consistency of responses with public data (e.g., proxy statements) and across years. Finally, participants have an incentive to match positions correctly and provide accurate data because they use the survey results to set pay levels and design management compensation programs.

The above data are supplemented with information from Compustat for financial data and CRSP for shareholder returns. While the Hewitt survey is conducted in April of each year and the compensation data describe the firm in the year of survey completion, some statistics (e.g., number of employees in the firm) represent the end of the most recent fiscal year. To maintain consistency, we match Compustat and CRSP data using the year prior to the year of the survey.

In Panel A of Table 1, we present descriptive statistics for the firms in the sample. While the dataset includes 141 firms, the exact number varies over the period, as firms enter and exit as survey participants. The firms in the sample are large firms with average sales of approximately $11.0 billion, assets of $12.1 billion, and a ratio of R&D expense to sales of 5%. In 63% of the firm-years, the firm reports a corporate R&D position and does not report divisional R&D managers. In 48% of the firm-years, the corporate R&D position reports directly to the CEO in the organizational hierarchy. Finally, the sample firms span many industrial sectors of the economy, with some concentration in the chemical, machinery, transportation equipment, paper, electrical, and instrumentation industries (Table 1, Panel B).

A natural question is whether the individuals recorded as R&D heads are indeed the key decision-makers, or rather outward-looking officials primarily responsible for being the R&D laboratories' "public face." While it is difficult to answer this question definitively, we can examine these individuals' titles. The ten most frequently represented titles are reported in Panel C of Table 1. These titles seem consistent with individuals who are involved with the day-to-day management of the firms' research efforts.

2.2. Innovation Data

The survey data for firms reporting a corporate R&D position are linked to patent data from the National Bureau of Economic Research (NBER) and publication data from Thomson/ISI's Web of Science.

For patent data, we employ the NBER Patent Citations Database, which includes all patent awards and patent citations between 1975 and 1999. We match the CUSIPs of the firms in Hewitt sample to those employed in the Citations Database. One complication is posed by firms that went public after 1989 that are included in the Hewitt database, as the CUSIPs for these firms are not included in the NBER database. In these instances, we add the CUSIP to the patents awarded to the firm and any subsidiaries in the NBER database.

From the NBER database, we collect the following information:

- The number of awards to the firm in a given year.
- The mean and median number of citations to the firm's patents awarded in a given year.

- The mean and median number of adjusted citations to the firm's patents awarded in a given year: that is, the number of citations adjusted by the expected number of citations that we would anticipate that the firms' patents would receive. We undertake this adjustment by estimating a regression using all patents awarded over this period, with controls for the year of the award, the technology subclass (see Hall, Jaffe, and Trajtenberg [2001] for a description), and a dummy indicating the patentee is a domestic entity.[4]
- The "generality" of the firm's awards in a given year. This frequently employed measure (see Jaffe and Trajtenberg [2002]) is one minus the Herfindahl Index across technology classes of the patent citations received by a patent. Thus, a patent with a generality score approaching zero suggests that the patent has very narrow use, while a measure of one suggests that a diverse array of subsequent patents draw upon the award. We compute the mean of the generality measure for all patents awarded each firm in every year.
- The "originality" of the firm's awards in a given year. This measure is computed similarly, but captures the concentration of the citations made by the patent to earlier awards. Once again, we average the patents awarded in each firm-year.
- The extent of concentration of the firm's awards in a given year. We compute the Herfindahl Index of the firm's awards, again employing the technology subclasses in the NBER Patent Citations Database.

[4]We employ the subclasses in the NBER scheme rather than U.S. Patent and Trademark Office's Patent Classification scheme due to the limitations of the latter scheme, which does not correspond well to technological classifications (see Lerner [1994] for a discussion). Foreign patentees may be cited less, as often their original patent filing in another nation is cited instead of the award in the United States.

While our primary focus is on patented technologies, we also wish to understand the changes in publications. We determine the number of publications by authors associated with each firm through the use of the Web of Science database. We use as keywords the names of the firms in the Hewitt database and their major subsidiaries.[5]

One challenging issue has to do with the timing of awards and R&D expenditures. The economics literature has argued that patent applications are generated nearly contemporaneously with R&D expenditures (Hall, Griliches, and Hausman [1986]). Thus, it would be clearly problematic to relate the number of patent awards in 1995 to compensation levels in 1995, as the patents would have been filed on average two years before (the typical patent took approximately two years to issue over this period[6]). Instead, we employ in our base specifications a two-year lag for patents, relating patents awarded in 1995 to compensation levels in 1993. Similarly, reflecting the relatively short pendencies at most applied science and engineering journals (Adams, Clemmons, and Stephan [2004]), we relate publications appearing in 1995 to compensation levels in 1994.

It might be wondered why we do not instead employ applications: for instance, relating applications filed in 1995 to compensation levels in that year. Our reluctance to do so reflects the facts that (a) the extent of patent pendency is not random and (b) the substantial truncation bias affecting the sample. Johnson and Popp [2003] show that more important patents appear to take longer to issue, with a significant tail of patents taking

[5]Our search procedure did not allow us to identify citations to these articles akin to those of patents. While Thomson offered to sell us the citation data, the cost would have been in the six figures.
[6]For instance, Popp, Juhl, and Johnson [2004] find that the median patent awarded between 1976 and 1996 took 23 months to issue.

10 years or more.[7] Since our compensation data begins in 1988, this would mean that the count of applications in a significant number of years (certainly, at least half the sample) would be truncated. Moreover, some of the most important patents would not be included in the tabulations of mean citations and other measures. If we could be assured that this pattern would introduce no systematic bias, we could perhaps ignore it, but it is hard to be confident. While the use of awards will introduce noise into the analysis (some awards will actually have been applied for less than two years before, while others will have been done so three or more years earlier), the approach should not raise concerns about systematic biases.

Below, we will examine the robustness of the analysis to different approaches. For instance, rather than employing a two-year lag between patent awards and compensation data, we employ a one- and three-year lag. Similarly, we employ the application data despite our reservations with it. The critical results continue to hold as before.

As noted above, the NBER Patent database includes all awards and citations through the end of 1999. Thus, in our regressions, we will be only employing data on compensation levels between 1988 and 1997.[8]

2.3. Summary Statistics

This study primarily focuses on compensation for executives with corporate R&D

[7]Until the end of the period under study, the U.S. Patent and Trademark Office only published issued patents. The fact that a firm had made a patent application that had not issued was not disclosed.

[8] An additional complication is introduced by the fact that few patents garner a significant number of citations in their first year of issue. When employing citation analyses, we explore the robustness to only employing patents that have had at least two years to be cited: for instance, we repeat Table 4, only employing compensation data between 1988 and 1995 in the citation regressions.

responsibility. We document each component of pay: salary, bonus, and long-term compensation. The pay tied to long-term components includes restricted stock, stock options, and other components of long-term compensation as calculated by Hewitt Associates.[9] We also report the ratio of bonus to cash compensation (or salary plus bonus) and the ratio of long-term compensation to cash compensation. We focus on long-term compensation because decisions made by corporate R&D executives have a longer-time horizon relative to decisions made by other executives, e.g., those responsible for manufacturing, marketing and sales. And, payoffs associated with investing in innovation are not likely to be realized immediately.

We analyze both cash compensation (salary and bonus) and total compensation. We also analyze several measures of performance-based pay as proxies for the incentives of corporate R&D executives. The first measure is the ratio of the value of long-term compensation to cash compensation. This measure is similar to that used in Holthausen, Larcker, and Sloan [1995]. We also analyze two distinct measures of long-term compensation: the ratio of the value of stock options to cash compensation and the ratio of restricted stock to cash compensation. Finally, as a measure of short-term incentives, we analyze the fraction of cash compensation from annual bonuses.

In Panel A of Table 2, we report summary statistics of several pay measures for the corporate R&D position, the CEO, and the General Counsel position. Compensation variables are denominated in 1996 dollars. Sample averages for the corporate R&D

[9] These measures represent ex ante assessments of the value of long-term compensation and are computed by Hewitt Associates. Stock options are valued using a modified version of Black-Scholes that takes into account firm-specific vesting and termination provisions in addition to the standard variables of interest rates, stock price volatility, and dividends. As is standard practice among compensation consulting firms, the other components of long-term incentives (i.e., restricted stock, performance units, and performance shares) are valued using an economic valuation similar to Black-Scholes that takes into account firm-specific vesting, term provisions, and the probability of achieving performance goals.

position for salary and bonus (or cash compensation), ratio of bonus to cash compensation (ST incentive ratio), ratio of long-term compensation to cash compensation (LT incentive ratio), and total compensation are $380,039, 27.7%, 59.2%, and $641,559, respectively. Comparable sample averages for the CEO position are $1,390,899, 35.7%, 98.9%, and $2,994,476 respectively. Finally, sample averages for the General Counsel position are $416,056, 28.8%, 60.2%, and $703,066, respectively. Consistent with the findings of the CEO literature, long-term compensation comprises a much greater proportion of CEO pay relative to both Corporate R&D and General Counsel positions. The long-term incentive ratio for the CEO, on average, is more than 50% greater than that for the other two positions.[10]

In Panel B of Table 2, we document changes in cash compensation and both the fraction of bonus and the fraction of long-term compensation of salary plus bonus for the corporate R&D position, the CEO, and the General Counsel position over the period of study. The table includes firms that appear in the dataset for two consecutive years. By focusing on this set of observations, we minimize biases from the exit and entry of firms. As we see, there is an upward trend in both annual and long-term compensation as a fraction of cash compensation for all three positions over time for this sample. Also, the increase in the ratio of long-term compensation is much greater than that of the ratio of

[10]This "flow" measure of long-term compensation understates incentive pay for the CEO relative to other executives because CEOs hold a much higher percentage of a firm's stock in comparison to other managers. Recent research on CEO compensation accounts for the incentives from the holding of stock and stock options (in addition to annual grants of restricted stock and options). In contrast to ExecuComp data, we only observe annual grants of options and restricted stock and not stock holdings. Thus, while we can calculate the implicit pay-performance sensitivity (PPS) for the sample as in Aggarwal and Samwick [1999], we do not have a long enough time-series to calculate a firm or executive-specific PPS measure. Furthermore, in order for us to construct an explicit measure of incentives for an executive based on stock ownership from annual grants of options and restricted stock, we would have to make many assumptions about initial holdings, exercising of options, and vesting restrictions on both options and restricted stock.

annual bonus and the increase in the former is much greater for the CEO relative to the other two positions. (The patterns for the whole sample are qualitatively similar.)

The ratio of long-term compensation to cash compensation is one measure of performance-based pay that might be particularly important in the effect it has on executive decisions to invest in innovation. It is also an *ex ante* measure in that its value is based on expectations of future performance.

At the same time, however, it is not a direct measure of pay-performance sensitivity. Much of the recent literature on executive incentives estimates pay-performance sensitivities, specifically the sensitivity of pay to changes in shareholder returns. This research documents that most of the pay-performance sensitivity for senior executives (or PPS) can be attributed to stock and stock option holdings (e.g., Hall and Liebman [1998], Aggarwal and Samwick [1999]). One important and relevant finding in the empirical literature is support for one of the main predictions of the principal agent model: pay-performance sensitivity is declining in the uncertainty of the environment in which the executive operates (Aggarwal and Samwick [1999]). The basic intuition is that performance-based pay is valued less by risk-averse agents in settings with high uncertainty.

Based on this agency-theoretic prediction, we evaluate whether the relationship between the fraction of performance-based pay and measures of innovation vary with uncertainty. We might expect managerial decisions to invest in innovation to depend on the amount of performance-based pay, but the relationship may be different in firms operating in highly volatile environments. In particular, we might expect the ability of managers to behave in an opportunistic manner to be greater in these instances. Long-run

incentive compensation could thus be anticipated to have a greater impact on research activities in these cases, whether providing positive incentives (as the Jensen view would suggest) or creating multi-tasking problems.[11]

Similar to Aggarwal and Samwick, we use shareholder return volatility as a measure of uncertainty faced by managers and define it as the standard deviation in monthly total return to shareholders over the 60 months preceding the sample year. For example, to compute the return standard deviation for a firm in 1993, we use the standard deviation of monthly returns from January 1988 to December 1992 from CRSP. The standard deviations range from a low of 3.62 to a high of 50.55 with a median of 8.06 and a mean of 8.71. We then calculate the empirical cumulative distribution function of the standard deviations for the firms in our sample in each year. To split our sample into firms with high volatility vs. low volatility, we define *hi_cdfdum* as a dummy variable equal to one if the firm's standard deviation is above the median in a given year and zero otherwise.

In Table 3, we report summary statistics of firm characteristics, pay measures for Corporate R&D and CEO positions, and innovation measures for both the high and low volatility samples. The high-volatility firms are characterized by more intensive R&D spending and more influential patents. These firms tend to be smaller, and to have lower levels of compensation and lower ratios of performance-based pay for the CEO and the central research director positions.

3. Results

[11]One natural question is why then low-volatility firms offer their R&D executives long-term incentives at all. This is a broader question than we cannot answer here, but presumably reflects the accounting and tax benefits or market offerings of these forms of compensation.

3.1. Baseline Analysis

In each table of regressions, we use firm-years as units of observation. We estimate regressions with the same nine measures of innovation as dependent variables introduced above. We typically employ a random effects specification. In these analyses, as well as the subsequent ones, we employ controls for each central R&D director separately.[12] Below we also examine the robustness of the results to the use of a fixed effects specification and the use of industry controls only.

In each case, we employ the logarithm of firm sales (denominated in 1996 dollars), the research intensity (the ratio of the firms' R&D to sales), and dummy variables for the year of the observation. (Again, we explore the robustness of the results to additional control variables below.)

In most tables, we report four sets of analyses. In these analyses, we vary the dependent variable measuring compensation. In particular, we employ:

- The overall compensation level of the corporate R&D director, where we employ the logarithm of compensation in 1996 dollars as the dependent variable.
- The ratio of long-term compensation of the corporate R&D director to the base compensation and bonus in that year.
- The ratio of long-term compensation of the corporate R&D director to base compensation and bonus in that year, as well as the ratio of short-run incentives (the ratio of bonus to base salary and bonus).

[12]We determine turnover of the central R&D head from the Hewitt data. In an alternative specification, we employ effects for each firm. We find that while the explanatory power is not quite as high, the results are qualitatively unchanged.

- The ratio of the two key components of long-term compensation of the corporate R&D director (stock options and restricted stock) to base compensation and bonus in that year.

Table 4 presents the base-line analyses for the firms with high volatility. Here, we see several distinct patterns:

- Higher compensation levels for the corporate R&D director are associated with more cited patents, as well as more concentrated patents. A one-standard deviation increase in the log of total compensation is associated with an increase of 0.77 in mean citations for the firm, which is 16.8% of the sample mean.
- Long-term incentives for the research leader are associated with more patent awards, more heavily cited patents, and patents with greater generality. A one-standard deviation increase in the ratio of long-term incentives to salary plus bonus is associated with an increase of 22.3 patents for the firm, which is 27.1% of the sample mean. A one-standard deviation increase in the ratio of long-term incentives to salary plus bonus is associated with an increase of 0.63 in mean citations for the firm, which is 13.8% of the sample mean.
- Short-term incentives appear to have little impact.
- The long-term incentive effect appears to work through both stock options and restricted stock. Restricted stock grants have the strongest relationship with citations, while options are associated with more patent awards and greater generality. A one-standard deviation increase in the ratio of the value of restricted stock to salary plus bonus is associated with an increase of 0.56 in

mean citations for the firm, which is 12.3% of the sample mean. For stock options, the associated increase is 10.7% of the sample mean.

- Turning to the control variables, larger firms appear to patent more frequent and widely (i.e., the Herfindahl Index of patent classes is lower), and to have fewer citations, as well as to publish more. More research-intensive firms publish more.

These results appear to be more consistent with the Jensen hypothesis: high-powered incentives appear to be associated with more research output and higher quality of research. There seem to be few of the anticipated costs associated with higher-powered incentives: these firms do not increase the concentration of their patent portfolio or reduce the number of publications. .

When we look at the low-volatility firms in Table 5, the results are much weaker. In the first analysis, the only significant patterns are that firms with higher compensation levels for the corporate R&D head patent more. More long-term incentives are only associated with more patents. When we repeat the analyses in Tables 4c and 4d in unreported analyses, few significant patterns emerge.

Moreover, these results are not robust to slight changes in the specification. For instance, when we repeat the analyses in Tables 4 and 5 with some slight changes, such as using random effects for each firm (rather than for each R&D executive) and winsorizing the compensation measures at the 99% level, the basic patterns in Table 4 remain, while the few significant results in Table 5 disappear.

Why do we find results that are specific to the high-volatility sample? One possible explanation is that stock return volatility is correlated with measures that

represent the ability of the corporate R&D head to have an effect on firm value. For example, diversified firms typically demonstrate lower stock return volatility. And, in diversified firms, there may be only one small business unit that is R&D intensive, thereby limiting the importance of R&D decisions. In fact, the data are consistent with this explanation. Using a simple diversification measure, i.e., the number of business segments as reported in Compustat, we find that more diversified firms have more volatile stock returns.

Furthermore, it might be that volatility and diversification are related to the structure of the firm's organization of R&D. Diversified firms might decentralize decision-making of R&D and in these organizations the scope of responsibility of the corporate R&D head is less broad. Consistent with this, we find that firms that only report corporate R&D positions and no R&D at the divisional level have fewer business segments and more volatile stock returns. More broadly, centralization and volatility appear to be working in similar ways. If we partition the sample into firms that are centralized versus those that report both corporate and divisional R&D positions, we find similar results when we partition the sample by volatility.[13]

3.2. Robustness Checks

We undertake a variety of robustness checks of the results. Tables 6 through 9 are four examples of the additional analyses we perform.

[13]These patterns are also consistent with Argyres and Silverman's (2004) finding that firms with centralized R&D organizations generate innovations that have a higher level of impact, and affect a broader range of technological areas, than do firms with decentralized R&D organizations.

First, we employ applications rather than awards, though as discussed above, the use of this measure may pose some concerns about truncation biases. The basic patterns go through as before. Higher compensation is associated more patenting, more citations, and more general awards. More long-term incentives are associated with more frequently cited and more general awards. The results continue to hold when we control for short-term compensation. When we divide the long-term compensation into stock options and restricted stock, however, only the restricted stock results remain statistically significant.

A natural concern is that these results reflect firm-wide compensation patterns. As noted above, earlier studies have suggested that CEO incentives affect innovative performance. In Table 7, we repeat the analysis adding measures of CEO compensation similar to those of the corporate R&D head. The basic patterns for the corporate R&D head remain similar: higher levels of compensation, and more long-term compensation in particular, are associated with more cited and general patents. In these specifications, long-term incentives are associated with more patent filings.

Two results, however, are more challenging to interpret:

- First, long-term compensation for the CEO is negatively associated with the number of and citations to the firm's patents. It is unclear why the effect of compensation on the CEOs would run against that of the corporate R&D director. It may be that while the corporate research directors' grants are closely linked to the performance of the research unit, the CEO's long-term incentives have little relationship.
- Second, when CEO compensation is included, research directors' higher long-term incentives are associated with fewer publications. This may reflect the

fact that researchers at these firms are encouraged to eschew publications in favor of patent filings. Why long-term incentives of the CEOs are associated with *more* publications is less clear.[14]

To further explore whether these results reflect firm-wide compensation patterns, we repeat the analysis of Table 4, but replace compensation of the corporate R&D head with compensation of three senior staff positions: General Counsel, Head of Human Resources, and Chief Financial Officer. In Table 8, we report the estimated coefficients on long-term incentives for these three positions for each measure of innovation. Each coefficient reported in the table is from a separate regression that is analogous to Table 4b for the high-volatility sample: that is, we regress the innovation measure on the ratio of long-term incentives to salary plus bonus, firm size, ratio of R&D to sales, firm and year indicators. While patents are positively correlated with long-term incentives, there is no association between the citation measures and long-term incentives for any of these positions. We might expect that the General Counsel's incentives directly affect the filing of patents, and consistent with this, we find a positive association between incentives and patents. It is more difficult to interpret why this should hold for the Head of Human Resources. Importantly, the uniqueness of the positive associations between long-term incentives and citations for the corporate R&D head are consistent with the explanation that incentives affect decisions for executives responsible for corporate R&D.

We also undertake a variety of unreported robustness checks. As noted above, we winsorize the compensation measures, to delineate the effects of outliers. We estimate

[14]One possibility is that these two forms of compensation are highly correlated with each other. In this case, errors-in-variables might lead to the two coefficients taking on opposite signs with inflated coefficients and statistical significance. When we use the measure of CEO compensation alone (i.e., without the variables measuring the central R&D director), however, the coefficients are of similar sign and magnitude.

ordinary least squares regressions merely employing dummy variables for each industry, but without fixed or random effects. In addition, we use the mean compensation of a number of other staff positions. We also vary the period that we lag the patent awards: that is, we look at the results if we assume the awards are issued one and three years after the application date. In each case, the same basic patterns appear.

When we repeat the specification in Table 4, employing fixed rather than random effects, however, the results are weaker. In the initial analysis of the overall level of compensation, the results disappear: it may well be that the level of compensation reflects fundamental characteristics of the firm. When we examine the effects of long-term incentives, the same qualitative patterns appear. The results, however, are weaker, particularly when we divide long-term compensation into stock options and restricted stock.

In Table 9 we undertake an analysis addressing the possibility that the above results may be driven by differences in the firms' organizational structures. It might be that more incentive-based compensation is associated with various organizational features, which in turn drive the nature of the innovation. Thus, we might be falsely imputing significance to the compensation variables, when it is really the organizational variables that are critical.

We are already partially addressing this issue by employing random and fixed effects in the regressions. A wealth of sociological literature (e.g., Baron, Hannon, and Burton [1999]) has suggested that organizational features are very persistent, and typically survive even as the management team turns over. Thus, these effects should absorb much of the differences.

Another way to address this concern is to explicitly control for the organizational structure. In particular, it might be argued that during this period, the decision-making authority of the corporate R&D head's position was considerably augmented. Put in the language of economic theory, R&D chiefs may have moved from having "formal" to "real" authority over the employees they supervised (Aghion and Tirole [1997], Dessein [2002]).

To control for this possibility, we examine whether the head of central R&D reports directly to the CEO. We add a dummy variable for such observations, as well as an interaction between the compensation measures and the dummy. We find that these controls make little difference to the results. The only major changes in the results are that (a) long-term compensation is positively related to the volume of patenting only when the R&D director reports directly to the CEO, and (b) more long-term compensation has no negative impact on publications only if the research director reports directly to the CEO (otherwise, the effect is negative).

3.3. Examining the Incentives Hypothesis

We have been circumspect in the interpretation of these results. The positive association between innovation measures and long-term incentives of corporate R&D directors is consistent with the hypothesis that equity-based incentives lead to better decisions about project selection at the corporate level. However, alternative explanations certainly exist, such as the possibility that these incentives are offered to

attract high-quality executives or that these awards are a reward for past successful performance.[15] Definitively establishing one hypothesis is very challenging.

Since agency theory predicts a negative relation between risk and incentives, if performance-based pay is offered to provide incentives, we should expect to see the sensitivity of pay to performance to decline in the volatility of the performance measure. To test this for the corporate R&D head position in our sample of firms, we replicate the analysis of Aggarwal and Samwick (1999) using total compensation, shareholder returns as the performance measure, and the empirical cumulative distribution function (CDF) of the standard deviation of monthly returns over the prior 60 months as the measure of risk. Based on the "implicit" method, we estimate a regression of total compensation for the corporate R&D head on stock returns, the CDF of return standard deviation, an interaction term between stock returns and the CDF, and firm and year indicators. Total compensation is defined as salary, bonus, and the value of long-term incentives. In Table 10, we report the estimated coefficients on the performance measure, the interaction term between performance and risk, and the risk measure based on two measures of shareholder returns. We first estimate the coefficients for the whole sample and then split the sample using two criteria: (i) firms that only report a corporate R&D head position and firms that report both corporate and divisional R&D managers; and (ii) firms above the sample median in the ratio of R&D to sales and firms below the median.

Based on the whole sample and for both shareholder return measures, we find a negative risk-incentive relation, i.e., the coefficient on the performance measure is positive and significant, while that on the interaction between performance and risk is

[15]Based on interviews with Hewitt Associates and human resource personnel, awarding stock options and restricted stock for past performance is relatively uncommon.

negative and significant. The sensitivity of pay is positively related to performance and declines in the volatility of the performance measure. These findings are consistent with offering stock-based pay to provide incentives. Furthermore, we find that this relation holds in the partition of firms with centralized R&D and R&D-intensive firms, but not in firms that report both corporate and divisional R&D managers or low R&D firms. These results are consistent with the explanation that stock-based pay is more effective when the decisions of the corporate R&D head have the greatest effect on stock returns: that is, in R&D-intensive firms with centralized decision-making.

4. Conclusions

Beginning in the late 1980s, American corporations began linking the compensation of central research personnel to the economic objectives of the corporation. This trend has attracted considerable concern in technology policy circles, while economic theory suggests widely different consequences.

This paper examines the relationship between innovation and the shifting compensation of the directors of corporate research laboratories over the 1990s. Among firms with high stock volatility, a clear relationship emerges: more long-term incentives are associated with more frequent and more heavily cited patents. These incentives also appear to be more weakly associated with patents of greater generality. When controls for CEO compensation are added to the specification, these appear to take on the opposite sign: more long-term incentives for the CEO lead to fewer, less heavily cited awards. The results appear to be robust to many of the controls we employ.

Two important limitations of this analysis—and opportunities for future work—should be noted. We confine our analysis here to the relationship between innovation and the shifting compensation on the head of the central research laboratory. It would certainly be interesting to examine the compensation schemes of divisional research directors as well. We intend to examine this question in future work.

At the same time, the Hewitt data does not enable us to examine what are arguably the most interesting compensation choices: the incentives offered rank-and-file scientists and engineers. Field-based evidence suggests that the compensation has traditionally been extremely flat (Orth, Bailey, and Wolek [1964], Neumayer [1973]). Understanding the extent to which this pattern still holds, and its implications for innovation, is an important challenge.

Second, it is by no means clear that our measures can capture shifts in truly groundbreaking research. It may be that profound changes in corporate research have occurred, but that the consequences of these shifts can only be measured after several decades. Nonetheless, the absence of deleterious patterns using the measures that we can employ is striking.

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Table 1 (Panel A): Summary Statistics

Variable	Mean	Std. Dev.	Min	Max	Obs
Firm Sales ($ millions)	11038	21307	86	165370	818
Assets ($ millions)	12142	29465	103	279097	818
R&D/Sales ratio	0.05	0.05	0.00	0.49	818
Volatility of Shareholder Returns	8.71	3.53	3.62	50.55	762
Patent Count	82.15	168.09	0.00	1936.00	735
Citations (mean)	4.58	4.48	0.00	29.00	735
Citations (median)	3.11	3.44	0.00	29.00	735
Adjusted Citations (mean)	0.56	2.99	-4.85	21.39	735
Adjusted Citations (median)	-0.74	2.33	-5.49	21.39	735
Generality (mean)	0.28	0.16	0.00	0.86	702
Originality (mean)	0.42	0.13	0.00	0.74	735
Firm Herfindahl of Patents (hhi)	0.28	0.20	0.00	1.00	735
Publications	112.67	323.41	0.00	2651.00	779
Centralized R&D only	0.63	0.48	0.00	1.00	818
Direct Report to CEO (corporate R&D position)	0.48	0.50	0.00	1.00	813

Note: Sample includes firms that report both a corporate R&D position in the compensation survey and R&D expenditures in Compustat. Volatility of Shareholder Returns is defined as the standard deviation of monthly returns (percentage) based on the previous 60 months. Patent count is defined as the sum of the number of patents awarded in that firm-year. Citations are defined as the mean and median of the number of citations in patents awarded in that firm-year. Adjusted citations is defined as the mean and median of the number of adjusted citations per firm-year, where the adjustment entails subtracting the mean number of patents received by awards in that technology class in the same award year. Generality is a measure of the breadth of patents that cite the firm's patents in a given year; originality the breadth of cited patents. Patent Herfindahl is an index of the number of patent classes into which the firm's patents fall. Publications are defined as publications by affiliates of that company included in the ISI Web of Science. Centralized R&D only is a dummy variable equal to one if the firm reports a corporate R&D position, but no divisional R&D positions in a firm-year, and zero otherwise. Direct Report to CEO is a dummy variable equal to one if the corporate R&D position reports directly to the CEO in the organizational hierarchy.

Table 1 (Panel B): Industries of Firms in Sample
Distribution of Sample by 2-digit SIC Code

Industry (2-digit SIC)	N (firm-yrs)	% of Sample
Chemical (28)	167	20.4
Machinery (35)	120	14.7
Transportation Equipment (37)	109	13.3
Paper (26)	66	8.1
Electrical (36)	57	7.0
Instrumentation (38)	56	6.8
Food (20)	52	6.4
Communications (48)	25	3.1
Other	166	20.3
Total	818	100

Note: Sample includes firms that report both a corporate R&D position in the compensation survey and R&D expenditures in Compustat.

Table 1 (Panel C): Ten Most Frequent Titles for Executive of Corporate Research and Development in Sample

Rank	Title
1	Vice President- Research and Development
2	Vice President- Technology
3	Vice President- Engineering
4	Senior Vice President- Technology
5	Senior Vice President- Research and Development
6	Director- Research and Development
7	Vice President- Science and Technology
8	Executive Vice President- Research and Development
9	Vice President- Research
10	Vice President – Corporate Technology

Table 2 (Panel A): Summary Statistics
Compensation of Corporate R&D, CEO, and General Counsel Positions

Variable	Mean	Std. Dev	Min	Max	Obs
Corporate R&D Position					
Salary+Bonus (constant 1996 $)	380039	204768	99952	1969598	817
ST incentive ratio (Bonus/(Salary+Bonus))	0.277	0.142	0.000	0.750	817
LT incentive ratio (Long-Term Incentive/(Salary+Bonus))	0.592	0.521	0.000	5.034	817
Total Compensation (constant 1996 $)	641559	502934	99952	5267421	817
Chief Executive Officer					
Salary+Bonus (constant 1996 $)	1390899	904192	361536	11100000	786
ST incentive ratio (Bonus/(Salary+Bonus))	0.357	0.182	0.000	0.870	786
LT incentive ratio (Long-Term Incentive/(Salary+Bonus))	0.989	0.911	0.000	11.027	786
Total Compensation (constant 1996 $)	2994476	3113832	364478	35600000	786
General Counsel Position					
Salary+Bonus (constant 1996 $)	416056	195188	79036	1481156	727
ST incentive ratio (Bonus/(Salary+Bonus))	0.288	0.145	0.000	0.668	727
LT incentive ratio (Long-Term Incentive/(Salary+Bonus))	0.602	0.463	0.000	3.471	727
Total Compensation (constant 1996 $)	703066	495383	81332	4908149	727

Note: Sample includes firms that report a corporate R&D position in the compensation survey and R&D expenditures in Compustat. Compensation variables are denominated in 1996 dollars. The annualized value of long-term compensation is computed by Hewitt Associates. Stock options are valued using a modified version of Black-Scholes that takes into account vesting and termination provisions in addition to the standard variables of interest rates, stock price volatility, and dividends. As is standard practice among compensation consulting firms, the other components of long-term incentives (i.e., restricted stock, performance units and performance shares) are valued using an economic valuation similar to Black-Scholes that takes into account vesting, term provisions, and the probability of achieving performance goals.

Table 2 (Panel B): Trends in Compensation of Corporate R&D, CEO and General Counsel Positions

	Corporate R&D Position			CEO			General Counsel Positions			
Year	Salary+Bonus	LT Incentive Ratio	ST Incentive Ratio	Salary+Bonus	LT Incentive Ratio	ST Incentive Ratio	Salary+Bonus	LT Incentive Ratio	ST Incentive Ratio	Firm-years (N)
1988	353661	0.387	0.278	1158623	0.637	0.341	376612	0.365	0.293	50
1989	355525	0.380	0.253	1215221	0.605	0.314	384022	0.403	0.272	51
1990	341902	0.455	0.222	1187175	0.738	0.296	373742	0.474	0.239	56
1991	344507	0.568	0.218	1128942	0.810	0.271	355705	0.541	0.226	62
1992	384016	0.524	0.262	1256524	0.848	0.319	388355	0.487	0.260	66
1993	353783	0.600	0.231	1267873	0.851	0.318	394381	0.534	0.238	72
1994	409573	0.610	0.321	1576426	0.911	0.416	461453	0.564	0.326	62
1995	438664	0.696	0.339	1741238	1.215	0.446	498237	0.749	0.351	54
1996	412076	0.822	0.307	1910300	1.517	0.422	526212	1.089	0.355	52
1997	430593	0.872	0.328	1908689	1.747	0.442	485094	0.988	0.327	48
1998	480092	0.868	0.345	2037057	1.677	0.444	504794	0.964	0.344	39

Note: Sample includes firms that report both a corporate R&D position in the compensation survey and R&D expenditures in Compustat for two consecutive years. Compensation variables are denominated in 1996 dollars. The annualized value of long-term compensation is computed by Hewitt Associates. Stock options are valued using a modified version of Black-Scholes that takes into account vesting and termination provisions in addition to the standard variables of interest rates, stock price volatility, and dividends. As is standard practice among compensation consulting firms, the other components of long-term incentives (i.e., restricted stock, performance units and performance shares) are valued using an economic valuation similar to Black-Scholes that takes into account vesting, term provisions, and the probability of achieving performance goals. LT incentive ratio is the ratio of long-term incentives, such as restricted stock and option grants, to salary and bonus. ST incentive ratio is the ratio of bonus to salary and bonus.

Table 3: Summary Statistics---Sample Split by Shareholder Return Volatility—High vs. Low

I. Firm Variables-Sample Means and Medians

	Sales	R&D/Sales	Volatility	Centralized R&D only	Direct Report to CEO	Sales	R&D/Sales	Volatility	Centralized R&D only	Direct Report to CEO
	Mean					Median				
Hi Volatility Sample	8662.48	0.053	10.63	0.68	0.45	2753.51	0.034	9.73	1	0
Lo Volatility Sample	14996.52	0.040	6.50	0.55	0.52	7049.15	0.031	6.40	1	1

II. Pay Measures—Sample Means and Median

	Total Comp. 1996 $	Bonus/ Cash	LT Comp./ Cash	Options/ Cash	Rest. Stock/ Cash	Total Comp. 1996 $	Bonus/ Cash	LT Comp./ Cash	Options/ Cash	Rest. Stock/ Cash
a. Corporate R&D Position										
	Mean					Median				
Hi Volatility Sample	603845	0.256	0.587	0.441	0.055	459213.4	0.270	0.435	0.297	0
Lo Volatility Sample	716332	0.307	0.635	0.457	0.044	617319.6	0.323	0.544	0.359	0
b. Chief Executive Officer Position										
	Mean					Median				
Hi Volatility Sample	2638013	0.327	0.970	0.721	0.089	1691900	0.355	0.736	0.460	0
Lo Volatility Sample	3257250	0.399	1.063	0.759	0.114	2643936	0.431	0.875	0.533	0

III. Innovation Measures—Sample Means

	Patent Counts	Mean of Citations	Median of Citations	Mean of Adj. Citations	Median of Adj. Citations	Mean of Generality	Mean of Originality	HHI for Firm	Publications	
Hi Volatility Sample	75.72	4.97	3.39	0.65	-0.80	0.30	0.43	0.29	62.50	
Lo Volatility Sample	98.07	3.93	2.52	0.28	-0.89	0.25	0.42	0.25	186.50	

Note: Sample includes firms that report a corporate R&D position in the compensation survey, R&D expenditures in Compustat and 60 months of historical stock returns to calculate standard deviations. Volatility of Shareholder Returns is defined as the standard deviation of monthly returns (percentage) based on the previous 60 months. The sample is split into firms with above and below median values of the empirical cumulative distribution function (CDF) of volatility of returns of sample firms in a given year. Options/ Cash and Restricted Stock/ Cash are the ratios of the value of stock option grants and restricted stock to salary plus bonus, respectively. Patent Count is the number of patent awards. Mean and median of citations are based on citations through 1999 and are computed on a yearly basis. Adjusted citations control for the technology subclass, year of the award, and the location of the patentee. Original and generality are based on citation patterns (see text). HHI for firm is the Herfindahl Index of the firms' patent filings in each year across technology subclasses. Publications are the number of publications in Web of Science. See earlier tables for other variable definitions.

Table 4a: Firm Innovation Measures and Corporate R&D Manager (log) Total Compensation---High Volatility Sample
Random Effects Specification (RD Corp Manager Random Effects)

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
	Patent Count	Mean of Citations	Median of Citations	Mean of Adjusted Citations	Median of Adjusted Citations	Mean of Generality	Mean of Originality	HHI for Firm	Publications
Log (total comp.) for RD Corp Manager	31.405*	1.253**	1.193***	1.152***	0.999***	0.026	-0.008	0.062**	2.578
	(16.806)	(0.498)	(0.382)	(0.445)	(0.319)	(0.017)	(0.017)	(0.026)	(18.885)
Log (firm sales)	73.850***	-0.582**	-0.539**	-0.594**	-0.508***	-0.010	-0.007	-0.071***	72.634***
	(13.096)	(0.295)	(0.216)	(0.246)	(0.169)	(0.009)	(0.009)	(0.014)	(13.565)
R&D/firm sales	263.845	11.239**	4.135	2.732	-3.652	0.315*	-0.261	-0.337	1,000.960***
	(237.990)	(5.387)	(3.947)	(4.493)	(3.085)	(0.168)	(0.172)	(0.262)	(246.852)
Constant	-989.434***	-3.646	-5.097	-9.088*	-9.770***	0.160	0.605***	0.042	-629.328***
	(202.897)	(5.625)	(4.282)	(4.966)	(3.535)	(0.189)	(0.188)	(0.287)	(222.840)
Observations	347	347	347	347	347	328	347	347	365
Number of RD Corp position managers	127	127	127	127	127	120	127	127	125

Table 4b: Firm Innovation Measures and Corporate R&D Manager LT Incentive Ratio---High Volatility Sample
Random Effects Specification (RD Corp Manager Random Effects)

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
	Patent Count	Mean of Citations	Median of Citations	Mean of Adjusted Citations	Median of Adjusted Citations	Mean of Generality	Mean of Originality	HHI for Firm	Publications
LT comp./ (salary+bonus) for RD Corp Manager	42.492***	1.207***	0.976***	0.886**	0.514**	0.031**	0.007	0.022	-6.313
	(13.512)	(0.397)	(0.306)	(0.358)	(0.261)	(0.013)	(0.013)	(0.021)	(14.904)
Log (firm sales)	79.451***	-0.373	-0.321*	-0.380*	-0.284*	-0.007	-0.011	-0.055***	74.268***
	(11.986)	(0.258)	(0.188)	(0.217)	(0.149)	(0.008)	(0.008)	(0.013)	(12.307)
R&D/firm sales	308.411	13.291**	6.377*	5.091	-1.108	0.347**	-0.300*	-0.161	1,011.875***
	(233.736)	(5.160)	(3.769)	(4.355)	(3.016)	(0.157)	(0.164)	(0.258)	(241.596)
Constant	-654.485***	10.181***	8.004***	3.552*	1.006	0.450***	0.529***	0.702***	-605.439***
	(101.665)	(2.205)	(1.611)	(1.862)	(1.291)	(0.068)	(0.070)	(0.110)	(105.217)
Observations	347	347	347	347	347	328	347	347	365
Number of RD Corp position managers	127	127	127	127	127	120	127	127	125

Table 4c: Firm Innovation Measures and Corporate R&D Manager LT Incentive and ST Incentive Ratio---High Volatility Sample
Random Effects Specification (RD Corp Manager Random Effects)

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
	Patent Count	Mean of Citations	Median of Citations	Mean of Adjusted Citations	Median of Adjusted Citations	Mean of Generality	Mean of Originality	HHI for Firm	Publications
LT comp./ (salary+bonus) for RD Corp Manager	42.824***	1.198***	0.974***	0.884**	0.527**	0.030**	0.006	0.022	-6.138
	(13.522)	(0.397)	(0.306)	(0.359)	(0.261)	(0.013)	(0.013)	(0.021)	(14.940)
Bonus/(salary+bonus) for RD Corp Manager	29.169	-0.664	0.011	-0.053	0.918	-0.054	-0.059	-0.024	11.605
	(39.512)	(1.320)	(1.050)	(1.242)	(0.932)	(0.046)	(0.046)	(0.071)	(48.088)
Log (firm sales)	78.461***	-0.348	-0.321*	-0.378*	-0.318**	-0.005	-0.009	-0.054***	73.848***
	(12.096)	(0.263)	(0.192)	(0.222)	(0.153)	(0.008)	(0.008)	(0.013)	(12.445)
R&D/firm sales	316.816	13.220**	6.382*	5.092	-1.044	0.344**	-0.306*	-0.165	1,013.967***
	(234.507)	(5.172)	(3.781)	(4.367)	(3.014)	(0.158)	(0.164)	(0.257)	(242.057)
Constant	-655.003***	10.168***	8.004***	3.551*	1.026	0.449***	0.528***	0.701***	-605.354***
	(101.885)	(2.209)	(1.616)	(1.867)	(1.290)	(0.068)	(0.070)	(0.110)	(105.350)
Observations	347	347	347	347	347	328	347	347	365
Number of RD Corp position managers	127	127	127	127	127	120	127	127	125

Table 4d: Firm Innovation Measures and Corporate R&D Manager LT Compensation Components (Stock Options and Restricted Stock)--High Volatility Sample
Random Effects Specification (RD Corp Manager Random Effects)

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
	Patent Count	Mean of Citations	Median of Citations	Mean of Adjusted Citations	Median of Adjusted Citations	Mean of Generality	Mean of Originality	HHI for Firm	Publications
Options/ (salary+bonus) for RD Corp Manager	46.749***	0.993**	0.772**	0.618	0.209	0.031**	-0.005	0.026	-8.171
	(15.010)	(0.429)	(0.326)	(0.383)	(0.274)	(0.014)	(0.015)	(0.023)	(16.604)
Rest. Stock/ (salary+bonus) for RD Corp Mgr.	-27.273	3.470***	2.979***	3.165***	2.387***	0.046	0.060*	0.068	-35.832
	(40.600)	(1.015)	(0.759)	(0.887)	(0.633)	(0.033)	(0.034)	(0.053)	(44.831)
Log (firm sales)	80.119***	-0.266	-0.228	-0.282	-0.208	-0.005	-0.009	-0.054***	73.816***
	(12.008)	(0.248)	(0.178)	(0.205)	(0.138)	(0.008)	(0.008)	(0.013)	(12.328)
R&D/firm sales	312.864	12.864**	6.247*	4.947	-0.873	0.338**	-0.287*	-0.180	1,023.242***
	(234.863)	(5.026)	(3.624)	(4.197)	(2.856)	(0.158)	(0.164)	(0.259)	(243.210)
Constant	-654.192***	9.438***	7.336***	2.868	0.474	0.440***	0.513***	0.692***	-600.224***
	(102.120)	(2.139)	(1.541)	(1.785)	(1.214)	(0.068)	(0.070)	(0.110)	(105.851)
Observations	347	347	347	347	347	328	347	347	365
Number of RD Corp position managers	127	127	127	127	127	120	127	127	125

Note: Sample includes firms that report a corporate R&D position in the compensation survey, R&D expenditures in Compustat, and 60 months of historical stock returns to calculate standard deviations. The sample is only those firms with above the median value of the empirical cumulative distribution function (CDF) of volatility of returns of sample firms in a given year. All regressions include unreported year fixed effects. See earlier tables for variable definitions.

Table 5a: Firm Innovation Measures and Corporate R&D Manager (log) Total Compensation---Low Volatility Sample
Random Effects Specification (RD Corp Manager Random Effects)

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
	Patent Count	Mean of Citations	Median of Citations	Mean of Adjusted Citations	Median of Adjusted Citations	Mean of Generality	Mean of Originality	HHI for Firm	Publications
Log (total comp.) for RD Corp manager	30.240**	-0.582	-0.439	-0.179	0.054	-0.032	-0.007	0.004	3.038
	(11.788)	(0.403)	(0.325)	(0.365)	(0.276)	(0.019)	(0.020)	(0.030)	(15.982)
Log (firm sales)	51.595***	0.434**	0.234	0.121	-0.057	0.015*	0.006	-0.064***	108.911***
	(8.575)	(0.189)	(0.144)	(0.168)	(0.114)	(0.008)	(0.010)	(0.013)	(20.028)
R&D/firm sales	901.080***	16.259***	2.855	7.233	-3.766	0.433	0.040	-0.313	762.587*
	(244.504)	(6.270)	(4.832)	(5.586)	(3.883)	(0.266)	(0.325)	(0.437)	(399.615)
Constant	-791.153***	10.975**	8.587**	1.990	-1.735	0.652***	0.427*	0.744**	-819.935***
	(144.964)	(4.661)	(3.746)	(4.214)	(3.160)	(0.221)	(0.228)	(0.346)	(234.108)
Observations	339	339	339	339	339	327	339	339	364
Number of RD Corp position managers	111	111	111	111	111	110	111	111	113

Table 5b: Firm Innovation Measures and Corporate R&D Manager LT Incentive Ratio---Low Volatility Sample
Random Effects Specification (RD Corp Manager Random Effects)

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
	Patent Count	Mean of Citations	Median of Citations	Mean of Adjusted Citations	Median of Adjusted Citations	Mean of Generality	Mean of Originality	HHI for Firm	Publications
LT comp./ (salary+bonus) for RD Corp Mgr.	24.491***	-0.319	-0.169	-0.293	-0.028	-0.003	0.014	0.002	-5.173
	(8.689)	(0.336)	(0.281)	(0.307)	(0.250)	(0.018)	(0.016)	(0.027)	(10.906)
Log (firm sales)	56.385***	0.343**	0.160	0.110	-0.044	0.009	0.003	-0.063***	112.242***
	(8.016)	(0.172)	(0.130)	(0.152)	(0.102)	(0.007)	(0.009)	(0.012)	(19.253)
R&D/firm sales	1,031.630***	12.959**	0.135	6.588	-3.299	0.213	-0.023	-0.292	790.679**
	(236.626)	(5.688)	(4.302)	(5.036)	(3.391)	(0.232)	(0.301)	(0.386)	(397.907)
Constant	-459.310***	4.496***	3.728***	-0.081	-1.153	0.306***	0.362***	0.784***	-808.685***
	(72.645)	(1.576)	(1.190)	(1.394)	(0.943)	(0.065)	(0.084)	(0.107)	(177.558)
Observations	339	339	339	339	339	327	339	339	364
Number of RD Corp position managers	111	111	111	111	111	110	111	111	113

Note: Sample includes firms that report a corporate R&D position in the compensation survey, R&D expenditures in Compustat, and 60 months of historical stock returns to calculate standard deviations. The sample is only those firms with below the median value of the empirical cumulative distribution function (CDF) of volatility of returns of sample firms in a given year. All regressions include unreported year fixed effects. See earlier tables for variable definitions.

Table 6a: Firm Innovation Measures and Corporate R&D Manager (log) Total Compensation---High Volatility Sample
Random Effects Specification (RD Corp Manager Random Effects)
Applications

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
	Patent Count	Mean of Citations	Median of Citations	Mean of Adjusted Citations	Median of Adjusted Citations	Mean of Generality	Mean of Originality	HHI for Firm	Publications
Log (total comp.) for RD Corp manager	31.580**	2.414***	2.369***	2.141***	2.128***	0.042**	0.009	0.059**	6.902
	(14.958)	(0.748)	(0.622)	(0.646)	(0.502)	(0.021)	(0.019)	(0.028)	(4.815)
Log (firm sales)	97.393***	-0.841**	-0.799**	-0.816**	-0.834***	-0.025**	-0.012	-0.070***	41.275***
	(12.990)	(0.422)	(0.331)	(0.342)	(0.250)	(0.012)	(0.010)	(0.015)	(6.674)
R&D/firm sales	565.434**	9.308	2.270	3.676	-2.308	0.186	-0.170	-0.441	237.681*
	(241.208)	(7.017)	(5.581)	(5.770)	(4.338)	(0.197)	(0.186)	(0.276)	(129.016)
Constant	-1,206.231***	-16.968*	-18.361**	-20.587***	-21.897***	0.082	0.426**	0.060	-373.348***
	(181.520)	(8.839)	(7.308)	(7.581)	(5.883)	(0.252)	(0.211)	(0.313)	(71.837)
Observations	297	236	236	236	236	236	297	297	291
Number of RD Corp position managers	111	93	93	93	93	93	111	111	105

Table 6b: Firm Innovation Measures and Corporate R&D Manager LT Incentive Ratio---High Volatility Sample
Random Effects Specification (RD Corp Manager Random Effects)
Applications

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
	Patent Count	Mean of Citations	Median of Citations	Mean of Adjusted Citations	Median of Adjusted Citations	Mean of Generality	Mean of Originality	HHI for Firm	Publications
LT comp./ (salary+bonus) for RD Corp Mgr.	2.828	2.030***	1.556***	1.827***	1.151**	0.038*	-0.001	0.003	-3.218
	(13.652)	(0.689)	(0.582)	(0.597)	(0.487)	(0.019)	(0.017)	(0.025)	(4.343)
Log (firm sales)	107.548***	-0.526	-0.440	-0.546*	-0.480*	-0.020*	-0.010	-0.053***	45.064***
	(12.031)	(0.394)	(0.315)	(0.321)	(0.249)	(0.011)	(0.009)	(0.014)	(6.247)
R&D/firm sales	668.704***	13.512**	7.247	7.260	2.465	0.256	-0.134	-0.233	253.378**
	(236.863)	(6.676)	(5.403)	(5.524)	(4.354)	(0.184)	(0.177)	(0.270)	(129.271)
Constant	-883.741***	10.549***	8.439***	3.887	2.011	0.564***	0.520***	0.683***	-312.808***
	(101.998)	(3.327)	(2.673)	(2.730)	(2.127)	(0.091)	(0.078)	(0.119)	(58.310)
Observations	297	236	236	236	236	236	297	297	291
Number of RD Corp position managers	111	93	93	93	93	93	111	111	105

Table 6c: Firm Innovation Measures and Corporate R&D Manager LT Incentive and ST Incentive Ratio---High Volatility Sample
Random Effects Specification (RD Corp Manager Random Effects)
Applications

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
	Patent Count	Mean of Citations	Median of Citations	Mean of Adjusted Citations	Median of Adjusted Citations	Mean of Generality	Mean of Originality	HHI for Firm	Publications
LT comp./ (salary+bonus) for RD Corp Mgr.	5.253	2.080***	1.649***	1.849***	1.239**	0.040**	-0.001	0.010	-2.442
	(13.723)	(0.698)	(0.588)	(0.605)	(0.490)	(0.020)	(0.017)	(0.025)	(4.372)
Bonus/(salary+bonus) for RD Corp Manager	46.701	1.146	2.032	0.503	1.734	0.046	0.018	0.165**	13.283
	(32.691)	(1.832)	(1.611)	(1.666)	(1.404)	(0.053)	(0.049)	(0.072)	(9.894)
Log (firm sales)	105.478***	-0.545	-0.472	-0.555*	-0.511**	-0.021*	-0.010	-0.059***	44.016***
	(12.125)	(0.397)	(0.317)	(0.324)	(0.249)	(0.011)	(0.009)	(0.014)	(6.282)
R&D/firm sales	685.044***	13.500**	7.215	7.246	2.433	0.256	-0.134	-0.229	273.046**
	(237.054)	(6.709)	(5.417)	(5.543)	(4.340)	(0.185)	(0.177)	(0.266)	(129.872)
Constant	-881.604***	10.365***	8.106***	3.808	1.762	0.557***	0.520***	0.683***	-309.417***
	(101.984)	(3.356)	(2.692)	(2.752)	(2.129)	(0.092)	(0.078)	(0.117)	(58.267)
Observations	297	236	236	236	236	236	297	297	291
Number of RD Corp position managers	111	93	93	93	93	93	111	111	105

Table 6d: Firm Innovation Measures and Corporate R&D Manager LT Compensation Components (Stock Options and Restricted Stock) --- High Volatility Sample
Random Effects Specification (RD Corp Manager Random Effects)
Applications

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
	Patent Count	Mean of Citations	Median of Citations	Mean of Adjusted Citations	Median of Adjusted Citations	Mean of Generality	Mean of Originality	HHI for Firm	Publications
Options/ (salary+bonus) for RD Corp Mgr.	2.940	1.562*	1.067	1.514**	0.801	0.026	-0.016	0.010	-1.349
	(15.410)	(0.846)	(0.709)	(0.732)	(0.593)	(0.024)	(0.020)	(0.030)	(4.797)
Rest. Stock/ (salary+bonus) for RD Corp Mgr.	-43.304	3.590***	3.156***	2.933***	2.124**	0.068**	0.039	-0.006	-27.629**
	(35.007)	(1.220)	(1.015)	(1.048)	(0.855)	(0.034)	(0.034)	(0.052)	(13.175)
Log (firm sales)	107.842***	-0.431	-0.350	-0.479	-0.419*	-0.018*	-0.008	-0.054***	45.213***
	(12.060)	(0.395)	(0.315)	(0.324)	(0.251)	(0.011)	(0.009)	(0.014)	(6.189)
R&D/firm sales	686.656***	13.398**	7.434	6.931	2.580	0.261	-0.103	-0.251	278.354**
	(238.187)	(6.786)	(5.475)	(5.640)	(4.456)	(0.187)	(0.180)	(0.275)	(128.697)
Constant	-883.705***	10.060***	7.947***	3.580	1.696	0.554***	0.507***	0.688***	-314.891***
	(102.369)	(3.338)	(2.668)	(2.747)	(2.142)	(0.092)	(0.079)	(0.120)	(57.896)
Observations	297	236	236	236	236	236	297	297	291
Number of RD Corp position managers	111	93	93	93	93	93	111	111	105

Note: Sample includes firms that report a corporate R&D position in the compensation survey, R&D expenditures in Compustat, and 60 months of historical stock returns to calculate standard deviations. The sample is only those firms with above the median value of the empirical cumulative distribution function (CDF) of volatility of returns of sample firms in a given year. All regressions include unreported year fixed effects. See earlier tables for variable definitions.

Table 7a: Firm Innovation Measures and Corporate R&D Manager and CEO (log) Total Compensation---High Volatility Sample
Random Effects Specification (RD Corp Manager Random Effects)

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
	Patent Count	Mean of Citations	Median of Citations	Mean of Adjusted Citations	Median of Adjusted Citations	Mean of Generality	Mean of Originality	HHI for Firm	Publications
Log (total comp.) for RD Corp manager	26.536	1.633**	1.583***	1.625***	1.481***	0.035*	0.006	0.063**	-29.352
	(20.313)	(0.637)	(0.489)	(0.568)	(0.404)	(0.021)	(0.021)	(0.032)	(23.160)
Log (total compensation) for CEO	6.914	-0.514	-0.505	-0.654	-0.711*	-0.018	-0.007	-0.021	43.100**
	(17.022)	(0.576)	(0.452)	(0.531)	(0.388)	(0.020)	(0.019)	(0.030)	(20.580)
Log (firm sales)	69.477***	-0.479	-0.446*	-0.472*	-0.376**	-0.006	-0.007	-0.065***	64.448***
	(13.438)	(0.329)	(0.243)	(0.278)	(0.191)	(0.010)	(0.010)	(0.016)	(14.516)
R&D/firm sales	367.144	11.811**	4.198	2.796	-3.605	0.352**	-0.203	-0.386	1,036.224***
	(251.526)	(5.720)	(4.150)	(4.703)	(3.175)	(0.173)	(0.172)	(0.265)	(260.016)
Constant	-987.454***	-2.159	-3.764	-6.948	-7.001*	0.256	0.523**	0.277	-763.258***
	(219.195)	(6.474)	(4.944)	(5.736)	(4.080)	(0.215)	(0.209)	(0.323)	(254.067)
Observations	333	333	333	333	333	316	333	333	351
Number of RD Corp position managers	123	123	123	123	123	117	123	123	121

Table 7b: Firm Innovation Measures and Corporate R&D Manager and CEO LT Incentive Ratio---High Volatility Sample
Random Effects Specification (RD Corp Manager Random Effects)

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
	Patent Count	Mean of Citations	Median of Citations	Mean of Adjusted Citations	Median of Adjusted Citations	Mean of Generality	Mean of Originality	HHI for Firm	Publications
LT comp./ (salary+bonus) for RD Corp Mgr.	70.621***	1.642***	1.358***	1.487***	1.069***	0.030*	0.009	0.004	-45.851***
	(15.007)	(0.501)	(0.390)	(0.457)	(0.332)	(0.017)	(0.017)	(0.026)	(17.024)
LT comp./ (salary+bonus) for CEO	-25.632***	-0.394	-0.323	-0.542**	-0.502***	0.002	0.005	0.008	41.620***
	(7.992)	(0.279)	(0.220)	(0.258)	(0.191)	(0.010)	(0.009)	(0.015)	(9.590)
Log (firm sales)	77.422***	-0.338	-0.296	-0.343	-0.262*	-0.008	-0.011	-0.056***	70.423***
	(11.857)	(0.263)	(0.190)	(0.218)	(0.146)	(0.008)	(0.008)	(0.013)	(12.462)
R&D/firm sales	417.844*	14.396***	6.938*	5.534	-0.856	0.383**	-0.222	-0.216	1,013.943***
	(245.466)	(5.390)	(3.880)	(4.451)	(2.985)	(0.161)	(0.161)	(0.258)	(254.597)
Constant	-633.359***	9.876***	7.786***	3.307*	0.892	0.454***	0.522***	0.719***	-584.007***
	(100.628)	(2.249)	(1.628)	(1.870)	(1.262)	(0.069)	(0.068)	(0.108)	(106.454)
Observations	333	333	333	333	333	316	333	333	351
Number of RD Corp position managers	123	123	123	123	123	117	123	123	121

Table 7c: Firm Innovation Measures and Corporate R&D Manager and CEO LT Incentive and ST Incentive Ratio---High Volatility Sample
Random Effects Specification (RD Corp Manager Random Effects)

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
	Patent Count	Mean of Citations	Median of Citations	Mean of Adjusted Citations	Median of Adjusted Citations	Mean of Generality	Mean of Originality	HHI for Firm	Publications
LT comp./ (salary+bonus) for RD Corp Mgr.	70.492***	1.618***	1.327***	1.463***	1.071***	0.030*	0.009	0.005	-45.017***
	(15.166)	(0.503)	(0.392)	(0.459)	(0.334)	(0.017)	(0.017)	(0.026)	(17.109)
Bonus/(salary+bonus) for RD Corp Manager	-18.111	-2.610	-1.923	-1.713	0.745	-0.031	-0.058	0.014	18.274
	(76.817)	(2.765)	(2.206)	(2.599)	(1.945)	(0.096)	(0.095)	(0.147)	(94.091)
LT comp./ (salary+bonus) for CEO	-24.526***	-0.389	-0.305	-0.533**	-0.494**	0.001	0.004	0.008	41.844***
	(8.155)	(0.282)	(0.222)	(0.261)	(0.193)	(0.010)	(0.010)	(0.015)	(9.699)
Bonus/(salary+bonus) for CEO	42.872	1.480	1.521	1.125	-0.127	-0.014	0.002	-0.024	10.164
	(59.058)	(2.144)	(1.716)	(2.023)	(1.519)	(0.075)	(0.074)	(0.115)	(72.153)
Log (firm sales)	75.699***	-0.297	-0.282	-0.322	-0.285*	-0.006	-0.009	-0.056***	69.293***
	(11.775)	(0.270)	(0.195)	(0.225)	(0.151)	(0.008)	(0.008)	(0.013)	(12.558)
R&D/firm sales	436.906*	14.512***	7.130*	5.673	-0.851	0.381**	-0.224	-0.223	1,018.019***
	(241.949)	(5.417)	(3.907)	(4.483)	(3.001)	(0.162)	(0.162)	(0.257)	(253.700)
Constant	-629.267***	9.808***	7.731***	3.254*	0.912	0.453***	0.520***	0.720***	-583.940***
	(99.064)	(2.258)	(1.637)	(1.881)	(1.267)	(0.069)	(0.068)	(0.108)	(106.038)
Observations	333	333	333	333	333	316	333	333	351
Number of RD Corp position managers	123	123	123	123	123	117	123	123	121

Table 7d: Firm Innovation Measures and Corporate R&D Manager and CEO LT Compensation Components (Stock Options and Restricted Stock)---High Volatility Sample Random Effects Specification (RD Corp Manager Random Effects)

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
	Patent Count	Mean of Citations	Median of Citations	Mean of Adjusted Citations	Median of Adjusted Citations	Mean of Generality	Mean of Originality	HHI for Firm	Publications
Options/ (salary+bonus) for RD Corp Mgr.	80.359***	1.239**	0.934**	1.060*	0.651*	0.016	-0.014	0.002	-62.957***
	(17.010)	(0.587)	(0.459)	(0.541)	(0.396)	(0.020)	(0.020)	(0.031)	(19.537)
Rest. Stock/ (salary+bonus) for RD Corp Mgr.	-8.493	4.199***	3.583***	3.810***	2.904***	0.057*	0.060*	0.056	-49.433
	(41.698)	(1.066)	(0.791)	(0.929)	(0.659)	(0.034)	(0.034)	(0.055)	(46.985)
Options/ (salary+bonus) for CEO	-30.583***	-0.217	-0.147	-0.380	-0.381*	0.011	0.014	0.009	50.094***
	(9.037)	(0.314)	(0.248)	(0.292)	(0.217)	(0.011)	(0.011)	(0.017)	(10.685)
Rest. Stock/ (salary+bonus) for CEO	5.366	-2.772**	-2.436***	-2.378**	-1.773**	-0.083**	-0.037	0.061	-24.319
	(33.960)	(1.186)	(0.932)	(1.099)	(0.810)	(0.042)	(0.041)	(0.063)	(42.318)
Log (firm sales)	77.822***	-0.232	-0.201	-0.259	-0.200	-0.005	-0.008	-0.055***	71.562***
	(11.887)	(0.251)	(0.178)	(0.208)	(0.138)	(0.008)	(0.008)	(0.013)	(12.475)
R&D/firm sales	452.344*	13.305**	6.312*	4.972	-0.878	0.350**	-0.218	-0.210	986.672***
	(247.381)	(5.214)	(3.700)	(4.325)	(2.889)	(0.158)	(0.161)	(0.260)	(257.126)
Constant	-633.959***	9.264***	7.221***	2.803	0.514	0.444***	0.505***	0.705***	-583.328***
	(101.147)	(2.167)	(1.545)	(1.806)	(1.211)	(0.067)	(0.067)	(0.108)	(107.064)
Observations	333	333	333	333	333	316	333	333	351
Number of RD Corp position managers	123	123	123	123	123	117	123	123	121

Note: Sample includes firms that report a corporate R&D position in the compensation survey, R&D expenditures in Compustat, and 60 months of historical stock returns to calculate standard deviations. The sample is only those firms with above the median value of the empirical cumulative distribution function (CDF) of volatility of returns of sample firms in a given year. All regressions include unreported year fixed effects. See earlier tables for variable definitions.

Table 8: Firm Innovation Measures and Long-Term Incentive Ratio for Senior Staff Positions—High Volatility Sample
Estimated Coefficients on Long-Term Incentive Ratio in Random Effects Specification (Table 4b with Firm Random Effects)
General Counsel, Head of Human Resources and Chief Financial Officer

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Estimated Coefficients on Long-Term Incentive Ratio for Senior Staff Positions	Patent Count	Mean of Citations	Median of Citations	Mean of Adjusted Citations	Median of Adjusted Citations	Mean of Generality	Mean of Originality	HHI for Firm	Publications
General Counsel	54.452***	-0.516	-0.203	-0.652	-0.402	-0.001	-0.008	-0.007	16.008
	(12.681)	(0.481)	(0.384)	(0.459)	(0.350)	(0.016)	(0.016)	(0.025)	(16.765)
Head of Human Resources	58.250***	0.406	0.244	0.292	0.145	-0.004	-0.003	-0.015	18.693
	(11.574)	(0.459)	(0.353)	(0.436)	(0.322)	(0.015)	(0.015)	(0.023)	(15.275)
Chief Financial Officer	16.250*	0.059	0.046	-0.156	-0.107	0.002	-0.005	-0.021	14.378
	(9.550)	(0.374)	(0.305)	(0.364)	(0.288)	(0.013)	(0.013)	(0.019)	(13.393)

Note: Coefficients and standard errors for Long-term Incentive Ratio for Senior Staff Positions are reported. Each estimated coefficient is from a separate regression. All regressions include the same control variables as those in Table 4b: log (firm sales), R&D/firm sales, firm random effects, and year indicators. Sample includes firms that report a corporate R&D position in the compensation survey, R&D expenditures in Compustat, and 60 months of historical stock returns to calculate standard deviations. The sample is only those firms with above the median value of the empirical cumulative distribution function (CDF) of volatility of returns of sample firms in a given year. See earlier tables for variable definitions.

Table 9a: Firm Innovation Measures, Corporate R&D Manager (log) Total Compensation and Reporting Relationship to CEO
High Volatility Sample
Random Effects Specification (RD Corp Manager Random Effects)

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
	Patent Count	Mean of Citations	Median of Citations	Mean of Adjusted Citations	Median of Adjusted Citations	Mean of Generality	Mean of Originality	HHI for Firm	Publications
Direct Report to CEO	65.688	5.866	6.944	3.816	7.698	0.220	0.434	-0.823*	-942.481***
	(298.198)	(8.734)	(6.846)	(7.899)	(5.848)	(0.309)	(0.308)	(0.469)	(303.025)
Log (total comp.) for RD Corp manager	30.612	1.338**	1.333***	1.190**	1.242***	0.028	0.006	0.036	-37.275*
	(19.281)	(0.573)	(0.449)	(0.518)	(0.383)	(0.020)	(0.020)	(0.031)	(21.046)
Log (total comp.) for RD Corp manager*Direct Report to CEO	-4.546	-0.465	-0.539	-0.311	-0.608	-0.017	-0.033	0.063*	75.907***
	(22.973)	(0.670)	(0.525)	(0.605)	(0.448)	(0.024)	(0.024)	(0.036)	(23.203)
Log (firm sales)	74.253***	-0.488*	-0.487**	-0.522**	-0.497***	-0.008	-0.008	-0.070***	76.606***
	(13.021)	(0.285)	(0.213)	(0.237)	(0.168)	(0.009)	(0.010)	(0.015)	(13.203)
R&D/firm sales	281.541	12.419**	5.120	3.762	-2.786	0.342**	-0.239	-0.382	902.770***
	(235.955)	(5.155)	(3.857)	(4.282)	(3.030)	(0.168)	(0.174)	(0.263)	(239.733)
Constant	-985.585***	-5.593	-7.445	-10.178*	-13.027***	0.111	0.425*	0.384	-150.997
	(234.065)	(6.653)	(5.198)	(5.979)	(4.407)	(0.231)	(0.234)	(0.356)	(252.447)
Observations	345	345	345	345	345	326	345	345	363
Number of RD Corp position managers	126	126	126	126	126	119	126	126	124

Table 9b: Firm Innovation Measures and Corporate R&D Manager LT Incentive Ratio and Reporting Relationship to CEO
High Volatility Sample
Random Effects Specification (RD Corp Manager Random Effects)

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
	Patent Count	Mean of Citations	Median of Citations	Mean of Adjusted Citations	Median of Adjusted Citations	Mean of Generality	Mean of Originality	HHI for Firm	Publications
Direct Report to CEO	-13.993	0.235	0.451	0.138	0.267	0.010	0.005	-0.026	4.380
	(17.930)	(0.563)	(0.446)	(0.521)	(0.394)	(0.020)	(0.020)	(0.031)	(19.860)
LT comp./ (salary+bonus) for RD Corp Manager	17.580	1.689***	1.585***	1.297**	1.063**	0.037*	0.013	-0.009	-51.464***
	(19.060)	(0.622)	(0.498)	(0.585)	(0.446)	(0.022)	(0.022)	(0.034)	(19.561)
LT comp./ (salary+bonus) for RD Corp Manager*Direct Report to CEO	42.294*	-0.736	-0.916	-0.633	-0.795	-0.012	-0.010	0.045	75.281***
	(22.995)	(0.709)	(0.563)	(0.659)	(0.499)	(0.025)	(0.025)	(0.039)	(23.552)
Log (firm sales)	78.253***	-0.307	-0.290	-0.333	-0.276*	-0.005	-0.011	-0.054***	74.104***
	(11.862)	(0.243)	(0.181)	(0.204)	(0.146)	(0.008)	(0.008)	(0.013)	(12.172)
R&D/firm sales	313.625	13.720***	6.644*	5.526	-0.853	0.351**	-0.302*	-0.160	951.277***
	(231.058)	(4.856)	(3.627)	(4.106)	(2.955)	(0.157)	(0.166)	(0.260)	(238.504)
Constant	-635.086***	9.369***	7.383***	2.976*	0.670	0.435***	0.526***	0.715***	-592.954***
	(101.422)	(2.098)	(1.568)	(1.777)	(1.281)	(0.069)	(0.072)	(0.112)	(104.812)
Observations	345	345	345	345	345	326	345	345	363
Number of RD Corp position managers	126	126	126	126	126	119	126	126	124

Table 9c: Firm Innovation Measures and Corporate R&D Manager LT Incentive, ST Incentive Ratio and Reporting Relationship to CEO
High Volatility Sample
Random Effects Specification (RD Corp Manager Random Effects)

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
	Patent Count	Mean of Citations	Median of Citations	Mean of Adjusted Citations	Median of Adjusted Citations	Mean of Generality	Mean of Originality	HHI for Firm	Publications
Direct Report to CEO	0.884	0.597	0.836	0.355	0.718	0.048*	0.029	-0.003	-30.524
	(23.778)	(0.774)	(0.618)	(0.726)	(0.550)	(0.028)	(0.028)	(0.043)	(26.519)
LT comp./ (salary+bonus) for RD Corp Manager	18.883	1.705***	1.614***	1.315**	1.099**	0.037*	0.013	-0.009	-50.034**
	(19.146)	(0.625)	(0.500)	(0.588)	(0.446)	(0.022)	(0.022)	(0.035)	(19.524)
LT comp./ (salary+bonus) for RD Corp Manager*Direct Report to CEO	42.490*	-0.713	-0.895	-0.616	-0.768	-0.009	-0.008	0.046	69.575***
	(23.037)	(0.712)	(0.565)	(0.661)	(0.498)	(0.025)	(0.025)	(0.039)	(23.642)
Bonus/(salary+bonus) for RD Corp Manager	52.649	0.326	0.940	0.807	1.925*	0.016	-0.020	0.011	-33.896
	(47.056)	(1.533)	(1.227)	(1.443)	(1.098)	(0.055)	(0.055)	(0.085)	(54.441)
Bonus/(salary+bonus) for RD Corp Manager*Direct Report to CEO	-66.922	-1.665	-1.684	-0.940	-1.894	-0.176**	-0.113	-0.105	162.005**
	(74.108)	(2.384)	(1.903)	(2.235)	(1.696)	(0.085)	(0.086)	(0.132)	(80.022)
Log (firm sales)	76.155***	-0.307	-0.311*	-0.355*	-0.331**	-0.005	-0.009	-0.054***	74.972***
	(11.983)	(0.247)	(0.183)	(0.207)	(0.145)	(0.008)	(0.008)	(0.013)	(12.258)
R&D/firm sales	319.019	13.593***	6.578*	5.450	-0.950	0.339**	-0.311*	-0.166	954.248***
	(231.218)	(4.843)	(3.597)	(4.068)	(2.867)	(0.159)	(0.166)	(0.260)	(237.682)
Constant	-633.286***	9.294***	7.294***	2.938*	0.589	0.428***	0.520***	0.710***	-591.843***
	(101.364)	(2.094)	(1.559)	(1.765)	(1.247)	(0.069)	(0.072)	(0.113)	(104.395)
Observations	345	345	345	345	345	326	345	345	363
Number of RD Corp position managers	126	126	126	126	126	119	126	126	124

Table 9d: Firm Innovation Measures and Corporate R&D Manager LT Compensation Components (Stock Options and Restricted Stock) and Reporting Relationship to CEO
High Volatility Sample
Random Effects Specification (RD Corp Manager Random Effects)

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
	Patent Count	Mean of Citations	Median of Citations	Mean of Adjusted Citations	Median of Adjusted Citations	Mean of Generality	Mean of Originality	HHI for Firm	Publications
Direct Report to CEO	-1.134	0.166	0.336	0.035	0.074	0.014	0.004	-0.020	21.873
	(17.505)	(0.536)	(0.419)	(0.489)	(0.363)	(0.019)	(0.019)	(0.030)	(19.495)
Stock options/ (salary+bonus) for RD Corp Manager	28.296	1.856***	1.705***	1.375**	0.983**	0.035	0.003	-0.006	-39.937*
	(19.478)	(0.620)	(0.491)	(0.576)	(0.434)	(0.022)	(0.023)	(0.035)	(20.862)
Stock options/ (salary+bonus) for RD Corp Manager*Direct Report to CEO	38.506	-1.524**	-1.532***	-1.304*	-1.250**	-0.006	-0.011	0.051	67.551***
	(24.542)	(0.730)	(0.573)	(0.669)	(0.500)	(0.027)	(0.027)	(0.041)	(26.117)
Restricted Stock/ (salary+bonus) for RD Corp Manager	-15.262	-0.230	-0.556	-0.790	-1.941	0.151	0.091	0.120	-22.533
	(94.309)	(2.976)	(2.359)	(2.765)	(2.082)	(0.109)	(0.109)	(0.166)	(109.697)
Restricted Stock/ (salary+bonus) for RD Corp Manager*Direct Report to CEO	-17.949	4.088	3.769	4.282	4.635**	-0.119	-0.037	-0.060	-29.121
	(93.169)	(3.013)	(2.399)	(2.816)	(2.130)	(0.111)	(0.110)	(0.168)	(109.217)
Log (firm sales)	77.938***	-0.164	-0.171	-0.217	-0.188	-0.004	-0.009	-0.055***	71.268***
	(12.077)	(0.228)	(0.166)	(0.189)	(0.132)	(0.008)	(0.008)	(0.013)	(12.272)
R&D/firm sales	296.928	13.971***	6.977**	5.860	-0.347	0.342**	-0.288*	-0.189	945.571***
	(235.248)	(4.646)	(3.403)	(3.888)	(2.743)	(0.158)	(0.166)	(0.262)	(241.378)
Constant	-632.395***	8.274***	6.484***	2.118	0.088	0.420***	0.510***	0.715***	-577.886***
	(103.593)	(2.010)	(1.473)	(1.683)	(1.188)	(0.069)	(0.072)	(0.113)	(106.286)
Observations	345	345	345	345	345	326	345	345	363
Number of RD Corp position managers	126	126	126	126	126	119	126	126	124

Note: Sample includes firms that report a corporate R&D position in the compensation survey, R&D expenditures in Compustat, and 60 months of historical stock returns to calculate standard deviations. The sample is only those firms with above the median value of the empirical cumulative distribution function (CDF) of volatility of returns of sample firms in a given year. All regressions include unreported year fixed effects. Direct Report to CEO is an indicator variable that equals one if the Head of Corporate R&D reports directly to the CEO in the organizational hierarchy. See earlier tables for all other variable definitions.

Table 10: Pay-Performance Sensitivities Based on Measures of Total Compensation for Corporate R&D Head
Firm Fixed Effects Regressions

		Sample Partition by Organization of R&D		Sample Partition by R&D Intensity	
	Whole Sample	Centralized R&D	Both Corporate and Divisional R&D	High R&D	Low R&D
Shareholder Returns excluding dividends					
Stock Return	2.488***	3.110***	1.352	2.778**	-2.099
	(0.964)	(1.092)	(1.776)	(1.414)	(1.412)
Stock Return*CDF of Std. Deviation	-2.489***	-3.148***	-0.499	-2.817**	6.374***
	(0.972)	(1.098)	(2.687)	(1.421)	(1.853)
CDF of Std. Deviation	373.09***	523.47***	248.77	423.99***	-41.10***
	108.33	140.60	157.89	162.00	152.56
Shareholder Returns including dividends					
Stock Return	2.825***	3.416***	3.214*	3.756***	-0.054
	(1.122)	(1.299)	(1.925)	(1.620)	(1.666)
Stock Return*CDF of Std. Deviation	-2.312*	-3.386**	-2.781	-3.807**	2.361
	(1.385)	(1.542)	(2.910)	(1.898)	(2.348)
CDF of Std.Deviation	392.58***	521.67***	160.88	548.42***	98.72
	112.54	139.46	173.71	169.62	149.95

Note: Sample includes firms that report a corporate R&D position in the compensation survey, R&D expenditures in Compustat, and 60 months of historical stock returns to calculate standard deviations. Centralized R&D sub-sample includes firms that only report corporate R&D heads, while both corporate and divisional R&D sub-sample includes firms that report both corporate and divisional R&D managers. High R&D sub-sample includes firms with ratio of R&D to sales above the sample median, while low R&D includes those below the sample median. The dependent variable is total flow compensation for the corporate R&D head: salary, bonus and the value of long-term incentives (including stock options, restricted stock, performance unit plans and performance share plans). Stock returns are measured as annual shareholder returns (excluding dividends) and annual total shareholder returns (average of monthly returns), both stated in percentage points. CDF of Std. Deviation represents the empirical cumulative distribution function of the standard deviation of monthly % returns over prior 60 months. Each regression includes firm and year indicators. See earlier tables for all other variable definitions.

Appendix A: Survey Representativeness

We evaluate the representativeness of Hewitt survey participants by comparing key financial measures of the survey participants to a matched sample from Compustat. We begin by matching each firm in the Hewitt dataset to the Compustat firm that is closest in sales within its two-digit SIC industry in the year the firm joins the sample. We then perform Wilcoxon signed rank tests to compare the Hewitt firms with the matched firms. While the firms in the Hewitt dataset are, on average, slightly larger in sales than the matched sample, we found no statistically significant difference in employment and profitability (return on sales).[16] We also found no statistically significant difference in sales growth, employment growth, or annual changes in profitability for all sample years. In sum, while the Hewitt firms are larger (measured by sales) on average than the matched sample, there is little additional evidence that these firms are not representative of the population of industrial firms that are leaders in their sectors.

We also calculate financial measures for the sample of Compustat firms with 10,000 employees or greater over the period from 1987 to 1998 (excluding firms operating in financial services). We find that, on average, survey participants are more profitable, but growing at a slower rate relative to the sample of large Compustat firms. Specifically, the sample average return on sales for survey participants is 17.8% versus 15.7% for the sample of large Compustat firms and the average sales growth is 5.7% vs. 7.4%. This is consistent with the observation that the firms in the sample are likely to be industry leaders (hence slightly more profitable) and also large (hence the slightly slower

[16] The Hewitt firms are larger in sales than the matched sample of firms because in a number of the cases, the Hewitt firm is the largest firm in the industry thus forcing me to select a matched firm smaller in size.

growth). To sum up, the survey sample is probably most representative of Fortune 500 firms.

Appendix B: Position Descriptions from Hewitt Survey

1. Chief Executive Officer (CEO). The highest executive authority in the corporation. Reports to the Board of Directors. May also be Chairman or President.

Research and Development Positions:

2. Corporate Level Research and Development. Responsible for applied research and development and design and development engineering for the entire corporation. Oversees and directs R&D activities of the corporation leading to new or improved products or processes. Provides technical assistance and, when necessary, correlates research activities with other functions and operating units.

3. Division Level Research and Development. The head of all applied R&D and design and development engineering for the division. Responsibilities include investigation and experimentation aimed at practical applications of scientific theories, as well as the application of existing engineering and scientific theories and techniques to the design and development of new products.

4. Principal Scientist. Top R&D technical position, responsible for research leadership in creating or improving products or processes. Originates and coordinates research projects, evaluates results, and makes recommendations to senior management. This is the top position on the technical (non-managerial) career ladder within R&D and may be equivalent to the R&D Director in terms of level.

Senior Staff Positions:

5. General Counsel. The head of all legal affairs of the company. Responsible for, or may be, Corporate Secretary; supervises outside legal counsel.

6. Human Resources. Head of all human resources with responsibility for establishing and implementing corporate-wide policies.

7. Chief Financial Officer (CFO). Functional head responsible for all financial operations of the corporation. Has responsibility for both the treasury and accounting functions. Indicate whether responsibilities also include data processing, investor relations, internal audit, and tax.