Innovation, R&D and Managerial Compensation

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Abstract

This paper investigates whether aligning manager and owner incentives can improve the innovation performance of firms. We find that equity-linked compensation works to align managerial actions to shareholder interests. As managerial wealth becomes more sensitive to the firm's stock price the innovation performance of a firm improves. Entrenched managers, however, are more likely to act myopically and follow strategies that result in a large number of low quality patents. Short-term cash incentives have little impact on innovation. Higher managerial tenure increases the probability of R&D spending and innovation quality and thus better aligns the managers' actions with a firm's long-term goals. CEO control of the firm, however, decreases its innovation performance.

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*"Poor Year Doesn't Stop CEO Bonuses," Wall Street Journal, March 17, 2009***.**

1. Introduction

At the end of the 2008 fiscal year, Warner Music Group Corp. paid CEO Edgar Bronfman Jr. a $3 million bonus for a fiscal year in which the company had a $56 million loss and its stock fell 25%. Varian Semiconductor Equipment Associates Inc. CEO Gary Dickerson received $1 million in incentive pay despite a 53% stock decline and a 31% drop in net income. Texas Instruments Inc.'s cut CEO Richard Templeton's annual bonus 40% from a year earlier in light of a 54% share decline, 28% net income drop and subpar performance relative to peers, but he still received a bonus of $1.5 million.[3] Such a stark contrast between the firm's financial performance and CEO compensation has generated tremendous public backlash and discussions about capping excessive executive pay. Central to these concerns is whether such compensation schemes ultimately create value for the firm.

Our paper answers this exact question. We look beyond the financial performance and delve deeper into whether such compensation can incentivize executives to create real value for the firm. We specifically ask whether executive pay can influence long-term non-financial outcomes, such as innovation, that may not always be fully captured in daily stock returns. We know that a firm with a greater number of high quality patents is associated with being more innovative, and this often translates into increased firm value. For shareholders the central question then, is how to incentivize managers to increase the patenting activities of the firm.[4]

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[3] These figures are taken from the Wall Street Journal, May 17th, 2009.

[4] Separation of ownership and control gives rise to the classic principal-agent problem, where asymmetric information between the owner (principal) and the manager (agent) may lead to a suboptimal outcome for the owner. Agency theory predicts that managers may use this superior information and make decisions to divert resources away from the principal's interest (Jensen and Meckling, 1976; Fama and Jensen, 1986). This setting gives rise to agency costs due to the misalignment of the principal's and agents' incentives. This is of particular importance in spheres where it is difficult to judge the decision of the manager, and assess performance based on measurable metrics. Innovation effort is one such area.

Two primary mechanisms through which this is achieved is compensation contracts and monitoring the manager's actions (Jensen and Meckling, 1976; Holstrom, 1979; Fama and Jensen, 1983; Jensen, 1986). In this paper we focus on how compensation contracts can improve patenting outcomes for firms and thus create real value for the firm.

An interesting point however, is that a firm cannot simply begin to obtain a larger number of patents just by top executives mandating that innovation should increase. Rather, these managers have to pursue strategies that will result in increased patenting, such as increases in R&D investments, patenting a large number of very small incremental innovations, or altering the technology mix of the patent portfolio in a way that increases the number of patents a firm obtains. However, not all patents are created equal, and the goal of shareholders (and society) is to incentivize managers to pursue strategies that increase high valued patents and not spawn a plethora of useless patents. In this paper we first examine what types of compensation mechanisms increase the patenting activity of the firm, and then investigate the channels through which this increase occurs.

Since managers control the day-to-day operations of the firms, they are likely to exercise effective control over it (Berle and Means, 1932) and possess better information when compared to the owners or share-holders (Pratt and Zeckhauser, 1985). This is of particular concern for innovation where the end product may not be a perfect signal of manager ability due to uncertainties in the innovation process. This may allow managers to invest in innovation projects that do not serve the interests of the owners. In addition, capital markets often cannot correctly value investment in long-term research and development (R&D) activities, leading to large information asymmetries and high agency costs. For example, a manager with an expected short tenure may forgo long-term R&D projects for short-term ones, even though the former may yield a higher expected positive net present value (NPV) for the principal than the latter.

In this paper we focus on compensation contracts as a mechanism for aligning the interests of managers with those of the owners. Payoff contracts between the principal and the agent usually specifies the rights of the parties involved, performance metrics, and the reward structure for agents (Fama and Jensen, 1983). These contracts are designed to incentivize managers to make decisions that are in the best interests of the owners (Jensen, 1986). Theoretical research has shown that agency costs are minimized when executive compensation is related to firm performance (Holmstrom, 1979; Grossman and Hart, 1983), and thus incentive alignment through compensation schemes increase firm value. However, there is considerable heterogeneity in findings on the empirical side. Some authors find that incentive alignment either has a positive or a non-monotonic effect on firm value, while others find no relationship.

We contribute to this literature by focusing on an important channel through which managers may increase firm value, namely innovation. Firm innovation has been shown to positively impact both the real and financial performance of a firm (Griliches, 1981; Connolly and Hirschey, 1988; Hall, 1993, 2000; Blundell et. al., 1999; Hall, Jaffe & Trachtenberg, 2005). Additionally, there is a large literature that links performance pay to managerial incentives and examines the influence of managerial compensation on both the financial performance (Morck et. al., 1988; Jensen and Murphy, 1990; McConnell and Servaes, 1990; Himmelberg et. al., 1999; Palia, 2001; Brick et. al., 2006; Coles et. al., 2006) and long-term productivity performance (Palia and Lichtenberg, 1999; Bulan et. al., 2010) of the firm. However, the empirical literature on the relationship between innovation and managerial incentives is limited, and this paper is one of the few[5] that empirically examines this link.

This paper examines how top executive compensation incentives influence the innovation strategies of firms. We characterize a firm's innovation strategy using four variables: patent

[5] The two papers that are closely related to this current paper are by Lerner and Wulf (2007) and Aghion et. al. (2009) and will be discussed in the next section.

counts (innovation magnitude), citation-based patent quality (innovation quality), research and development expenditures (R&D) and technology class concentration. A firm with a greater number of patents is generally associated with being more innovative. Hall et. al. (2005) measure the quality of a patent by its citations, and show that patent quality increases the value of a firm (Tobin's Q). Additionally, we examine investments in R&D since it is an important channel through which managers may influence a firm's innovation performance. Last, we study how the technology class concentration of a firm's innovation portfolio evolves with changes in managerial incentives, i.e. do firms get inward or outward looking in terms of their technological expertise.

We focus on a firm's top three executives which includes the Chief Executive Officer (CEO), Chief Financial Officer (CFO) and the Chief Operating Officer (COO), one of whom is also the President of the company in a majority of cases. These are the three most influential people in the company in charge of charting out a company's future and thus their actions should have important consequences for the innovation strategy of a firm. In this paper we examine both the short-term and long-term compensation incentives faced by the top managers and their influence on the firm's innovation performance.

Our central finding is that as the managers' wealth becomes more sensitive to their firm's stock price (increasing pay-performance sensitivity), and hence manager and shareholder goals become better aligned, the innovation performance of a firm improves. Specifically, we find that innovation magnitude, quality, R&D and technology concentration have a non-monotonic relationship with pay-performance sensitivity. These metrics of innovation first increase with pay-performance sensitivity, and then decrease at very high levels of pay-performance sensitivity. However, the quadratic term is economically insignificant in all cases and the overall impact is a positive relationship between pay-performance sensitivity and innovation.

We examine two other facets of managerial pay, namely, managerial equity holdings and their annual bonus to salary ratio. We find that as managers get more invested in the firm, they are unwilling to take greater risk that may jeopardize their wealth, as shown by the negative effect of increased managerial stock holdings on patent counts and R&D investment. Additionally, short-term incentives, as measured by the annual bonus to salary ratio, do not influence the innovation performance of the firm. Interestingly, managerial tenure has a positive impact on R&D expenditures, showing that as managers stay in the same firm for a longer period of time, some of their career concerns may be mitigated and they are more willing to take on potentially value enhancing risky investments such as R&D. Last, we also address endogeneity concerns that may be raised due to the potential feedback effects from innovation performance to managerial compensation, and find that out empirical results remain unchanged.

The rest of the paper is organized as follows. Section 2 briefly discusses the empirical literature on the relationship between the innovation performance of a firm and managerial incentives. Section 3 describes the data and variable construction. Section 4 explains the empirical methodology and the results. Section 5 describes the endogeneity corrections and conducts some robustness analysis. The last section concludes.

2. The Incentive Innovation R&D Relationship

Innovation is one of the key drivers of future competitive advantage and productivity (Scherer 1984). In the 1990's innovation (as measured by patenting activity), productivity growth and the stock market surged. At the same time, top executive pay in the U.S. dramatically shifted towards stock and stock option grants (Hall and Liebman, 1998). It is therefore of interest to examine whether the incentives to innovate are driven, in part, by managerial pay.

Two closely related papers that examine the relationship between managerial incentives and innovation are by Lerner and Wulf (2007) and Aghion, Van Reenen and Zingales (2009). Our paper complements the findings of both. Using a sample of 140 publicly traded U.S. firms between 1987 and 1998, Lerner and Wulf (2007) find that the long-term incentive compensation of corporate R&D managers is positively associated with patent citations, patent awards and patent originality. Our paper is different from theirs in two respects. First, instead of R&D managers, we focus on the firm's top three executives. While we acknowledge that the corporate R&D manager has direct authority over research and development decisions within the firm, we believe that the top executives retain authority over the "big-picture" strategic direction of R&D. Moreover, their findings apply to a subset of firms with a centralized R&D organizational structure identified by the presence of a corporate R&D head. For firms without a corporate R&D head, long-term incentives are not related to their innovation measures. In these instances, we believe the top executives would have more influence on R&D decision-making.

Second, we measure managerial incentives using three different metrics: managerial equity holdings, the pay-performance sensitivity of these executives, and short-term incentives such as the bonus to salary ratio. Lerner and Wulf measure long-term incentive compensation as the value of restricted stock, stock options, performance units and performance shares granted to the manager. They acknowledge that in their data, they are limited to observing incentive compensation flows as opposed to the stock of incentive compensation. In our data, we do not have this limitation and hence, we are able to construct these measures of managerial incentives that are more closely related to performance than just the flow value of compensation.

Aghion et. al. (2009) focus on CEOs rather than R&D managers and also find a strong link between managerial incentives and innovation, as measured by patenting activity of the firm. They document a positive relationship between cite-weighted patents (patenting activity) and institutional ownership. They explain this finding in a theoretical model where the presence of institutional investors (external monitors) alleviates a CEO's aversion to risky R&D due to his possible termination in the event of failure. Unsuccessful innovation strategies may be a result of bad luck and not necessarily due to bad managers. More effective monitoring of managerial actions can "insulate the manager against the reputational consequences of bad income realizations," thus creating greater incentives for CEOs to undertake risky innovation. Our work builds on this paper by illustrating one of the channels through which the institutional investors may influence managerial decision-making, namely managerial compensation contracts.

Additionally, we examine in greater detail the innovation strategies that managers may pursue by characterizing four different facets of such strategies: patent counts, patent quality, R&D expenditures and technology class concentration. We use these four characteristics because there is no single route that leads to success in developing innovations and new technology. A firm's innovation performance is affected by a myriad of institutional and environmental factors, all of which influence the final innovation outcome.

We argue that if obtaining a greater number of patents is a firm's objective, then this may be achieved through one of the following channels: increasing R&D, altering patent quality, and altering the technology concentration. Increasing R&D is often seen as a primary driver of innovation and represents a long-term investment by the firm, albeit with high uncertainty. The theoretical literature shows that there is a greater probability of obtaining a greater number and /or higher valued innovations as R&D expenditures increase (Kortum, 1993). Second, managers may wish to change the quality of the innovation. It is possible that managers may pursue a short-term goal and attempt to increase the number of patents without increasing the R&D budget. This may be done by trading off (reducing) innovation quality for quantity. Third, altering the technology profile of innovations within a firm, by either concentrating on their core technology areas or expanding into other areas of exploration may also result in a greater number of patents. The influence of managerial incentives on these latter two channels, especially technology concentration, has received scant attention in the literature. The bulk of the attention has been focused on R&D, although even here the literature is fairly limited.

Earlier research has shown that R&D spending is influenced by a firm's size, industry and market structure (Scherer, 1984; Acs and Audretsch, 1990), patent protection and strategic alliances (Griliches, 1989, MacIntosh and Cumming, 2000) and corporate strategy (Hoskisson and Hitt, 1988; Baysinger and Hoskisson, 1989; Baysinger et al. 1991). If we believe that top managers are influenced by career concerns, then this is one of the most fundamental investment decisions made by them. There is of course a large literature that debates the role that top managers play in key firm decisions (Weiner and Mahoney, 1981; Thomas, 1988; Barker and Mueller, 2002). However we argue that top managers have the discretion to control R&D spending, and will actively monitor such decisions because of the riskiness of such investments (Kothari et. al, 1995) and the resultant effect on the manager's career in the firm (Holthausen et. al, 1995; Aghion et. al, 2009).

3. Data and Variables

3.1. Data

Our primary interest is to investigate how managerial incentive alignment affects the innovation strategy of firms, and the channels through which it occurs. Using patents as a metric of innovation, we empirically model how the magnitude of innovation (patent counts) by firms is related to the top three executives' compensation structures. In addition we explore the channels through which managers may affect innovation magnitudes, namely: change in R&D spending, change in innovation (patent) quality, and change in technology class concentration. For firm *i* in year *t* and in industry *j*, each of these four innovation characteristics (Y_{jt}) is modeled as a function of executive payoff structure ($exec\_pay_{it}$), firm financial variables ($firm_{it}$), existing firm innovation culture captured by variables such as past patenting activity ($innov_{ijt}$), industry conditions such as market concentration and other industry characteristics (ind_{jt}), and a set of year dummies.

$$Y_{it} = \left(exec\_pay_{it}, firm_{it}, innov_{it}, ind_{jt}\right) \qquad (1)$$

Thus the primary categories of data that this paper relies on are: 1) information on patents, 2) data on financial and other firm characteristics, and 3) variables characterizing incentive contracts. The patent data is from the NBER's (National Bureau of Economic Research) 'Patent Citations Database' which was originally constructed by Hall, Jaffe and Trajtenberg (1999). We use the updated version of this dataset that contains information on all patents granted in the US from 1976 to 2005. These comprise application and grant years, geographical distribution of these patents, technology classifications, backward[6] and forward citations (i.e. citations to and from a patent), standardized assignee names, and assignee numbers that help in tracking patent assignees across years. In addition, for publicly traded companies it matches the unique GVKEY identifier from the COMPUSTAT database with unique assignee numbers[7], the key component for correctly assigning patents to specific firms.

We obtain firm characteristics from the COMPUSTAT database that contains financial data on all publicly traded companies in the US. Matching the COMPUSTAT firm data with the patent database, we find that a large number of corporations do not patent. These zero patent firms are included in our dataset as well. We then match the above data to the annual executive compensation data from ExecuComp for the period 1992-2005. Our estimation sample begins in 1992, when ExecuComp came into existence, and extends to 2005. We limit our sample to firms that have at least one patent during our sample period.

[6] US citation only.
[7] The updated match was provided by Prof. James Bessen.

3.2 Variable Construction

3.2.1 Dependent Variables

We have four dependent variables that characterize a firm's innovation strategy in a given year: patent counts, citation based patent quality, R&D expenditures and technology class concentration. To measure the magnitude of a firm's innovation, we construct patent counts by firm and year[8] and use the natural log[9] of patent counts as the primary dependent variable. Our next dependent variable is R&D expenditures in 2000 dollars[10]. This variable has a significant number of zeros and missing observations. Next we construct measures of patent quality. The number of citations received per patent in a given year is often used as a measure of patent quality. It is based on the idea that patents that make significant contributions will have more citations, i.e. a greater number of other patents will cite these, than those that embody minor innovations (Pakes, 1985; Jaffe, 1986; Griliches, Pakes, and Hall, 1987; Connolly and Hirschey, 1988; Griliches, Hall, and Pakes, 1991; Hall, 1993; Blundell, Griffith, and van Reenen, 1999).

However, the raw number of citation that a patent receives can be misleading. First, there may be truncation issues depending on the application year of the current. The 2006 NBER database reports truncation corrected citations. Patents may receive more citations simply because there are a greater number of patents in a given field in the following years that cite the previous patents, or it may come from a field where it is customary to cite frequently. To solve this, we purge the citations of these field effects as suggested by Hall et. al (2001). We then divide the truncation corrected citations and the field-effect adjusted citations by the total number of patents obtained by a firm in given application year, to create the unadjusted and

8 We count patents by application year, i.e. say for all patents applied for in 1990, how may were granted.
9 For patent counts equal to zero we use the log (10^{-10}).
10 Again since we use log values, for zero R&D we use the log (10^{-10}).

adjusted average citations respectively. We use the natural log of these two quality measures as our dependent variables. The last variable is the technology class concentration. It is based on the technology class characteristics of granted patents. This measures how concentrated each firm is in patent technology classes in each year, i.e. are they patenting in a narrow set of classes (concentration) or a broad set of classes (diversification). This is constructed as a Hirschman-Herfindahl index.[11]

3.2.2 Measuring Incentive Alignment

We use three measures of incentive alignment for the top three executives by rank, i.e. the CEO, CFO and the COO. First, we construct top 3 executive *holdings* using the standard definition of the fraction of equity shares of the top 3 executives, i.e. the number of shares of the firm held by the Top 3 Executives divided by the total shares outstanding. Theory suggests that when managers own more shares of their firm, they benefit more from value-maximizing decisions since these result in share-price increases. This is the "incentive alignment" effect. However, when managers own a large fraction of corporate shares they can become "entrenched," i.e. independently powerful and difficult to dislodge. In this case, they may attempt to benefit themselves at the expense of less powerful shareholders. This is the entrenchment effect. Thus, we could expect an inverse U-shaped relationship between executive ownership and corporate performance.

However, stock ownership is just one component of managerial pay and is an incomplete measure of equity-linked incentives. It does not reflect option contracts and does not capture the sensitivity of managerial wealth, *per se*, to share performance. The manager's wealth sensitivity

[11] For each firm, in a given year, we first calculate the number of unique and repeated patent technology classes. We then create shares where the denominator is 500, since there are approximately 500 patent technology classifications at the USPTO. We then construct the $HHIit = 10000\Sigma(\text{no. of patent class}_{it}/500)^2$, where i=patent technology class

to changes in the stock price (pay-performance sensitivity or *delta* as it is popularly called in the finance literature) is more indicative of managerial incentives than just equity ownership since the former is more closely tied to firm performance. A manager's expected risk and return will depend, in large part, on pay-performance sensitivity.

We thus define *pay-performance sensitivity* as the top three executives' wealth sensitivity to changes in the firm's stock price and construct this as the average dollar change in the top three executives' stock and option holdings in response to a one-percent change in the firm's stock price. Higher pay-performance sensitivity means managers benefit more from stock price increases and is generally thought to align managerial incentives with shareholder wealth maximization. Again, this is the incentive alignment effect. However, at very high levels of pay-performance sensitivity, risk-averse managers may forgo risky yet value-enhancing innovation projects. This is the risk-aversion effect. These opposing forces could create an inverse U-shaped relationship between pay-performance sensitivity and firm innovation.[12] We capture this relationship using a quadratic form for pay-performance sensitivity in our empirical model. Our measure of pay-performance sensitivity is constructed following Core and Guay (2002) who develop a methodology to estimate these sensitivities using information from the firm's most recent proxy statement. This is further described in the appendix.[13]

Our third measure of managerial compensation moves away from equity-based constructs and assesses the *short-term incentives* faced by the managers. This measure is constructed as the average ratio of bonus to total salary received by the top 3 managers. Total salary comprises the base salary and an annual bonus. Base salary is the fixed component of managerial pay that modestly increases from year to year. Base salary is usually benchmarked at the industry level

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[12] See Berle and Means (1935), Jensen and Meckling (1976), Demsetz (1983), Fama and Jensen (1983), Smith and Stulz (1985)

[13] In the finance literature, pay sensitivity is often called *delta*. Palia (2001), Coles, Lemmon and Meschke (2007) and Brick, Palia and Wang (2005) use similar measures for CEO pay-performance sensitivity.

and is highly correlated with firm size, especially for firms that have strong stock return performance. Annual bonus is calculated as a percentage of base salary and is very often tied to short term performance (e.g. if certain targets for accounting profitability are met for the year).[14] Thus, this variable should capture the short-term incentives faced by the mangers. Last, we use the average *total compensation* of the top 3 managers to capture the size of the compensation portfolio. This includes the base salary, bonuses, other cash compensation and current valuation of stocks and options.

3.2.3 Innovation Environment of the Firm

We use five variables to capture the existing innovation environment of the firm: the stock of R&D expenditure, stock of own firm and rival firm past patents, average quality of past patents and the technology concentration of the firm in the previous year.[15] R&D is a critical input in any innovation process and greater R&D usually leads to more patents after factoring in uncertainties within the innovation and patent process. We create the stock of R&D expenditure by using a 12 percent depreciation rate for past R&D and using the current and past 4 years of R&D expenditure. This should have a positive impact on innovation magnitude and quality. It may have a negative impact on technology concentration since firms with larger R&D budgets may tend to explore newer technology areas.

The stock of own firm past patents is created in a similar manner as the R&D stock, and captures the past innovation portfolio of the firms. We can interpret this as a critical input to current innovation and a firm with a greater stock of past patents has a larger input base to use in current innovation. Thus a firm with a larger stock of patents may be expected to obtain a larger number of current patents, invest more in R&D and have a higher quality of current patents.

[14] See Murphy (1999).
[15] We note that while our dependent variables measure the "flow" or "change" in a firm's innovation strategies in a particular year, these control variables measure the "stock" of a firm's innovation in a given year. In our regression analysis, we lag these stock measures by 2 years.

However, the effect on technology concentration is unclear. Larger patent portfolios may lead firms to further concentrate on core technologies that they have found success in earlier, or they may explore new technology fields.

To create the stock of patents owned by other firms in the same industry, we create the stock of patents in the same 6 digit NAICS code as the current firm, and exclude the patents of the current firm. This variable captures the innovation landscape facing the firm in its industrial sector. Apriori, the effect of this variable on innovation and R&D is ambiguous. On one hand, firm's belonging to a highly innovative industry may patent more and spend more on R&D to keep up with its competitors. On the other hand, a large number of patents may imply that the competitors are crowding the innovation space leaving little room for the current firm, thus creating a negative externality. The same ambiguity persists for the effect of competitor's innovation activity on the quality and concentration of innovation of the current firm.

The average quality of past patents is constructed as the average patent quality from the previous four years and proxies for the quality of innovation inputs in the firm. Our measures of patent qualityhave been described earlier in the paper. We hypothesize that a firm with high quality innovation inputs will generate a larger number of patents. However, the effect on R&D and technology concentration is ambiguous. Existence of high quality innovation inputs may allow a firm to invest less in current research and live off its earlier research output. In addition, higher quality innovation inputs may increase technology concentration since the firm may invest only in those technology fields that it has already found success in. On the other hand, such firms already have a solid base of inputs and may attempt to innovate outside their core areas.

Last, the technology concentration, as mentioned earlier measures whether the firms are focused in a few core areas or whether they have a broad technology portfolio. We hypothesize that greater technology concentration would increase the number of patents and innovation quality since the firms would be building a narrow set of past knowledge fields in which they had gained expertise. The effect on R&D is unclear. Firms may actually have to spend less on R&D if they concentrate on a few technology areas rather than explore a broad set of fields.

2.2.4 Measuring Firm Characteristics

To evaluate what aspects of the executive reward structure influence innovation, we need to control for other confounding factors. First, we use two measures of managerial characteristics of the firm – managerial tenure and CEO control. Managerial tenure is measured as the difference between the current year and year the executive became CEO/CFO/COO, as reported in ExecuComp. This variable should control for career concerns of the managers. Apriori, the effect on innovation and R&D is ambiguous. On one hand a new manager may be less willing to invest in greater R&D and innovation if these are considered risky activities, compared to a manager with a longer tenure. On the other hand, new managers may invest in innovation since they are not entrenched and are willing to take risks. Next, we account for the control that the CEO has over the company. We use a dummy to indicate whether the CEO is also the chairman of the board of directors of the company. In such cases, the top 3 manager's activities may be subject to weak monitoring. This may allow them to maintain the status quo and thus depress innovation activities.

Following previous work, we also control for firm size (total number of employees), firm age, industry concentration (Herfindahl index), and other managerial characteristics. Firm size is measures by the log of total employees[16]. Firm age is measured by the difference between the current year and the incorporation year[17], if the latter is available. If the incorporation year is

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[16] The use of total assets or total sales as a measure of firm size leaves our results mostly unchanged and qualitatively similar.

[17] We are grateful to John Ritter for the use of his data on incorporation dates.

unavailable, we use the earliest year on CRSP that a firm has a positive stock price or the earliest year in Compustat that a firm has non-missing data for total assets. Industry concentration is measured by the Herfindahl Index based on Compustat data. This is given by: $\Sigma\alpha_i^2$ where α_i is the output (sales) share of each firm in the industry in that particular year and is summed over all firms in the industry. This measure varies between zero and one, with a more competitive industry having a Herfindahl Index closer to zero. Table I provides summary statistics for our estimation sample.

4. Empirical Methodology and Results

4.1 Innovation Magnitude

Our four dependent variables - patent counts, patent quality, R&D expenditures, and technology class concentration have some peculiar characteristics that are different from other types of data. Patent counts are non-negative integer numbers, and thus we cannot use the usual least squares estimation approach.[18] The alternative approach is to use a negative binomial panel fixed effects model[19], which accounts for the count nature of the dependent variable, and controls for firm specific fixed effects. As a robustness check we use a panel data tobit model with industry fixed effects,[20] and a linear fixed effects model with errors clustered at the industry

[18] Using OLS will yield some negative predicted values. But since the dependent variable is non-negative, the predicted values should also be non-negative for all explanatory variables. If all values of the dependent variable were strictly positive, we could have used a log transformation. However, since some of the values are zero we may prefer using a count data model.

[19] An alternative is to use a Poisson model, but our data violate the assumption of mean-variance equality and displays over-dispersion. Hence a negative binomial model is used.

[20] We assume that the random effects, v_i, are normally distributed with zero mean and constant variance σ^2_v, i.e. $N(0, \sigma^2_v)$. Thus we have: $\Pr(y_i \mid x_i) = \int_{-\infty}^{+\infty} \frac{e^{-v_i^2/\sigma_v^2}}{\sqrt{2\pi\sigma_v}} \left(\prod_{t=1}^{n_i} F(x_{it}\beta + v_i) \right) dv_i$

level. All specifications include year fixed effects. There are a large number of firms that have only 1 patent. We wanted to test whether our conclusions would hold if we treated these firms as having zero patents. Thus we use the tobit model to account for the left-censored data (at one, in this case) or a "corner solution outcome" (Wooldridge, 2001)[21]. We estimate the model below using the estimation techniques outlined above. Here, i indexes the firm, j indexes the industry and t indexes the year while the dependent variable is patent counts. Table 2 presents the results.

$$Patno_{it} = \alpha + \sum_{k=1}^{4} \beta_4 Exec\_pay_{it} + \sum_{l=1}^{L} \gamma_l Firm_{it} + \sum_{m=1}^{M} \delta_m Innov_{it} \sum_{p=1}^{P} \phi_p Ind_{jt} + \varepsilon_{it} \qquad (3)$$

Theory suggests that when managers own more shares of their firm, they benefit more from value-maximizing decisions since these, result in share-price increases, or they can become "entrenched," and attempt to benefit themselves at the expense of less powerful shareholders. From column (1) and (3) we find that managerial holdings have a very weak negative impact on the innovation magnitude of a firm. However, from the tobit specification in column 2 this coefficient is significant. We find that patent counts decline as managers become more entrenched, i.e. greater managerial holdings have a negative effect on innovation magnitude.[22] Thus if owners are looking to put firms on an increased innovation trajectory, increasing the shareholding of top managers will not achieve that goal.

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where: $$F(\Delta_{it}) = \begin{cases} (-1/\sqrt{2\pi\sigma_\varepsilon})e^{-(y_{it}-\Delta_{it})^2 /)2\sigma_\varepsilon^2)} & \text{if } y_{it} \text{ is non-censored,} \quad \Phi\left(\frac{y_{it}-\Delta_{it}}{\sigma_\varepsilon}\right) \quad \text{if } y_{it} \text{ is left-censored} \\ 1-\Phi\left(\frac{y_{it}-\Delta_{it}}{\sigma_\varepsilon}\right) & \text{if } y_{it} \text{ is right-censored} \end{cases}$$

This model is estimated in Stata by Gauss-Hermite quadrature. The error has two components: v_i - the random disturbance that varies by group but not over time ($v_i \sim N(0, \sigma^2_v)$) and ε_{it} - is the idiosyncratic error component ($\varepsilon_{it} \sim N(0, \sigma^2_\varepsilon)$

[21] The issue here is not that we do not observe data below a certain threshold – as is the case with most censored models. But we are interested in E(y|x, y>0). Therefore a simple OLS model would be inconsistent.

[22] The tobit specification is slightly different from the other two columns since it treats the firms having 1 patents as those that have zero patents (truncation is at 1 patent).

Equity ownership, however, is an incomplete measure of the managers' equity-based incentives. It does not reflect option contracts and does not capture the sensitivity of manager wealth, *per se*, to stock price performance. We thus use the pay-performance sensitivity of the top 3 executive's compensation package as a more nuanced measure of incentive alignment. This is measured as the sensitivity of managers' wealth to percent changes in his firm's stock price, and depends on the amount of shares he owns, the number of options he owns, and various properties of the options such as maturity and strike prices.

From all columns we find that innovation magnitude has an inverted U-shape relationship with pay-performance sensitivity. Patenting initially increases with pay-performance sensitivity, consistent with the incentive-alignment effect, i.e. as managers wealth becomes more sensitive to their firm's share price, their incentives become more aligned with those of the shareholders. This can be related directly to Hall et. al's (2000) finding that the event of a patent grant has a positive impact on a firm's financial value through changes in stock price. If manager's wealth portfolios are very sensitive to such price changes, then they would be more willing to increase the number of patents obtained by the firm since it will directly increase their wealth. However, for very large price pay sensitivities, patenting activity is dampened. The negative effect on patenting for higher values for pay-performance sensitivity is more consistent with the risk-aversion hypothesis. Managers, whose personal wealth is very closely tied to the financial performance of the firm, become averse to investing in risky investments such as R&D. Overall a one standard deviation change in pay-performance sensitivity increases patents by 0.07 percent (column 1).[23]

This conclusion is also consistent with evidence presented in Coles, Daniel and Naveen (2006) that looks at the empirical relationship between CEO pay-performance sensitivity and

[23] This is calculated at the median sensitivity and median patents. The pure elasticity is 0.02 when calculated at the median.

specific firm policies. They find that high pay-performance sensitivity induces CEOs to take less risky decisions, such as more capital expenditures and less R&D. However, the difference with their result is that in our case, the negative effect is an order of magnitude smaller than the positive effect, and occurs at extremely high levels of pay-performance sensitivity. Thus, increasing the price pay sensitive of a managers' wealth portfolio over a broad range can induce them to increase patenting activity. These effects are robust across specifications. Additionally, short-term incentives have no impact on innovation. However, the total compensation received by top managers positively affects the innovation magnitude of a firm. A one standard deviation change in the total compensation variable increases patenting between 0.02 to 0.04 percent, depending on the specification.

In addition, we find that the innovation environment of the firm and other firm characteristics have significant impacts on the patenting behavior of firms. Higher input quality, as measured by the average quality of past patents, has a significant positive impact of current patenting. Also, a higher technology concentration leads to a lower number of patents. This supports the view that firms may be better off by innovating in a broad number of fields rather than concentrating on some core technology areas where diminishing returns may set in. In addition, firms with a higher quality of past innovation which are concentrated in a small number of fields have fewer patents. This finding complements those of Lanjouw and Schankerman (2004) who find that there is an inverse relationship between patents per R&D dollar and patent quality. In our case firms with a high quality past patent portfolio who innovate in a narrow field of technology may have less need to constantly improve their innovation performance. Overall, from column 1, we find that a 1 percent increase in part patent quality increases patents by 0.03 percent while a 1 percent increase in technology concentration decreases patents by 0.02 percent. In our sample, if a firm is in a highly innovative industry as evidence by the stock of patents owned by the firm's competitors, it increases the innovation performance of the firm, hinting at positive inter-firm innovation externalities or an effort to 'escape competition' (Aghion et. al. 2005).

We also find that older firms tend to have a greater number of patents, while the negative and significant quadratic terms on age (column 1) suggests that there is an optimal age after which innovation declines. However, this result is not robust to alternative specifications. Next, we find that the interaction term between age and size is negative and significant, implying that for our sample, large old firms are less successful in patenting than smaller and younger firms. Overall, when all the interactions are taken into account, a 1 percent increase in age leads to a 0.14 percent decrease in patenting, while a 1 percent increase in size leads to a 0.08 percent increase in patenting.

Managerial tenure appears to have little impact suggesting that both new and long-term executives approach innovation strategy in a similar manner holding everything else constant. In columns 2 and 3, the coefficient for the CEO control dummy is negative and significant, implying that firms whose CEOs are also the executive directors patent less than their counterparts where these two roles are played by separate people. Thus CEO control dampens patenting of these firms by 0.04 percent. Last, from column 1 we find that firms in a competitive industry generate more patents as evidenced from the positive and significant coefficient on the Hirschman-Herfindahl index. This implies that firms in a competitive industry may be patenting more either to gain competitive advantage or building a patent thicket around its core innovations (Bessen, 2003) to prevent future litigation. However, this result is not robust to the alternative specifications in column 2 and 3.

The significance of the innovation environment of the firm in the success of patenting leads us to explore whether managers are influencing various facets of the innovation environment, which in turn generates more patents. On a related theme we also want to investigate the channels through which the managers are pursuing a prolific patenting strategy. For instance, are they increasing R&D expenditures to obtain more patents, are they broadening their technology areas, or are they slicing up the existing innovations into more 'thinner' patents, such that average patent quality for the firm suffers. If incentive pay could make managers undertake the former two strategies, it would be value enhancing for the firm in the long run and align the incentives of the owners and managers. However, if the incentive structure makes managers adopt the "cutting the salami thin" strategy then this is detrimental to long term firm value. Next we examine how these pay incentives have influenced the R&D expenditures of firms, the quality of patents they are producing and their core technology fields.

4.2 R&D Spending

R&D is a continuous variable and can usually be estimated using linear fixed effect models. For our sample 40 percent of the firms conduct no R&D, since some old economy manufacturing firms do not invest in R&D. For the econometrician observing the data from outside, this presents a unique challenge. One is always faced with the question about what these zeros represent. Do they represent the decision not to conduct R&D, or are these just zero dollars spent on R&D? Although we can use econometric tests to select one over the other, one should also draw from qualitative evidence about firm conduct. In this case we believe that the zeroes represent a decision not to conduct R&D. For most firms, a critical minimum amount of R&D is required before the firm can observe any innovation activity or accrue benefits from that research. Thus some firms may choose not to engage in R&D. In the data we find that the R&D magnitude is zero throughout our sample period for most firms who choose not to invest in R&D. Only in a handful of cases do firms switch between zero and positive R&D.

Suppose R&D decisions are a two-step process. In this case, in the first stage the managers decide whether the firm should engage in R&D at all, depending on its expected future benefits for the managers from investing in R&D. The second level decision would involve determining the optimal amount of R&D that would maximize the present discounted value of the top 3 executive's benefit function subject to various institutional constraints. In this context, both unobserved heterogeneity and selection issues are a problem. A number of studies have addressed selection issues and unobserved heterogeneity under conditions of strict exogeneity of explanatory variables (Kyriazidou, 1997; Verbeek and Nijman, 1992) and with endogenous regressors (Vella and Verbeek, 1999; Wooldridge, 2002; Fernandez-Val and Vella, 2007). Using methodology developed by these studies, we first test whether selection is a concern for our specification.

Each year the manager decides whether to invest in R&D or not (y_{it}), depending on whether it gives her positive net benefits. The latent unobserved variable is the net benefit stream for the manager from patenting (y^*_{it}). Thus the decision is modeled as:

$$\begin{aligned} y^*_{it} &= x'_{it}\varphi + u_{it}, \quad \text{where i} = 1,\text{...n and t} = 1,\text{.......T}_\text{i} \\ y_{it} &= 1 \quad \text{if } \text{y}^*_{\text{it}} > 0, \text{and 0 otherwise} \end{aligned} \tag{2}$$

where: u_{it} is the error term independent of x_{it}, which represents the vector of covariates and comprise top 3 executive characteristics, firm attributes and industry characteristics. Although this is a panel specification[24], testing for sample selection and consistent estimation of the two-stage model requires that we estimate a cross-section probit equation for each year between 1993 and 2005 (Wooldridge, 1995, 2002) with a R&D dummy[25] for the dependent variable. We use

[24] Following Chamberlain's approach (1980, 1982) we could have used the panel specification, but it would require certain linearity assumptions that may not be warranted for our specification.
[25] R&D dummy equals1 if the firm engages in positive R&D for that year.

age, age square, firm size, industry concentration, long-term debt, a lagged patent dummy[26] showing past patenting activity, lagged mean adjusted innovation quality, current tenure of the top 3 executives, a dummy for whether the CEO is new, and industry dummies as explanatory variables in the probit regression. We present the results of a random effects panel probit model in Table 3, column (1), to show how various factors affect the decision to engage in R&D.

We find that controlling for firm characteristics and the innovation environment in the firm, greater executive holdings decreases the probability of engaging in R&D. Thus, increasing the shareholdings of managers may not serve to enhance the innovation capabilities of a firm in so far as they invest less in R&D. Other pay-performance measures do not influence the R&D decision. Interestingly we find that higher managerial tenure increases the probability of R&D spending and better aligns the managers' actions with a firm's long-term goals. In addition, a new CEO (joined in the last 6 months) is much more likely to invest in R&D. Firms with past innovation experience are more likely to invest in research, and more leveraged firms tend to do little research. Last, greater industry concentration seems to induce a firm to engage in more R&D. We derive the inverse Mills ratio[27] (IMR) for each firm *i* for *t* years (from our year by year probit model) and use it to test for sample selection in the second stage.

To test whether selection issues are a problem in our specification we estimate equation (4) below (without the IMR term) using a fixed effects panel data model that accounts for time-invariant heterogeneity and has robust S.E. This test was first proposed by Nijman and Verbeek (1992) and later modified by Wooldridge (1995). However, the estimates for the other coefficients are inconsistent as shown in Wooldridge (2002), and thus results are not presented. We find that selection is a significant concern for the R&D specification, since the inverse Mills

[26] This dummy equals 1 if the firm has patented in the past year.
[27] The inverse Mill's ratio captures the non-selection hazard, and is given by $\phi(x_{it}'\beta)/\Phi(x_{it}'\beta)$, where φ(.) and Φ(.) denote the PDF and CDF of the standard normal distribution respectively.

ratio is significant in all specifications. This validates our earlier assertion that R&D should be treated as a two-step process.

The second stage is then observed, conditional on participation in research activities. [28] Here we investigate the factors that influence the magnitude of R&D spending given that the firm has decided to engage in research. The dependent variable is log of positive R&D spending (in 2000 dollars) and the estimation equation is given by:

$$\ln RD_{it} = \alpha + \sum_{k=1}^{4} \beta_4 Exec\_pay_{it} + \sum_{l=1}^{L} \gamma_l Firm_{it} + \sum_{m=1}^{M} \delta_m Innov_{it} \sum_{p=1}^{P} \phi_p Ind_{jt} + \rho IMR_{it} + \varepsilon_{it} \qquad (4)$$

To account for selection effect, we include inverse Mills ratio (IMR_{it}) that is calculated based on the probit equation of the first stage[29]. Following Wooldridge (2002), we estimate the above equation using a pooled OLS model, and correct the errors for heteroscedasticity, and for the inclusion of the estimated inverse Mills ratio. We find that the coefficient on the inverse Mills ratio is positive and significant (0.270) indicating the presence of selection.[30] Hence, a two-stage model is warranted instead of a tobit specification. Results are presented in Table 3, column (2). As a robustness check we present results from a panel data tobit model in column (3).

From both specifications, we find that the incentive pay characteristics of managers have a significant impact on R&D expenditures, conditional on firms engaging in R&D. We find that controlling for firm characteristics and the innovation environment in the firm, a one standard deviation increase in top 3 executive holdings decreases R&D expenditures by approximately 0.2 percent. This may imply that as managers own more shares they become entrenched and invest

[28] The exclusion restrictions are satisfied since there are 3 variables in the selection model that are excluded from the levels equation since we believe that these affect only the decision to conduct R&D and the level of expenditure.
[29] For calculation of the inverse Mills ratio see Wooldridge (2002) and Fernandez-Val and Vella (2007).
[30] To capture the time-varying nature of selection we included the interaction between the IMR and year dummies – however in all specifications the interactions were insignificant showing that the selection effect does not vary with time. Thus the interactions have been dropped from the final model.

less in R&D. The returns from such expenditures may be realized in the long term and given the short tenure of most managers, it may not be in their best interest to pursue such actions.

Again, increasing the shareholdings of managers may not serve to enhance the innovation capabilities of a firm. The pay-performance sensitivity on the other hand, may be a better incentive mechanism for increasing R&D expenditures. We find that the relationship between R&D and pay-performance sensitivity is non-monotonic. R&D initially increases with pay-performance sensitivity and then declines at very high levels of pay-performance sensitivity. However, the negative quadratic term is small and economically insignificant. Overall, increasing the pay-performance sensitivity of managers' portfolios by one standard deviation, increases R&D spending between 0.72 percent (column 2) and 1.06 percent (column 3).[31]

From the selection corrected specification in column 2[32], we also find that both short-term incentives and the total compensation have a positive influence on R&D expenditures. A 1 standard deviation change in the short-term incentives and total compensation increases R&D by 0.06 and 0.1 percent respectively. However, the results are not robust across specifications. Other managerial characteristics also influence how much R&D a firm performs. From column 3, executive tenure has a positive impact on R&D, a result documented by Barker and Mueller (2002) in their study on the effects of CEO characteristics on R&D spending. Thus managers that have stayed in the firm longer invest more in research. More years in a firm implies greater entrenchment for the manager, which may make him want to preserve the status quo. However, we find evidence contrary to this entrenchment hypothesis. One possible explanation could be that as managers stay at a firm longer it mitigates the myopic decision problem faced by managers with a short tenure. Long-term managers may take a long-term view of the firm's

[31] Evaluated at the median. The pure elasticity varies between 0.15 (column 2) and 0.20 (column 3) percent.
[32] All marginal effects and elasticities are calculated for the selection corrected second stage only, without taking into account the effect of the variables in the first stage.

planning horizon and may invest more in longer horizon growth strategies such as investing in R&D. A 1 percent increase in tenure increases R&D by 0.01 percent (column 3). Also, similar to Table 2, firms with greater CEO control spend less on R&D than their counterparts (column 2).

We also find that that the innovation environment of the firm and other firm attributes impact R&D expenditures. Firms with higher quality past patent portfolio invest more in research (column 2) showing that firms build on their past innovation successes, while technology concentration does not influence R&D expenditures.[33] Additionally, firms with a past history of innovation, as captured by the past patent portfolio spend more on R&D and a 1 percent increase in the own firm past patent stock increases current R&D between 0.28 (column 2) and 0.31 (column 3) percent, while a 1 percent increase in the rival firms' past patent stock increases R&D between 0.04 (column 2) and 0.21 (column 3) percent.

Large older firms do more R&D than smaller younger firms. The results for patents are the reverse of this. From Table 2 we had found that large old firms have a lower number of patents than small young firms. This may point to diminishing returns in terms of R&D productivity. Overall, a 1 percent increase in size increases R&D between 2.4 (column 2) and 5.5 (column 3) percent, whereas it increased patents by only 0.08 percent. Additionally, firms with a large amount of cash tend to invest more in R&D. Last, the effect of cash holding on R&D is positive (column 2) confirming the finding by Baber et. al (1991) who show that R&D is strongly influenced by current period income effects. In conclusion, the findings on the effect of incentive alignment contracts on R&D and patenting imply that simply increasing managerial holdings will not increase innovation, while increasing the pay-performance sensitivity on a

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[33] One may have expected that if firms want to gain expertise in a narrow number of areas it may require greater R&D expenditures since it may be more difficult to generate inventions in a set a narrow over-researched areas. In other words, firms would increase R&D investments to overcome the diminishing returns that may come with a narrowly focused technology field. Alternatively, firms' with more concentrated portfolios may be able to spend less on R&D since they already have expertise in a technology area.

manager's portfolio may achieve the long term goal of increasing R&D and innovation for a firm. It may discourage managers from following the "cutting the salami thin" strategy, and may induce managers to produce better quality patents. We investigate this idea in the next section.

4.3 Patent Quality

Patent quality, as measure by citations, are an indicator of the 'importance' of a patent, and as such, provides a way of understanding the vast heterogeneity in the value of patents. Patents with a greater amount of citations are considered more 'valuable; and have a significant link to the private, social and market valuation of a firm (Griliches, 1981, Griliches et. al, 1991, Hall et. al. 2004; Harhoff et. al, 1999, Jaffe et. al., 2002; Trajtenberg, 1990). Hall et. al. (2005) finds that the market valuation of a firm increases by 3 percent for every additional citation. Thus as the pay-performance sensitivity of managers increase, they should follow innovation strategies that would potentially yield higher valued patents with more citations.

We use two metrics to measure patent quality: the log of the average adjusted and unadjusted quality of a firm's patent portfolio[34]. We use the average citations instead of the aggregate citations since the latter may not be a true reflection of quality. In an environment where firms are getting more patents than in previous years, total citations to a firm's portfolio of patents may increase simply because the number of patents obtained by the firm is increasing, or because there are more citing patents in the particular technology class. Thus an increase in total number of citations may not be a true indicator of quality increase. Mean quality is thus a better metric. This would increase if and only if the rate of increase in citations is greater than the rate of increase in the number of patents. We want to assess whether the compensation schemes are

[34] Average adjusted quality is measured by the mean number of truncation corrected citations purged of field effects that each firm/assignee receives. When we purge the citations of field effects, this in essence controls for technology class fixed effects. The unadjusted mean is based on the truncation corrected citations without the field-effect adjustment.

aligning the incentives of managers to create the groundwork for long-term performance by increasing the quality of innovation, or are they leading to myopic short-term innovation activity.

We use the log of these average quality measures as our dependent variable in Table 4. There is a substantial proportion of zeros in the data since most patents never get cited.[35] This creates two problems. We cannot use a linear fixed effects model ionce again since this invalidates the OLS assumptions. Both quality variables are bounded by zero on the lower end of the distribution. Although we are only interested in the positive citation numbers, discarding the zeroes would bias our results. Thus we estimate a random effects tobit model to account for the left-censored data[36] similar to the patent specification. Results are presented in Tables 4. [37] We find very similar results for average unadjusted and adjusted patent quality and thus, we shall discuss the results for the average unadjusted patent quality from columns (1).

First, we find that quality decreases with an increase in managerial holdings, and a one standard deviation increase in holdings leads to a 0.35 percent decrease in average quality. This implies that as managers become more entrenched, they pursue policies that have a detrimental effect on innovation quality. This finding coupled with those on R&D and patent magnitude implies that such entrenched managers, invest less in R&D, produce a lower number of patents that are also of lower quality. However, similar to the innovation magnitude and R&D response, increases as the pay-performance sensitivity increases patent quality. If better quality patents increase the stock prices of the firm by a larger amount, then managers will tend to invest in producing better quality patents as their pay-performance sensitivity increases, since this directly increases their personal wealth. There is a small negative effect of risk-aversion at very high

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[35] When taking logs, the magnitudes are undefined at zero. Thus we substitute the zeros with a very small positive number (10^{-4}).

[36] Censoring occurs where the average quality takes a zero value, i.e. log(average quality) = log(10^{-4})

[37] However, this does not allow one to correct errors for clustering and heteroscedasticity. As a robustness check we use a random effects GLS model[37] with clustered and robust standard errors when estimating the average quality specification, as well as a censored normal, and the results are stable across all specifications.

levels of pay-performance sensitivity. Overall, a 1 standard deviation change in pay-performance sensitivity increases patent quality by 1.08 percent. Short-term monetary incentives or the total amount of compensation have no influence of patent quality.

We also find the tenure of the top 3 executives has no impact on patent quality while CEO control has a weak negative impact[38]. Additionally, as firms age they suffer a decline in patent quality. However when size is factored in, large old firms appear to have higher quality patents than smaller younger firms. This result combined with the earlier findings that large old firms also have a lower number of patents and invest more in R&D compared to their smaller and younger counterparts may imply that such firms are not using patents primarily as a strategic tool, but rather their patents are embodying fundamental innovations. Overall, a one percent increase in age and size increases quality by 0.05 percent and 0.18 percent respectively. Industry concentration on the other hand has a negative impact on quality. This result combined with the positive effect of industry concentration on patent magnitude implies that in very competitive industries, firms may be obtaining a vast amount of patents primarily to build patent thickets (Bessen, 2003) rather than come up with better innovation to escape competition (Aghion et. al., 2005).

In addition, higher R&D leads to better quality patents and a one percent increase in R&D expenditures increases quality by 0.33 percent. Interestingly, technology class concentration is also positively related to patent quality, showing that firms who stick to their core areas of expertise produce better quality innovation, albeit these are fewer in number (Table 2). Thus for shareholders who are trying to increase both the quality and magnitude of innovations, the effect of incentive pay on managerial decisions about diversifying into broader

[38] The coefficient is significant at 12 percent.

technology fields versus concentrating in core expertise may not be obvious. We explore this idea further in the next section.

4.4 Diversification versus Concentration

Previously we observed that firms that concentrate on a narrow range of core technologies have a lower number of patents which are, however, of better quality. Thus for shareholders with a long-term view of the firm, inducing managers to follow a strategy of concentration rather than diversification may improve firm performance in the longer run due to better quality innovations. In Table 5 we report the results of our estimation of the relationship between managerial incentives and patent technology concentration . In column (1) we use a random effects tobit model since the concentration index is theoretically bound between 0 and 10000. In column (2) we use a linear fixed effects model with standard errors clustered at the industry level. We find that only managerial holdings influences technology concentration. A one standard deviation increase in holdings decreases technology concentration by 0.68 percent, i.e. managers tend to focus the firm's innovation activities on a broader range of technologies. This result complements the earlier findings that broadening the technology area of the firm increases the absolute number of patents but decreases quality. Thus entrenched managers, who are also less likely to invest in R&D may choose to follow strategies that result in a larger number of low quality patents.

We also find that greater R&D increases the technological concentration of the firm, and as firms age, they first broaden their technology base and then primarily concentrate on core areas. Additionally, older and larger firms are more concentrated in their technology portfolio. Overall, a one percent increase in age decreases concentration by 0.02 percent and the size elasticity is 1.12. Viewed together all the results suggest that managerial holdings and pay-performance sensitivity of the managerial portfolio has a significant influence in shaping a firm's innovation strategy. Increased sensitivity leads to a larger number of high quality patents. Increased managerial holdings, on the other hand, leads to managerial entrenchment and myopic decision making that reduces R&D expenditures. This is detrimental to innovation quality, as managers only focus on obtaining more patents. Short-term monetary incentives and total compensation do not influence innovation strategies for the most part.

5. Attempts at Solving Endogeneity

The findings above show the important linkage between corporate executive compensation strategies and the innovation performance of firms. However, one may also be concerned about endogeneity in our specifications. We have argued that the reason top 3 managers want to influence a firm's innovation performance is because it has a direct impact on their compensation packages, i.e. they may have "career concerns" about the effects of current performance on future compensation (Gibbons and Murphy, 1992). This implies that past innovation performance may directly impact current compensation packages. In addition, there may be some exogenous unobservables that may impact both innovation and managerial compensation. For example, more innovative firms may choose top managers who can provide leadership in newer innovation strategies. These feedback and selection issues are not fully controlled for in our specifications despite using a one year lag of the compensation variables.

To address the potential endogeneity in the relationship between innovation and the compensation of R&D managers, Lerner and Wulf (2007) use the compensation of the non-R&D managers as additional variables in their regression, and show that these do not influence innovation. In our case this strategy is difficult to defend. We cannot argue conclusively that the next managers after the top 3, such as the marketing manager, do not influence the innovation strategy of the firm. Thus we cannot use the compensation of the next-level non-R&D managers as instruments for the top 3 executives. However, from the corporate finance literature we know the compensation packages of the top executives are highly correlated within an industry, and in fact salaries are often benchmarked at the industry median. Additionally, there is little reason to believe that the compensation of other managers outside the firm will impact its innovation performance.

In Table 6 we estimate an instrumental variables regression where the second stage is estimated by a negative binomial fixed effects regression identical to that in Table 2, column 1, except that we use the instrumented compensation variables for the top 3 managers. In column 1 we use the mean compensation variables and in column 2 we use the median compensation variables of the top 3 managers of other firms in the same six digit NAICS code as the current firm.[39] We find that similar to Table 2 pay-performance sensitivity displays an inverted U-shape with respect to patenting activity and managerial tenure has a positive impact as well. The major difference is in the effect, or lack thereof, of the total compensation variable. The fact that we get similar signs and significance on four out of five of the compensation variables shows that endogeneity may not be a problem for our results.[40]

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[39] We use the methodology outlined in (Wooldridge,2002) to test whether compensation is endogenous with regard to patenting. First we regress the compensation variables on the instruments and all other regressors included in patenting specification in Table 2. Next, we obtain the predicted residuals from this regression and re-estimate the specification in Table 2 with the predicted residuals included as a regressor If the coefficient on this predicted residual is significant we reject the null hypothesis of exogeneity. In our case we fail to reject the hypothesis at 10 percent. Staiger and Stock (1997) however, suggest that this standard endogeneity tests can be misleading in case of weak instruments, and the correlation between the instrument and the endogeneous variable can be artificially high due to the presence of other control variables. They suggest evaluating the partial correlation of the instruments and the endogenous variable, and as a rule of thumb, observing whether the partial F-statistic exceeds a value of 10 to ensure that the instruments are not weak. In our case the F-statistic is considerably over 10.

[40] Since we perform a manual instrumental variables regression (two stage least squares), we bootstrap the standard errors for the inclusion of the predicted variables from the first stage. The instruments used are all the regressors from Table 2 column 1 along with the mean/median compensation variables of the top 3 managers of other firms in the same industry. Additionally we perform a Hausman test for overidentifying restrictions to confirm the validity of our instruments.

6. Robustness Checks

In Tables 7A – 9B we present robustness checks for our results. Table 7A and B investigates whether managers respond differently to compensation contracts in high and low technology industries. Table 7A uses patents while 7B uses R&D expenditures to differentiate between the high-tech and low-tech cohorts.[41] First, we find that R&D responds negatively to managerial holdings while increasing pay sensitivity increases patent quality in both industry segments. In high-tech industries (column b in all tables), increasing managerial holdings lowers innovation magnitudes, increases concentration but does not influence patent quality. Increasing pay-performance sensitivity increases patent magnitude and quality. Increasing total compensation on the other hand, increases R&D, but decreases quality. However, our results in Table 2 - 5 are not being driven by the high-tech sector alone. Increasing pay-performance sensitivity and total compensation is an effective mechanism to enhance R&D expenditures in low-tech industries. Increasing managerial holdings, however, lowers patent quality and technology concentration in such firms.

In Table 8A and B we investigate whether the effect of managerial compensation differs depending on firm age and size[42]. Table 8A shows that for new firms, increasing managerial holdings lowers patenting (column 1a) and leads a firm to diversify its technology portfolio (column 4a), while pay-sensitivity works as a good incentive alignment mechanism increasing patent magnitude (column 1a) and quality (column 3a). Increasing total compensation and the tenure of managers also increases patenting (column 1a) for these firms. For older firms, increasing managerial holdings increases patenting (column 1a), while pay-sensitivity appears to

[41]We define low (high) tech firms as those that are below (above) the mean patent or R&D magnitudes for our estimation sample. The mean is the overall mean for years 1993 – 2005.

[42] We define new (old) firms as ones that are below (above) the mean firm age for our estimation sample. The small (large) firms are defines as ones who are below (above) the mean firm size (measures by number of employees) for our estimation sample. The mean is the overall mean for years 1993 – 2005.

have no impact on patent magnitude, quality or concentration. Managers in new and old firms respond in a similar manner in terms of R&D spending (column 2a and b), although in older firms CEO control appears to lower R&D (column 2b). On average, compensation contracts appear to better align incentives in newer firms. From Table 8B we find that pay sensitivity is a good incentive alignment mechanism for both large and small firms, while managerial holdings have a negative impact on quality only for large firms (column 3b). Total compensation increases patenting (column 1a) and technology concentration (column 4a), while managerial tenure lowers quality and concentration in small firms only. Again, the R&D response to managerial compensation is similar in small and large firms (column 2a and b).

Table 9A and B investigates whether the relationship between managerial compensation and innovation performance is altered as the corporate governance structure of firms change. Compensation contracts are just one mechanism for aligning managerial incentives with shareholder interests. Several studies show that monitoring managers' actions, either internally (by directors on the board) or externally (by outside shareholders), is an alternative control mechanism (Lippert and Moore, 1995; Fahlenbrach, 2009), and executive compensation and a firm's governance structure act as substitutes in helping to align managers' actions with shareholder goals. This implies that managerial compensation contracts are more incentive-compatible in weakly governed firms, i.e. those with a smaller fraction of independent directors on the board and firms with less concentrated institutional investor ownership. Specifically, Fahlenbrach (2009) shows that weakly governed firms are associated with higher managerial pay-sensitivity and higher excess pay.[43] Given the significant incentive alignment effects of higher pay-sensitivity we might expect our findings to be driven by weakly governed firms.

[43] Excess pay is defined as industry-adjusted compensation.

Based on data from the IRRC Director's database and Thomson Financial's Institutional Ownership database we construct two governance metrics: board independence, as measured by the fraction of directors who are not affiliated with the company[44], and institutional investor ownership concentration (Hartzell and Starks, 2003), as measured by the ownership of the top five institutional investors[45] as a fraction of the shares held by all institutional investors. We find no systematic relationship between the governance structure and the innovation response to managerial compensation. We find that incentive contracts align managerial actions with shareholder interests to increase patenting in firms with more independent boards (Table 9A, column 1b). Stronger governance through greater institutional holdings does not alter the relationship between managerial compensation, and patenting and R&D. Pay-sensitivity, however, is a better incentive alignment mechanism and improves patent quality for weakly governed firms (Table 9A and B, column 3a). In firms with lower institutional holdings, increasing pay sensitivity increases technology concentration (Table 9B, column 3a).

7. Conclusion

This paper investigates whether compensation schemes can successfully align the incentives of managers, who are typically myopic, with those of the owners, who usually take a longer term view, to improve the innovation performance of firms. We find that pay-performance sensitivity, i.e. the sensitivity of managers' wealth to percent changes in his firm's stock price is an important incentive mechanism that aligns managers' and shareholders' goals. Specifically, we find that innovation magnitude, R&D and innovation quality have an inverted U-shape relationship with pay-performance sensitivity. These variables initially increase with pay-performance sensitivity, consistent with the incentive-alignment effect, i.e. managers'

[44] These are directors who have no significant connection to the firm as reported by IRRC.
[45] These are the institutions with the five largest shareholdings in the firm.

incentives are aligned with those of shareholders. They decrease at very high levels of pay-performance sensitivity. However, the quadratic term is economically insignificant is all cases and the overall impact is a positive one. Overall a one standard deviation change in the pay-performance sensitivity of the top 3 executives increases patenting, R&D and patent quality by 0.07, 0.2, and 1.08 percent respectively. We explain this behavior by drawing on Hall's (2004) finding that the event of a patent grant provides a positive shock to a firm's stock price. If manager's wealth portfolios are very sensitive to such price changes, then they would be more willing to undertake strategies that will increase the number of patents and produce better quality patents, since it will directly increase their wealth. Thus increasing the pay-sensitivity of managers appears to be a successful strategy if owners want to increase the innovation performance of firms.

We also find that as managers become more entrenched, i.e. their share holdings increase, they pursue policies that have a detrimental effect on innovation outcomes. They invest less in R&D, and produce a lower number of patents that are also of lower quality. They also tend to focus on the firm's innovation activities on a broader range of technologies, which may increase the absolute number of patents but decrease quality. Thus entrenched managers are more likely to act myopically and follow strategies that result in a large number of low quality patents. If owners are looking to put firms on a long-term successful innovation trajectory, increasing the shareholding of top managers will not achieve that goal. Interestingly we find that higher managerial tenure increases the probability of R&D spending and innovation quality and thus better aligns the managers' actions with a firm's long-term goals. CEO control of the firm, however, decreases its innovation performance.

The firms' innovation environment contributes in important ways to its current innovation outcomes. Higher input quality, as measured by the average quality of past patents, has a significant positive impact on current patenting. Firms with a concentrated technology portfolio have a higher quality patent portfolio, albeit a lower number of patents. Large older firms do more R&D and have higher quality patents than smaller younger firms, although they have lower number of patents than the latter. This result may imply that such firms are not using patents primarily as a strategic tool, but rather their patents are embodying fundamental innovations. Last, patenting by rivals and the competitive landscape also influences patenting behavior. In conclusion, accounting for all these factors, increasing pay-performance sensitivity appears to be the best tool to improve innovation performance of a firm.

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TABLE 1
Summary Statistics

	Mean	Median	SD	Min	Max
Dependent Variable					
Patent Count	37.715	3.000	161.903	0	4344
Log Patent Count	1.658	1.099	1.714	0	8.377
R&D Dummy	0.708	1.000	0.455	0	1.000
Log R&D Expenditure (2000 $ Mill.)	-4.309	-1.818	5.231	-11.513	4.729
Log Average Unadjusted Patent Quality	-4.511	-0.453	6.985	-11.513	5.832
Log Average Adjusted Patent Quality	-5.932	-3.325	5.584	-11.513	2.620
Log Aggregate Unadjusted Patent Quality	-3.224	0.777	8.350	-11.513	11.558
Log Aggregate Adjusted Patent Quality	-4.540	-1.655	7.061	-11.513	8.677
Log Technology Class Concentration	-0.195	6.441	9.396	-11.513	9.210
Incentive Alignment (Lag 1 Yr.)					
Holdings (%)	3.190	0.428	7.236	0.0001	45.148
Pay-performance sensitivity ($ ’00M)	0.390	0.101	1.130	0.0002	9.778
Short-Term Incentive	37.511	37.932	17.539	0.018	88.765
Total Compensation ($ ’00 M)	0.252	0.144	0.325	0.018	2.238
Firm Innovation Environment Lag 2 Yrs.)					
Log Mean (Adjusted) Patent Quality	-5.041	-1.384	5.580	-11.513	2.780
Log Technology Class Concentration	0.478	6.685	9.270	-11.513	9.210
Log Own Patent Stock of Firm					
Past Patent Activity Dummy	0.978	1.000	0.146	0	1.000
Log (R&D Stock)($M)	-3.512	-0.945	5.563	-11.513	5.701
Log Patent Stock of Other Firms in same Industry	5.508	5.675	2.987	0	10.652
Firm & Executive Characteristics					
Top 3 Executive Tenure (Lag 1 Yr.)	12.036	8.000	11.005	0	55.000
New CEO Dummy	0.216	0	0.412	0	1.000
CEO Control: CEO Executive Director Dummy (Lag 1 Yr.)	0.729	1	0.444	0	1
Firm Age	1.591	1.629	1.853	-11.513	7.496
Firm Size: Log (Employees)	7.099	7.027	2.023	0.000	13.713
Log Long Term Debt (Lag 2 Yrs.)	-1.572	0.318	5.104	-11.513	8.357
Log Cash (Lag 2 Yrs.)	-0.319	-0.240	2.222	-11.513	6.782
Industry Characteristics					
Log Industry Concentration	6.148	6.217	1.737	-11.513	9.002

Note: There are 8631servations in the sample. All monetary values are in 2000 real dollars. “$M” and “$’00M” implies that the values are in millions and hundreds of millions of dollars respectively.

TABLE 2
Incentive Alignment and Innovation Magnitude

	(1)	(2)	(3)
Dependent Variable	Patent Count	Log (Patent Count)	
Model	FE Neg. Binom	RE Tobit	Linear FE
Incentive Alignment (Lag 1 Yr.)			
Holdings (%)	-0.003	-0.008***	-0.003
	(0.002)	(0.003)	(0.004)
Pay-performance sensitivity ($ ’00 M)	0.059**	0.097**	0.056*
	(0.028)	(0.041)	(0.031)
Pay-performance sensitivity Squared	-0.006**	-0.009**	-0.005*
	(0.003)	(0.004)	(0.003)
Short-Term Incentive (%)	-0.0001	0.0001	-0.0001
	(0.001)	(0.001)	(0.001)
Total Compensation ($ ’00 M)	0.075**	0.146***	0.126***
	(0.029)	(0.044)	(0.044)
Firm Innovation Environment (Lag 2 Yrs.)			
Log Mean (Adjusted) Patent Quality	0.036***	0.137***	0.095***
	(0.010)	(0.015)	(0.018)
Log Technology Class Concentration	-0.032**	-0.144***	-0.103***
	(0.015)	(0.021)	(0.025)
Log Mean (Adj.) Patent Quality * Log	-0.002*	-0.013***	-0.008***
Tech. Class Conc.	(0.001)	(0.002)	(0.002)
Log Patent Stock of Other Firms in same	-0.042***	0.038***	0.027***
Industry	(0.008)	(0.013)	(0.009)
Firm & Executive Characteristics			
Top 3 Executive Tenure (Lag 1 Yr.)	0.002	-0.0001	0.001
	(0.001)	(0.002)	(0.002)
CEO Control (Lag 1 Yr.)	-0.017	-0.058**	-0.036*
	(0.019)	(0.025)	(0.021)
Firm Age	0.026***	0.010*	-0.049***
	(0.004)	(0.006)	(0.016)
Firm Age Squared	-0.0001***	-0.0001	-0.0001
	(0.00001)	(0.0001)	(0.0001)
Firm Size	0.107***	0.159***	0.167*
	(0.023)	(0.029)	(0.099)
Firm Size * Firm Age	-0.002***	0.005***	-0.002
	(0.001)	(0.001)	(0.002)
Industry Concentration	0.018*	-0.041	-0.053
	(0.009)	(0.027)	(0.083)
R-Square/Chi-Sq Statistic	1202.63	2496.873	0.167

Note: Specifications are estimated using: Col. (1)- panel data negative binomial model with industry fixed effects; Col. (2) - linear fixed effects panel data model with robust standard errors clustered at the industry level; Col. (3) - random effects panel data tobit model with industry fixed effects and censoring occurring when a the number of patents granted to a firm is 0. There are 2872 censored observations. The sample for all the specifications is restricted to firms that have atleast 1 patent during our sample period. Table reports the coefficients (or unconditional marginal effects). The panel is unbalanced with minimum observations per group=2 and max=13. Total Obs: 8631, No. of Firms = 1174. Range: 1993-2005. All specifications contain a constant and year fixed effects. ‘***’, ‘**’ & ‘*’ denotes significance at 1, 5 and 10 percent respectively.

TABLE 3
Channels of Influence: RD Expenditure

Dependent Variable	RD Dummy	Log(RD Expenditure)	
Model	(1) 1st Stage: Probit	(2) 2nd Stage: Pooled OLS	(3) RE Tobit
Incentive Alignment (Lag 1 Yr.)			
Holdings (%)	-0.017***	-0.034***	-0.026***
	(0.003)	(0.006)	(0.008)
Pay-performance	0.063	0.389***	0.492***
sensitivity ($ ’00 M)	(0.059)	(0.076)	(0.119)
Pay-performance	-0.005	-0.031***	-0.037***
sensitivity Squared	(0.006)	(0.007)	(0.012)
Short-Term Incentive	-0.001	0.003*	0.001
(%)	(0.001)	(0.0016)	(0.002)
Total Compensation ($	0.015	0.315***	0.045
’00 M)	(0.085)	(0.075)	(0.125)
Firm Innovation Environment (Lag 2 Yrs.)			
Log Mean (Adjusted)	0.066***	0.015**	0.018
Patent Quality	(0.004)	(0.007)	(0.012)
Log Technology Class		-0.006	0.001
Concentration		(0.004)	(0.007)
Log Patent Stock of		0.281***	0.307***
Own Firm		(0.027)	(0.058)
Log Patent Stk of Other		0.040**	0.205***
Firms in same Industry		(0.016)	(0.069)
Past Patent Activity	0.755***		
Dummy	(0.128)		
Firm & Executive Characteristics			
Top 3 Executive	0.011***	0.003	0.008
Tenure (Lag 1 Yr.)	(0.002)	(0.002)	(0.005)
CEO Control (Lag 1		-0.127***	-0.099
Yr.)		(0.044)	(0.071)
New CEO Dummy	0.265***		
	(0.048)		
Firm Age	-0.002	-0.019***	-0.074***
	(0.001)	(0.005)	(0.026)
Firm Age Square		0.0001**	0.0004**
		(0.00006)	(0.0002)
Firm Size	-0.011	0.242***	0.171**
	(0.020)	(0.084)	(0.084)
Firm Age * Firm Size		0.003**	0.016***
		(0.001)	(0.003)
Log Cash (Lag 2 Yrs.)	0.006	0.213**	0.030
	(0.010)	(0.019)	(0.025)
Log Long Term Debt	-0.013**		
(Lag 2 Yrs.)	(0.005)		
Industry Concentration	0.228***	0.099	0.0001
	(0.086)	(0.117)	(0.087)
R-Square/ Chi-Sq	2312.77	0.763	1481.69

Note: Col (1): RE probit 1st stage selection, R&D dummy = 1 if RD>0. Col (2): Selection corrected 2nd stage pooled OLS. Robust S.E.s clustered by firm. Significant Mills ratio. Col. (3): RE Tobit. Obs. = 8813, 5173 positive (non-censored) obs. 1993-2005. Constant & year fixed effects. ‘***’, ‘**’ & ‘*’: significance at 1, 5 and 10 % resp.

TABLE 4
Channels of Influence: Quality Change

Dependent Variable	Log (Average Unadjusted Patent Quality)	Log (Average Adjusted Patent Quality)
	(1)	(2)
Incentive Alignment (Lag 1 Yr.)		
Holdings (%)	-0.048**	-0.038**
	(0.024)	(0.018)
Pay-performance sensitivity ($ '00 M)	1.018***	0.786***
	(0.359)	(0.280)
Pay-performance sensitivity Squared	-0.074**	-0.056*
	(0.037)	(0.029)
Short-Term Incentive (%)	-0.004	-0.003
	(0.007)	(0.005)
Total Compensation ($ '00 M)	0.143	0.108
	(0.395)	(0.309)
Firm Innovation Environment (Lag 2 Yrs.)		
Log Technology Class Concentration	0.176***	0.137***
	(0.016)	(0.013)
Log (R&D Stock)(2000 M$)	0.330***	0.266***
	(0.044)	(0.035)
Firm & Executive Characteristics		
Top 3 Executive Tenure (Lag 1 Yr.)	0.0001	-0.0001
	(0.013)	(0.010)
CEO Control (Lag 1 Yr.)	-0.353	-0.276
	(0.229)	(0.179)
Firm Age	-0.166***	-0.134***
	(0.031)	(0.024)
Firm Age Square	0.001***	0.001***
	(0.0001)	(0.0001)
Firm Size	-0.027	-0.041
	(0.201)	(0.158)
Firm Age * Firm Size	0.025***	0.020***
	(0.005)	(0.004)
Industry Concentration	-1.021*	-0.926**
	(0.547)	(0.428)
Chi-Sq Statistic	2920.451	2996.998

Note: We estimate each equation using a random effects panel data tobit model, with censoring occurring when a the number of citations =0. There are 8365 total observations and 4017 censored observations. In both columns the citations are truncation corrected. In Column 1 we use the simple truncation corrected average patent quality (truncation corrected citations/ no. of patents for a given application year for a firm). In Column 2, the truncation corrected citations are further purged of patent-class fixed effects. Table reports the coefficients (or unconditional marginal effects). The panel is unbalanced with minimum observations per group=2 and max=13. Range: 1993-2005. All specifications contain a constant, industry and year fixed effects. '***', '**' & '*' denotes significance at 1, 5 and 10 percent respectively.

TABLE 5
Diversification v/s Concentration
Dependent Variable: Log Technology Class Concentration

	(1)	(2)
Model	RE Tobit	Linear FE
Incentive Alignment (Lag 1 Yr.)		
Holdings (%)	-0.094***	-0.046**
	(0.035)	(0.021)
Pay-performance sensitivity ($ ’00 M)	0.599	0.297
	(0.527)	(0.316)
Pay-performance sensitivity Squared	0.004	-0.006
	(0.055)	(0.035)
Short-Term Incentive (%)	0.009	0.001
	(0.010)	(0.007)
Total Compensation ($ ’00 M)	0.147	0.135
	(0.584)	(0.462)
Firm Innovation Environment (Lag 2 Yrs.)		
Log (R&D Stock)(2000 M$)	0.534***	0.115*
	(0.069)	(0.067)
Firm & Executive Characteristics		
Top 3 Executive Tenure (Lag 1 Yr.)	0.004	0.005
	(0.020)	(0.017)
CEO Control (Lag 1 Yr.)	-0.421	-0.139
	(0.338)	(0.207)
Firm Age	-0.235***	-0.639***
	(0.050)	(0.092)
Firm Age Squared	0.002***	0.001
	(0.0005)	(0.001)
Firm Size	0.017	0.392
	(0.314)	(0.387)
Firm Age * Firm Size	0.029***	0.009
	(0.008)	(0.009)
Industry Concentration	-0.636	-0.228
	(0.776)	(0.452)
Chi-Square/ R Square	1283.01	1283.07

Note: We estimate column (1) the equation using a fixed effects panel tobit model with industry fixed effects since the concentration index is bounded between 0 and 10000. However, for a positive number of patents, there is no censoring at the lower tail, and only 20 obs. are top censored. Column (2) uses a panel data fixed effects models with standard errors clustered by industry code. The panel is unbalanced with minimum observations per group=2 and max=13, and Total Observations = 8285 with 1160 firms. Range: 1993-2005. All specifications contain a constant and year fixed effects. ‘***’, ‘**’ & ‘*’ denotes significance at 1, 5 and 10 percent respectively.

TABLE 6
Corrections for Endogeneity

Dependent Variable	Patent Count	
	(1)	(2)
Incentive Alignment (Lag 1 Yr.) #		
Holdings (%)	-0.043	-0.001
	(0.028)	(0.006)
Pay-performance sensitivity ($ '00 M)	0.398***	0.559**
	(0.145)	(0.028)
Pay-performance sensitivity Squared	-0.275***	-0.246***
	(0.039)	(0.038)
Short-Term Incentive (%)	-0.001	-0.002**
	(0.004)	(0.001)
Total Compensation ($ '00 M)	-0.0000001	-0.00000001
	(0.0000001)	(0.0000001)
Firm Innovation Environment (Lag 2 Yrs.)		
Log Mean (Adjusted) Patent Quality	0.028**	0.031***
	(0.011)	(0.011)
Log Technology Class Concentration	-0.022*	-0.026*
	(0.012)	(0.014)
Log Mean (Adj.) Pat. Quality * Log Tech. Class Conc.	-0.002	-0.002
	(0.001)	(0.001)
Log Patent Stock of Other Firms in same Industry	-0.102***	-0.096***
	(0.012)	(0.012)
Firm & Executive Characteristics		
Top 3 Executive Tenure (Lag 1 Yr.)	0.003**	0.003***
	(0.001)	(0.001)
CEO Control (Lag 1 Yr.)	-0.009	-0.012
	(0.020)	(0.020)
Firm Age	0.002	0.010**
	(0.011)	(0.005)
Firm Age Squared	-0.000	-0.000*
	(0.000)	(0.000)
Firm Size	0.096**	0.149***
	(0.040)	(0.027)
Firm Size * Firm Age	-0.002***	-0.003***
	(0.001)	(0.001)
Industry Concentration	-0.178***	-0.118***
	(0.043)	(0.024)
Chi-Sq Statistic	1177.007	1180.007

Note: Instrumental variables regression, 2nd stage estimated by fixed effects negative binomial, standard errors are bootstrapped to correct for the inclusion of predicted variables from 1st stage. '#' denotes predicted compensation variables. The instruments, apart from all the regressors in the table, are the mean (Col. 1) and median (Col. 2) top 3 executives' compensation variables for the other firms in the same 6 digit NAICS code. Table reports the coefficients. Obs. 7388, No. of Firms. 1109. Range: 1993-2005. All specifications contain a constant and year fixed effects. '***', '**' & '*' denotes significance at 1, 5 and 10 % resp.

TABLE 7A
High and Low Patenting Firms: Incentives & Innovation Performance

Dependent Variable	**Patent Count**		**Log (RD Expenditure)**	
Model	FE Negative Binomial		OLS	
	Low (1a)	High (1b)	Low (2a)	High (2b)
Holdings (%)	0.0002	-0.014**	-0.035***	-0.030***
	(0.002)	(0.006)	(0.007)	(0.009)
Pay-performance sensitivity ($ ’00 M)	0.035	0.066*	0.459***	0.132
	(0.031)	(0.040)	(0.103)	(0.083)
Pay-performance sensitivity Squared	-0.004	-0.004	-0.041***	-0.002
	(0.003)	(0.004)	(0.010)	(0.008)
Short-Term Incentive (%)	-0.0001	0.0001	0.002	0.002
	(0.001)	(0.001)	(0.002)	(0.002)
Total Compensation ($ ’00 M)	0.118***	-0.044	0.505***	0.083
	(0.036)	(0.035)	(0.104)	(0.083)
Top 3 Executive Tenure (Lag 1 Yr.)	0.001	-0.0002	0.002	0.003
	(0.001)	(0.001)	(0.003)	(0.003)
CEO Control (Lag 1 Yr.)	-0.039**	0.011	-0.052	-0.093
	(0.020)	(0.027)	(0.049)	(0.060)
Observations	7343	1215	3792	996
Chi-Sq/R-Sq.	841.923	556.968	0.631	0.840

Dependent Variable	**Log (Avg. Unadj. Quality)**		**Log (Tech. Concentration)**	
Model	RE Tobit		RE Tobit	
	Low (3a)	High (3b)	Low (4a)	High (4b)
Holdings (%)	-0.065**	0.008	-0.118***	0.012**
	(0.030)	(0.014)	(0.045)	(0.006)
Pay-performance sensitivity ($ ’00 M)	1.209**	0.228*	0.831	0.013
	(0.499)	(0.117)	(0.730)	(0.046)
Pay-performance sensitivity Squared	-0.084	-0.023**	0.007	-0.003
	(0.052)	(0.012)	(0.076)	(0.005)
Short-Term Incentive (%)	-0.005	0.000	0.013	-0.001
	(0.010)	(0.002)	(0.014)	(0.001)
Total Compensation ($ ’00 M)	0.103	-0.210*	0.819	-0.018
	(0.599)	(0.113)	(0.876)	(0.042)
Top 3 Executive Tenure (Lag 1 Yr.)	-0.005	-0.001	0.002	0.001
	(0.019)	(0.004)	(0.028)	(0.002)
CEO Control (Lag 1 Yr.)	-0.498	0.113	-0.573	-0.044
	(0.318)	(0.077)	(0.468)	(0.030)
Observations	7087	1226	7325	1226
Chi-Sq/R-Sq.	1954.249	1753.836	1002.054	298.865

Note: The ‘low’ (`high’) sample comprise firms below (above) the mean number of patents. Col. (1a & b)- panel data negative binomial model with industry fixed effects (similar to Table 2); Col. (2a & b) - Selection corrected 2^{nd} stage pooled OLS. Robust S.E.s clustered by firm (similar to Table 3, col. 2).; Col. (3a - 4b) - random effects tobit model with industry fixed effects and censoring occurring when dep. var = 0 (similar to Table 4 and 5 respectively). Table reports the coefficients (or unconditional marginal effects). Unbalanced panel. Range: 1993-2005. ‘***’, ‘**’ & ‘*’ denotes significance at 1, 5 and 10 percent respectively.

TABLE 7B
High and Low R&D Firms: Incentives & Innovation Performance

Dependent Variable	**Patent Count**		**Log (RD Expenditure)**	
Model	FE Negative Binomial		OLS	
	Low (1a)	High (1b)	Low (2a)	High (2b)
Holdings (%)	0.001	-0.042***	-0.033***	-0.020**
	(0.002)	(0.009)	(0.007)	(0.009)
Pay-performance sensitivity	0.066*	0.146***	0.416***	0.076
($ ’00 M)	(0.036)	(0.045)	(0.104)	(0.070)
Pay-performance sensitivity	-0.008**	-0.009*	-0.038***	0.002
Squared	(0.004)	(0.004)	(0.010)	(0.007)
Short-Term Incentive (%)	-0.001	-0.000	0.001	0.001
	(0.001)	(0.001)	(0.002)	(0.002)
Total Compensation ($ ’00	0.092**	0.006	0.338***	0.108*
M)	(0.039)	(0.044)	(0.104)	(0.061)
Top 3 Executive Tenure (Lag	0.000	0.001	0.001	0.002
1 Yr.)	(0.001)	(0.002)	(0.003)	(0.003)
CEO Control (Lag 1 Yr.)	-0.028	0.028	-0.035	-0.034
	(0.020)	(0.038)	(0.042)	(0.048)
Observations	7319	1258	3712	1076
Chi-Sq/R-Sq.	802.668	701.165	0.548	0.755

Dependent Variable	**Log (Avg. Unadj. Quality)**		**Log (Tech. Concentration)**	
Model	RE Tobit		RE Tobit	
	Low (3a)	High (3b)	Low (4a)	High (4b)
Holdings (%)	-0.058**	-0.017	-0.119***	-0.030
	(0.028)	(0.060)	(0.044)	(0.076)
Pay-performance sensitivity	1.011**	0.450	0.886	-0.256
($ ’00 M)	(0.508)	(0.321)	(0.762)	(0.390)
Pay-performance sensitivity	-0.061	-0.041	0.009	0.028
Squared	(0.054)	(0.032)	(0.080)	(0.039)
Short-Term Incentive (%)	-0.003	-0.010	0.007	0.002
	(0.009)	(0.008)	(0.013)	(0.009)
Total Compensation ($ ’00	0.279	0.044	0.966	0.117
M)	(0.613)	(0.316)	(0.918)	(0.377)
Top 3 Executive Tenure (Lag	-0.000	-0.003	0.006	0.004
1 Yr.)	(0.017)	(0.014)	(0.026)	(0.017)
CEO Control (Lag 1 Yr.)	-0.407	-0.056	-0.538	0.116
	(0.294)	(0.259)	(0.442)	(0.310)
Observations	7054	1259	7284	1267
Chi-Sq/R-Sq.	1973.684	1318.114	1050.191	151.637

Note: The ‘low’ (`high’) sample comprise firms below (above) the mean R&D expenditure. Col. (1a & b)- panel data negative binomial model with industry fixed effects (similar to Table 2); Col. (2a & b) - Selection corrected 2nd stage pooled OLS. Robust S.E.s clustered by firm (similar to Table 3, col. 2).; Col. (3a - 4b) - random effects tobit model with industry fixed effects and censoring occurring when dep. var = 0 (similar to Table 4 & 5 respectively). Table reports the coefficients (or unconditional marginal effects). Unbalanced pael. Range: 1993-2005. ‘***’, ‘**’ & ‘*’ denotes significance at 1, 5 and 10 percent respectively.

TABLE 8A
Old and New Firms: Incentives & Innovation Performance

Dependent Variable	**Patent Count**		**Log (RD Expenditure)**	
Model	FE Negative Binomial		OLS	
	New (1a)	Old (1b)	New (2a)	Old (2b)
Holdings (%)	-0.006**	0.011**	-0.028***	-0.048***
	(0.003)	(0.004)	(0.006)	(0.013)
Pay-performance sensitivity	0.080**	0.060	0.355***	0.459***
($ '00 M)	(0.034)	(0.049)	(0.101)	(0.160)
Pay-performance sensitivity	-0.007**	-0.006	-0.029***	-0.071***
Squared	(0.003)	(0.006)	(0.009)	(0.027)
Short-Term Incentive (%)	-0.001	0.001	0.005**	-0.000
	(0.001)	(0.001)	(0.002)	(0.002)
Total Compensation ($ '00	0.113***	0.045	0.293***	0.232*
M)	(0.038)	(0.047)	(0.087)	(0.121)
Top 3 Executive Tenure	0.004*	0.000	-0.002	0.005
(Lag 1 Yr.)	(0.002)	(0.001)	(0.005)	(0.003)
CEO Control (Lag 1 Yr.)	-0.030	-0.011	-0.063	-0.102*
	(0.026)	(0.026)	(0.060)	(0.057)
Observations	4705	3842	2865	1923
Chi-Sq/R-Sq.	751.438	551.105	0.724	0.849

Dependent Variable	**Log (Avg. Unadj. Quality)**		**Log (Tech. Concentration)**	
Model	RE Tobit		RE Tobit	
	New (3a)	Old(3b)	New (4a)	Old (4b)
Holdings (%)	-0.040	-0.047	-0.103**	-0.029
	(0.030)	(0.043)	(0.046)	(0.063)
Pay-performance sensitivity	1.084**	0.834	0.579	0.743
($ '00 M)	(0.460)	(0.615)	(0.703)	(0.868)
Pay-performance sensitivity	-0.086*	-0.052	0.007	-0.060
Squared	(0.047)	(0.075)	(0.071)	(0.107)
Short-Term Incentive (%)	-0.009	0.004	0.009	0.011
	(0.010)	(0.010)	(0.015)	(0.015)
Total Compensation ($ '00	0.551	-0.371	0.568	-0.540
M)	(0.541)	(0.594)	(0.825)	(0.845)
Top 3 Executive Tenure	-0.016	0.009	-0.027	0.010
(Lag 1 Yr.)	(0.027)	(0.014)	(0.042)	(0.020)
CEO Control (Lag 1 Yr.)	-0.415	-0.490	-0.182	-0.903**
	(0.326)	(0.323)	(0.494)	(0.460)
Observations	4513	3800	4678	3873
Chi-Sq/R-Sq.	1538.584	1460.210	757.694	621.835

Note: The 'new' ('old') sample comprises firms below (above) the mean age. Col. (1a & b)- panel data negative binomial model with industry fixed effects (similar to Table 2); Col. (2a & b) - Selection corrected 2^{nd} stage pooled OLS. Robust S.E.s clustered by firm (similar to Table 3, col. 2).; Col. (3a & b, 4a & b) - random effects tobit model with industry fixed effects and censoring occurring when dep. var = 0 (similar to Table 4 and 5 respectively). Table reports the coefficients (or unconditional marginal effects). Unbalanced panel. Range: 1993-2005. '***', '**' & '*' denotes significance at 1, 5 and 10 percent respectively.

TABLE 8B
Large and Small Firms: Incentives & Innovation Performance

Dependent Variable	**Patent Count**		**Log (RD Expenditure)**	
Model	FE Negative Binomial		OLS	
	Small (1a)	Large (1b)	Small (2a)	Large (2b)
Holdings (%)	0.004	-0.006	-0.037***	-0.034***
	(0.003)	(0.004)	(0.008)	(0.007)
Pay-performance sensitivity	0.113**	0.100***	0.579***	0.285***
($ '00 M)	(0.055)	(0.034)	(0.134)	(0.077)
Pay-performance sensitivity	-0.015**	-0.010***	-0.055***	-0.021***
Squared	(0.007)	(0.003)	(0.015)	(0.008)
Short-Term Incentive (%)	-0.002**	0.001	0.004*	0.002
	(0.001)	(0.001)	(0.002)	(0.002)
Total Compensation ($ '00	0.138**	0.031	0.397***	0.261***
M)	(0.056)	(0.036)	(0.136)	(0.077)
Top 3 Executive Tenure	0.001	0.000	0.001	0.002
(Lag 1 Yr.)	(0.003)	(0.001)	(0.005)	(0.002)
CEO Control (Lag 1 Yr.)	-0.044	-0.028	-0.076	-0.069
	(0.029)	(0.024)	(0.053)	(0.051)
Observations	4154	4378	2643	2145
Chi-Sq/R-Sq.	553.486	757.146	0.626	0.818

Dependent Variable	**Log (Avg. Unadj. Quality)**		**Log (Tech. Concentration)**	
Model	RE Tobit		RE Tobit	
	Small (3a)	Large (3b)	Small (4a)	Large (4b)
Holdings (%)	-0.030	-0.064*	-0.113**	-0.055
	(0.034)	(0.036)	(0.054)	(0.050)
Pay-performance sensitivity	1.466**	0.683*	1.558	0.130
($ '00 M)	(0.734)	(0.379)	(1.152)	(0.542)
Pay-performance sensitivity	-0.072	-0.048	-0.006	0.026
Squared	(0.086)	(0.038)	(0.137)	(0.054)
Short-Term Incentive (%)	-0.005	-0.006	-0.004	0.017
	(0.012)	(0.008)	(0.018)	(0.012)
Total Compensation ($ '00	1.375	-0.304	2.578**	-0.413
M)	(0.837)	(0.412)	(1.315)	(0.589)
Top 3 Executive Tenure	-0.087***	0.015	-0.096**	0.025
(Lag 1 Yr.)	(0.030)	(0.013)	(0.047)	(0.019)
CEO Control (Lag 1 Yr.)	-0.439	-0.230	0.149	-0.696*
	(0.382)	(0.275)	(0.586)	(0.392)
Observations	4055	4258	4172	4379
Chi-Sq/R-Sq.	1217.551	1931.961	676.632	698.937

Note: The 'large' ('small') sample comprise firms above (below) the mean size. Col. (1a & b)- panel data negative binomial model with industry fixed effects (similar to Table 2); Col. (2a & b) - Selection corrected 2nd stage pooled OLS. Robust S.E.s clustered by firm (similar to Table 3, col. 2).; Col. (3a - 4b) - random effects tobit model with industry fixed effects and censoring occurring when dep. var = 0 (similar to Table 4 and 5 respectively). Table reports the coefficients (or unconditional marginal effects). Unbalanced panel. Range: 1993-2005. '***', '**' & '*' denotes significance at 1, 5 and 10 percent respectively.

TABLE 9A
Board Independence: Incentives & Innovation Performance

Dependent Variable	**Patent Count**		**Log (RD Expenditure)**	
Model	FE Negative Binomial		OLS	
	Low (1a)	High (1b)	Low (1a)	High (1b)
Holdings (%)	-0.002	-0.005	-0.037***	-0.033***
	(0.003)	(0.006)	(0.008)	(0.009)
Pay-performance sensitivity	-0.049	0.215***	0.427***	0.268***
($ ’00 M)	(0.043)	(0.046)	(0.125)	(0.084)
Pay-performance sensitivity	0.003	-0.017***	-0.030***	-0.025***
Squared	(0.004)	(0.005)	(0.011)	(0.008)
Short-Term Incentive (%)	-0.001	0.002*	0.005**	-0.000
	(0.001)	(0.001)	(0.002)	(0.002)
Total Compensation ($ ’00	0.134***	-0.012	0.179*	0.395***
M)	(0.046)	(0.045)	(0.105)	(0.085)
Top 3 Executive Tenure	-0.001	-0.001	0.003	0.004
(Lag 1 Yr.)	(0.002)	(0.001)	(0.004)	(0.003)
CEO Control (Lag 1 Yr.)	0.038	-0.051*	-0.053	-0.166***
	(0.030)	(0.027)	(0.069)	(0.054)
Observations	3272	3780	1689	2354
Chi-Sq/R-Sq.	544.923	831.033	0.744	0.814

Dependent Variable	**Log (Avg. Unadj. Quality)**		**Log (Tech. Concentration)**	
Model	RE Tobit		RE Tobit	
	Low (3a)	High (3b)	Low (3a)	High (3b)
Holdings (%)	-0.085**	-0.019	-0.144***	-0.0001
	(0.034)	(0.051)	(0.054)	(0.071)
Pay-performance sensitivity	0.977*	0.838	0.334	0.536
($ ’00 M)	(0.518)	(0.567)	(0.800)	(0.792)
Pay-performance sensitivity	-0.046	-0.090	0.082	-0.013
Squared	(0.054)	(0.057)	(0.084)	(0.079)
Short-Term Incentive (%)	-0.020*	0.003	-0.016	0.022*
	(0.012)	(0.009)	(0.018)	(0.013)
Total Compensation ($ ’00	0.542	0.440	1.207	0.210
M)	(0.620)	(0.536)	(0.951)	(0.734)
Top 3 Executive Tenure	-0.008	-0.005	-0.032	0.013
(Lag 1 Yr.)	(0.022)	(0.015)	(0.036)	(0.022)
CEO Control (Lag 1 Yr.)	-0.862**	-0.255	-0.882	-0.581
	(0.393)	(0.313)	(0.606)	(0.425)
Observations	3224	3814	3318	3889
Chi-Sq/R-Sq.	1177.077	1868.805	610.999	872.126

Note: The ‘low’ (‘high’) sample comprise firms below (above) the mean level of board independence as measures by the percentage of independent directors on the board. . Col. (1a & b)- panel data negative binomial model with industry fixed effects (similar to Table 2); Col. (2a & b) - Selection corrected 2^{nd} stage pooled OLS. Robust S.E.s clustered by firm (similar to Table 3, col. 2); Col. (3a & b, 4a & b) - random effects tobit model with industry fixed effects and censoring occurring when dep. var = 0 (similar to Table 4 and 5 respectively). Table reports the coefficients (or unconditional marginal effects). Unbalanced panel. Total Obs: 8631, No. of Firms = 1174. Range: 1993-2005. ‘***’, ‘**’ & ‘*’ denotes significance at 1, 5 and 10 percent respectively.

TABLE 9B
Institutional Holdings: Incentives & Innovation Performance

Dependent Variable	**Patent Count**		**Log (RD Expenditure)**	
Model	FE Negative Binomial		OLS	
	Low (1a)	High (1b)	Low (1a)	High (1b)
Holdings (%)	-0.009*	0.004	-0.028***	-0.038***
	(0.005)	(0.004)	(0.009)	(0.009)
Pay-performance sensitivity	0.094**	0.223***	0.292***	1.087***
($ ’00 M)	(0.043)	(0.077)	(0.099)	(0.222)
Pay-performance sensitivity	-0.006	-0.012	-0.026**	-0.212***
Squared	(0.005)	(0.008)	(0.010)	(0.039)
Short-Term Incentive (%)	-0.000	-0.001	0.003	-0.002
	(0.001)	(0.001)	(0.002)	(0.002)
Total Compensation ($ ’00	0.051	-0.099	0.419***	0.815***
M)	(0.047)	(0.099)	(0.105)	(0.273)
Top 3 Executive Tenure	0.004***	0.001	0.003	-0.000
(Lag 1 Yr.)	(0.002)	(0.003)	(0.003)	(0.005)
CEO Control (Lag 1 Yr.)	-0.034	-0.012	-0.116*	-0.081
	(0.028)	(0.040)	(0.062)	(0.069)
Observations	2856	1922	1972	1284
Chi-Sq/R-Sq.	827.393	305.803	0.778	0.719

Dependent Variable	**Log (Avg. Unadj. Quality)**		**Log (Tech. Concentration)**	
Model	RE Tobit		RE Tobit	
	Low (3a)	High (3b)	Low (3a)	High (3b)
Holdings (%)	-0.058	-0.045	-0.057	-0.132**
	(0.036)	(0.033)	(0.050)	(0.055)
Pay-performance sensitivity	1.412***	0.118	1.184*	1.096
($ ’00 M)	(0.474)	(0.897)	(0.638)	(1.371)
Pay-performance sensitivity	-0.117**	0.099	-0.075	0.055
Squared	(0.052)	(0.101)	(0.069)	(0.152)
Short-Term Incentive (%)	-0.001	-0.010	0.011	-0.033
	(0.009)	(0.013)	(0.012)	(0.020)
Total Compensation ($ ’00	0.520	0.768	-0.196	-0.134
M)	(0.535)	(1.341)	(0.718)	(2.046)
Top 3 Executive Tenure	0.003	-0.026	0.028	0.020
(Lag 1 Yr.)	(0.015)	(0.026)	(0.021)	(0.042)
CEO Control (Lag 1 Yr.)	-0.353	-0.179	-0.567	-0.119
	(0.300)	(0.445)	(0.396)	(0.686)
Observations	2865	1986	2922	2035
Chi-Sq/R-Sq.	1647.909	792.001	529.762	420.70

Note: The ‘low’ (‘high’) sample comprise firms below (above) the mean level of institutional holdings. Col. (1a & b)- panel data negative binomial model with industry fixed effects (similar to Table 2); Col. (2a & b) - Selection corrected 2nd stage pooled OLS. Robust S.E.s clustered by firm (similar to Table 3, col. 2).; Col. (3a - 4b) - random effects tobit model with industry fixed effects and censoring occurring when dep. var = 0 (similar to Table 4 and 5 respectively). Table reports the coefficients (or unconditional marginal effects). Unbalanced panel. Range: 1993-2005. ‘***’, ‘**’ & ‘*’ denotes significance at 1, 5 and 10 percent respectively.

Appendix: Incentive Alignment Measures

Managerial *Holdings* = number of shares of the firm held by the Top 3 Executives /total shares outstanding

Top 3 *pay-performance sensitivity (PPS)* = Top 3 Equity *PPS* + Top 3 Option *PPS* (or Equity *PPS* if Option *PPS* is missing).

Top 3 Equity $PPS = \left[\partial(\text{equity value}) / \partial(\text{stock price})\right]$ * stock price * 0.01

= number of shares outstanding * stock price * 0.01

Top 3 Option $PPS = \sum_{j=1}^{N} \left[\partial(\text{option value}_j) / \partial(\text{stock price})\right]$ * stock price * 0.01

Equity value is the number of shares outstanding multiplied by the stock price. We use the fiscal year end stock price reported by Execucomp, and if missing, we obtain it from Compustat. Option value is calculated using the Black-Scholes (1973) formula for European call options for every option grant *j* awarded to the top 3 executives, accounting for dividends according to Merton (1973). Thus, we require five inputs in addition to the stock price, namely: the options' exercise price and time to maturity, stock return volatility, the firm's dividend yield and the risk free rate. We follow Core and Guay's (2002) methodology to estimate option values, which involves using information from the firm's most recent proxy statement (available from Execucomp). For new option grants in a particular year, the exercise price and time to maturity are disclosed in the proxy statement. For options granted in previous years, we do the following: 1) We estimate the exercise price as the difference between the stock price and the average realizable value per option.[46] 2) The time to maturity of unexercisable option grants is the time to maturity of the most recent fiscal year's grant minus one year while the time to maturity of exercisable option grants is the time to maturity of unexercisable option grants minus three years. If no new grants were made in the most recent fiscal year, the time to maturity for unexercisable and exercisable option grants are nine and six years, respectively. Finally, we measure stock return volatility as the annualized standard deviation of monthly returns for the previous 60 months, reported by ExecuComp. If this is missing, it is calculated using CRSP data.[47] The dividend yield is the firm's average dividend yield over the past 3 years, reported by Execucomp. We use risk free rates (yields on U.S. Treasuries) corresponding to the time to maturity of the options. CEO *delta* is calculated in 2003 dollars. Please see Core and Guay (2002) for more details.

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[46] Realizable value is the value realized by the manager if the stock price is greater than the exercise price and the option is exercised. This is reported in Execucomp separately for exercisable and unexercisable options.
[47] Our findings are unchanged if we use the standard deviation of daily returns for the previous 252 trading days.