Incentivizing Managers to Build Innovative Firms

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July 2010

JEL codes: G32, G30, L2, O3
Keywords: Patents, Executive Compensation, Pay-for-Performance Sensitivity

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Incentivizing Managers to Build Innovative Firms

Abstract

We investigate whether the equity-linked components of top executive pay have an effect on patenting activity within a firm. We find a positive relationship between firm patenting activity and managerial alignment incentives created by stock and stock option grants. Prior work has shown that the market value of a firm reflects the value of its patents. Thus, our finding suggests innovation is one such channel through which equity alignment incentives positively impact firm value. On the other hand, we find that the risk-taking incentive from stock options does not increase patenting.

"Rahm Emanuel, President Obama's chief of staff, recently echoed Machiavelli when he said, "You never want a serious crisis to go to waste." He's correct. Now more than ever is the time for innovative managers and entrepreneurs to come up with ideas that lead to opportunities to launch new ventures."

– Wall Street Journal, March 18, 2009, "How to Innovate in a Downturn?"

I. Introduction

The recent economic crisis may have presented strategic incentives for managers to innovate. Under more normal circumstances however, we expect managerial contracts should play this role. Executive compensation packages are structured to align managerial actions with firm performance. The existing literature remains mixed on whether compensation contracts effectively induce managers to work in the best interest of the shareholders. In this paper, we investigate whether the compensation contracts of a firm's top executives create incentives to innovate within the firm.

In the 1990s, top executive pay in the U.S. dramatically shifted towards stock and stock option grants (Hall and Liebman, 1998). At the same time, productivity growth and the stock market surged. Firm innovation has been shown to positively impact both the real (productivity) and financial (market value) performance of a firm.[2] It is therefore of interest to examine whether the incentives to innovate are driven, in part, by managerial pay.

Using patent counts as a measure of innovation, we find a positive relationship between equity alignment incentives and the extent of patenting activity within a firm. Patenting increases as managerial wealth from stock and stock options becomes more sensitive to changes in the firm's share price. Thus, equity alignment incentives increase innovative activity within a firm.

[2] Griliches (1981), Hall (1993), Hall, Jaffe and Trajtenberg (2005).

Assuming innovative strategies are inherently riskier than traditional capital expenditures, stock option grants have often been used to compensate risk-averse managers for taking on these types of risks. We find that this risk-taking incentive (measured by the sensitivity of managerial wealth to stock return volatility or *volatility sensitivity*) does not increase patenting.

One interpretation of these results is that equity alignment incentives are more likely to induce managers to invest in safer R&D projects that result in patents. On the other hand, although the risk-taking incentive may very well induce managers to pursue riskier R&D projects that can potentially increase firm value, these riskier projects do not result in increased patenting activity.

At a time when executive pay is heavily concentrated in stock and stock options, our results underscore the importance of careful structuring of managerial compensation contracts, especially if one corporate objective is to build innovative firms.[3] Our findings warrant further investigation into these issues in order to determine the compensation contracts ideally suited for such firms.

II. Data and Methodology

A. Sample Selection

We obtain patent data from the updated version of the NBER's 'Patent Citations Database.' This data contains comprehensive information on all patents granted to U.S. firms from 1976 to 2006.[4] We construct a panel dataset with firm–year observations

[3] A related paper is by Lerner and Wulf (2007). They find that the long-term incentive compensation of R&D managers is positively associated with patent citations, patent awards and patent originality.
[4] This data was originally constructed by Hall, Jaffe and Trajtenberg (2001). The current version updates the database till 2006. Please see the NBER website for more details.

where each observation is dated by patent application year. We gather firm level information from Compustat and data on compensation and other attributes of a firm's top executives from ExecuComp. Our estimation sample comprises the intersection of these three data sources from 1994 – 2005, limited to manufacturing firms that have at least one patent during this period.

B. Key Variables

1. Innovation Variables

We follow existing work[5] and use the number of patents granted to a firm as our measure of innovation ("advances in knowledge"). The use of patent counts to measure innovation has a long history in the literature. Patents are generally viewed as an imperfect measure of new inventions (Pakes and Griliches, 1984). To account for the "knowledge impact" or the "quality" of these new inventions, patent counts are weighted by the number of forward citations. The idea is that patents that make significant contributions will have more citations.[6] The NBER database reports patents granted and citations observed through 2007. For the latter years in our sample, this creates a truncation issue. Hall, et al. (2001) propose a methodology for correcting for this bias and we use the truncation-corrected citations measure reported by the NBER data base.[7] Furthermore, 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 the patent may come from a field where it is customary to cite frequently. Hence, we also purge citations of these field effects as suggested by Hall, et al. (2001).

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[5] Lerner and Wulf (2007), Aghion, van Reenen and Zingales (2009) among many others.

[6] Pakes (1985), Jaffe (1986), Griliches, Hall, and Pakes (1991), Blundell, Griffith, and van Reenen (1999), Hall (2000).

[7] We end our time period in 2005 to ensure that each patent in our sample has at least two years worth of citations.

In our analysis, we use two measures of patent counts: *straight patent counts* and *cite-weighted patent counts*.[8] The former measures the raw number of patents granted while the latter adjusts for patent quality. These measures have a fair number of zeros for the following reasons: first, firms with zero patents in a given year will have a zero value; and for the latter measure, patents that do not receive citations are weighted by zero. Hence, we use the transformed dependent variable, *Log(1+Patents)*, in our regressions.

There is a large body of work that examines the relationship between research and development (R&D) expenditures and patenting activity. R&D is generally seen as a primary driver of innovation while the number of patents reflects the success of a firm's R&D program (Hall, et al., 2005). R&D expenditures also represent a long-term investment by the firm that is often associated with greater risk when compared to capital expenditures (Coles, Daniel and Naveen, 2006). The theoretical literature shows that there is a greater probability of obtaining a greater number of and /or higher valued innovations as R&D expenditures increase (Kortum, 1993). Moreover, some firms may inherently be R&D-intensive and prone to patenting. Thus, we expect greater stocks of R&D and patents will lead to more patents and/or better quality patents. We create the stock of R&D using the current and past four years of R&D expenditure with a twelve percent depreciation rate. The stock of patents is created similarly. These measures control for the firm's stock of knowledge capital.

We also control for a firm's technology concentration, which measures whether the firm is focused in a few core areas or whether it has a broad technology portfolio. We

[8] *Straight Patent Counts* = number of patents granted to a firm dated by application year. *Cite-Weighted Patent Count s*= $\sum_{i=1}^{P} Patent_i \times ForwardCitations_i$ where P is the number of patents and Forward Citations is the number of citations adjusted for truncation bias and field effects.

construct a Hirschman-Herfindahl index (HHI) based on the NBER patent technology classes. A high value of this index denotes patenting in a narrow set of classes (concentrated) while a low value denotes patenting in a broad set of classes. While less technology concentration may lead to more patenting due to the greater diversity in innovation projects, a higher technology concentration may also be related to better quality patents since the firm would be building on a narrower knowledge field in which it has gained expertise.[9]

2. Managerial Variables

We focus on the portfolio of stock and stock options of a firm's top five managers[10] since these compensation awards are most closely related to a firm's financial performance, and hence shareholder goals. We characterize these compensation awards by the pay-for-performance incentives they create. In particular, we define *share price sensitivity* as the top executives' wealth sensitivity to changes in the firm's stock price. This is the average dollar change in the value of the top five executives' stock and stock option holdings[11] in response to a one-percent change in the firm's stock price. Higher share price sensitivity means managerial wealth increases more when the share price increases. This is generally thought to align managerial incentives with shareholder wealth maximization and is called the *alignment incentive*. However, at very high levels of share price sensitivity, managers may forgo risky yet value-enhancing innovation projects because their personal wealth is very closely tied to their firm's stock

[9] Another possible effect of managerial compensation on innovation is the reallocation of R&D dollars to a broader or narrower set of technology classes. Thus, patenting activity may remain unchanged but managerial incentives could still affect the composition of a firm's patent portfolio. We do not explicitly address this question here but this is an important issue to consider for future work.

[10] These are the five highest paid executives in the firm, which include the chief executive officer (CEO), and (almost always) the president, chief operating officer and chief financial officer.

[11] This includes both old and new grants. Hence, our incentive measures are based on the total number of shares and stock options that the managers currently own.

performance.[12] This is the *risk-aversion effect*. These opposing forces could create an inverse U-shaped relationship between share price sensitivity and firm innovation.[13] We capture this relationship using a quadratic form for share price sensitivity in our empirical model.

If managers are risk averse because their compensation is very closely linked to their firm's stock performance, then it is quite possible that some risky (R&D) projects would not be undertaken. This is particularly relevant with regards to innovation since unfavorable outcomes may be beyond managerial control. Thus, we also define *volatility sensitivity* as the top executives' wealth sensitivity to changes in the firm's stock return volatility. This is calculated as the average dollar change in the value of the top five executives' stock option holdings in response to a one-percent change in the firm's stock return volatility.[14] This measure captures the convexity in compensation structures created by the down-side protection offered by stock option grants. Higher volatility sensitivity is thought to encourage managers to make riskier yet value-enhancing investment choices since they can enjoy the benefits of share price increases without suffering the consequences of negative outcomes. This is called the *risk-taking incentive* which offsets the risk-aversion effect mentioned above.[15]

Table 1A presents summary statistics while Table 1B provides sample correlations for all variables used in our analysis. The median share price sensitivity is

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[12] Thus, managers are exposed to high volatility in their stock price.
[13] See Berle and Means (1935), Jensen and Meckling (1976), Demsetz (1983), Fama and Jensen (1983), Smith and Stulz (1985)
[14] In the finance literature, share price sensitivity and volatility sensitivity are also called *delta* and *vega*, respectively. For more details on these performance pay measures, please refer to Core and Guay (2002). The volatility sensitivity of stock holdings is an order of magnitude less than that of stock option holdings. Hence, following Guay (1999), we use stock option holdings in calculating volatility sensitivity.
[15] See Haugen and Senbet (1981). Coles, et al. (2006) find that higher CEO volatility sensitivity results in riskier firm policies (lower capital expenditures, higher R&D and higher leverage).

$80,000. However, the distribution is skewed with a mean share price sensitivity of $310,000. Volatility sensitivity effects are smaller with a median (mean) value of $20,000 ($50,000).

C. Empirical Model

We estimate the following empirical model relating patenting activity to managerial pay-for-performance incentives:

$$Log(1+Y_{it}) = \beta_0 + \beta \, Managerial\,Variables_{\mathrm{it}} + \gamma \, Controls_{it} + \mu_{it} \qquad (1)$$

where *Y* is the number of patents (straight counts or cite-weighted) granted to firm *i* dated by application year *t*. *Managerial Variables* consists of share price sensitivity and volatility sensitivity. We also include the average cash bonus (as a percentage of salary plus bonus) and average tenure of the top executives as additional measures of managerial incentives related to short-term firm performance and career horizon concerns, respectively. These variables are lagged one year to minimize endogeneity problems. *Controls* include the R&D stock, patent stock, technology concentration, firm size, firm age, industry concentration[16] and volatility[17]. We use one or two lags for most of these variables to minimize potential feedback with our dependent variables. We estimate equation (1) using a panel data tobit model with year and industry fixed effects.[18] We use the tobit model to account for the large number of zeros in our dependent variables or left-censored data[19] (Wooldridge, 2002).

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[16] This is an HHI index using firm sales and based on the Fama-French 49 industry classification.
[17] Volatility is the annualized standard deviation of a firm's daily stock returns.
[18] We follow the Fama-French 49 industry classification obtained from Ken French's website.
[19] *Y*=0 if the number of patents equal zero or the number of forward citations equals zero. Thus, the distribution is censored at zero.

III. Results

Studies have shown that the value of a firm's patents is reflected in its market value. Thus, if innovation is one such channel through which managers choose to increase shareholder wealth, we expect both alignment incentives and risk-taking incentives to positively affect patenting activity within a firm.

A. Patenting Activity

Table 2 presents the results of estimating equation (1). We find that the alignment incentive measured by share price sensitivity has a positive relationship with patenting.[20] An increase in share price sensitivity from the 25th percentile to the 75th percentile ($ 185,000) increases patenting by 3 to 4 percent (columns 3 and 6). Hall, et al. (2005) show that a firm's market valuation is positively associated with its patents and citations per patent. If each additional patent increases a firm's market value, then managers benefit more (i.e. managerial wealth is higher) from it when alignment incentives are greater. Thus, managers are likely to choose projects that will result in patents, which in turn increases shareholder wealth. Figure 1, that shows the annual averages of patenting activity and share price sensitivity, is consistent with this positive relationship.

On the other hand, we find that volatility sensitivity has a negative coefficient that is significant in relation to straight patent counts but insignificant in relation to cite-weighted patent counts. Volatility sensitivity measures the risk-taking incentive from stock option grants that is intended to induce risk-averse managers to undertake risky yet value-enhancing projects that they would otherwise not pursue. This risk-taking incentive allows managers to benefit more when firm risk (volatility) is higher. Coles, et al. (2006)

[20] Although the quadratic term is negative and significant, the maximum point is achieved at the tail end of the share price sensitivity distribution and hence, the resulting relationship is positive (and concave).

have found that higher volatility sensitivity implements riskier policy choices such as greater investments in R&D. Thus, if these risky R&D projects result in new patents,[21] we would expect a positive coefficient on volatility sensitivity. However, our findings suggest that this is not the case.

There are several interpretations for these results: First, Ross (2004) shows that under certain conditions, more stock option grants can actually make a manager more risk-averse resulting in forgone risky but possibly value-enhancing projects. Assuming value is measured by the additional patents generated by these projects, this could explain the negative coefficient on volatility sensitivity. Second, managers may indeed engage in riskier value-enhancing projects, however, the success of these projects might not be fully captured by the number of patents. For example, Cohen, Nelson and Walsh (2000) find that keeping trade secrets, as opposed to patenting (which involves public disclosure) is another means by which firms protect their innovations.[22] Third, managers may pursue other risky projects not necessarily related to innovation that could increase the firm's share price in the short-run (Peng and Röell, 2008). Under this scenario, the gains to innovation (i.e. patents) are crowded out by efforts to improve firm performance in the short term. We note that the latter two scenarios could still hold if volatility sensitivity is insignificant in our regressions (Table 2, column 4). Thus, what can we can infer from our findings is that the risk-taking incentive from stock option grants does not increase

[21] This assumes value is partly measured by new patents, which relies on both Kortum (1993) and Hall, et al. (2005). Kortum (1993) argues that higher R&D increases the probability of obtaining a greater number of and /or higher valued innovations. In Table 2, we do find that the stock of R&D is positively related to patenting activity. Hall, et al. (2005) show that a firm's market valuation is positively associated with the firm's patents.

[22] They also find that the motivations for patenting differ bv industry. Certain high risk industries may also be less prone to patenting. In fact, Table 2 shows that volatility (firm risk) has a negative coefficient, indicating that firms in high risk areas are less likely to patent. We use industry dummies to capture some of these effects. However, we acknowledge that patents are not the only output of a firm's R&D program.

patenting activity. In Figure 2, we plot the annual averages for patenting activity and volatility sensitivity. The figure tends to support this conclusion.

B. Robustness Tests

The choice of R&D expenditures, in addition to patenting, is likely to be affected by managerial incentives. In Table 2 we use twice-lagged R&D stock (whereas managerial incentives are lagged once) in order to minimize this potential simultaneity problem. As an alternative dependent variable, we use the firm's patent-to-R&D ratio.[23] While *patent counts* is a measure of "new inventions," the ratio of patents-to-R&D is a measure of the productivity or efficiency of a firm's R&D program (assuming patents measure the success of the R&D program). This alternative specification can account for some of the potential effects of managerial incentives on contemporaneous R&D expenditures that may not necessarily be reflected in patent counts alone.[24,25]

Table 3 shows share price sensitivity is not related to patents-per-R&D. Hence, while managerial alignment incentives positively impact a firm's patenting activity, it does not affect the firm's R&D productivity. Furthermore, in column (1), where we use straight patent counts, we find volatility sensitivity has a negative coefficient, while in column (4), where we use cite-weighted patent counts, it has a positive coefficient. While the former is consistent with our findings in Table 2, the latter is not.

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[23]Following standard practice, this is measured as the number of patents (dated by application year) divided by R&D expenditures in the same year. Thus, the estimation sample is limited to firms with non-zero R&D in the current year. Additional control variables for the patent-to-R&D regression include the firm's cash, long-term debt and advertising expense. These control for free cash flow and the availability of funds for use in R&D. We expect these variables to be negatively related to patents-to-R&D.

[24] Since we control for the stock of R&D in the former specification, one can also interpret our results in Section III.A in terms of patents-per-dollar of R&D stock or patenting propensity. The difference in this alternative specification is that patents and R&D are measured contemporaneously.

[25] An interesting fact is that the U.S. patent-to-R&D ratio has been declining since the 1970s while R&D spending has continued to increase over the same period (Lanjouw and Schankerman, 2004).

Investigating further, we combine the two previous models into a two-equation seemingly unrelated regression (SUR) model with patents and patents-per-R&D as the dependent variables. The advantage of this model is it accounts for possible correlation in the error terms of the two equations. Its shortcoming is it does not address the censored nature of our data. This issue is more severe with citation-weighted patent counts compared to straight patent counts since there is more censoring in the former compared to the latter. Table 4 shows the results of the SUR estimation. Overall, the table shows that our earlier findings regarding patenting activity continue to hold. Our findings regarding R&D productivity, particularly when measured using cite-weighted patent counts, do not appear to be robust.[26] Thus, for the remainder of the paper, we focus on patenting activity.

C. Sample Splits

To examine what is driving our results, we sort firms according to their R&D intensity (R&D/sales) and technology intensity. For the latter, we define a high-tech industry as one of the following: Aircraft, Chemicals, Electronic Equipment, Pharmaceutical Products, Electrical Equipment, Machinery, Medical Equipment, Software and Telecommunications.[27]

Table 5 shows the effect of share price sensitivity on patenting activity is stronger among R&D intensive and high-tech firms. This suggests that the positive impact of alignment incentives on patenting comes from firms that are more innovation-driven. For

[26] Of course, one possible reason the results from the SUR model are not consistent with the tobit results is that the SUR model does not account for the censoring issue. Furthermore, we believe an analysis of R&D productivity and managerial compensation is an important issue that requires a more comprehensive look into the different facets of innovation, which we leave to future work.

[27] The mean straight patent counts (cite-weighted patent counts) across sub-samples are: Low R&D/Sales = 12.8 (9.9), High R&D/Sales = 65 (66), Low-Tech = 27.5 (25), High-Tech = 60 (61).

straight patent counts, an increase in share price sensitivity from the 25th to the 75th percentile increases patenting by 4.4% to 5.4%, or approximately 2.6 to 3.5 patents among the R&D intensive and hi-tech firms. For cite-weighted patent counts, the equivalent effect is 7 % or 4.5 more cite-weighted patents on average.

With regards to volatility sensitivity, we continue to find that its negative impact on patenting is significant only for straight patent counts and not for cite-weighted patent counts, similar to Table 2. In the straight patent count regressions, this negative effect is stronger among R&D intensive and low-tech firms. An increase in volatility sensitivity from the 25th to the 75th percentile results in 2 fewer patents among R&D intensive firms and 0.74 fewer patents among low-tech firms. These effects are economically smaller than those for share price sensitivity and do not appear to be driven entirely by innovation-intensive firms.

IV. Conclusion

In this study, we investigate whether top executive compensation incentives from stock and stock option grants are associated with patenting activity within a firm. We find that the equity alignment incentive increases patenting while the risk-taking incentive does not. Prior work has shown that the market value of a firm reflects the value of its patents. Thus, our first finding suggests innovation is one such channel through which equity alignment incentives positively impact firm value.

Overall, one interpretation of these results is that equity alignment incentives are more likely to induce managers to invest in safer R&D projects that result in patents. On the other hand, although the risk-taking incentive may very well induce managers to pursue riskier R&D projects that can potentially increase share value, these riskier projects do not result in increased patenting activity. There are other avenues through which risky R&D investments can increase firm value and not necessarily be inconsistent with our findings. The challenge for future work is to tease out these various channels through which innovation strategies influence firm value and the corresponding effects of managerial pay on such strategies.

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TABLE 1A: Summary Statistics

Variable	Mean	Median	S.D.	Min	Max.	Obs.
Dependent Variables						
Straight Patent Counts	38.82	3	167.23	0	4344	7738
Cite-Weighted Patent Counts	37.86	0	199.24	0	5869.19	7738
Patents/R&D (per $M)	44.23	21.44	104.56	0	4752.33	5203
Cite-Weighted Patents/R&D (per $M)	31.48	5.81	76.76	0	1348.21	5203
R&D ($M)	1.56	0.17	5.97	0	113.22	7738
Managerial Variables						
L.Share Price Sensitivity ($M)	0.31	0.08	0.87	0.0002	7.57	7738
L.Volatility Sensitivity ($M)	0.05	0.02	0.08	0	0.51	7738
L.Bonus/Cash Compensation %	35.54	36.02	17.15	0.011	86.25	7738
L.Tenure (Years)	11.28	7.5	10.52	0	53	7738
Controls						
L2.R&D Stock ($M)	4.43	0.45	17.70	0	299.04	7738
L2.Patent Stock	152.24	14.72	626.86	0	15601.25	7738
L2.Cite-Weighted Patent Stock	177.45	8.87	796.39	0	19965.08	7738
L2.Technology Class Concentration	2036.43	833.33	2887.79	0	10000	7738
Firm Age	37.67	35	21.33	2	126	7738
Firm Size: L2.Total Assets ($M)	86.92	10.27	381.85	0.001	8066.12	7738
Industry Concentration (HHI)	669.07	500.27	653.96	126.36	8118.98	7738
L.Volatility %	47.10	40.50	25.44	11.50	412	7738
L.Cash ($M)	7.45	0.96	36.21	0	1227.12	7738
L.Long-Term Debt ($M)	18.59	1.65	133.16	0	4258.57	7738
L.Advertising Expense ($M)	0.81	0.001	3.20	0	46.75	7738

Notes: The summary statistics presented are for the estimation sample from 1994-2005 comprised of 1174 firms. Straight Patent Counts is the raw number of patents granted to a firm dated by application year. *Cite-Weighted Patents* is the number of patents granted to a firm weighted by all existing citations through 2007 and corrected for truncation bias and field effects. Share price sensitivity is the dollar change in managerial stock and stock option wealth per one percent increase in the firm's share price. Volatility sensitivity is the dollar change in managerial stock option wealth per one percent increase in the firm's stock return volatility. Bonus is calculated as a percentage of cash compensation where the latter is the sum of cash salary and cash bonus. Tenure is the number of years that the executive has been with the same firm. Managerial variables are averaged over the five highest paid executives, which includes the CEO. The R&D stock is the average of the current and past four years of R&D expenditures with a 12 percent depreciation rate. The patent stock is calculated similarly. Technology class concentration is a Hirschman-Herfindahl index (HHI) based on NBER patent technology classes. Firm age is based on incorporation year data from John Ritter. If the incorporation year is unavailable, we use the earliest year on the CRSP database 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 a HHI calculated using firm sales and based on the Fama-French 49 industry classification. Volatility is the annualized standard deviation of daily stock returns. All dollar variables are measured in real terms. L denotes the lag operator.

TABLE 1B: Estimation Sample Correlations

	Straight Patent Counts	Cite-Wtd. Patent Counts	Straight Patents/ R&D	Cite-Wtd. Patents/ R&D	R&D	L.Share Price Sensi-tivity	L.Vol. Sensi-tivity	L.Bonus/Cash Comp.	L.Tenure
Cite-Weighted Patent Counts	0.9207	1							
Straight Patents/R&D	0.0762	0.0754	1						
Cite-Weighted Patents/R&D	0.1674	0.2352	0.5408	1					
R&D	0.5508	0.479	-0.0621	-0.0318	1				
L.Share Price Sensitivity	0.1163	0.0928	-0.049	-0.014	0.1517	1			
L.Volatility Sensitivity	0.2148	0.1269	-0.0615	-0.0681	0.3378	0.4183	1		
L.Bonus/Cash Compensation	0.1432	0.1256	0.0157	0.0089	0.1719	0.1786	0.3484	1	
L.Tenure	0.1174	0.1073	0.0242	0.0199	0.1392	0.0884	0.0957	0.1138	1
L2.R&D Stock	0.5534	0.4766	-0.0551	-0.0307	0.9296	0.0982	0.3179	0.1503	0.1319
L2. Patent Stock	0.8155	0.629	0.0269	0.0572	0.6032	0.0953	0.2855	0.1448	0.1338
L2. Cite-Weighted Patent Stock	0.8992	0.7453	0.0429	0.1058	0.5884	0.1065	0.2516	0.135	0.1288
L2.Technology Class Concentration	-0.0697	-0.0537	-0.0546	0.0272	-0.0604	0.0007	-0.0638	-0.091	-0.0968
Firm Age	0.1232	0.0836	0.0626	-0.0273	0.1371	-0.0439	0.1604	0.1772	0.3294
Firm Size: L2. Total Assets	0.2054	0.1653	-0.0257	-0.0153	0.3442	0.0945	0.3151	0.2262	0.1344
Industry Concentration	0.0077	0.0096	-0.0133	-0.0109	0.0272	0.0422	0.0073	0.014	-0.0298
L.Volatility	-0.0788	-0.0827	-0.0566	-0.0753	-0.0957	-0.0548	-0.1469	-0.1965	-0.3227
L.Cash	0.153	0.1219	-0.0541	-0.0383	0.3169	0.135	0.2888	0.221	0.0927
L.Long-Term Debt	0.1069	0.0788	-0.0214	-0.0184	0.2294	0.0448	0.2011	0.1343	0.0605
L.Advertising Expense	0.3216	0.2887	-0.041	-0.0192	0.606	0.1891	0.3088	0.171	0.1616

	L2.R&D Stock	L2. Patent Stock	L2.Cite-Wtd, Patent Stock	L2.Technology Class Conc.	Firm Age	Firm Size	Indus-try Conc.	L.Volatility	L.Cash	L.Long-Term Debt
L2. Patent Stock	0.6451	1								
L2. Cite-Wtd. Patent Stock	0.6255	0.9645	1							
L2.Technology Class Conc.	-0.0708	-0.0803	-0.071	1						
Firm Age	0.173	0.1712	0.1395	-0.204	1					
Firm Size: L2. Total Assets	0.385	0.2548	0.233	-0.0713	0.1805	1				
Industry Concentration	0.0324	0.0119	0.0013	0.0311	0.0189	-0.0549	1			
L.Volatility	-0.0917	-0.0701	-0.0641	0.1548	-0.404	-0.146	0.0095	1		
L.Cash	0.3152	0.1822	0.1722	-0.0454	0.089	0.7738	-0.0434	-0.0793	1	
L.Long-Term Debt	0.2628	0.1423	0.1246	-0.0452	0.1131	0.8088	-0.0312	-0.0898	0.5306	1
L.Advertising Expense	0.6442	0.3424	0.3453	-0.0627	0.2247	0.3185	0.0373	-0.1523	0.2384	0.2271

TABLE 2: Patenting Activity and Managerial Incentives

Dependent Variable: Log (1+ Patents)

	Straight Patent Counts			Cite-Weighted Patent Counts		
Managerial Variables	(1)	(2)	(3)	(4)	(5)	(6)
L.Share Price Sensitivity ($M)	0.176***	0.050***	3.0 %	0.227***	0.065***	3.9 %
	(0.034)	(0.009)		(0.076)	(0.021)	
L.Share Price Sensitivity Squared	-0.018***			-0.024**		
	(0.005)			(0.010)		
L.Volatility Sensitivity ($M)	-0.479***	-0.023***	-2.02 %	-0.183	-0.009	
	(0.136)	(0.006)		(0.311)	(0.015)	
L.Bonus/Cash Compensation %	0.002***	0.002***	0.13 %	0.001	0.001	
	(0.001)	(0.001)		(0.001)	(0.001)	
L.Tenure (Years)	-0.001	-0.013		-0.002	-0.021	
	(0.001)	(0.012)		(0.002)	(0.025)	
Controls						
L2.Log R&D Stock ($M)	0.011***	0.011***	0.45 %	0.037***	0.037***	1.52%
	(0.004)	(0.004)		(0.008)	(0.008)	
L2.Log Patent Stock	0.565***	0.565***	23.2 %	0.622***	0.622***	21.1%
	(0.015)	(0.015)		(0.021)	(0.021)	
L2.Log Technology Class	-0.000	-0.000		0.001	0.001	
Concentration	(0.001)	(0.001)		(0.003)	(0.003)	
Firm Age	-0.011***	-0.062*	-5.46 %	-0.037***	-0.316***	-27.5%
	(0.002)	(0.035)		(0.005)	(0.071)	
Firm Age Squared	0.000***			0.000***		
	(0.000)			(0.000)		
Firm Size (L2.Log Total Assets $M)	0.069***	0.113***	4.41 %	0.036	0.135***	5.26%
	(0.016)	(0.011)		(0.033)	(0.023)	
Firm Size* Firm Age	0.001***			0.003***		
	(0.000)			(0.001)		
Log Industry Concentration (HHI)	-0.011	-0.011		-0.025	-0.025	
	(0.010)	(0.010)		(0.019)	(0.019)	
L.Volatility %	-0.002***	-0.002***	-0.12 %	-0.005***	-0.005***	-0.31 %
	(0.001)	(0.001)		(0.001)	(0.001)	
Relevant Statistics						
Observations	7738			7738		
Censored Observations	204			3898		
Number of Firms	1174			1174		
Rho	0.355 (0.019)			0.337 (0.021)		
Chi-Square Statistic	6791.106			6584.487		

Notes: Unbalanced panel. Range: 1994-2005.Estimation is done using a random effects panel data tobit model with year and industry fixed effects and censoring occurring when the number of Patents/Cite-Weighted Patents equals zero. The sample is restricted to firms that have at least 1 patent during our sample period. Columns 1 & 4 report coefficient estimates, columns 2 & 5 report elasticities evaluated at the means, while columns 3 & 6 report the percentage change in the patent counts corresponding to an increase in the independent variable from the 25th to the 75th percentile. Standard errors are reported in parenthesis. ***, ** & * denotes significance at 1, 5 and 10 percent levels respectively. L is the lag operator.

TABLE 3: R&D Productivity and Managerial Incentives

Dependent Variable: Log(1+Patents/R&D)

	Straight Patent Counts			Cite-Weighted Patent Counts		
Managerial Variables	(1)	(2)	(3)	(4)	(5)	(6)
L.Share Price Sensitivity ($M)	0.005	0.001		-0.142	-0.038	
	(0.052)	(0.013)		(0.114)	(0.029)	
L.Share Price Sensitivity Squared	-0.002			0.011		
	(0.007)			(0.016)		
L.Volatility Sensitivity ($M)	-0.700***	-0.033***	-2.94%	1.047**	0.049**	4.36%
	(0.199)	(0.009)		(0.456)	(0.021)	
L.Bonus %	-0.002**	-0.002**	-0.14%	-0.002	-0.002	
	(0.001)	(0.001)		(0.002)	(0.002)	
L.Tenure (Years)	-0.004**	-0.040**	-4.92%	-0.007**	-0.081**	-10.0%
	(0.002)	(0.018)		(0.003)	(0.037)	
Controls						
L2.Log Patent Stock	0.284***	0.284***	15.1%	0.575***	0.575***	26.4%
	(0.019)	(0.019)		(0.028)	(0.028)	
L2.Log Technology Class Concentration	-0.000	-0.000		0.010**	0.010**	
	(0.002)	(0.002)		(0.004)	(0.004)	
Firm Age	-0.003	0.040		-0.039***	-0.348***	-32.7%
	(0.005)	(0.070)		(0.008)	(0.106)	
Firm Age Squared	0.000**			0.000***		
	(0.000)			(0.000)		
Firm Size (L2.Log Total Assets $M)	-0.177***	-0.253***	-11.1%	-0.193***	-0.223***	-9.81%
	(0.026)	(0.020)		(0.050)	(0.038)	
Firm Size* Firm Age	-0.002***			-0.001		
	(0.001)			(0.001)		
Log Industry Concentration (HHI)	-0.010	-0.010		-0.036	-0.036	
	(0.020)	(0.020)		(0.028)	(0.028)	
L.Volatility %	-0.0003	-0.0003		-0.004**	-0.004**	-0.27 %
	(0.001)	(0.001)		(0.002)	(0.002)	
L.Log Cash ($M)	-0.032***	-0.032***	-1.57%	-0.018	-0.018	
	(0.010)	(0.010)		(0.021)	(0.021)	
L.Log Long-Term Debt ($M)	-0.001	-0.001		-0.011	-0.011	
	(0.004)	(0.004)		(0.008)	(0.008)	
L.Log Advertising Expense ($M)	0.001	0.001		0.014	0.014	
	(0.005)	(0.005)		(0.009)	(0.009)	
Relevant Statistics						
Observations	5203			5203		
Censored Observations	40			1933		
Number of Firms	833			833		
Rho	0.619 (0.016)			0.347 (0.023)		
Chi-Square Statistic	2164.392			3763.552		

Notes: Unbalanced panel. Range: 1994-2005. Estimation is done using a random effects panel data tobit model with year and industry fixed effects and censoring occurring when the number of Patents/Cite-Weighted Patents equals zero. The sample is restricted to firms that have at least 1 patent during our sample period and non-zero R&D in the current year. Columns 1 & 4 report the coefficients, columns 2 & 5 report elasticities evaluated at the means, while columns 3 & 6 report the percentage change in R&D productivity corresponding to an increase in the independent variable from the 25th percentile to the 75th percentile. Standard errors are reported in parenthesis. ***, ** & * denotes significance at 1, 5 and 10 percent levels respectively. L is the lag operator.

TABLE 4: Patenting Activity and R&D Productivity

Two-Equation SUR Model

	Straight Patent Counts		Cite-Weighted Patent Counts	
Managerial Variables	(1): Log(1+ Patents)	(2): Log(1+ Patents/R&D)	(3): Log(1+ Patents)	(4): Log(1+ Patents/R&D)
L.Share Price Sensitivity ($M)	0.253***	0.063	0.290***	0.006
	(0.041)	(0.055)	(0.060)	(0.073)
L.Share Price Sensitivity Squared	-0.026***	-0.004	-0.029***	-0.005
	(0.006)	(0.008)	(0.008)	(0.010)
L.Volatility Sensitivity ($M)	-0.306*	-1.017***	-0.955***	-0.069
	(0.175)	(0.236)	(0.258)	(0.310)
L.Bonus %	0.003***	0.001	0.003***	0.001
	(0.001)	(0.001)	(0.001)	(0.001)
L.Tenure (Years)	-0.003***	-0.004**	-0.004***	-0.007***
	(0.001)	(0.001)	(0.002)	(0.002)
Controls				
L2.Log R&D Stock ($M)	0.099***		0.073***	
	(0.005)		(0.007)	
L2.Log Patent Stock	0.729***	0.545***	0.593***	0.493***
	(0.010)	(0.013)	(0.011)	(0.013)
L2.Log Technology Class	-0.004***	0.002	-0.022***	0.006**
Concentration	(0.001)	(0.002)	(0.002)	(0.003)
Firm Age	-0.008***	0.005*	-0.011***	-0.013***
	(0.002)	(0.003)	(0.003)	(0.003)
Firm Age Squared	0.000***	0.000	0.000***	0.000***
	(0.000)	(0.000)	(0.000)	(0.000)
Firm Size (L2.Log Total Assets $M)	0.029*	-0.271***	0.062***	-0.096***
	(0.015)	(0.021)	(0.022)	(0.027)
Firm Size* Firm Age	-0.001**	-0.002***	0.000	-0.003***
	(0.000)	(0.000)	(0.000)	(0.001)
Log Industry Concentration (HHI)	-0.005	-0.013	-0.011	-0.025**
	(0.006)	(0.008)	(0.009)	(0.011)
L.Volatility %	-0.001**	-0.002***	-0.002***	-0.003***
	(0.001)	(0.001)	(0.001)	(0.001)
L.Log Cash ($M)		-0.151***		-0.074***
		(0.008)		(0.009)
L.Log Long-Term Debt ($M)		0.000		-0.003
		(0.003)		(0.003)
L.Log Advertising Expense ($M)		-0.012***		-0.009***
		(0.002)		(0.003)
Relevant Statistics				
Observations	5203	5203	5203	5203
R-Squared	0.811	0.500	0.729	0.574

Notes: Unbalanced panel. Range: 1994-2005. The table reports coefficient estimates from a seemingly unrelated regression model with year and industry fixed effects. The sample is restricted to firms that have at least 1 patent during our sample period and non-zero R&D in the current year. Standard errors are reported in parenthesis. ***, ** & * denotes significance at 1, 5 and 10 percent levels respectively. L is the lag operator.

TABLE 5: R&D and Technology Intensity

Dependent Variable: Log(1+Patents)

Panel A: Straight Patent Counts	(1)	(2)	(3)	(4)
Managerial Variables	Low R&D/Sales	High R&D/Sales	Low-Tech	High-Tech
L.Share Price Sensitivity ($M)	0.048	0.316***	0.107***	0.295***
	(0.033)	(0.057)	(0.037)	(0.070)
L.Share Price Sensitivity Squared	-0.007	-0.031***	-0.011**	-0.035***
	(0.005)	(0.008)	(0.005)	(0.010)
L.Volatility Sensitivity ($M)	-0.239*	-0.704***	-0.543***	-0.394
	(0.132)	(0.231)	(0.145)	(0.290)
L.Bonus %	0.001***	0.001	0.003***	-0.000
	(0.001)	(0.001)	(0.001)	(0.001)
L.Tenure (Years)	-0.002*	0.000	-0.004***	0.006***
	(0.001)	(0.002)	(0.001)	(0.002)
Relevant Statistics				
Observations	3869	3869	5015	2723
Censored Observations	139	65	133	71
Number of Firms	649	646	747	427
Rho	0.432	0.348	0.296	0.422
Chi-Square Statistic	3451.795	4099.616	5907.364	2012.492

Panel B: Cite-Weighted Patent Counts	(1)	(2)	(3)	(4)
Managerial Variables	Low R&D/Sales	High R&D/Sales	Low-Tech	High-Tech
L.Share Price Sensitivity ($M)	-0.009	0.428***	0.071	0.459***
	(0.117)	(0.098)	(0.096)	(0.124)
L.Share Price Sensitivity Squared	0.002	-0.046***	-0.005	-0.056***
	(0.016)	(0.014)	(0.013)	(0.018)
L.Volatility Sensitivity ($M)	-0.667	-0.100	-0.621	0.377
	(0.482)	(0.396)	(0.389)	(0.507)
L.Bonus %	0.002	0.0003	0.002	-0.001
	(0.002)	(0.002)	(0.002)	(0.002)
L.Tenure (Years)	-0.001	-0.003	-0.006**	0.009**
	(0.003)	(0.003)	(0.003)	(0.004)
Relevant Statistics				
Observations	3869	3869	5015	2723
Censored Observations	2503	1395	2788	1110
Number of Firms	649	646	747	427
Rho	0.266	0.375	0.276	0.435
Chi-Square Statistic	1955.023	4568.909	4104.008	2681.129

Notes: Unbalanced panel. Range: 1994-2005.The table reports coefficient estimates from a random effects panel data tobit model with year and industry fixed effects and censoring when Patents/Cite-Weighted Patents equals zero. The sample is restricted to firms that have at least 1 patent during our sample period. The sample is split by the median value of R&D/sales in columns 1 and 2 while in columns 3 and 4, the sample is split according to their Fama-French industry classification. High-tech industries include the following: Aircraft, Chemicals, Electronic Equipment, Pharmaceutical Products, Electrical Equipment, Machinery, Medical Equipment, Software and Telecommunications. Standard errors are reported in parenthesis. ***, ** & * denotes significance at 1, 5 and 10 percent respectively. L is the lag operator. Unreported control variables include: L2.Log R&D Stock, L2.Log Patent Stock, L2.Technology Class Concentration, Firm Age, Firm Age Squared, Firm Size, Firm Size*Firm Age, Log Industry Concentration and L.Volatility.

Fig. 1: Patents & Share Price Sensitivity

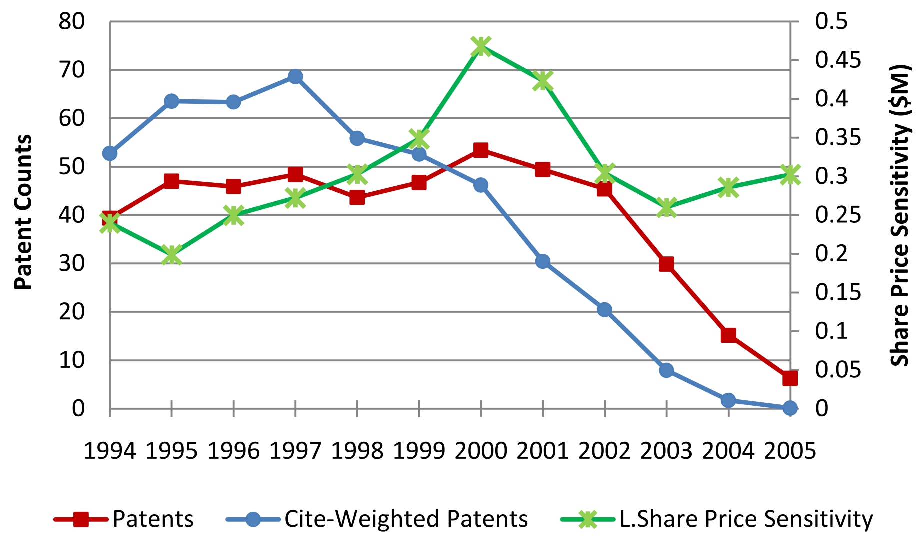
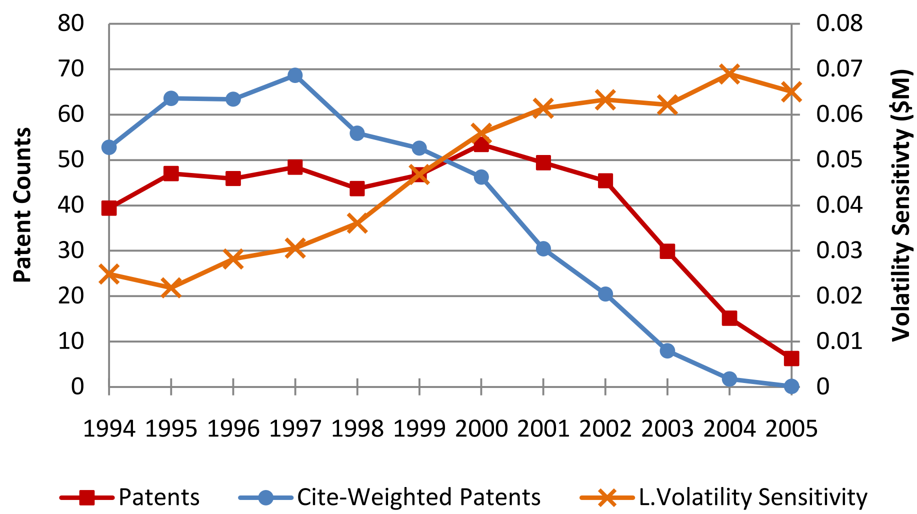


Fig. 2: Patents & Volatility Sensitivity



Note: All values are annual averages for the estimation sample.