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Are CEOs Myopic? A Dynamic Model of the Ongoing Debate

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Abstract

We study the events that motivate CEOs to under-invest in R&D long-term projects (CEO myopia). Based on the existing literature in earnings management and agency theory, myopia is likely to become more problematic under five circumstances: when the CEO nears retirement (the CEO horizon problem), R&D projects have very long time horizons (the project horizon problem), the firm's financial health is deteriorating (the cover-up problem), ownership structure is heavily weighted toward insider owners (minority owner oppression problem), and when the threat of hostile takeover increases (the entrenchment problem). We setup a dynamic simulation model in which rational CEOs maximize the total value of their bonus compensation over their tenure. Our findings related to the five circumstances are consistent with the extant literature. However, we found an unexpected stable, non-linear (inverted U-shaped) relationship between CEO tenure and R&D investment. We discuss the theoretical implications of our model and offer suggestions for future research.

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INTRODUCTION

In the neoclassical theory of the firm, productivity and growth is a consequence of increases in labor and capital (Solow 1956). More recently, growth has been attributed to increases in intangible investments in human resources, new technology, research and development, and brand building (Denison 1967, Kendrick 1976, Penrose, 1964). Studies have shown that the rate of firm growth resulting from intangible investments has outstripped that related to fixed capital formation (cf. Patel and Pavitt 1995). This is because intangible investments allow firms to increase the absorptive capacity for new knowledge, undertake organizational renewal, and innovate, which is the basis for a sustained competitive advantage (Cohen and Levinthal 1989). Additionally, empirical research has shown a relationship between such intangible investments as R&D and productivity, earnings, and shareholder value at the national, industry and company levels of analyses (e.g. Griliches 1995, Lev and Sougiannis 1996). In sum, the basis for firm growth and profitability has increasingly shifted from tangible to intangible capital accumulation.[1]

Yet, such observers as Jacobs (1991), Porter (1992), and Jensen (1998) have pointed out the chronic underinvestment in intangible assets of U.S. companies, relative to their German and Japanese counterparts. While the exact causes are unclear, we surmise that the link between CEO compensation and accounting earnings (Murphy 1999), given that R&D and marketing expenditures are expensed under U.S. Generally Accepted Accounting Principles (henceforth

[1] Increases in business-funded R&D in real terms and as a percentage of GDP since the late 60's support the view that investments in innovation have gained relevance in developed economies. Patel and Pavitt (1995) report an average increase of over 100% between 1967 and 1990 for the five major OECD countries, with a 900% increase for Japan.

GAAP), rather than capitalized as with equipment and buildings, may be one reason. This link may give rise to a natural conflict between the firm's long-term competitive interests and its CEOs' performance incentives (Drucker 1986, Jacobs 1991, Porter 1992, Bange and Bondt 1998).

There appears to be a widespread perception that U.S. capital markets reward short term accounting returns more than they do long term investments[2]. This perception belies the workings of the efficient capital market and does not shed light on the causes of this phenomenon. Our paper attempts to theoretically address this issue and provides an elaboration of an unintended consequence of accounting-based contingent compensation systems – earnings management, which can be achieved by discretionary adjustments such as short term expense reductions or income smoothing techniques (Healy 1985). In this paper, we explore the phenomenon of underinvestment (or myopia) in intangible assets, with a focus on R&D expenditures.

First, building from agency theory and the earnings management literature, we examine five drivers (tenure, investment horizon, the firm's ownership structure, the firm's financial performance and height of takeover defenses) of myopia in R&D expenditures. We focus on R&D expenditures because there is evidence to suggest CEOs resort to reducing discretionary expenditures such as R&D to meet short term earnings goals (Jacobs 1991), and it appears that managerial agency contracts do not or cannot completely eliminate this problem.[3]

[2] Abegglen and Stalk (1985), in a survey of 500 large U.S. and Japanese firm executives, indicated that the former ranked stock price increases as second out of nine most important objectives, whereas the latter considered stock price the least important factor. Drucker (1986) reports 82% of U.S. CEOs blamed the stock market's focus on short-term accounting earnings for the decline in long-term investments.

[3] For example, Dechow and Sloan (1991) found that CEOs systematically reduced spending on R&D in their final year of office.

We believe that this study provides a potentially useful framework for understanding why and how accounting-based contingent compensation systems can lead to aggressive earnings management at the expense of long-term competitive advantage. The results, in brief, suggest that CEOs begin to gradually become myopic (i.e. underinvest in R&D) after a critical point in time over their tenure at a firm, in contrast to what an efficient capital market notion would predict. This is caused by the emphasis on short run performance, as a result of the factors we explore in the paper, that lead to a systematic underinvestment in intangible assets (e.g. Jacobs 1991, Porter 1992, Larcker and Sloan 1995). We find that investment myopia starts sooner (i.e. R&D investments start to diminish earlier) as insider ownership is higher, as the firm is more protected from hostile takeovers, as the firm's earnings worsen, and when R&D have longer investment return horizons.

The implications of these findings agree with Morck, Shleifer and Vishny (1988), Cho (1988) and Hadlock (1998), who show that when insider ownership is low, the monitoring effect of a large block of shareholders creates a convergence of interests between managers and owners, while high insider ownership can lead to managerial entrenchment and cause CEOs to act opportunistically. Our findings are also consistent with Bronwyn and Hall (1990), who find no evidence that the threat of hostile takeovers increases the probability of investment myopia, and with the work of Gibbons and Murphy (1992), who suggest that managers far from retirement are willing to take more costly observable actions to change the market's belief about their abilities. Similarly, our findings support Jacobs (1991) and Jensen (1998) who point that myopia in U.S. companies is driven by differences in investment time horizons when compared to their Japanese and German counterparts. Finally, we were able to demonstrate agreement with

Baber, Fairfield, and Haggard (1991), and Perry and Grinaker (1994) that R&D expenditures may be cut when earnings fall short of expectations.

Generally speaking, our findings are consistent with the literature on the managerial horizon problem, in which an agency conflict between CEOs and shareholders occurs because the CEO's career horizon is shorter than the shareholders' investment horizons[4]. Previous research on managerial horizon problems tends to look at CEOs nearing retirement and proposes a linear relationship between the CEO's age and the effect of incentive compensation. In this paper, we provide new evidence on the managerial horizon problem and demonstrate the existence of a concave relationship between R&D investment and CEO tenure. Focusing on bonus awards, we argue that CEOs do not exhibit investment myopia early in their tenures because the typical bonus structure provides the right incentives to maximize lifetime bonuses since there is ample time for the CEO to realize the benefits from future expected returns on R&D projects. However, we find that myopia occurs if the bonus structure does not account for the fact that CEO tenure is limited and that as she approaches retirement at that firm, the incentives to invest in risky R&D will fade. Thus, unless firms offset these incentives by adjusting the proportion of cash bonuses and base salary to CEOs approaching retirement, those chief executive officers will focus on short term outcomes and forgo profitable long term investment opportunities[5].

In short, our paper sorts out the mixed evidence in the earnings management and managerial myopia literature, which have focused on the role of the firm in predicting R&D

[4] See Hirshleifer (1993) for a review of the antecedents to managerial reputation in the context of investment choices.

[5] Recently, Ryan and Wiggins (2001) found a concave relation between the CEO's age and cash bonus, suggesting that firms choose to focus on stock based awards for managers who have incentives to focus on short term goals. Our results compliment their study by providing new evidence on the influence of poor incentive alignment on investment decisions, which leads to managerial investment myopia.

spending but generally overlook the specific attributes and compensation schemes of CEOs involved in allocating corporate resources. We provide evidence regarding the influence of a firm's monitoring mechanisms, ownership structure and R&D project and managerial specific characteristics on its CEO's investment decisions and shed new light on the required incentive systems that would mitigate investment myopia problems.

EARNINGS MANAGEMENT AND INVESTMENT MYOPIA

The agency theoretic notion of the separation of ownership and control is now the traditional starting point in corporate finance problems (Jensen, 1998). This separation can create problems for the efficient allocation of corporate resources (Jensen and Meckling, 1976). In brief, the natural conflict in self-interests between managers and owners, as result of their separation, can lead to myopic investment behaviors (Porter, 1992; Jensen, 1998). In the context of this paper, myopic investment behavior can be regarded as a form of earnings management, a phenomenon describing situations in which CEOs structure transactions to influence financial reports in order to mask the actual economic performance of a company, or to influence contractual outcomes that depend on reported accounting numbers (Schipper, 1989).

Earnings management was first described in an early attempt to derive a positive theory of the determinants of accounting standards. Gordon (1964) introduced the proposition that CEOs select accounting procedures to maximize their own utility, which is a function of job security and level (and growth rate) of management income and firm size. In particular, he theorized that the achievement of management utility maximization is dependent in part on the satisfaction of stockholders with the growth and stability of the corporation's income. According to Gordon (1964), CEOs maximize their own wealth and utility by choosing accounting procedures that reduce the variance in earnings (within the latitude allowed by accounting rules).

However, a common characteristic of investment expenditures and accounting methods is that they can both affect the level of reported earnings. Therefore, so the theory goes, CEOs inflate reported earnings to maximize the value of their annual bonus awards through the manipulation of accounting methods *and* discretionary investment expenditures.

Financial economists are less sure about the existence of this problem because it contradicts the efficient markets hypothesis. Because the market is not systematically fooled by inflated earnings, CEOs who act against shareholder interests will eventually be punished by lowered stock prices. This traditional view holds that there is no meaningful difference between maximizing short or long run stock prices, as both will lead to the same efficient investment decisions. As a result, earnings management will only be a problem if CEOs do not sufficiently care about stock prices because they hold little stock in their firms, they misunderstand the forces that determine their stock values (Jensen, 1986) or shareholders are unconcerned about the stock price[6].

The upshot is that we are left with a conundrum. If earnings management exists on a widespread basis, as regulators and Wall Street seem to suggest, then it would lead to a distortion of the market signals on which investors rely for information. On the other hand, if markets are able to detect earnings management, then it would not be possible for a sustained period of price inflation and its resulting effects on managerial myopia to exist. Recently, other perspectives have arisen to explain the existence of managerial myopia despite the presence of efficient markets. For example, Stein (1989) shows that, even in a fully efficient market, CEOs who care about stock prices can behave myopically, and the more concerned they are about current stock prices, the worse the problem becomes. He proposes a "signal jamming" model in which the

[6] The last condition can occur if a shareholder has long term commercial interests in the firm that are more valuable than its equity interests. For example, Japanese keiretsu companies hold each other's shares to cement commercial relationships and not for investment purposes (Phan and Yoshikawa, 2000).

market uses a firm's earnings to make rational forecasts about its future value. The result is that CEOs will attempt to manipulate stockholders' signals by inflating accounting earnings to raise the forecasted values. Because the market is efficient, it correctly infers a certain amount of earnings inflation and CEOs know they cannot fool the market in the long run. However, because they act out of self-interest, CEOs are locked in, what is equivalent, to a prisoner's dilemma with the stock market, in which the preferred analogous cooperative equilibrium involving no myopia cannot be sustained as a Nash-equilibrium. If, on the other hand, the market conjectures no myopia, CEOs will have an incentive to fool it by boosting current earnings, and the more they care about short run stock prices, the higher their incentives to pump-up the bottom line. Hence, managerial myopia, which results from the information asymmetry between CEOs and shareholders and the invisibility (and indivisibility) of managerial action, does not contradict the efficient markets hypothesis.

With regard to the relationship between myopia and R&D investments, we hypothesize a conflict resulting from the time horizon difference between the returns on R&D expenditures and a CEO's tenure in a firm. Here, myopia occurs because CEO's wealth is tied to the performance of the firm over her predictable tenure, whereas shareholders' wealth is tied to the less predictable performance of the firm over a generally unbounded time period. In this paper, we explore the conditions under which myopia in R&D investments may exist and is exacerbated. We offer a model to further investigate the unobvious relationship between R&D expenses and tenure. The questions we ask are whether, "CEOs have an incentive to underinvest in R&D for the purposes of inflating current earnings and bonuses?" and if so, "Under what circumstances does this problem become worse; i.e., when does myopia occur sooner?"

In the following theoretical model, we build a framework for conceptualizing the decision to spend on R&D as a function of a CEO's compensation and tenure. The model includes 5 conditions in which the effect of tenure may be strengthened. We then explore the simultaneous impact of changes on the 5 conditions on the R&D spending decision. Finally, we speculate on the implications of our model and suggest future research directions.

A DYNAMIC MODEL OF R&D AND CEO COMPENSATION AND TENURE

Based on the theoretical review that we presented, our model begins with a rational CEO, whose compensation consists exclusively of bonuses, must select a level of R&D expenditures in each year of her tenure at a firm. For parsimony, we do not include base pay because it is relatively insensitive to annual changes in marginal product and thus not figure prominently in the CEO's decision.

We focus on bonus rather than stock compensation for a number of reasons. First, R&D expenditures have been shown to be positively related to stock prices (Lev and Sougiannis 1996, Sougiannis 1994). Consequently, when examining their effect on the total compensation package, the negative impact of R&D expenditures on current earnings and thus on current accounting based bonuses may be mitigated by their positive effect on stock price based compensation. Focusing on the bonus portion helps us isolate this effect. Second, we assume that CEOs can better control the size of accounting based annual bonuses than stock based compensation, since bonuses can be affected, within certain boundaries, by earnings management, but stock prices also depend on exogenous factors such as interest rates, inflation, and investor bandwagon and contagion effects.

Thus, everything else equal, the CEO's annual compensation is determined by the firm's annual level of earnings, which is affected by current annual R&D expenditures and income

from past R&D investments. In sum, by selecting the level of annual R&D expenditures, the CEO can affect the level of current and future expected annual bonuses.

The CEO's Bonus

Let t represent the CEO's tenure at the present time and b_t her bonus at t. Over time, the CEO selects a series of R&D expenditure levels so as to maximize her discounted expected total bonus over her total tenure T (in years). Let r_t, which is greater than or equal to 0, be the R&D expenditures budgeted by the CEO at the beginning of time period t. The CEO's objective function is thus formally expressed as,

$$\max_{r_t,\, t\in\{1,2,\ldots,T\}} \sum_{t=1}^{T} l^{t} b_t , \qquad (1)$$

where $l \in [0,1]$ is a discount factor that captures the notion that most individuals allocate more value to early rather than late rewards (i.e., more value attributed to immediate rather than delayed consumption).

The Profit Equation

A CEO's bonus is evaluated as a percentage of the firm's profit which, at period t, is denoted by p_t and is an increasing function of the previous period profit and total compounded return on past R&D expenditures (investments) made k_t periods prior to t, but a decreasing function of actual R&D expenditures at t.

We assume that because R&D projects are internal to the firm they are hard to observe accurately by shareholders, which make estimating their true value and the time lag to positive cash flows unreliable. According the agency theory, this results in the separation of decision management and decision control, resulting in the control of R&D investment decisions by the

CEO. Thus, shareholders have no direct decision rights over the type of R&D projects selected annually in terms of risk levels, time horizon and investment size. We note that k_t is the R&D investment horizon for an investment made at time period *t*, i.e., the total number of periods it takes from the time the R&D investment is made until the time it generates its last payout. For simplicity, we interpret k_t to be the average time it takes from the time of investment to the time of last payout.[7] As the average time horizon of a project can vary, we model k_t as a random variable that follows a discrete uniform distribution on the set {1,2,3,…,*K*}. Formally,

$$p_t = a\ p_{t-1} + g\ r_{t-k_t} \prod_{i=t-k_t+1}^{t} [1 + ROI_i] - q_t r_t, \qquad (2)$$

where a and g are positive parameters representing, respectively, the percentage of firm profit transferred from one time period to the next and total compounded return on average R&D expenditures made over k_t periods prior to *t*. In our model, a is the level of earnings smoothing, which is the transfer of earnings from one period to the next[8]. A higher a indicates a larger transfer of earnings from the previous year to the current one, which happens when current profits are expected to be significantly lower than last year's profits. U.S. GAAP allows some flexible allocation of earnings[9] using smooth ('systematic') formulas[10].

[7] For example, if a firm has 3 investments receiving their last payout at the current time period, where one was made 7 years ago, one 5, and the third 3 years ago, then for analytical simplicity, we assume on average that the firm has a single project that was made 5 years ago.

[8] Especially high current earnings may trigger increased demands from stockholders and employees for higher payouts from cash flows, from the government for more taxes, or even attract new entrants into the industry. Especially low earnings may trigger stock sell-offs, which can depress the price of a stock and expose the firm to an increased threat of takeover. Thus, CEOs have incentives to engage in earnings smoothing when expected current earnings exceed the range that is perceived to be 'normal'.

[9] An example is the way GAAP allows companies to accept income tax allocations, which both lower and stabilize reported income.

[10] Formulas that use smooth allocation techniques are, for example, the straight-line and double-declining-balance formulas for depreciation and the compound interest formula for reporting on liabilities. A company selects each formula at the beginning of the period of allocation, supposedly to represent the effects of prospective underlying economic events. Financial report issuers cannot possibly have that foreknowledge about events that may occur after they select the formulas, and events do not occur as regularly as the use of the formulas implies. Moreover, allocation does not necessarily reflect the effects of underlying economic events.

ROI_i is the expected returns on R&D investments at time period i (in percentages), and q_t is the firm's CEO's propensity to invest in R&D at t, thus making $q_t r_t$ the actual R&D expenditures at t. Another simplifying assumption we make in this model is that the CEO founded the company, which means that the CEO's tenure at t equals the age of the firm at t. Thus, we set $t - k_t$ to zero whenever the value for k_t is larger than t, and $r_0 = 0$.

The Returns on Investment Function

Investors expect positive returns on their investments, in the form of interests, dividends, or rents. Typically, an investment is not made unless it is expected to earn more than the cost of capital invested. The cost of capital is an opportunity cost and represents the rate of return expected in the future from investments with the same degree of risk. Given that there are numerous possible cash flows from various R&D projects, it is difficult to evaluate the actual annual return on each R&D spending decision. However, we can proxy the minimal annual hurdle rate of return on R&D projects as the cost of capital using the capital asset pricing model (CAPM) (Sharpe, 1964; Lintner, 1965). Drawing from the basic risk return relationship established in the CAPM, the minimal expected rate of return on any risky investment should be at least as high as the rate of return on a risk free investment and the adjusted return on a market indexed investment[11].

Therefore, the annual average hurdle rate of return on R&D expenditures made at time period t can be formally expressed as,

$$ROI_t = R^f + b\,[R^m - R^f], \qquad (3)$$

[11] For ease of interpretation, we assume that the benchmark project has the same capital cost structure as that of the firm, and thus the cost of capital is equal to the cost of equity proxied by the CAPM model.

where R^f is the annual average rate of risk free investment (i.e. cash), R^m the annual average rate of return of an appropriate asset class, benchmarked to the market such as the 5-year Nasdaq Technology Index, and b a measure of the volatility of a stock (i.e., risk level) relative to the overall market.

In our model, we assume that b is time invariant. The economic meaning of a constant b in our context is that the firm is involved in projects with the same average risk level throughout the CEO's tenure (e.g. a firm only invests in projects in its industry)[12]. This represents a conservative test of our model since we assume that CEOs do not gamble by diversifying into areas for which the firm has no competencies.[13]

The CEO's Propensity to Invest

Because a CEO's tenure is limited, given by her average retirement age, the net present value of her investment decisions with longer term consequences will be lower the closer she gets to retirement. This is because the time horizon of long term investment decisions eventually exceeds her remaining tenure in the firm. Therefore, everything else equal, as a CEO approaches retirement, her career concerns will diminish and she will tend to focus more on maximizing shorter-term performance rather than long-term value creation, from which she is less likely to benefit. In an earnings based compensation regime, this effect is likely to be heightened (Healy, 1985).

Additionally, although shareholders have no direct investment decision rights in our model, CEOs are still monitored by shareholders and disciplined by the threat of takeover (Jensen, 1998). According to Porter (1992), when a firm has a fragmented ownership structure,

[12] Further analysis (not shown here), using time varying betas did not change the direction of our results.
[13] Empirically, we use the geometric average annual market (NYSE Composite) and T-bill rates for the last 20 years, which yield an estimated value of 5.4% for R^f and 14.7% for R^m. Values for b (between .4 and 2.9) are taken from *Value Line*.

partly due to the enforcement of anti-trust regulation and the preference for liquidity, institutional investors tend to diversify their portfolios and manage their holdings on short-term financial performance. They rarely take an active role in the monitoring of management or have any influence on the board of directors and so are more likely to reward quarterly earnings by purchasing or holding on to shares and are consequently less concerned with long term R&D projects, for which future cash flows are difficult to evaluate (De Long, Shleifer, Summers and Waldmann, 1991).

Consequently, we model a CEO's propensity to invest in R&D as inversely proportional to her tenure in the firm and inversely proportional to the percentage s_t of outside shareholders at year t. s_t (≥ 0) is a positive random variable that follows a continuous uniform distribution on the interval $[u,v]$.

We also model a CEO's propensity to invest in R&D as directly proportional to the height of her firm's anti-takeover devices, given by the firm's governance index g, and the percentage $[1-s_t]$ of insider ownership[14]. We posit that, compared to atomistic shareholders, higher insider ownership will be more inclined and able to align the CEO's interests with their own[15], and that higher takeover defenses will allow CEOs to make higher investments in R&D, as the fear of reporting lower *current* earnings and thus being susceptible to takeover attempts will be mitigated.

Finally, we posit a positive relationship between future total compounded expected return on R&D expenditures and the propensity to invest, as CEOs are expected to be more enthusiastic

[14] Based on Gompers Ishii and Metrick (2003), who measure 24 governance charter amendments to proxy for the level of shareholder rights and takeover defenses in more than 1500 large firms during the 1990s. The index uses numerical values of 1-24, in which a value of 1 indicates low takeover defenses and high shareholder rights (high takeover threat), and a value of 24 indicates high takeover defenses and low shareholder rights (low takeover threat).

[15] For example, James (1999) demonstrates in a two-period model how founding management family ownership provides incentives to invest according to the market rule (i.e., positive NPV projects) to the benefit of shareholders.

to invest in more profitable projects. Also, a CEO would have a lower propensity to invest in projects with longer (expected) time horizons, k_t since she would prefer earlier rather than later cash flows, especially given her limited tenure. Formally,

$$q_t = \frac{d}{t} + \frac{e}{s_t} + w \; g + h[1 - s_t] + r \prod_{i=t+1}^{t+k_t} [1 + ROI_i] + \frac{t}{k_t}, \qquad (4)$$

where d, e, w, h, r, and t are positive parameters representing, respectively, marginal propensities to invest in R&D from the tenure time, percentage of outside shareholders, governance index, percentage of insider ownership, future expected rate of return on current R&D investments, and return horizon of R&D projects. If $t+k_t$ is larger than T, then $t+k_t$ is set to T, reflecting the fact that CEOs do not care about incomes received after their tenure at a firm.

THEORY DEVELOPMENT

A CEO's bonus is calculated as a percentage of the firm's profit and, as a result, if the firm's profit is non-positive, the CEO earns no bonus in the corresponding time period. Formally,

$$b_t = c \; p_t, \qquad (5)$$

if $p_t > 0$ and $b_t = 0$ if $p_t \leq 0$, where c is the marginal bonus per dollar of profit.

At first glance, there appears to be a non-obvious solution to this decision problem because it is dynamic. If a CEO plans to invest more in R&D in the current time period, current profit, and hence bonus, will be decreased. However, by investing in R&D, she can increase future profit and hence future bonuses in those periods when cash flows are positively affected. In addition, if she has invested in R&D in the past (i.e., k_t periods prior to the current time period) current profits, and current bonus, would have been positively impacted. Therefore, our model asks the question, "What does the CEO consider her optimal R&D investment strategy in

order to maximize her *total* bonuses during her tenure at the firm?" Because the problem does not appear to have an analytical solution, we employ a dynamic simulation to arrive at a converged solution.

The Simulation Approach

We use a dynamic simulation to refine theory development. A simulation approach forces us to make explicit assumptions, hence clarify theoretical boundaries by enabling us to explore the effects of changes in the parameters of our model. Given the nature of our model's evolutionary dynamics, simulation is the most appropriate approach as it enables us to generate multiple temporal combinations of R&D expenditures and CEO bonuses (i.e., evolutionary paths) that may emanate from the same set of initial conditions. These multiples paths can then be used to generalize the mechanisms and processes that produced them and hopefully lead to more theoretical insights. Moreover, this approach allows us to trace evolution of the dynamics over extended periods of time of R&D expenditures and CEOs bonuses and hence provide insights into the complex relationships between financial variables that one might not otherwise be able to capture due to data limitations[16].

We keep the simulation tractable by limiting R&D expenditures at t to be either $r_t = 0$ or $r_t = a + b[t-1]$, for $t = 1,\ldots,T$ ($r_0 = 0$).[17] For given sets of parameter values, 1000 simulations were run where, for periods 1,2, …, T: (1) R&D investment time horizon at t, k_t, was simulated

[16] As noted by Stein (1989), testing directly for myopia may be quite difficult, as the existence of many important types of myopic behavior cannot be empirically refuted using accounting data in a conventional fashion.

[17] To avoid multiple periods in which actual R&D expenditures could be maximized (when all $r_t = 0$), we used $r_T \in \{M, a+b[T-1]\}$ where $M = 1$. This lower bound M on how much R&D expenditures can be made at the last period can provide (when sufficiently large) more than one optimal solution. Sufficiently large R&D expenditures at the last period has a negative effect on that period's profit but no positive effects on future profits since it is the end of the planning horizon. As a result, it is possible to reach negative profit at this last period without affecting other periods, and when profits are negative the corresponding bonus is 0. Since this can happen for both possible non-zero values of R&D investment (recall that in each period the CEO can only choose from a set of two possible R&D expenditures: 0 or $a+[t-1]b$ for $t=1,2,\ldots,9$ and $M>0$ or $a+9b$ for $t=10$), two optimal solutions are possible. Thus, we keep the lower bound sufficiently small.

from a discrete uniform probability density on {1,2,3,…,K}, and (2) firm's percentage of outside owners at t, s_t, was simulated from a continuous uniform probability density on the interval [u,v]. For each simulation, we identified the R&D expenditures strategy (r_1,r_2,…,r_T) that maximizes a CEO's total discounted bonus based on the formal model described earlier. Table 1 summarizes the time-invariant parameters and the sets of values used to develop the propositions that follow.

The baseline values for those parameters in the model were chosen from empirical observations in past studies and from current data. Because we were interested in observing the relationships between the variables in the model, rather than explore their empirical limits, we chose values that could be defended as uncontroversial and within the range given by past empirical observation. For example, the range of governance indices was chosen by referring to the Gompers Ishii and Metrick (2003) governance index. The risk free rate, market returns and b were chosen based on average historical values, and the CEO's tenure was fixed to ten years, which closely corresponds to the average tenure time of a CEO in a firm as reported by Khurana (2002), and Lucier, Schuyt and Spiegel (2003).

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Exploring the Effects of Tenure

Implications for theory

Exhibit 1 reports on the base model showing the simulated relationship between CEO tenure and R&D expenditures. Each simulation of 1000 runs demonstrated a *stable* inverted U-shaped relationship between actual R&D expenditure, $q_t r_t$, and tenure, t. We ran 150 simulations of 1000 runs each to ensure the stability of our findings. Hereafter, we denote the critical year in which the mean of actual R&D expenditures over 1000 simulation runs is maximized by t*. Note

that the specific numerical value of t^* is not important. What is important is that t^* characterizes the point at which a CEO begins to exhibit investment myopia by gradually reducing the amount spent on R&D expenditures over time.

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Insert Exhibit 1 about here
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The simulation finding suggests two stylized conclusions. First, CEOs do not exhibit myopia early in their tenures because the typical bonus structure provides the right incentives to maximize lifetime bonuses since there is ample time for the CEO to realize the benefits from future expected returns. Second, myopia occurs if the bonus structure does not account for the fact that CEO tenure is limited and that as she approaches retirement at that firm, the incentives to invest in risky R&D will fade. Furthermore, this effect is enhanced if the CEOs retirement at the firm coincides with her retirement from her career, so that she becomes less worried about being punished by the managerial labor markets for bad performance and, as a result, is more willing to engage in opportunistic myopic behaviors. Our model thus suggests that,

> PROPOSITION 1. The relationship between R&D expenditure and CEO tenure is inverted U-shaped such that there exists a critical year t^* before which a CEO's actual R&D expenditures increase and after which they begin to decrease.

Consistency with theoretical and empirical evidence

The existing literature provides some explanations to the phenomenon of myopic behavior of CEOs close to retirement. Chief among these are the studies related to career concerns. Gibbons and Murphy (1992) describe career concerns as "concerns about the effects of current performance on future compensation" (pp. 468). These concerns occur whenever a labor market uses a worker's current output to estimate her future performance and assesses wages

based on these estimations. A worker who is far from retirement is willing to take more costly observable actions to change the market's belief about her abilities, and thus, an employee far away from retirement has stronger career concerns and generally works harder to create a positive impression in the labor market. However, Gibbons and Murphy (1992) found little empirical evidence to support their conjecture. They reason that CEOs may be switching to projects with more immediate payoffs without changing the total investment expenditure, long-run investment decisions are made by management teams with varying individual time horizons, or that the extra wealth generated by changing investment policies close to retirement are too small to cause a shift in managerial behavior.

Holmstrom and Ricart I Costa (1986) formalize the notion of career concerns using models based on learning about managerial talent. In their analysis, the misalignment of incentives between shareholders and managers arise not because of unobservable effort, but because managers aim at maximizing the returns on their human capital, while shareholders want to maximize the firm's financial returns. As CEOs know that their reputation and career opportunities depend on past performance, they may engage in earnings management to influence their performance evaluations.

Lastly, Hill and Phan (1991) found empirical evidence to suggest that since tenure increased the information asymmetry problem between CEOs and board of directors, and thus the power that CEOs have over their boards, the more tenured the CEO, the more likely she will pursue her own interests over those of the shareholders. As a result, CEOs are able to engineer compensation packages that reflect a weaker relationship between pay and stock returns. Adding to Hill and Phan's findings, we suggest that if CEOs can replace stock based pay with accounting

based bonuses the closer they get to retirement, then the shorter their time horizon, the greater their incentives to manage earnings to inflate earnings-based bonuses in their final years.

Exploring the Effects of Investment Horizon

Implications for theory

We next explore the impact of investment time horizons, given by K, on myopia. The reason we care about investment horizons is because they are correlated with risk levels as future cash flows of investments with longer horizons are more uncertain. In the context of the global capital and product markets, the increasing pressure to show for performance will tend to shorten the planning horizons of decision makers simply because they cannot be sure of retaining their market position indefinitely.

We can interpret K as different types of R&D investments and thus explore the impact of dynamic changes in investment portfolios on CEO myopia. Generally, basic research, because it starts from first principles, take longer to bear fruit than developmental research, which is generally more applied and therefore quicker to yield results. Thus, large values of K can be interpreted as a basic research project while small values of K can be interpreted as an applied research project. The firm's average strategic investment horizon will have an implication on the uncertainty of its future cash flows such that a portfolio weighted toward longer term investments will tend to display higher expected uncertainty in returns. Thus, investors with a lower tolerance for uncertainty may prefer CEOs to engage in investments with shorter term horizons. This leads us to our next proposition,

> Proposition 2. As the firm engages in R&D projects with longer time horizons, the critical year t^* decreases, implying that myopia sets in earlier in the CEO's tenure.

…….
Insert Exhibit 2 about here
…….

Exhibit 2 shows that for a given set of parameter values (Table 1, Column 2) as the upper bound *K* on the random investment horizon increases, the average year at which R&D expenditures are maximized decreases, implying that myopia sets in earlier. The rationale for this finding lies in the increase over time of the uncertainty of the benefits from R&D projects with longer time horizons. The CEO's preferences for earlier and thus more certain cash flows cause her to reduce R&D as she nears retirement. This result demonstrates that as investment horizons expand, myopic behavior will start sooner and thus prefer investments with shorter time horizons where cash flows are more predictable. This result appears to be robust to the parameter levels in our model.

Consistency with theoretical and empirical evidence

Porter (1992) identified several competitive disadvantages in the U.S. system of investment vis-à-vis its German and Japanese counterparts. He argues, for example, that regulations preventing extreme ownership concentration coupled with a preference for liquidity have led institutional investors to diversify their portfolios and become more focused on short-term financial performance. These institutional investors rarely take part in the selection of boards of directors and have neither direct influence on, nor useful informational exchanges with, managers. Thus, he claims, U.S. publicly held companies have shortened investment horizons and consequently have lower levels of investments in intangible assets and technological capabilities compared to their German and Japanese counterparts that take the long view[18].

[18] See also Lazonick and O'Sullivan (1996) and Roe (1998a, p. 340).

Jacobs (1991) and Jensen (1998) have also pointed out the chronic underinvestment in profitable long-term intangible assets of U.S. companies in comparison to their Japanese and German counterparts, based on differences in investment time horizons, risk and regulation, banking regulations, and regulatory impediments to shareholder influence.

Poterba and Summers (1995), working on a survey of CEOs at Fortune 1,000 firms, found that many U.S. firms use hurdle rates that are higher than standard cost-of-capital analysis would suggest. Such hurdle rates make it more difficult to approve long term risky projects. They also report that U.S. CEOs themselves believed their firms had systematically shorter time horizons than their major competitors in Europe and (especially) Asia. This is also consistent with the findings of Lucier, Schuyt & Spiegel (2003), which suggest that CEO performance-related turnover rates are generally higher in the U.S. than in either Europe or Asia. These results may also explain the impact of investment time horizons on investment decisions and investment myopia.

Exploring the Effects of Ownership Structure

Implications for theory

We next explore the impact of outsider ownership and insider ownership, given by s_t and $[1-s_t]$, respectively, on investment myopia. The financial economics literature widely supports the idea that ownership structure is one of the main corporate governance mechanisms influencing the scope of a firm's agency costs, especially those derived from the conflicts of interests characterizing the relationships among agents in imperfect capital markets (Jensen and Meckling, 1976). The share of insider (i.e., managerial) and outsider ownership is expected to systematically impact a CEO's ability to make discretionary investment decisions.

Exhibit 3 explores the impact of ownership structure on CEO myopia (Table 1, Column 3). It demonstrates that as the firm's percentage of outsider ownership (s_t) increases and, consequently, as the percentage of insider ownership decreases, the average year at which R&D expenditures are maximized has a tendency to increase, implying that the CEO's myopia begins later. Agency theory provides the rational for this result. Specifically, a high percentage of outside owners reflect greater incentives to monitor managers and thus mitigate agency problems, but a high percentage of insider ownership may also result in managerial entrenchment and investment myopia. Furthermore, when ownership and control are separated, and given the information asymmetry between managers and shareholders with respect to R&D investments, CEOs have great discretion in the decision making process, and rather than engage in long term shareholder wealth generating investments, use cash flow to maximize their personal wealth. Formally,

> Proposition 3a. As the percentage of outsider ownership increases, the critical year t^* increases, implying that myopia sets in later in the CEO's tenure.
>
> Proposition 3b. As the percentage of insider ownership increases, the critical year t^* decreases, implying that myopia sets in earlier in the CEO's tenure.

…….
Insert Exhibit 3 about here
…….

Consistency with theoretical and empirical evidence

Graves and Waddock (1990) argue that shareholders who behave more like traders (engage in frequent transactions held for very short periods of time) than owners and place excessive focus on short-run cash flows can cause managers to become myopic. Managers that fear large-scale institutional selling and stock price under-evaluation as a result of earnings

disappointments will attempt to actively manage earnings by behaving myopically (Jacobs, 1991). This situation is worsened when ownership is fragmented, so managers have de facto control over the deployment of the firm's assets. On the other hand, others suggest that high levels of outsider ownership have an advantage if the concentration of sophisticated investors is high enough to mitigate agency problems by the direct monitoring of management via an active board of directors (Monks and Minow 1995, Dobrzynski 1993).

Financial literature points out that both insider ownership (as a consequence of the convergence of interest and entrenchment effects) and outsider ownership concentration (as a result of the monitoring and expropriation effects) have a non-linear influence on the scope of the firm's agency costs, and are thus non-linearly related to firm value (see, for example, Morck, Shleifer and Vishny, 1988; McConnell and Servaes, 1990; Gedajlovic and Shapiro, 1998). Moreover, the non-linearity of ownership structure with respect to firm value is likely to influence the relationship between ownership structure and investments, as shown in Cho (1998). Following Morck, Shleifer and Vishny (1988), Cho (1988) estimates a piecewise linear regression of investment on insider ownership, imposing the breakpoints of 7% and 38% found in the value-ownership relation. His results show that the level of investment rises as insider ownership increases up to 7% and it decreases as insider ownership rises from 7% to 38%, not being affected by insider ownership beyond 38%.

Hadlock (1998) investigates the non-linear effect of insider ownership on investment-cash flow sensitivity. Using the breakpoint of 5%, the estimated coefficient on cash flow interacted with an ownership variable indicative of convergence of interest is positive, while the sign of the coefficient on the interaction of cash flow with a variable reflecting entrenchment is negative. According to Hadlock, these results show that investment-cash flow sensitivities first

increase and, after the point where the entrenchment effect is likely to arise, then decrease as insider ownership rises. In sum, the extant literature seems to support our findings, indicating that when insider ownership is low (and outsider ownership, s_t is high), the monitoring effect of a large block of shareholders creates a convergence of interests effect between managers and owners, mitigating the impact of myopia. However, when insider ownership increases (and outsider ownership, s_t decreases), the managerial entrenchment effect starts to kick in and CEOs become myopic sooner. Our results are also robust to the investment time horizon, K, for 2, 6 and 10 years of project horizon, as presented in Exhibit 3.

Exploring the Effects of Hostile Takeovers

Implications for theory

Exhibit 4 shows that, for a given set of parameter values (Table 1, Column 4) as the firm's governance index (g) decreases (i.e., the firm is more exposed to the threat of hostile takeovers) the average year at which R&D expenditures are maximized has a tendency to increase and the CEO's myopia begins later. The rational behind this result is consistent with the free cash flow theory posited by Jensen (1998), who suggests that the threat of takeover is driven by the undervaluation of a firm's stock and therefore forces management to focus on maximizing the value of the firm. Therefore, when a firm is more exposed to takeover CEOs will behave less myopically and invest cash flows into projects with maximum positive NPV yields, including high risk R&D projects. Formally,

> Proposition 4. As the firm becomes more exposed to the threat of hostile takeover, the critical year t^* increases, implying that myopia sets in later in the CEO's tenure.

…….
Insert Exhibit 4 about here
…….

Consistency with theoretical and empirical evidence

The wave of corporate takeovers during the 80s and 90s has intensified the debate over their economic effects. Some argue that takeovers allow the acquiring firms to generate economies of scale and scope, apply superior knowledge/skills to create a value improving synergy, and discipline managers to align their goals with those of shareholders (Grossman and Hart 1980, Easterbrook and Fischel 1981, Scharfstein 1985, Jensen 1986). However, others argue that the fear of takeover induces managers to make decisions that overvalue current profits and undervalue future ones, since a temporary drop in earnings may undervalue the share price and provoke a hostile takeover (Kuttner 1986, Auletta 1986, Scherer 1988). They argue that this is likely to occur when managers have limited stock holdings and their compensation system encourages them to increase accounting earnings rather than firm value.

Empirical evidence in the hostile takeover literature on their effect on investment decisions is mixed. For instance, a study by the office of the chief economist of the Securities and Exchange Commission (1985) found that firms with low R&D expenditures are not taken over less frequently than those with higher R&D spending, suggesting that investors can tell the difference between efficient and inefficient long term investment decisions. In another study, Bronwyn and Hall (1990) analyzed 600 acquisitions by U.S. firms and concluded that the acquired firms did not have higher R&D expenditures (in relation to sales) than non-acquired firms. However, Pugh, Page and Jahera (1992) provide evidence that R&D and fixed capital expenditures systematically increase after the passage of anti-takeover charter amendments. This mixed evidence is reflected in the contradictory theoretical explanations for the phenomenon.

Short-termism theory (Narayanan 1985, Stein 1988) suggests that the likelihood of firms facing takeover threats and of managers being fired subsequent to a takeover may encourage

managers to sacrifice long-term for short-term investments. Concentrating on short-term investments enables managers to boost current returns and hence send, what they believe to be, positive signals to the market. The theory suggests that while R&D may lead to higher profits in the long run, because they are more difficult to evaluate, firms investing heavily in such projects may be more susceptible to takeover attempts because of poorer current earnings. Managers will therefore prefer to sacrifice long-term investments as a response to the threat of takeover, which is inconsistent with Proposition 4. However, an assumption for short-termism to work is that investors cannot tell the difference between positive NPV and negative NPV long-term projects, such that all long term projects are viewed with the same degree of uncertainty.

Managerial entrenchment theory asserts that takeover threats induce managers to over-invest in activities that are highly specific and complementary to their skills. They do this to create a holdup situation in which shareholders will incur a high opportunity cost of firing managers because the firms' assets are more valuable under incumbent management (Shleifer and Vishny 1989). Thus, managers who foresee the threat of takeover may increase their investments in R&D in order to entrench themselves. Hence, this theory predicts that takeover threats will induce an overinvestment problem, another form of earnings manipulation, which is also consistent with Proposition 4.

Exploring the effects of Firm's Financial Health

Implications for theory

As discussed earlier, a common strategy encountered in earnings management is the transfer of profits from one period to the next. This form of smoothing reduces the negative effects of uncertainty, i.e., stock price declines, resulting from earnings volatility. Such tactics are likely when a CEO anticipates financial difficulties as shown in a pattern of earning

declines[19]. In particular, if CEOs feel threatened by termination because of continuing poor performance, they would have an incentive to make accounting or investment decisions that mask the firm's deteriorating financial health in order to delay termination (Murphy and Zimmerman 1993).

…….
(Insert Exhibit 5 about here)
…….

Exhibit 5 shows that for a given set of parameter values (Table 1, Column 5), as the percentage of firm profit transferred from one time period to the next (a) increases, the average year at which R&D expenditures are maximized decreases, suggesting that myopia sets in earlier. The rational behind this result is that for cash to be made available for smoothing, discretionary expenditures such as R&D must be cut. As a firm's financial health is anticipated to worsen in future periods, cuts in R&D in current periods must begin earlier in order to conserve cash. Therefore, the greater the anticipated percentage of profit is to be shifted from one period to the next, the earlier that myopic behavior has to begin. Formally,

> Proposition 5. As the firm's financial health worsens and the percentage of profit that has to be shifted increases, the critical year *t** decreases, implying that myopia sets in earlier in the CEO's tenure.

Consistency with theoretical and empirical evidence

Since CEO turnover is generally preceded by bad firm performance (Weisbach 1988, Murphy and Zimmerman 1993), CEOs are likely to cover-up bad accounting earnings in order to meet short-term earnings targets (Bushee 1998). For instance, they may inflate accounting earnings to avoid contracting costs (DeFond and Jiambalvo 1994), or attempt to boost earnings

[19] Other forms of smoothing are common when current earnings are expected to be especially high. Such tactics can reduce high taxes, high salary expenses and increased dividend payments.

by shifting profit from one period to the next to avoid earnings declines for stock market reasons (Dechow and Skinner 2000). Therefore, CEOs' incentives to cut R&D expenditures to boost current earnings and cash compensation are likely to be stronger when future earnings are anticipated to decline.

There is much evidence that when R&D costs are expensed, firms manage their earnings by adjusting operational transactions, such as cutting R&D expenditures to meet earnings thresholds, to avoid losses or negative shifts in earnings. For example, Baber, Fairfield, and Haggard (1991) report that managers are more likely to consider current period income effects when making R&D decisions than when making capital spending decisions whose costs are amortized over a number of years. They find that R&D spending is relatively lower for firms that can manage to hit their earning goal by reducing their R&D expenditures, and conclude that regulation of accounting practices has direct and non-trivial economic consequences, suggesting that the U.S. immediate expensing rule results in manipulation of R&D spending in order to achieve specific net income goals.

Perry and Grinaker (1994) also examine the relation between R&D expenditures and earnings, and they find an approximately linear relation between unexpected R&D spending and unexpected earnings, suggesting that R&D expenditures may be cut when earnings fall short of expectations. In a study that examines a number of tools of real earnings management, Roychowdhury (2003) finds that firms that report small profits have unusually low discretionary expenses (advertising, R&D and selling, general and administrative), suggesting that they manage earnings via R&D expenditures.

Darrough and Rangan (2004) document the negative association between R&D expenditure and the level of inside trades (managerial selling) in an initial public offering. In

summary, there is considerable evidence that many firms engage in "real" earnings management by cutting R&D expenditures to meet earnings targets. These findings seem to be consistent with Proposition 5.

CONCLUSIONS

Starting from standard agency theory formulations, we attempted to explore the implications of an accounting earnings based CEO compensation system for R&D expenditures with cash flow streams that may exceed the tenure of a CEO. Given that under GAAP R&D investments have to be fully expensed, we argue that CEOs have an incentive to resist long run investment projects in order to inflate earnings that materially drive their bonuses.

We used the earnings management literature to build a theoretical model to explore the question of whether CEOs manage their firm's earnings by systematically under-investing in R&D. In this model, we considered a rational CEO with a defined tenure. We explored five circumstances in which the incentive for underinvestment in R&D projects for the purposes of meeting current earnings goals is strengthened. Our model assumes that CEO's primary goal is to maximize total lifetime compensation and that the way to do so may change depending on the stage of their careers, the nature of the R&D investments they have to make, the financial health of their firm, and the degree of monitoring by shareholders or discipline by the takeover market. We then created a dynamic optimization simulation model in which the CEO maximizes a stream of current and expected earnings related bonuses over her tenure, and does so primarily by deciding how much to spend on R&D every period. R&D has the effect of increasing future earnings but decreasing current earnings.

While our results are generally in line with other findings in earnings management and investment myopia literature, what is surprising is the concave relationship between the R&D

spending and a CEO's tenure. Specifically, we find that the relationship between R&D spending and tenure is non-linear such that at some point during their tenure, managers gradually start to decrease the amount of money spent on R&D investments. This result suggests the existence of investment myopia although it does not occur uniformly across a CEO's tenure. This non-linear relationship has, to our knowledge, not been anticipated in the literature. The dynamic simulation approach we used, based on received theory, was able to tease out this relationship, which we believe is a contribution to the theoretical literature. We also find that investment myopia starts sooner as CEOs are more tenured, the proportion of insider ownership is increasing, the firm is more protected from hostile takeovers, and the firm's financial health is declining.

As with all theoretical models, we had to make simplifying assumptions to make the analysis tractable. First, our model was set up to explore accounting based compensation schemes. We did this to isolate a specific phenomenon, earnings management, pointed out by observers that may be the cause of a systematic under-investment in R&D.

More specific to the simulation model, we used historical values for b, R^f and R^m, which is the default approach used by other researchers to arrive at the rate of return in the CAPM model. This approach relies on a few assumptions that may represent some limitations. This approach assumes that the risk preference of investors does not systematically change over time. We do not believe this assumption to be too limiting because whereas risk preferences may change from year to year, empirical data suggests that over a long period of time it generally tends toward historical means. Second, the historical approach assumes that the risk level of risky investment portfolio (stock index) has not changed in a systematic way across time, which may be unrealistic. Using these values is thus based on the commonly held assumption that the actual premiums delivered over long time periods are equal to the expected future premiums.

This may not work very well in the case of long term, high risk R&D investments for which expected future premiums are difficult to forecast.

Obviously, our theoretical model begs empirical investigation. However, the difficulty with such an empirical study may be trying to detect myopia. Conceptually, myopia occurs when the difference between actual R&D expenditures and an 'optimal' level of R&D that maximizes the net present value of a firm is negative. However, calculating this 'optimal' level will be difficult. One approach is to take a historical perspective to calculate the marginal productivity of R&D given a representative portfolio of stocks in an industry. Jensen (1993) gives us an example of how something like this can be done. The marginal productivity of R&D so calculated should give us the 'optimal' R&D level, given the industry's actual rate of return in the next period.

Finally, our model has corresponding managerial implications. First, our main conclusion is that when a CEO is annually compensated with accounting based pay she may maximize total lifetime compensation by under-investing in R&D projects, which are essential to long-term productivity, earnings and shareholder value. This is primarily due to a mismatch between the CEO's tenure and the time horizon of the projects' cash flow streams and the fact that R&D is expensed rather than capitalized under GAAP. This time horizon disparity becomes more problematic when managerial actions taken by the CEO are unobservable to the firm's shareholders, as often happens in the case of R&D investments. The implication is that a CEO should be indemnified against the loss of current earnings resulting from positive NPV investments in long term R&D projects. One way to do this is to more loosely couple annual compensation from earnings or to index compensation to long term investments in R&D with a balloon payment at the final period. Indeed, most CEO compensation packages are multi-

dimensional, including earnings based bonuses, stock based options and bonuses, and golden parachutes and handcuffs. Therefore, to the extent that the other components of a compensation package are significant, the problem with under-investment may be mitigated.

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Exhibit 1. R&D expenditure pattern with respect to tenure

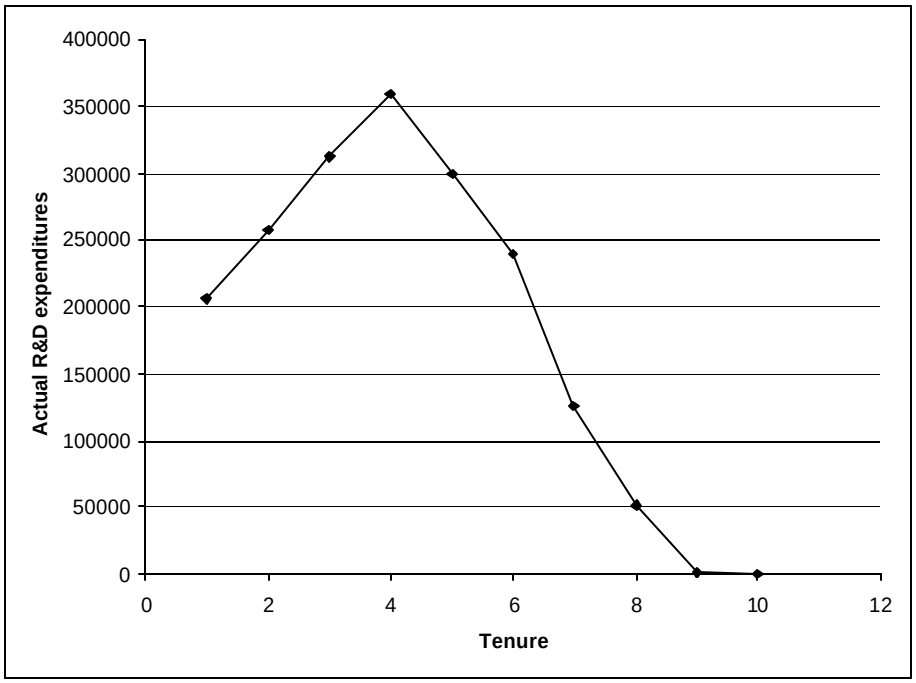

Exhibit 2. Myopia sensitivity with respect investment horizon

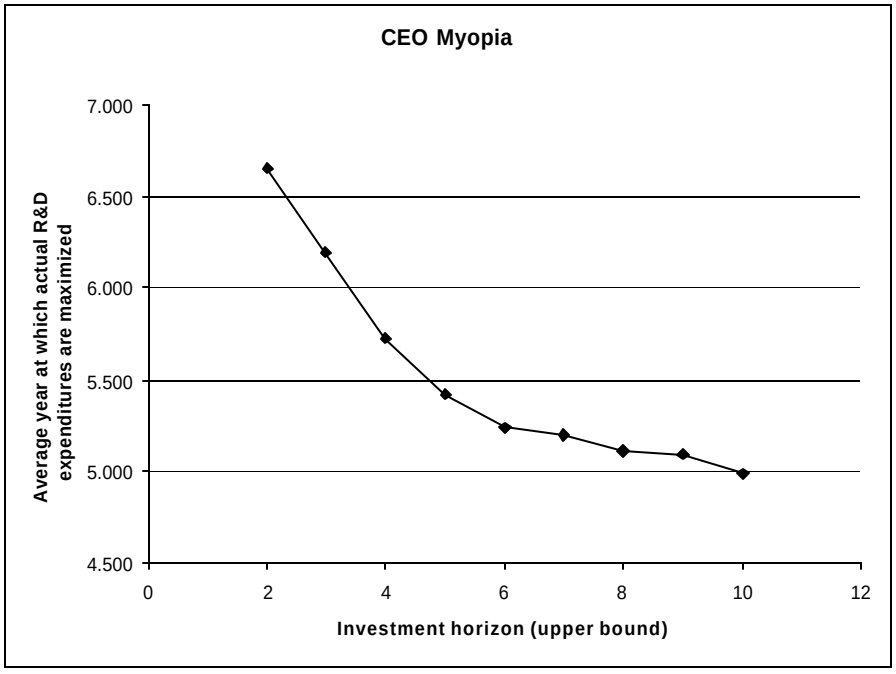

Exhibit 3. Myopia sensitivity with respect to ownership structure

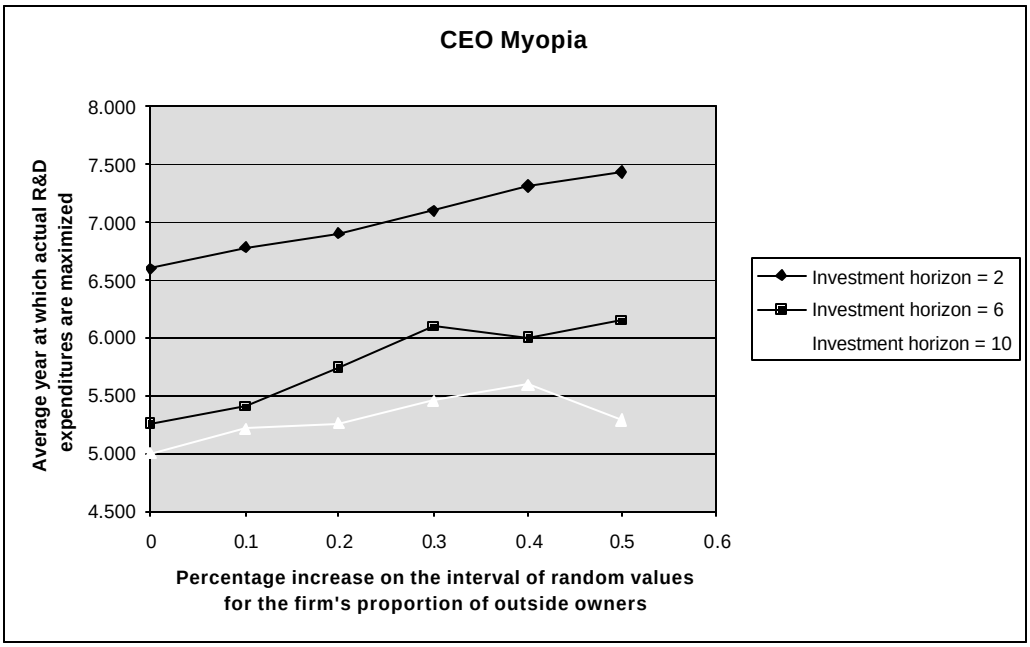

Exhibit 4. Myopia sensitivity with respect to takeover threat

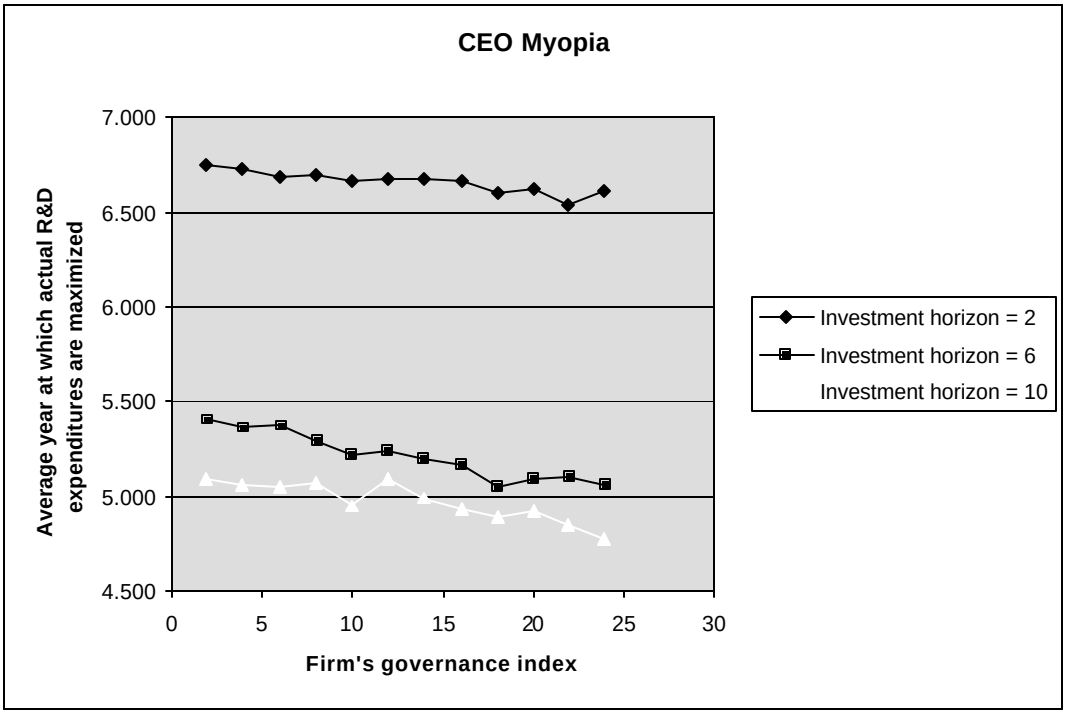

Exhibit 5. Myopia sensitivity with respect to the percentage of earnings smoothing

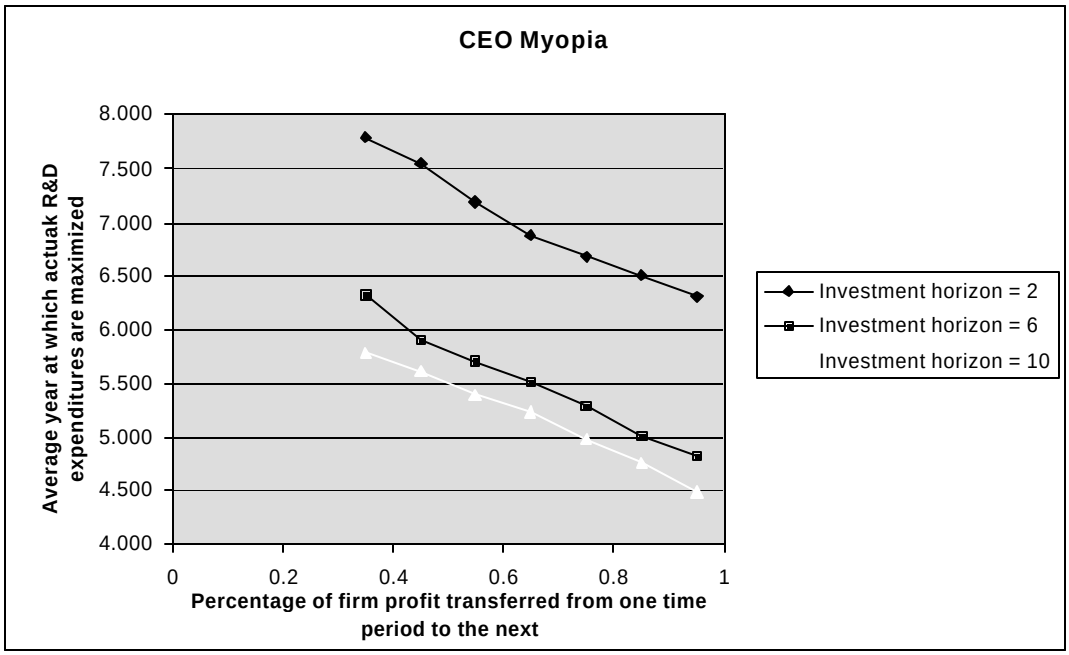

Table 1. Model parameters and their numerical values

Notation	Description	1	2	3	4	5
T	CEO's tenure in the firm	10	10	10	10	10
l	Discount factor	.95	.95	.95	.95	.95
K	Upper bound on R&D investment horizon	{6}	Varies	{2,6,10}	{2,6,10}	{2,6,10}
u	Lower bound on a firm's percentage of shareholder ownership	.1	.1	Varies	.1	.1
v	Upper bound on a firm's percentage of shareholder ownership	.5	.5	Varies	.5	.5
c	Marginal bonus per dollar of profit	.05	.05	.05	.05	.05
a	Percentage of firm profit transferred from one time period to the next	.75	.75	.75	.75	Varies
g	Marginal firm profit from total compounded return on R&D expenditures made k periods earlier	1	1	1	1	1
R^f	Rate of risk free investment (i.e. cash)	.054	.054	.054	.054	.054
R^m	Rate of return of an appropriate asset class	.147	.147	.147	.147	.147
b	Time-invariant measure of the volatility of a stock relative to the overall market	.8	.8	.8	.8	.8
d	Marginal propensity to invest in R&D from the tenure time	.5	.5	.5	.5	.5
e	Marginal propensity to invest in R&D from the percentage of outside shareholders	.01	.01	.01	.01	.01
w	Marginal propensity to invest in R&D from the governance index	.01	.01	.01	.01	.01
h	Marginal propensity to invest in R&D from the percentage of insider ownership	1	1	1	1	1
r	Marginal propensity to invest in R&D from the expected rate of return on current R&D investments	.01	.01	.01	.01	.01
t	Marginal propensity to invest in R&D from a R&D investment's time horizon	.04	.04	.04	.04	.04
g	Firm's governance index	10	10	10	Varies	10
p_0	Initial firm profit – initial capital for a startup firm	50,000	50,000	50,000	50,000	50,000
a	Initial (t=1) feasible R&D expenditure	250,000	250,000	250,000	250,000	250,000
b	Rate at which a feasible R&D expenditure increases over time	100,000	100,000	100,000	100,000	100,000