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ABSTRACT

We present a multiperiod agency model of stock based executive compensation in a speculative stock market, where investors are overconfident and stock prices may deviate from underlying fundamentals and include a speculative option component. This component arises from the option to sell the stock in the future to potentially overoptimistic investors. We show that optimal compensation contracts may emphasize short-term stock performance, at the expense of long run fundamental value, as an incentive to induce managers to pursue actions which increase the speculative component in the stock price. Our model provides a different perspective for the recent corporate crisis than the increasingly popular `rent extraction view' of executive compensation.

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1 Introduction

The classical view of executive compensation is that it is an optimal form of compensation designed to solve an agency problem between the firm's managers and their shareholders. As the seminal work of Mirrlees (1975) and Holmstrom (1979) establishes, compensation contracts based on the firm's performance motivate firm managers to work in the interest of shareholders. More recently, Holmstrom and Tirole (1993) have extended the classic moral hazard framework to settings where the firm's stock is traded in a secondary market and where the manager's compensation can be tied to the stock price. A key assumption in their analysis is that stock markets are efficient in the sense that stock prices are an unbiased estimate of the firm's fundamental value. As a result, stock prices provide useful information to shareholders about managerial effort choice, and therefore affect managerial compensation.

In this paper we depart from Holmstrom and Tirole (1993) by introducing a 'speculative stock market' where stock prices reflect not only the fundamental value of the firm but also a short-term speculative component and we analyze the implications for executive compensation. There is growing evidence that stock prices can deviate from fundamental values for prolonged periods of time.[1] While many economists believe in the long run efficiency of stock markets they also recognize that US stock markets have displayed an important speculative component during the period between 1998 to 2000.[2] In addition, several recent studies have shown that it is difficult to reconcile the stock price levels and volatility of many internet and high-tech firms during this period with standard discounted cash-flow valuations.[3] In some highly publicized cases the market value of a parent company was even less than the value of its holdings in an "internet" subsidiary. The trading volume for these stocks was also much higher than that for more traditional companies, a likely indicator of differences of opinion among investors regarding the fundamental values of these stocks.[4]

Many questions arise concerning the use of stocks in CEO compensation contracts when stock prices may not always reflect the fundamental value of the firm. For example, what

[1] See Shleifer (2000) and Shiller (2000) for supporting arguments and Fama (1998) for a contrarian view.
[2] *e.g.* Malkiel (2003)
[3] See Lamont and Thaler (2003), Ofek and Richardson (2003), and Cochrane (2002).
[4] An extreme example is the trading volume in Palm stock, which turned over once every day according to Lamont and Thaler (2003, Table 8).

kind of incentive would stock compensation provide to firm managers in such an environment? Would investors be willing to use stocks for compensating managers if they knew that stock prices could deviate substantially from fundamental value? More generally, what is "shareholder value" in such a speculative market? Our goal in this paper is to set up a tractable theoretical model to address these questions and to provide an analysis of optimal CEO compensation in speculative markets.

We consider an optimal contracting problem in a two-period principal-agent model similar to Holmstrom and Tirole (1993). We let a risk-averse CEO choose some costly hidden actions, which affect both the long-run fundamental value of the firm (in period 2) and its short-run stock valuation (in period 1). For optimal risk diversification reasons, when the stock price is an unbiased estimate of the fundamental value of the firm, the optimal (linear) CEO compensation scheme has both a short-run and a long-run stock participation component.

Our fundamental departure from Holmstrom and Tirole (1993) is the introduction of a 'speculative stock market'. Specifically, we build on the model of equilibrium stock-price dynamics in the presence of 'overconfident' investors by Scheinkman and Xiong (2002).[5] In this model, overconfidence provides a source of heterogeneous beliefs among investors, which lead them to speculate against each other. The holder of a share then has not only a claim to future dividends but also an option to sell the stock to a more optimistic investor in the future. Stock prices in this model have two components: a long-run fundamental and a short-term speculative component. Investors are willing to pay more than what they believe to be the stock's long-run fundamental value because they think they may be able to sell their shares in the short-term to other investors with more optimistic beliefs.[6]

Another departure from Holmstrom and Tirole (1993) is that the manager faces a multi-task problem similar to Holmstrom and Milgrom (1992). That is, the CEO can divide his time between increasing the long-term value of the firm and encouraging speculation in the

[5] Overconfidence is a frequently observed behavioral bias in psychological studies. See Barber and Odean (2001), and Daniel, Hirshleifer and Teoh (2002) for reviews of the related psychological studies and the applications of overconfidence in economics and finance.

[6] In a thought-provoking account of the internet bubble, Michael Lewis (2002) has given a vivid description of the thought process of many investors, when he explained the reasoning behind his purchase of the internet company stock Exodus Communications at the end of 1999: "I figured that even if Exodus Communications didn't wind up being a big success, enough people would believe in the thing to drive the stock price even higher and allow me to get out with a quick profit." [Michael Lewis, 2002].

stock in the short-term by pursuing projects over which investors are likely to have diverging beliefs. In times of great investor overconfidence, the optimal incentive contract is designed to partially or completely induce the CEO to pursue the strategy that tends to exacerbate investors' differences of opinion and to bring about a higher speculative option value. Importantly, both initial shareholders and the CEO can gain from this strategy since it may increase the stock price in the short run.[7]

Our model provides a new perspective on the question of the efficiency of stock compensation following the recent collapse of several major publicly traded companies such as Enron and Worldcom.[8] An increasingly influential view holds that the frequently observed CEO compensation contracts that allow for the short term 'exit' of CEOs are a form of managerial abuse brought about by a lack of adequate board supervision (see Bebchuk, Fried and Walker 2002).[9] The theory outlined in this paper provides another reason why short term 'exit' of CEOs was facilitated. This may have been an optimal form of compensation designed to induce CEOs to focus on speculative ventures during an unusually speculative phase of stock markets.[10] Indeed, we show that when markets are highly speculative the optimal managerial compensation is tilted towards short-term performance at the cost of neglecting long run value. An implication of our analysis is that failure to maximize long-run firm value is not necessarily a symptom of weak corporate governance. Similarly, policies aimed at strengthening board supervision alone would not necessarily result in different or more long-term oriented CEO compensation.

Rent-seeking behavior by managers is always present, but the existing rent seeking theories fail to explain why rent-seeking behavior would have been particularly successful during the bubble period. In contrast, our model suggests that short-termist behavior is likely to be en-

[7]In some cases these initial shareholders are venture capitalists, who typically structure the manager's contracts in new firms.

[8]The Financial Times has conducted a survey of the 25 largest financially distressed firms since January 2001 and found that, although hundreds of billions of investor wealth together with 100,000 jobs disappeared, top executives and directors in these firms walked away with a total of $3.3 billion by selling their stock holdings early. On the other hand, investors had lost hundreds of billions of dollars (see Financial Times, July 31, 2002).

[9]Murphy (2002) proposes instead that compensation committees have under-estimated the cost of issuing stocks and options to managers.

[10]"In the bubble, the carrots (stock options) became managerial heroin, encouraging a focus on short-term prices with destructive long-term consequences. ... It also encourages behavior that actually reduced the value of some firms to their shareholders - such as making an acquisition or spending a fortune on an internet venture to satisfy the whims of an irrational market."Michael Jensen, an early proponent of increasing performance based compensation for CEOs, as quoted in the Economist, November 16, 2002.

couraged in firms in new industries, where it is usually more difficult to evaluate fundamentals and therefore easier for disagreement among potential investors to arise.

Short-termist behavior by managers has been highlighted before (most notably, Stein 1988, 1989, Shleifer and Vishny 1990, and Von Thadden 1995). In contrast to our theory, managerial short-termism in these models is not induced by some optimal incentive scheme but arises against the wishes of shareholders. More closely related to our paper is Froot, Perold and Stein (1992) who provide a discussion of the potential link between the short-term horizon of shareholder and short-term managerial behavior. However, their paper does not provide a formal model or analysis of optimal incentive compensation. Another related literature deals with the incentive effects of early 'exit' by managers or large shareholders (for example Maug 1998, Kahn and Winton 1998, Bolton and von Thadden 1998, and Aghion, Bolton and Tirole 2000). However, this literature assumes that stock markets are efficient. More recently, Bebchuk and Bar-Gill (2003) have analyzed the cost of permitting better informed managers to sell shares early, but they do not study the optimal compensation scheme that would be chosen by shareholders in their framework.

The paper proceeds as follows. Section 2 describes the model. Section 3 derives the optimal CEO compensation contract under the classical assumption that stock markets are efficient. In Section 4, we introduce overconfident investors and characterize the optimal contract in the presence of a speculative market. Section 5 discusses comparative statics. In Section 6, we provide some discussion and empirical implications.

2 The model

We consider a publicly traded firm run by a risk-averse CEO. There are three dates: $t = 0, 1, 2$. The firm is liquidated at $t = 2$. At $t = 0$, the manager can choose to work on two projects: a project that has a better long term perspective or another project that has an inferior long-run perspective but might become overvalued in a speculative market. For simplicity, we assume that there the interest rate is equal to zero. We also assume that shareholders and potential investors are risk-neutral and the CEO is risk-averse. [11]

[11] The usual way to justify this assumption is that shareholders can diversify firm specific risk, while the CEO cannot.

The firm's long-term value at $t = 2$ has three additive components:

$$e = u + v + \epsilon.$$

- u represents the terminal value of a project. It is normally distributed with mean $h\mu$ - where $\mu \geq 0$ denotes a CEO's hidden "effort" and $h > 0$ is a parameter affecting the expected return on this effort - and variance σ^2 (or precision $\tau = 1/\sigma^2$). The variance is outside the manager's control.

- v is also normally distributed and has mean 0 and standard deviation σ_v (or precision $\tau_v = 1/\sigma_v^2$). The standard deviation of v is affected by the CEO's choice of action $\omega \geq 0$ at $t = 1$:

$$\sigma_v = l\omega,$$

  where $l > 0$ is a parameter measuring how easily the standard deviation of v can be increased.

- The third component ϵ is just noise. It is a normally distributed random variable with mean 0 and variance σ_ϵ^2 (or precision $\tau_\epsilon = 1/\sigma_\epsilon^2$).

The CEO's total cost of effort takes the following simple quadratic form:

$$\psi(\mu, \omega) = \frac{1}{2}(\mu + \omega)^2.$$

Intuitively, one can think of μ and ω as time spent on the two separate tasks. This would imply that the two activities are substitutes. Also, the strict convexity of the cost function implies that there are diminishing returns to spending more time on each task. The central problem for shareholders at $t = 0$ will be to design a CEO compensation package to motivate the CEO to allocate her time optimally between 'work' and 'leisure' and between the two tasks without exposing her to too much risk.

The CEO can affect the mean performance of the project with outcome u. In contrast she cannot change the average performance of the second project. We think of this component as a "castle-in-the-air" venture that adds noise to the overall performance. We will show that in an efficient stock market, optimal compensation design would lead the CEO to spend no effort on project v. However we will also show that this will not be the case in the presence of a speculative stock market.[12]

At $t = 1$, three signals are publicly observed by all participants. Signal s provides information about u, and the other two signals, θ_1 and θ_2, information about v:

$$\begin{aligned} s &= u + \epsilon_s, \\ \theta_1 &= v + \epsilon_1, \\ \theta_2 &= v + \epsilon_2, \end{aligned}$$

where ϵ_s, ϵ_1 and ϵ_2 are again normally distributed with mean 0 and variances σ_s^2, σ_θ^2 and σ_θ^2. These three signals allow participants to revise their beliefs about the long-term value of the firm.

After observing the signals investors can trade the firm's stocks, in a competitive market, at $t = 1$. The determination of investors' beliefs and the resulting equilibrium price p_1 are a central part of our analysis. We normalize the initial number of shares held by investors to one. It is also helpful to make the following simplifying assumption:

Assumption 1: $\sigma_\theta^2/\sigma_v^2 = \frac{\tau_v}{\tau_\theta} = \eta.$

This assumption implies that the informativeness of the signals θ_1 and θ_2 are constant and independent of the variance of v which is determined by the manager's action ω. In practice, more information might become available about the castle-in-the-air project when it becomes more risky. If that was the case, the manager would be somewhat deterred from choosing a very high ω.

If we denote the financial compensation to the CEO by the random variable W, the CEO's objective can be described as follows:

$$\max_{\mu,\omega} \ \mathrm{E}(W) - \frac{\gamma}{2} Var(W) - \frac{1}{2}(\mu + \omega)^2,$$

where $\gamma > 0$ is the CEO's coefficient of risk aversion.

As is standard in the theoretical literature on executive compensation, we will only consider linear compensation contracts of the form:

$$W = ap_1 + be + c, \tag{1}$$

[12] Examples of this type of project are the internet ventures cited in the quote in footnote 10.

where a represents the weighting of the CEO's compensation on short-run stock price performance, b the weighting on long-run performance, and c the non-performance based cash component. We can think of a as being the amount of shares that are issued by the firm and given to the CEO and that she is allowed to sell in period 1. Similarly b is the number of shares that the firm gives to the CEO and that she must hold until period 2. In any case the CEO is not allowed to do any additional trading on the stock. The initial shareholders' or board of director's problem is to choose the contract $\{a, b, c\}$ to maximize the firm's stock price at $t = 0$ subject to the manager's participation and incentive constraints. That is, initial shareholders' problem is given by:

$$\max_{a,b,c} \quad p_0$$
$$\text{subject to } \max_{\mu,\omega} \quad \mathrm{E}(W) - \frac{\gamma}{2} Var(W) - \frac{1}{2}(\mu + \omega)^2 \geq \bar{W},$$

where $\bar{W}$ is the reservation utility of the manager.

Sometimes this formulation of the optimal contracting problem is misinterpreted as meaning that shareholders have all the bargaining power (a patently counterfactual assumption) and can force the CEO to her reservation utility level. But the solution to the dual problem

$$\max_{a,b,c} \quad \{\mathrm{E}(W) - \frac{\gamma}{2} Var(W) - \frac{1}{2}(\mu + \omega)^2\}$$
$$\text{subject to } \quad p_0 \geq \overline{p}_0,$$

would be the same up to a constant. The bargaining power of the manager determines the level of her total compensation (c), but not the structure of the compensation package (a and b).

The timing of events is as follows: At $t = 0$, initial shareholders determine the managerial contract $\{a, b, c\}$. Then the manager chooses her actions μ and ω. At $t = 1$, market participants trade stocks based on the realized signals s, θ_1, and θ_2. At $t = 2$, the firm is liquidated and the final value e is divided among shareholders after deducting the CEO's pay.

3 Optimal executive compensation in an efficient market

To set a benchmark, we begin by solving for the optimal CEO compensation contract under the assumption that there are no overconfident investors. This section mostly builds on and adapts the analysis of Holmstrom and Tirole (1993). In an efficient market, the stock price p_1 would incorporate all the information in the short-term signals s, θ_1 and θ_2. Since the short-term stock price p_1 is not a sufficient statistic for the manager's effort choice μ and ω and the CEO is risk-averse, one should expect the CEO's compensation package to have both a short-run and long-run component.

If all the market participants are fully rational, equilibrium stock prices at $t = 0$ and $t = 1$ are given by:

$$p_0 = \mathrm{E}(p_1) \quad \text{and} \quad p_1 = \mathrm{E}(e - W|s, \theta, \theta_2),$$

where W is the compensation to the manager.

In a rational expectations equilibrium shareholders correctly expect the manager to choose the optimal actions μ^* and ω^* under the CEO compensation contract, and form the following conditional expectation:

$$\begin{aligned}
\mathrm{E}(e|s,\theta) &= \mathrm{E}(u|s) + \mathrm{E}(v|\theta_1, \theta_2) \\
&= h\mu^* + \frac{\tau_s}{\tau + \tau_s}(s - h\mu^*) + \frac{\tau_\theta}{\tau_v + 2\tau_\theta}\theta_1 + \frac{\tau_\theta}{\tau_v + 2\tau_\theta}\theta_2 \qquad (2) \\
&= h\mu^* + \frac{\tau_s}{\tau + \tau_s}(u - h\mu^* + \epsilon_s) + \frac{1}{\eta + 2}\theta_1 + \frac{1}{\eta + 2}\theta_2. \qquad (3)
\end{aligned}$$

Equation (2) is the standard expression for the conditional expectation given that u, s, v, θ_1 and θ_2 are normally distributed random variables with respective precisions $\tau, \tau_s, \tau_v, \tau_\theta$ and τ_θ (see, e.g. DeGroot 1970). Equation (3) follows immediately upon substitution of $\sigma_\theta^2/\sigma_v^2 = \tau_v/\tau_\theta = \eta$.

Given this expectation we obtain an expression for the stock price at $t = 1$:

$$p_1 = \mathrm{E}(e - W|s, \theta_1, \theta_2) = \mathrm{E}[e - (ap_1 + be + c)|s, \theta_1, \theta_2].$$

Or, solving out for p_1,

$$p_1 = \frac{1 - b}{1 + a}\mathrm{E}(e|s, \theta_1, \theta_2) - \frac{c}{1 + a}, \qquad (4)$$

where the factors $\left(\frac{1-b}{1+a}\right)$ and $\left(\frac{c}{1+a}\right)$ represent the residual stock value net of the manager's stake.

Substituting the equilibrium price p_1, given by equation (4), into the equation (1) that defines the manager's payoff, we obtain:

$$W = \alpha\mathrm{E}(e|s, \theta_1, \theta_2) + \beta e + \delta,$$

with α, β and δ given by:

$$\alpha = \frac{a}{1+a}(1-b), \quad \beta = b, \quad \delta = \frac{c}{1+a}.$$

α is the percentage ownership in the firm that the manager is allowed to sell in the first period. β is the percentage ownership in the firm that the manager must hold until the end. Finally, δ represents the manager's non-performance based compensation. In practice, CEO compensation packages typically have $0 \leq \beta < 1$ and $0 < \alpha < 1 - \beta$. That is, CEOs are not allowed to short the stock of their company and generally do not hold more than a small fraction of the firm's equity. Although for some parameter values an optimal contract may violate these constraints we impose:

Assumption 2: $\alpha \geq 0$, $\beta \geq 0$ and $\alpha + \beta \leq 1$.

Given a contract $\{\alpha, \beta, \delta\}$, the manager chooses her actions μ and ω by solving

$$\max_{\mu,\omega} \mathrm{E}\left[\alpha \mathrm{E}(e|s,\theta_1,\theta_2) + \beta e\right] - \frac{1}{2}(\mu+\omega)^2 - \frac{\gamma}{2} Var\left[\alpha \mathrm{E}(e|s,\theta_1,\theta_2) + \beta e\right].$$

It is immediately apparent that it is optimal for the manager to set $\omega^*(\alpha,\beta) = 0$ under any contract $\{\alpha, \beta, \delta\}$. This is to be expected. Since spending effort ω on the 'castle-in-the-air' project does not affect the equilibrium stock price in an informationaly efficient market, it never pays to set $\omega > 0$. A higher ω only increases the variance of the manager's payoff and involves a higher effort cost. Thus, in an informationaly efficient stock market, the CEO would not engage in any short-termist behavior.[13]

Setting $\omega = 0$ and substituting for the expression for $\mathrm{E}(e|s,\theta_1,\theta_2)$ in equation (3) the CEO's problem can be reduced to choosing μ to solve:

$$\max_{\mu} \left(\frac{\tau_s}{\tau+\tau_s}\alpha + \beta\right) h(\mu - \mu^*) - \frac{1}{2}\mu^2$$

The first order condition of the CEO's optimization problem directly implies that the manager will choose

$$\mu^*(\alpha,\beta) = h\left[\frac{\tau_s}{\tau+\tau_s}\alpha + \beta\right].$$

[13] This result contrasts with Stein (1989) and Von Thadden (1995) where short-termist behavior can take place in an efficient stock market for 'signal jamming' reasons.

Note that any combination of long-term and short-term stock participation such that $\left(\frac{\tau_s}{\tau+\tau_s}\alpha+\beta\right)$ is constant would give the same incentive to choose μ.

Substituting for $\omega^*(\alpha,\beta)$ and $\mu^*(\alpha,\beta)$ in (3) we obtain that

$$\mathrm{E}(e|s,\theta) = h\left[\frac{\tau_s}{\tau+\tau_s}\alpha+\beta\right]\left(\frac{\tau}{\tau+\tau_s}\right)+\frac{\tau_s}{\tau+\tau_s}(u+\epsilon_s)+\frac{1}{\eta+1}\theta. \tag{5}$$

In addition, the manager's individual rationality constraint is binding under an optimal contract, so that

$$\frac{h^2}{2}\left(\frac{\tau_s}{\tau+\tau_s}\alpha+\beta\right)^2+\frac{\gamma}{2}Var\left[\alpha\mathrm{E}(e|s,\theta)+\beta e\right]+\delta=\bar{W},$$

with:

$$\begin{aligned}
Var\left[\alpha\mathrm{E}(e|s,\theta)+\beta e\right] &= Var\left[\left(\frac{\tau_s}{\tau+\tau_s}\alpha+\beta\right)(v-h\mu^*)+\frac{\tau_s}{\tau+\tau_s}\alpha\epsilon_s+\beta\epsilon\right]\\
&= \left(\frac{\tau_s}{\tau+\tau_s}\alpha+\beta\right)^2/\tau+\frac{\alpha^2\tau_s}{(\tau+\tau_s)^2}+\beta^2/\tau_\epsilon.
\end{aligned}$$

Combining these three equations we can formulate the investors' optimal contracting problem as follows:

$$\begin{aligned}
\max_{\alpha,\beta}\ p_0 &= \max_{\{\alpha,\beta\}}\ \mathrm{E}[e-W]\\
&= \max_{\{\alpha,\beta\}}\Bigg\{h\left[\frac{\tau_s}{\tau+\tau_s}\alpha+\beta\right]-\bar{W}-\frac{h^2}{2}\left(\frac{\tau_s}{\tau+\tau_s}\alpha+\beta\right)^2\\
&\qquad -\frac{\gamma}{2}\left[\frac{1}{\tau}\left(\frac{\tau_s}{\tau+\tau_s}\alpha+\beta\right)^2+\frac{\alpha^2\tau_s}{(\tau+\tau_s)^2}+\frac{\beta^2}{\tau_\epsilon}\right]\Bigg\}.
\end{aligned}$$

Alternatively, since any contract with the same value for $\left(\frac{\tau_s}{\tau+\tau_s}\alpha+\beta\right)$ would give the same incentive, α and β should be determined to reduce the manager's risks

$$\min_{\{\alpha,\beta\}}\ \frac{\gamma}{2}\left[\frac{1}{\tau}\left(\frac{\tau_s}{\tau+\tau_s}\alpha+\beta\right)^2+\frac{\alpha^2\tau_s}{(\tau+\tau_s)^2}+\frac{\beta^2}{\tau_\epsilon}\right],$$

$$\text{subject to}\ \ h\left(\frac{\tau_s}{\tau+\tau_s}\alpha+\beta\right)=\mu.$$

Thus, we can first solve for the optimal α and β for any given level of μ, and then solve for the optimal level of μ.

The optimal contract when the stock market is informationaly efficient is described by the following proposition.

Proposition 1 *When the manager is sufficiently risk averse so that* $\gamma/\tau > h - \frac{\tau_s+\tau\epsilon}{\tau+\tau_s+\tau_\epsilon}h^2$*, then the optimal level of effort is given by*

$$\mu = \frac{h^2}{h^2 + \gamma\left(\frac{1}{\tau} + \frac{1}{\tau_s+\tau_\epsilon}\right)}.$$

The optimal weighting of short and long term stock participation is then

$$\alpha = \frac{(\tau_s+\tau)\mu}{(\tau_s+\tau_\epsilon)h}, \quad \beta = \frac{\tau_\epsilon\mu}{(\tau_s+\tau_\epsilon)h}.$$

When the manager is not very averse to risk so that $\gamma/\tau \leq h - \frac{\tau_s+\tau\epsilon}{\tau+\tau_s+\tau_\epsilon}h^2$*, then the optimal level of effort is given by*

$$\mu = \frac{h^2\tau^2\tau_\epsilon + h\gamma\tau_s(\tau+\tau_s+\tau_\epsilon)}{h^2\tau^2\tau_\epsilon + \gamma(\tau+\tau_s+\tau_\epsilon)(\tau+\tau_s)}$$

The optimal weighting of short and long term stock participation is then

$$\alpha = \frac{\tau+\tau_s}{\tau}(1-\mu/h), \quad \beta = \frac{(\tau+\tau_s)\mu}{\tau h} - \frac{\tau_s}{\tau}.$$

Proof: see the Appendix.

In the second case the constraint $\alpha+\beta \leq 1$ is binding because the manager has a high risk tolerance. Indeed, as one would expect in this case, it is optimal to effectively 'sell the firm' to the manager and let her take on all the risk. This solution involves only a small "insurance" cost but provides maximal effort incentives. Note, however, the difference in the optimal contract relative to the standard result that the firm should be sold entirely to the manager when she is risk neutral. Here, when the manager is close to being risk neutral it may be optimal to have her 'own' the entire firm at time 0. However, for diversification reasons she will want to sell part of her holdings at time $t = 1$. The limit on the portion of the firm that she can sell at time $t = 1$ (α) is necessary to induce buyers to pay p_1. When the manager's risk tolerance is low then it is optimal to set $\alpha+\beta < 1$, and to choose α and β to minimize the "insurance" costs.

4 Optimal CEO compensation in a speculative market

A critical assumption in existing models of executive compensation is that stock markets are informationaly efficient and that stock prices reflect the expected fundamental value of the firm. If stock prices reflect fundamental value and if the CEO's actions affect the firm's long run fundamental value then it seems quite sensible to incentivize the CEO through some form of equity based compensation. But how should CEOs be compensated when stock prices can systematically deviate from fundamental value? This is the question we now address. To be able to analyze this problem, however, we need a model of equilibrium stock prices which systematically depart from fundamentals. We will use a simplified version of Scheinkman and Xiong (2002).

The model of the stock market in the remainder of the paper includes overconfident investors. The addition of overconfidence is the only difference from the model in the previous section. All investors are still assumed to be risk-neutral, but now they are also overconfident in the way in which they process information about firm value at $t = 1$. Due to their overconfidence investors have different beliefs at $t = 1$ about the firm's terminal value, even if they start with the same prior at $t = 0$. As a result equilibrium prices may deviate from fundamentals at $t = 1$ and also at $t = 0$ since initial shareholders will "price in" possible short-term trading profits at the expense of "over-optimistic" investors at $t = 1$. In other words, stock prices at $t = 0$ will reflect both the fundamental value of the firm and an additional speculative component. This speculative component can be increased by inducing the manager to devote more effort to the castle-in-the-air project at the expense of the long-run value of the firm.

4.1 Equilibrium asset prices in a speculative market

To model speculative trading, we assume that there are two groups of investors: A and B. Each group starts with the same prior beliefs but ends up with different posterior beliefs as a result of their overconfidence. Specifically, investors in group A over-estimate the informativeness of signal θ_1, while those in group B over-estimate the informativeness of signal θ_2. That is, A-investors exaggerate the precision of signal θ_1 and take it to be $\phi\tau_\theta$ instead of τ_θ, where $\phi > 1$ is a parameter measuring overconfidence. Symmetrically, B-investors exaggerate the precision of signal θ_2 and take it to be $\phi\tau_\theta$ instead of τ_θ. For simplicity, we have chosen the same overconfidence level for the two groups of investors. However, relaxing this assumption would not affect our main results. Not only are investors overconfident with respect to the informativeness of some of the signals they receive, they are also aware of the overconfidence of other investors.

For simplicity we confine investors' overconfidence to just the signals θ_1 and θ_2. Investors use the correct precision for signal s. Thus, in accordance with Bayes rule investors in groups A and B share the same posterior belief about u at $t = 1$:

$$\hat{u} = \hat{u}^A = \hat{u}^B = h\mu + \frac{\tau_s}{\tau_s + \tau}(s - h\mu).$$

In the remainder of this paper we shall use superscripts A and B to denote the variables associated with the respective groups of investors.

The overconfident investors' posteriors on v differ as follows:

$$\begin{aligned} \hat{v}^A &= \frac{\phi\tau_\theta}{\tau_v + (\phi+1)\tau_\theta}\theta_1 + \frac{\tau_\theta}{\tau_v + (\phi+1)\tau_\theta}\theta_2 = \frac{\phi}{\eta+\phi+1}\theta_1 + \frac{1}{\eta+\phi+1}\theta_2 \\ \hat{v}^B &= \frac{\tau_\theta}{\tau_v + (\phi+1)\tau_\theta}\theta_1 + \frac{\phi\tau_\theta}{\tau_v + (\phi+1)\tau_\theta}\theta_2 = \frac{1}{\eta+\phi+1}\theta_1 + \frac{\phi}{\eta+\phi+1}\theta_2. \end{aligned}$$

Thus, the difference in posterior beliefs is

$$\hat{v}^A - \hat{v}^B = \frac{\phi-1}{\eta+\phi+1}\theta_1 - \frac{\phi-1}{\eta+\phi+1}\theta_2.$$

This difference in investors' beliefs induces stock trading at $t = 1$. In particular, A-investors will sell their shares to B-investors when they have higher posteriors, and vice versa. Under risk-neutral preferences, one would then expect to see unbounded bets between overconfident and rational investors. In practice, however, it is usually difficult and costly to sell stocks short. For simplicity we rule out short sales. It is important for our analysis is that there are limits on short sales. Setting these limits to zero is a technical convenience.

When stock selling is limited by short sales constraints, the price of a stock will be driven up to the valuation of the most optimistic investor. Incumbent shareholders in either group A or B have the option to sell their shares at $t = 1$ to investors in the other group when they have higher valuations. For the remainder of this section we will take the effort vector (μ, ω) as fixed and ignore the managers compensation. Thus, the equilibrium value of the firm at $t = 1$ is given by

$$\begin{aligned} V_1 &= \max(\hat{e}^A, \hat{e}^B) = \max(\hat{u}^A + \hat{v}^A, \hat{u}^B + \hat{v}^B) \qquad (6) \\ &= h\mu + \frac{\tau_s}{\tau_s+\tau}(s - h\mu) + \max\left(\frac{\phi\theta_1 + \theta_2}{\eta+\phi+1}, \frac{\theta_1 + \phi\theta_2}{\eta+\phi+1}\right). \end{aligned}$$

At $t = 0$ it is convenient to assume that all shareholders are A-investors, as we will now assume. This is not the only way of specifying the initial state of the firm. In a previous version we considered an alternative specification where all initial shareholders (and the CEO) were fully rational and only potential stock buyers were overconfident. We prefer our current formulation since it makes clear that our analysis does depend on "rational insiders" taking advantage of less sophisticated outside investors.[14]

Initial shareholders expect that in some states of the world they will be able to resell their shares at $t = 1$ to more optimistic investors and they will price in this option at $t = 0$.[15] Taking account of this option, we obtain the following proposition.

Proposition 2 *The equilibrium value of the firm, given the effort vector* (μ, ω) *and ignoring manager's compensation, at* $t = 0$ *is*

$$V_0 = h\mu + \frac{\phi - 1}{\eta + \phi + 1}\sqrt{\frac{\eta(\phi + 1)}{2\pi\phi}}l\omega. \tag{7}$$

Proof: See the Appendix.

A critical difference with the situation considered before is that now the stock price at $t = 0$ is an increasing function of ω, while before the gross stock valuation was independent of ω. Notice that in the limit when $\phi \to 1$ the stock price is independent of ω. In other words, in the presence of overconfident investors, the 'castle-in-the-air' project becomes valuable to incumbent rational shareholders because it may be overvalued by overconfident investors at $t = 1$.

This is the key distortion that is introduced by speculative markets. As we shall illustrate below, this systematic bias in stock prices, far from discouraging rational shareholders from exposing the CEO to stock based remuneration, will instead induce them to put more weight on short run stock performance. Indeed, incumbent shareholders would be willing to sacrifice some long-term value in μ for a higher ω, in order to exploit short-term speculative profits.

[14] In general we could assume that insiders and outside investors have different degrees of overconfidence. Another way of modelling initial shareholders and the CEO is to have them all identical at $t = 0$, but have them draw the same group identity at $t = 1$ with equal probability.

[15] Note that the symmetry of our model and the common initial beliefs of investors imply that the resale option is worth the same to investors whether they belong to group A or B. It makes no difference to which group initial shareholders belong.

4.2 The CEO's problem

As before, we consider a linear incentive contract of the form $ap_1 + be + c$. We can again interpret a as the number of shares that are issued and given to the CEO, and that she can sell at time 1. We will assume that the CEO also belongs to group A. Since the CEO is risk-averse she will always sell all the shares in the firm that she is allowed at $t = 1$. The buyers of her equity stake would belong to the group with higher beliefs at that time.[16]

Under any such contract the market value of the firm at $t = 1$ is given by:

$$p_1 = \max\left\{\mathrm{E}^A[e - (ap_1 + be + c)], \mathrm{E}^B[e - (ap_1 + be + c)]\right\},$$

or,

$$p_1 = \frac{1-b}{1+a}\left(\hat{u} + \max\{\hat{v}^A, \hat{v}^B\}\right) - \frac{c}{1+a}.$$

Making again the change of variables,

$$\alpha = \frac{a}{1+a}(1-b), \quad \beta = b, \quad \delta = \frac{c}{1+a}$$

we have

$$p_1 = (1 - \alpha - \beta)\left(\hat{u} + \max\{\hat{v}^A, \hat{v}^B\}\right) - \delta.$$

The market value at $t = 0$ is given by the expectation of p_1:

$$p_0 = (1 - \alpha - \beta)\mathrm{E}^A[\hat{u} + \max\{\hat{v}^A, \hat{v}^B\}] - \delta.$$

Except for the change in expected gross firm value at $t = 0$, given by equation (7), there is little change in the basic optimal contracting problem. Given a contract $\{\alpha, \beta, \delta\}$ the manager chooses her best actions by solving

$$\max_{\mu,\omega} \mathrm{E}^A\left[\alpha\left(\hat{u} + \max\{\hat{v}^A, \hat{v}^B\}\right) + \beta e\right] - \frac{1}{2}(\mu+\omega)^2 - \frac{\gamma}{2}Var^A\left[\alpha\left(\hat{u} + \max\{\hat{v}^A, \hat{v}^B\}\right) + \beta e\right] \quad (8)$$

Initial shareholders choose $\{\alpha, \beta\}$ to maximize the firm's net expected value subject to the manager's incentive constraint in equation (8) and participation constraint. In equilibrium,

[16] In fact, the assumption that the CEO has the same beliefs as initial shareholders is not important. We could have modelled the CEO as belonging to either group. This would not change the basic outcome at $t = 1$, since a risk-averse CEO would always want to sell all the shares that she is allowed at $t = 1$.

all investors correctly expect the manager to choose her optimal action pair μ^* and ω^*, and determine the firm's fundamental value based on this anticipation.

From equation (6) we can easily infer the equilibrium share price at $t = 1$:

$$\begin{aligned} p_1 &= (1-\alpha-\beta)\left[h\mu^* + \frac{\tau_s}{\tau_s+\tau}(s - h\mu^*)\right] \\ &\quad +(1-\alpha-\beta)\max\left(\frac{\phi\theta_1+\theta_2}{\eta+\phi+1}, \frac{\theta_1+\phi\theta_2}{\eta+\phi+1}\right) - \delta. \end{aligned}$$

By substituting for p_1 in the manager's compensation formula $W = ap_1 + be + c$ it is straightforward to derive the following expression for the manager's mean compensation and its variance.

Lemma 3 *The manager's expected compensation is*

$$\alpha h\mu^* + \frac{\alpha\tau_s}{\tau_s+\tau}h(\mu-\mu^*) + \alpha Bl\omega + \beta h\mu + \delta$$

with the coefficient

$$B = \frac{\phi-1}{\eta+\phi+1}\sqrt{\frac{\eta(\phi+1)}{2\pi\phi}}. \tag{9}$$

The variance of the manager's compensation is

$$\left(\frac{\alpha\tau_s}{\tau_s+\tau}+\beta\right)^2/\tau + \frac{\alpha^2\tau_s^2}{(\tau_s+\tau)^2}/\tau_s + \beta^2/\tau_\epsilon + Al^2\omega^2$$

with coefficient

$$A = \frac{\eta\alpha^2(1+\phi)}{2\phi(\eta+\phi+1)^2}\left[(1+\phi^2) - \frac{1}{\pi}(\phi-1)^2\right] + \left(\alpha\frac{\phi+1}{\eta+\phi+1}+\beta\right)^2$$

Proof: See Appendix.

Using this lemma we can formulate the manager's optimization problem as

$$\max_{\mu,\omega} \quad \left(\frac{\alpha\tau_s}{\tau_s+\tau}+\beta\right)h\mu + \alpha Bl\omega - \frac{1}{2}(\mu+\omega)^2 - \frac{\gamma}{2}Al^2\omega^2.$$

It is easy to see from this formulation that the manager's marginal return to increasing the risk on the 'castle-in-the-air' project ω is increasing in the coefficient B. Moreover, B itself is increasing in ϕ, the measure of overconfidence of investors. In other words, it is immediately apparent from this expression that the return to hyping the speculative project is increasing in the degree of overconfidence of investors.

To see this more explicitly, we solve the manager's optimization problem under an arbitrary contract $\{\alpha, \beta, \delta\}$ and obtain the following characterization:

Proposition 4 *Given a compensation contract $\{\alpha, \beta, \delta\}$, the manager's best-response is described by the following three cases:*

1) Fundamentalist:

$$\omega = 0 \text{ and } \mu = h\left(\frac{\alpha\tau_s}{\tau_s + \tau} + \beta\right)$$

when $\alpha Bl \leq h\left(\frac{\alpha\tau_s}{\tau_s+\tau} + \beta\right)$,

2) Short-termist:

$$\begin{aligned} \omega &= \frac{\alpha B}{\gamma Al} - \frac{h}{\gamma Al^2}\left(\frac{\alpha\tau_s}{\tau_s + \tau} + \beta\right) > 0 \quad \text{and} \\ \mu &= h\left(1 + \frac{1}{\gamma Al^2}\right)\left(\frac{\alpha\tau_s}{\tau_s + \tau} + \beta\right) - \frac{\alpha B}{\gamma Al} \geq 0 \end{aligned}$$

when $h\left(\frac{\alpha\tau_s}{\tau_s+\tau} + \beta\right) < \alpha Bl \leq h\left(1 + \gamma Al^2\right)\left(\frac{\alpha\tau_s}{\tau_s+\tau} + \beta\right)$,

3) Purely speculative:

$$\omega = \frac{\alpha Bl}{1 + \gamma Al^2} \text{ and } \mu = 0,$$

when $\alpha Bl > h\left(1 + \gamma Al^2\right)\left(\frac{\alpha\tau_s}{\tau_s+\tau} + \beta\right)$.

Proof: See Appendix.

For any fixed contract $\{\alpha, \beta, \delta\}$, the CEO faces a lower marginal cost of effort on μ than on ω. Indeed, her marginal cost of action μ is only $(\mu + \omega)$ while her marginal cost on ω is $[(\mu + \omega) + \gamma Al^2\omega]$. That is, there is an additional cost of increasing the volatility of the castle-in-the-air project coming from the manager's aversion to risk. Therefore, it only pays the manager to engage in short-termist behavior (by raising ω above zero) if the marginal return on the castle-in-the-air project exceeds that of the long-term project, or equivalently if $\alpha Bl > h\left(\frac{\alpha\tau_s}{\tau_s+\tau} + \beta\right)$. A sufficient condition for the manager not to engage in any castle-in-the-air activity is that $Bl < \frac{h\tau_s}{\tau_s+\tau}$, which holds when ϕ or l are small, or when h is big. That is, when there is either little overconfidence or it is difficult to increase the risk of v, or it is easy to improve fundamentals.

In contrast, in a speculative bubble, where the returns to castle-in-the-air projects are high, the CEO pursues only that type of activity. This is the case when

$$\alpha Bl > h\left(1 + \gamma Al^2\right)\left(\frac{\alpha\tau_s}{\tau_s + \tau} + \beta\right).$$

In other words, when the marginal return on ω exceeds that of μ even after adjusting for the additional risk taking cost of increasing ω. A sufficient condition is that ϕ is large enough.

It is only when speculative conditions are moderate, that it pays the manager to divide her attention between the two activities.

4.3 The shareholders' problem

The general form of shareholders' constrained optimization problem is the same as before. They choose $\{\alpha, \beta, \delta\}$ to maximize the market value of the firm at $t = 0$ subject to the manager's incentive and participation constraints. Again, we can substitute out for δ in the manager's participation constraint to reduce the optimal contracting problem to the following assuming that all shares can be traded at $t = 1$ unconstrained problem:

$$\begin{aligned}
&\max_{\alpha,\beta}\; p_0 \\
= &\max_{\alpha,\beta}\; h\mu(\alpha,\beta) + (1-\beta)Bl\omega(\alpha,\beta) - \frac{1}{2}(\mu(\alpha,\beta) + \omega(\alpha,\beta))^2 - \frac{\gamma}{2}Al^2\left(\omega(\alpha,\beta)\right)^2 \\
&\qquad -\frac{\gamma}{2}\left[\left(\frac{\alpha\tau_s}{\tau_s+\tau} + \beta\right)^2/\tau + \frac{\alpha^2\tau_s^2}{(\tau_s+\tau)^2}/\tau_s + \beta^2/\tau_\epsilon\right] - \bar{W}, \qquad (10)
\end{aligned}$$

where $\mu(\alpha, \beta)$ and $\omega(\alpha, \beta)$ satisfy the first-order conditions of the CEO's optimization problem described in Proposition 4. $h\mu(\alpha, \beta) + (1-\beta)Bl\omega(\alpha, \beta)$ is the total value of the firm at time 0, including the stake of the manager and accounting for the fact that a portion β of the shares of the firm cannot be traded at time 1. The remaining terms in (10) reflect the expected monetary payoff to the manager, which equals her reservation utility plus her cost of effort and a premium for risk.

Although the shareholders' problem is conceptually identical to the previous one, it is more involved technically. Due to the nonlinearity in the objective function, an analytical solution for the optimal contract $\{\alpha, \beta, \delta\}$ is not generally available. However, we are able to explicitly characterize the optimal contract in the special case where the CEO is risk-neutral. In this extreme case the optimal contract is as follows:

Proposition 5 *When the manager is risk neutral ($\gamma = 0$), the optimal contract induces either: a) Purely speculative behavior by the manager, when $Bl > h$. In that case the optimal contract*

is such that $\alpha = 1$ and $\beta = 0$, and the resulting managerial actions are $\mu = 0$ and $\omega = Bl$, or b) fundamentalist behavior, when $Bl \leq h$. In that case the optimal contract is such that $\alpha = 0$ and $\beta = 1$, and the resulting managerial actions are $\mu = h$ and $\omega = 0$.
Proof: see Appendix.

In accordance with standard agency theory, when the manager is risk-neutral it is optimal to make her a 'residual claimant' on the firm's cash-flow (see Jensen and Meckling 1976). Interestingly, however, in our set-up with speculative capital markets this is not the final word on the optimal contract. It remains to determine whether the manager should be encouraged to have an extreme speculative short-termist perspective or a fundamentalist long-term one. When investors have a high degree of overconfidence so that the speculative option value at $t = 0$ is high ($Bl > h$) then it is optimal to induce the manager to focus on the short-term strategy by allowing her to sell all her shares at $t = 1$. In contrast, when investors are likely to be relatively less speculative, so that $Bl \leq h$, the manager will choose to focus on the long-term fundamental value of the firm and will sell no shares at $t = 1$.

This special case with a risk-neutral CEO illustrates in a simple way one basic effect of speculative trading generated by investor overconfidence on the CEO incentive contract. However in this case, there is no real agency costs, which only arise because the CEO is risk averse. We now turn to the case of $\gamma > 0$.

It is easy to see that an optimal contract always exists. First, the feasible set of coefficients $\{\alpha, \beta\}$ defined by the inequalities in Assumption 2 is bounded and closed. Second, the objective in equation 10 is continuous over this set of contracts. Therefore, standard considerations guarantee that:

Proposition 6 *Under assumptions 1 and 2, there always exists at least one optimal contract that maximizes the objective of initial shareholders.*

5 Comparative statics

As it will become apparent from the numerical exercises that follow, the optimal contracting problem does not yield simple comparative statics results. For this reason we proceed directly to numerical solutions using a standard MATLAB routine.

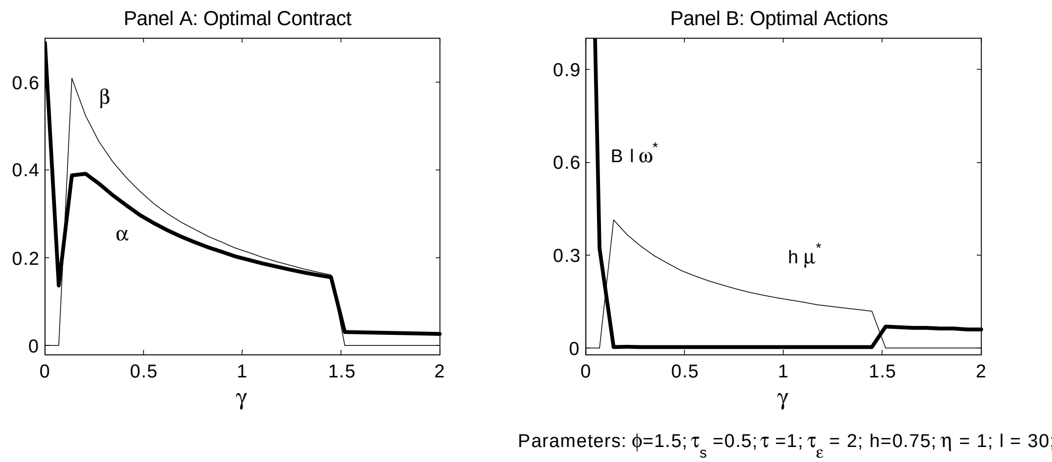

Figure 1: Optimal contract and actions as a function of γ, for intermediate ϕ.

We begin by discussing how the CEO's risk-aversion affects the optimal contract and equilibrium actions.

5.1 CEO risk aversion γ

In the standard model, an optimal contract puts positive weight on both short-term and long-term performance since both are informative about the agent's action choice. In addition, exposure to both types of risk provides diversification benefits to the CEO. In the presence of speculative distortions, we expect that the optimal contract will put more weight on short-term performance, but otherwise continues to base compensation on both short and long-term performance. As the CEO becomes more risk-averse, we expect that there will be greater benefits to diversification and that therefore there will be a more balanced weighting on both performance measures. For high coefficients of risk aversion, we expect the manager to put more weight on the less risky long-term value of the firm.

These predictions are generally borne out by our numerical solutions. However, these solutions also highlight the subtle effects of risk-aversion on short-termist speculative incentives. We provide one illustration below in Figure 1 for an intermediate value of ϕ.[17]

[17] In a previous version we also report solutions for high and low values of ϕ.

This Figure reveals the somewhat surprising finding that the manager is induced to focus exclusively on the short-term project *both* when her coefficient of risk aversion is very small (less than 0.1 in the illustrated example) and when it is very large (above 1.5 in our example). When the manager's risk aversion increases above 0.1 but remains less than 1.5, she switches to pursuing only the firm's fundamental value but her compensation is based on a combination of long-term and short-term stock performance. Finally, when her coefficient of risk aversion γ increases beyond 1.5, she switches back to pursuing only the short-term speculative project and her compensation is again only based on the firm's short-term performance. The figure provides some clues to the reasons for this non-monotonic pattern. When the manager's coefficient of risk-aversion increases, it becomes more and more expensive for shareholders to induce her to pursue the long-term value of the firm. Therefore, in equilibrium the manager scales back her effort and chooses lower μ. At some point, the overall benefit of pursuing the long-term value in this way is so small that shareholders prefer to switch to the speculative strategy. This explains the non-monotonic relation between γ and (μ^*, ω^*). This figure illustrates the complex interaction between several effects and the difficulties in characterizing a complete analytical solution for the optimal contract.

5.2 Overconfidence ϕ

It is natural to expect that the optimal contract will put more weight on short run performance, the higher the overconfidence of investors ϕ. More precisely, as ϕ becomes larger, posterior beliefs between the two groups of investors at $t = 1$ become more dispersed. Therefore the speculative component in stock prices, or the value of the resale option, becomes larger. This should encourage shareholders to take a more short-termist outlook. Similarly, we expect shareholders to give the CEO a more short-term weighted compensation contract, which will induce her to put more effort into the castle-in-the-air project (a higher ω). Figure 2 shows how the optimal contract and optimal actions vary with ϕ. When ϕ is small the optimal contract puts weights on short and long term performance. The optimal contract is close to the equilibrium contract obtained in the standard case ($\phi = 1$.) For high ϕ, on the other hand, the optimal contract only uses short term stock participation, as expected.

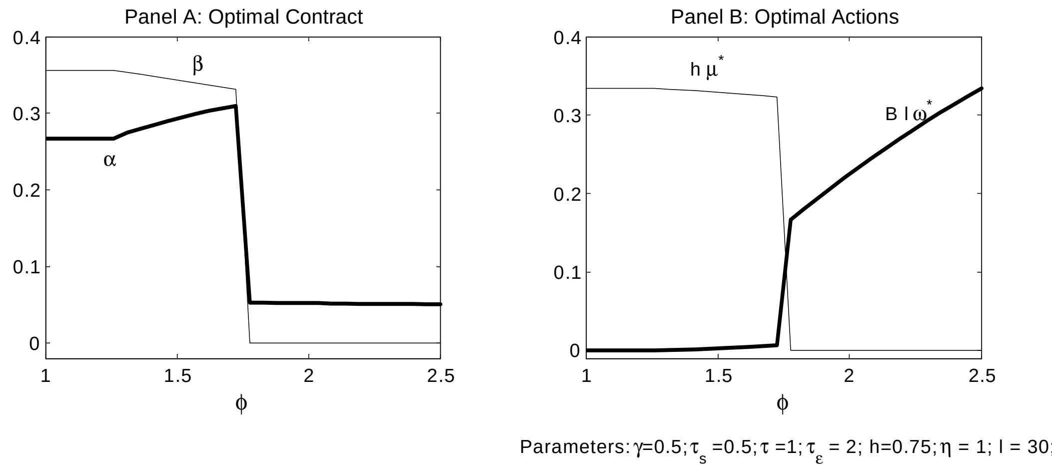

Figure 2: Optimal contract and actions as a function of ϕ.

As is apparent from the formula

$$B = \frac{\phi - 1}{\eta + \phi + 1}\sqrt{\frac{\eta(\phi+1)}{2\pi\phi}}$$

the effects of changes in η are similar to those with ϕ (when $\eta \leq \phi + 1$). Therefore, we do not report our results for this parameter change.

5.3 The manager's return on effort h and l

The comparative statics results with respect to marginal return on effort on the fundamental project are as one would expect. The higher is h, the higher will be the equilibrium effort μ. This is can be seen clearly in Figure 3 below.

Similarly, when the manager's effort on the castle-in-the-air project are more efficient (as measured by l) shareholders induce the manager to put more effort in that project, provided that investors are sufficiently overconfident. This is illustrated in Figure 4 for $\phi = 2$.

5.4 Fundamental risk τ, τ_s and τ_ϵ

Given a fixed compensation contract $\{\alpha, \beta, \delta\}$ the CEO is likely to increase her effort μ when the precisions τ, τ_s and τ_ϵ increase, since investment in the long-term project exposes her to

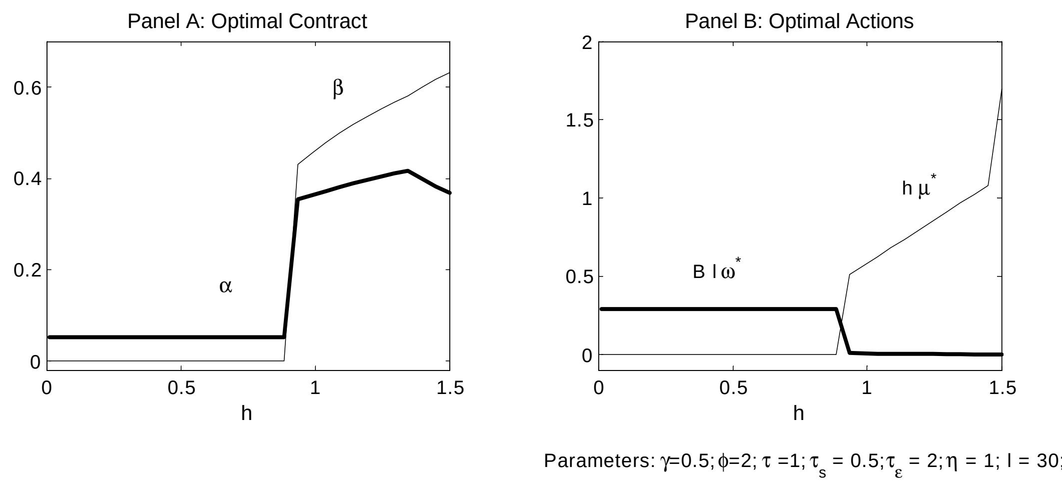

Figure 3: Optimal contract and actions as a function of h.

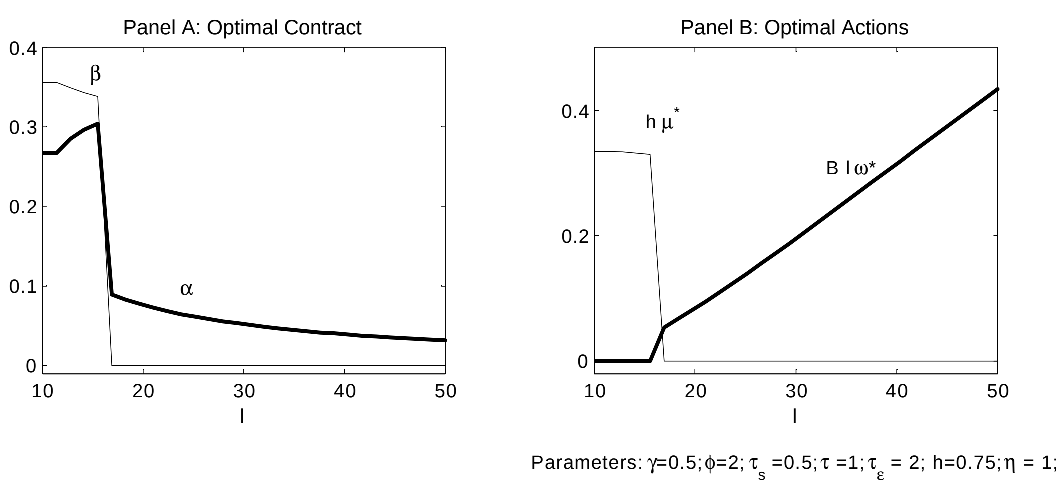

Figure 4: Optimal contract and actions as a function of l.

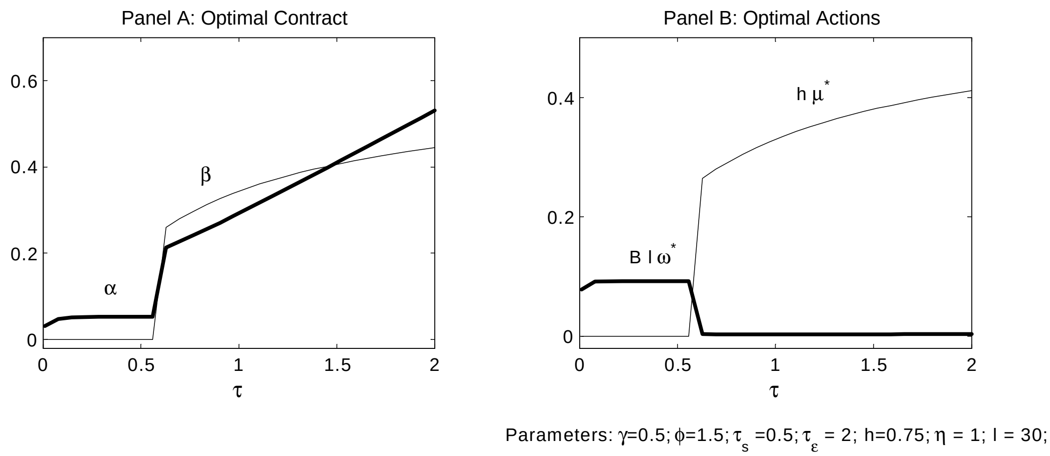

Figure 5: Optimal contract and actions as a function of τ.

less risk. In other words, the cost to shareholders of inducing the CEO to supply a given level of effort μ is reduced as these precisions increase. Therefore we would expect shareholders to 'buy' more effort from the CEO, which means that $\alpha + \beta$ should increase. Figure 5 illustrates this point. This figure also shows that μ increases with τ. This is natural, since for τ small the long term project is very risky, and hence the optimal contract induces the manager to focus on the short-term project. For higher values of τ, the underlying risk on u is reduced and the manager is induced to switch to pursuing the long-term fundamental value of the firm. But the contract still provides for some diversification of risk by putting positive weight on both short-term and long-term performance.[18]

6 Discussion and Empirical Implications

In this paper we used an optimal contracting or agency approach to explain the structure of CEO compensation, making only one substantive change to the standard theory. Instead of modelling stock markets as efficient, we have allowed for investor overconfidence and consequently speculative deviations of stock prices from fundamentals. We have shown how the introduction of a speculative component in the stock price creates a distortion in CEO compensation leading to a

[18] In an earlier version we showed that the comparative statics with respect to τ_s and τ_ε are similar to those with respect to τ.

short-term orientation. For some parameter values CEOs are encouraged to pursue short-term speculative projects even at the expense of long-term fundamental value.

Our analysis has implications for corporate governance and the regulation of CEO stock-option plans. Reacting to the recent corporate scandals, many commentators have argued that the current structure of CEO pay in the US cannot be rationalized on the basis of agency theory (see most notably, Bebchuk, Fried and Walker 2002). These commentators argue that the main problem with CEO compensation in the US is a failure of corporate governance and call for a regulatory response to strengthen boards of directors, as well as audit and remuneration committees.

If, as we propose, the explanation for the corporate failures is in part related to speculative stock markets, and if the recent CEO compensation excesses are partly a by-product of the technology bubble, then different policy implications emerge. Further strengthening of boards may not make a major difference. On the other hand, limits on CEOs' ability to unwind their own stock holdings in short horizons could provide a more effective deterrent to the pursuit of short-term strategies.

Another frequently discussed proposal is to force firms to expense option grants. This measure seems to aim at two different effects. The first is to increase the clarity of corporate accounting. The second is to increase the cost of performance based compensation. To the extent that the non-expensing of stock options provides a greater subsidy to long-run stock options (with greater time to expiration) relative to options with short horizons, expensing of stock options may increase the cost of providing incentives for managers to pursue strategies that maximize fundamentals. Hence the accounting change concerning option expensing may have a perverse effect on manager's incentives.

An interesting question that our analysis raises is when are firms likely to encourage such short-termist behavior. Our comparative statics analysis provides some helpful hints. First, we expect short-termist behavior to be more likely in new industries where it is likely to be harder to evaluate the fundamental profitability of the industry and therefore there is likely to be substantial disagreement among investors. In terms of our model, firms in such industries would have a high l parameter, and a low precision τ. In addition this behavior should be more prevalent in periods of higher investor overconfidence.

Second, firms with dwindling existing business-lines (low h parameter in our model) would also be more prone to pursue castle-in-the-air strategies. Third in our model we assumed that stocks are perfectly liquid. If, however, stocks are not perfectly liquid and trade for less than their expected final payoff, short term strategies are less effective. Therefore, we expect that firms with illiquid stocks are less likely to pursue short-term strategies.

In our model all initial shareholders are identical. In reality managerial compensation contracts reflect the motives of shareholders that influence the compensation committees. Frequently these are institutions. In this case our model would predict a correlation between institutional shareholder turnover and the firm manager's short-termist behavior. Indeed, Bushee (1998) provides some evidence of this type. He shows that managers in firms where a large proportion of institutional owners have a high turnover tend to reduce R&D expenses in order to boost short-term earnings.

A Some Proofs

A.1 Proof to Proposition 1

We denote $x = \mu/h = \frac{\alpha\tau_s}{\tau_s+\tau} + \beta$. Note that $0 \le x \le 1$. For given level of x, investors can determine the combination of α and β:

$$\min \quad \frac{\alpha^2\tau_s}{(\tau_s+\tau)^2} + \frac{\beta^2}{\tau_\epsilon}$$

subject to the constraint that

$$0 \le \beta \le 1, \quad 0 \le \alpha \le (1-\beta).$$

It is immediate to establish the following results: If $x < \frac{\tau_s+\tau_\epsilon}{\tau+\tau_s+\tau_\epsilon}$, the optimal combination is

$$\alpha = \frac{\tau_s+\tau}{\tau_s+\tau_\epsilon}x, \quad \beta = \frac{\tau_\epsilon}{\tau_s+\tau_\epsilon}x.$$

Otherwise, if $x \ge \frac{\tau_s+\tau_\epsilon}{\tau+\tau_s+\tau_\epsilon}$, the constraint $\alpha+\beta$ is binding and the optimal combination is

$$\alpha = \frac{\tau+\tau_s}{\tau}(1-x), \quad \beta = \frac{\tau+\tau_s}{\tau}x - \frac{\tau_s}{\tau}.$$

Next, we determine the optimal level of x. If $x < \frac{\tau_s+\tau_\epsilon}{\tau+\tau_s+\tau_\epsilon}$, the objective of the shareholders can be derived as

$$L = hx - h^2x^2/2 - \frac{\gamma}{2}[x^2/\tau + \alpha^2\tau_s/(\tau_s+\tau)^2 + \beta^2/\tau_\epsilon]$$

It is direct to verify that the maximum of this function is reached at

$$x = \frac{h}{h^2 + \gamma\left(\frac{1}{\tau} + \frac{1}{\tau_s+\tau_\epsilon}\right)},$$

which is less than $\frac{\tau_s+\tau_\epsilon}{\tau+\tau_s+\tau_\epsilon}$ if $\gamma/\tau > h - \frac{\tau_s+\tau\epsilon}{\tau+\tau_s+\tau_\epsilon}h^2$.

On the other hand, if $x \ge \frac{\tau_s+\tau_\epsilon}{\tau+\tau_s+\tau_\epsilon}$, the objective function can be derived as

$$L = hx - h^2x^2/2 - \frac{\gamma}{2}\left\{x^2/\tau + \frac{\tau_s}{\tau^2}(1-x)^2 + \frac{[(\tau_s+\tau)x - \tau_s]^2}{\tau^2\tau_\epsilon}\right\},$$

and its maximum is reached at

$$x = \frac{h\tau^2\tau_\epsilon + \gamma\tau_s(\tau+\tau_s+\tau_\epsilon)}{h^2\tau^2\tau_\epsilon + \gamma(\tau+\tau_s+\tau_\epsilon)(\tau+\tau_s)}$$

which is larger than $\frac{\tau_s+\tau_\epsilon}{\tau+\tau_s+\tau_\epsilon}$ if $\gamma/\tau < h - \frac{\tau_s+\tau\epsilon}{\tau+\tau_s+\tau_\epsilon}h^2$.

A.2 Proof to Proposition 2

The expected value of the firm at $t = 0$ is

$$\begin{aligned} V_0 &= \mathrm{E}^A[\max(\hat{e}^A, \hat{e}^B)] \\ &= \mathrm{E}[\hat{e}^A + \max(0, \hat{v}^B - \hat{v}^A)] \end{aligned}$$

Next, observing that for a random variable z with Gaussian distribution $z \sim N(0, \sigma_z^2)$,

$$\mathrm{E}[\max(0, z)] = \int_0^\infty z \frac{1}{\sqrt{2\pi\sigma_z^2}} e^{-\frac{z^2}{2\sigma_z^2}} dz = \frac{\sigma_z}{\sqrt{2\pi}},$$

we obtain the desired expression.

A.3 Proof to Lemma 3

The manager's expected monetary compensation is:

$$\begin{aligned} & \mathrm{E}^A[ap_1 + be + c] \\ = \;& \alpha h\mu^* + \frac{\alpha\tau_s}{\tau_s + \tau} h(\mu - \mu^*) + \alpha \frac{\phi - 1}{\eta + \phi + 1} \sqrt{\frac{\eta(\phi + 1)}{2\pi\phi}} l\omega + \beta h\mu + \delta. \end{aligned}$$

And the variance of the manager's payoff is:

$$\begin{aligned} & Var^A[\alpha p_1 + \beta e] \\ = \;& Var^A\left[\alpha \frac{\tau_s}{\tau_s + \tau}(s - h\mu^*) + \alpha \max\left\{\frac{\phi\theta_1 + \theta_2}{\eta + \phi + 1}, \frac{\theta_1 + \phi\theta_2}{\eta + \phi + 1}\right\} + \beta e\right] \\ = \;& Var^A\left[\frac{\alpha\tau_s(u + \epsilon_s)}{\tau_s + \tau} + \beta(u + \epsilon)\right] + Var^A\left[\left(\alpha \frac{\phi + 1}{\eta + \phi + 1} + \beta\right) v\right] \\ & + Var^A\left[\frac{\alpha}{\eta + \phi + 1} \max\{\phi\epsilon_1 + \epsilon_2, \epsilon_1 + \phi\epsilon_2\}\right] \end{aligned}$$

The first two variances are straightforward to derive. To derive the third one, it is important to note that from the manager's perspective, ϵ_1 and ϵ_2 are independent with variances of σ_θ^2/ϕ and σ_θ^2, respectively. To simplify notation, we let $\epsilon_1 = \sigma_\theta x/\sqrt{\phi}$ and $\epsilon_2 = \sigma_\theta y$ with x and y as two independent random variables with standard normal distribution. Then,

$$\mathrm{E}[\max\{\phi\epsilon_1 + \epsilon_2, \epsilon_1 + \phi\epsilon_2\}] = \sigma_\theta(\phi - 1)\sqrt{\frac{\phi + 1}{2\pi\phi}}$$

and

$$
\begin{aligned}
& \mathrm{E}^M[\max\{\phi\epsilon_1+\epsilon_2,\epsilon_1+\phi\epsilon_2\}]^2 \\
= \;& \sigma_\theta^2 \mathrm{E}[\max\{\sqrt{\phi}x+y, x/\sqrt{\phi}+\phi y\}]^2 \\
= \;& \sigma_\theta^2 \int_{-\infty}^{\infty} dy \frac{1}{\sqrt{2\pi}} e^{-\frac{y^2}{2}} \left\{ \int_{-\infty}^{\sqrt{\phi}y} dx \frac{1}{\sqrt{2\pi}} e^{-\frac{x^2}{2}} (\sqrt{\phi}x+y)^2 \right. \\
& \left. + \int_{\sqrt{\phi}y}^{\infty} dx \frac{1}{\sqrt{2\pi}} e^{-\frac{x^2}{2}} (x/\sqrt{\phi}+\phi y)^2 \right\} \\
= \;& \frac{(1+\phi)(1+\phi^2)}{2\phi}\sigma_\theta^2
\end{aligned}
$$

Therefore,

$$
Var^A[\max\{\phi\epsilon_1+\epsilon_2,\epsilon_1+\phi\epsilon_2\}]^2 = \frac{1+\phi}{2\phi}\left[(1+\phi^2)-\frac{1}{\pi}(\phi-1)^2\right]\sigma_\theta^2.
$$

Thus, by collecting all the terms,

$$
\begin{aligned}
& Var^A[\alpha p_1+\beta e] \\
= \;& \left(\frac{\alpha\tau_s}{\tau_s+\tau}+\beta\right)^2\sigma^2 + \frac{\alpha^2\tau_s^2}{(\tau_s+\tau)^2}\sigma_s^2 + \beta^2\sigma_\epsilon^2 + Al^2\omega^2
\end{aligned}
$$

where,

$$
A = \frac{\eta\alpha^2(1+\phi)}{2\phi(\eta+\phi+1)^2}\left[(1+\phi^2)-\frac{1}{\pi}(\phi-1)^2\right] + \left(\alpha\frac{\phi+1}{\eta+\phi+1}+\beta\right)^2
$$

We have used $\sigma_\theta^2 = \eta l^2\omega^2$ to derive A.

A.4 Proof to Proposition 4

We need to maximize

$$
\max_{\mu,\omega} \;\; \left(\frac{\alpha\tau_s}{\tau_s+\tau}+\beta\right)h\mu + \alpha Bl\omega - \frac{1}{2}(\mu+\omega)^2 - \frac{\gamma}{2}Al^2\omega^2
$$

subject to $\mu \geq 0$ and $\omega \geq 0$. We can use Lagrange method:

$$
L = \left(\frac{\alpha\tau_s}{\tau_s+\tau}+\beta\right)h\mu + \alpha Bl\omega - \frac{1}{2}(\mu+\omega)^2 - \frac{\gamma}{2}Al^2\omega^2 + \lambda_1\mu + \lambda_2\omega
$$

where $\lambda_1 \geq 0$, $\lambda_2 \geq 0$, $\lambda_1\mu = 0$ and $\lambda_2\omega = 0$. The first order conditions are

$$
\begin{aligned}
\frac{\partial L}{\partial\mu} &= \left(\frac{\alpha\tau_s}{\tau_s+\tau}+\beta\right)h - (\mu+\omega) + \lambda_1 = 0 \\
\frac{\partial L}{\partial\omega} &= \alpha Bl - (\mu+\omega) - \gamma Al^2\omega + \lambda_2 = 0
\end{aligned}
$$

Solving these first order conditions under the constraints above, we can directly get the three cases given in the proposition.

A.5 Proof to Proposition 5

For a risk-neutral manager, her optimal actions for a given contract $\{\alpha, \beta\}$ is

$$\begin{aligned}
&\text{if } \alpha Bl < h\left(\frac{\alpha\tau_s}{\tau_s+\tau}+\beta\right), \quad \mu = h\left(\frac{\alpha\tau_s}{\tau_s+\tau}+\beta\right), \quad \omega = 0; \\
&\text{if } \alpha Bl \geq h\left(\frac{\alpha\tau_s}{\tau_s+\tau}+\beta\right), \quad \mu = 0, \quad \omega = \alpha Bl.
\end{aligned}$$

This is just a simplified version of Proposition 4 with $\gamma = 0$.

Then, the shareholders' problem is

$$\max_{\alpha,\beta} \quad h\mu + (1-\beta)Bl\omega - \frac{1}{2}(\mu+\omega)^2.$$

If $\alpha Bl < h\left(\frac{\alpha\tau_s}{\tau_s+\tau}+\beta\right)$, by substituting μ and ω into the objective, we have

$$\max_{\alpha,\beta} \quad h^2\left[\left(\frac{\alpha\tau_s}{\tau_s+\tau}+\beta\right) - \frac{1}{2}\left(\frac{\alpha\tau_s}{\tau_s+\tau}+\beta\right)^2\right].$$

It is easy to see that the maximum is reached at $\frac{\alpha\tau_s}{\tau_s+\tau}+\beta = 1$, which is only feasible with $\alpha = 0$ and $\beta = 1$. With this contract, the value of the objective function is $\frac{h^2}{2}$, and the condition for the case $\alpha Bl < h\left(\frac{\alpha\tau_s}{\tau_s+\tau}+\beta\right)$ is always satisfied.

If $\alpha Bl \geq h\left(\frac{\alpha\tau_s}{\tau_s+\tau}+\beta\right)$, the objective function becomes

$$\begin{aligned}
&\max_{\alpha,\beta} \quad B^2l^2[(1-\beta)\alpha - \alpha^2/2] \\
= &\max_{\alpha,\beta} \quad B^2l^2[(1-\beta)^2/2 - (1-\beta-\alpha)^2/2].
\end{aligned}$$

It is easy to see that the maximum of $\frac{B^2l^2}{2}$ is reached at $\alpha = 1$ and $\beta = 0$. This contract only satisfies the condition of the case, $\alpha Bl \geq h(\frac{\alpha\tau_s}{\tau_s+\tau}+\beta)$, when $Bl \geq \frac{h\tau_s}{\tau_s+\tau}$.

By summarizing these two cases, we have the following optimal contract for a risk-neutral manager: If $Bl \geq h$, $\alpha = 1$ and $\beta = 0$; Otherwise, $\alpha = 0$ and $\beta = 1$.

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