Department of Finance

Working Paper Series 1998

FIN-98-088

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December 9, 1998

This Working Paper Series has been generously supported by a grant from

CDC Asset Management
AMERICAS

Contract Renegotiation and the Optimality of Resetting Executive Stock Options[1]

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December 7, 1998

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Abstract

Recent empirical work has documented the tendency of corporations to reset strike prices on previously-awarded executive stock option grants when declining stock prices have pushed these options out-of-the-money. This practice has been criticised as counter-productive since it weakens incentives present in the original award.

This paper sets up a theoretical model for study of this issue. We find that when the menu of compensation contracts is unlimited, resetting cannot increase, and may actually reduce, shareholder value. In more realistic settings, however, when only commonly-observed compensation instruments may be used, we find that allowing for the possibility of resetting can, in fact, result in increased shareholder value; we identify specific conditions on the effort-aversion of the manager under which this is always the case. We also find that the relative importance of resetting may increase as the impact of external (economy- or industry-wide) factors on the firm's performance increases; this offers one possible explanation for why resetting has been far more common in small firms than large ones. Finally, we also analyze the relationship between the relative optimality of resetting and managerial control over returns generation. In summary, our results suggest that current criticism of the practice of resetting may be misguided, and that resetting may be a value-enhancing aspect of corporate compensation contracts.

1 Introduction

In recent years, stock options have become an important component of overall executive compensation. For such options to serve as a credible incentive device, it would appear important that the terms of the original contract not be amended, especially when declining share prices have pushed the options out of the money. Nonetheless, a considerable amount of evidence suggests that such "resetting" or "repricing" does often take place in practice, typically in the form of a reduction in the original exercise price to bring the options closer to the money (see Section 2). Criticism of this practice has also grown in recent years, notably in the popular press.[1] It is argued that resetting amounts to rewarding management for poor performance, and destroys incentives present in the original contract. Defending the practice, however, corporations have suggested that resetting plays a vital role in "reincentivizing" employees who have become demotivated by underwater options.

The optimality and incentive effects of resetting have not thus far been addressed theoretically in the literature. This paper sets up a framework for study of these issues. We build on the usual agency setting in which an effort-averse manager (the "agent") is provided incentives through choice of a compensation contract by a firm's shareholders (collectively called the "principal"). The general question we examine is the following: suppose we are given an initial compensation contract for the manager, and interim information becomes publicly available on the "state of the world." From the standpoint of ex-ante value maximization, is it optimal for the principal to agree to amend the terms of the original contract to reflect this additional information?

In an idealised context in which no restrictions exist on the form of state-contingent contracts that may be offered, the answer, we find, is unambiguous: allowing for resetting can *never* improve, and may even destroy, shareholder value. At first sight, this would appear to be a sharp indictment of the practice of resetting. However, the assumption that the menu of compensation contracts is unlimited is not an inncouous one. It is well-known that under these circumstances, theoretical equilibria predicted by principal/agent models may be unrealistically complex, with payoffs depending on realized outcomes in very fine ways. In contrast, pay-performance sensitivity in practice is induced using a relatively limited array of instruments such as call options on equity that are typically set at-the-money at the time of issue.

Motivated by this, we rework our analysis in a situation in which realistic limits exist on the extent of state-dependence permissible in the contract. We find that resetting now has real "bite," and a dramatic reversal of the earlier result may take place. We describe a class of models in which it is strictly ex-ante value maximizing for the principal to agree to reset contract terms in certain contingencies, despite the negative effect this may have on initial incentives. The intuition underlying this construction is robust; it extends more generally to

[1] See, e.g., "Stock Swings make Options a Hot Topic" by Joann Lublin, *Wall Street Journal*, October 29, 1997; "Stock Options that Raise Investors' Ire" by Adam Bryant, *New York Times*, March 27, 1998; or "If the Price isn't Right, Just Change It" by David Johnston, *New York Times*, July 15, 1998.

all models in which the manager's effort-aversion is small in an appropriate sense.

Having established the possible optimality of resetting in general, we turn to a specific issue: how is the relative optimality of resetting affected by the presence of "macro" (economy-wide or industry-wide) factors that have an impact on corporate performance and share prices, but that are—by definition—beyond the manager's control? Such factors have been cited in practice as a justification for resetting. However, it has been argued that resetting in these circumstances may actually be counter-productive. Since options contracts do not typically correct for market or industry performance, managers are able to reap the full *upside* of a positive trend in these factors; resetting in a down market provides a form of insurance that may aggravate moral hazard problems.

Our examination of this issue shows that such disincentivization need not necessarily result; indeed, we find in our model that the greater the influence of the macro factors, the *more*—not less—relatively optimal resetting becomes. This result is more intuitive than might appear at first blush. The relative optimality of resetting depends in a central way on the strength of the negative feedback effect. When external factors increase in importance, the manager effectively faces a higher level of "background risk" that cannot be eliminated. In general, this makes him worse off in the continuation equilibrium. The lower continuation utility translates into a lower feedback effect on earlier behavior. In turn, this increases the likelihood of resetting being ex-ante optimal.

Our paper also examines several other issues including the role of managerial "control" over returns distributions, and the effect of allowing either party to initiate a termination of the principal/manager relationship after the interim information revelation. Under reasonable and general conditions, none of these alter our broad qualitiative conclusions; in particular, we find that the tighter the "human resource" constraint, viz., the explicit or implicit (productivity-related) costs of replacing the incumbent manager, the more profitable—and therefore likely—resetting will be as a compensation strategy. Based on all these results, we conclude that the popular criticism of the practice of resetting may be misguided; indeed, in many situations, resetting appears to be a value-enhancing aspect of corporate compensation contracts.

Some empirically-relevant features of our paper are worth emphasizing here. First, although our model allows resetting to occur at any point, in equilibrium it only occurs after poor performance. This is consistent with empirical evidence that resetting is a practice overwhelmingly (indeed, almost exclusively) associated with *negative* shareholder returns (see, e.g., Brenner, et al [6], or Chance, et al [7]). Second, since resetting only follows a poor performance, the reincentivization effect of resetting in our model provides a testable implication: that post-resetting returns distributions should be superior to those that preceded the resetting. Third, empirically it is known that resetting has a strong inverse relationship to firm size, with its incidence increasing significantly as firm size declines (see, e.g., Brenner, et al [6]). Since small firms are also likely to be more vulnerable to movements in macro-level factors, our result that the relative optimality of resetting may increase with an increase in background risk offers one possible explanation of this phenomenon. Lastly, because the feedback effect acts to reduce initial incentives, we find that a substantially larger number of options are awarded in our model when resetting is possible than when it is ruled out.

Before turning to the main body of the paper, it is worth noting that the framework we develop here has analogies to a number of other settings in financial economics as well. One of particular interest is the design of bankruptcy procedures. On the one hand, bankruptcy systems which encourage renegotiation between the concerned parties (as in the US) are akin to the situation where the option is reset contingent on a bad outcome being realized. Such systems have the advantage that continuation values are efficiently realized, but they have an evident feedback effect that could increase the probabilities of bankruptcies occurring. On the other hand, systems which tacitly encourage liquidation of the firm under bankruptcy (as in Germany) are analogous to pre-commitment strategies that eliminate renegotiation possibilities or, at least, make them very difficult. This leads to potentially inefficient continuations, but may have a beneficial feedback effect that lowers the occurrence of bankruptcies. Many other similar applications of the model evidently exist.

The remainder of this paper is organized as follows. Section 2 describes the related literature. Section 3 presents our model, identifies the strategies of interest, and defines an equilibrium in each case. Section 4 analyzes the model when compensation contracts are unrestricted in form, while Section 5 examines the situation where only a limited set of instruments may be used for this purpose. Section 6 looks at the impacts of background risk and managerial quality on resetting. Section 7 focusses on various extensions of the model. Section 8 concludes. Proofs of all results omitted in the main body of the paper are provided in the Appendix.

2 The Related Literature

The resetting of executive stock options has been the focus of a number of empirical studies. Gilson and Vetsuypens [10] and Saly [21] have examined resetting induced by extraordinary circumstances. Gilson and Vetsuypens look at incidences of resetting by firms in financial distress during the period 1981–87. Saly focuses on incidences of resetting following the stock market crash of 1987.

More recently, Brenner, Sundaram and Yermack [6] and Chance, Kumar, and Todd [7] have each looked at resetting under "normal" circumstances, and have characterized the typical reset option. We describe relevant features of the former paper here. Brenner, et al examine a sample of around 1,500 firms of all sizes. They find that resetting is overwhelmingly associated with *negative* stock returns, with its incidence increasing as firm performance worsens. A strong inverse relationship between resetting and performance continues to hold even after correcting for industry performance. In the vast majority of cases, the new strike price of the reset options was set to the prevailing stock price at reset time; this resulted, on average, in a drop of around 40% in the strike price. Only around half of the reset options also had their maturities extended, with a mean increase of around 30 months. Importantly, the authors strongly reject the hypothesis that resetting is a substitute for other elements of an executive's pay, in particular, for the award of new options.

On the theoretical front, Saly [21] models resetting in an optimal contracting framework. In Saly's model, there are two possible economic environments that could prevail, with the abnormal one signifying an economic downturn. The principal and agent agree upon a compensation contract presuming the normal environment will prevail. The state of the world is revealed after they have entered into the contract, but before the agent takes any payoff-relevant action. If the normal state of the world does actually obtain, the agreed-upon contract is implemented; if not, the contract is reset. The most significant difference between Saly's model and ours is that the interim state of the world in Saly's model is exogenous, and not related to an earlier action of the agent. Thus, there can be no "feedback" effect from resetting in her model, so the model cannot be meaningfully used to examine the relative optimality of pre-commitment and resetting strategies; indeed, it is apparent that pre-commitment is strictly suboptimal under Saly's assumptions.

Less directly related to our paper, but of definite relevance, is the extensive literature beginning with Hart and Moore [12] which has examined the impact of renegotiation on equilibrium outcomes when contracts are incomplete.[2] One branch of this literature (e.g., Aghion, et al [2], Hart and Moore [12], Hart and Tirole [16]) studies the problem of bilateral bargaining. A typical model involves a buyer and a seller who agree to a trade in the future under specified terms; however, the initial contract also specifies a mechanism for renegotiating these terms as interim information becomes available on the valuations of the item being traded to the parties. Allowing for renegotiation typically has an impact on equilibrium outcomes, but the precise nature of the effect is sensitive to the structure of the renegotiation game. Using a particular bargaining structure, for example, Hart and Moore [12] show that the opportunity to rescind the original contract may result in the first-best solution being attainable, but Aghion, et al [2] show that this situation is reversed if the game is appropriately modeified.

A second branch of the renegotiation literature has looked at the effect of recontracting on debt (e.g., Aghion and Bolton [1], Bolton and Scharfstein [4],[5], Gale and Hellwig [9], Hart and Moore [13],[14],[15]). A central point of this literature is that the possibility of renegotiation has a feedback effect that hurts ex-ante efficiency. Two kinds of default are considered in these models: *liquidity* defaults which occur when the firm does not have enough cash to meet its obligations, and *strategic* defaults, which arise from the non-verifiability of firm cash flows. Debt structures that lead to inefficient renegotiation are beneficial in that they deter strategic default, but they are also costly if defaults are liquidity-driven and beyond the manager's control. The objective of this literature, therefore, is to design a debt contract and renegotiation process that is sufficiently flexible to ensure that the costs of liquidity defaults are not excessive, while simultaneously keeping in check the incentives for strategic defaults. As one example, Bolton and Scharfstein [5] use the number of creditors who affect the outcome of debt renegotiation following default as the variable with which to achieve this.

[2]Our references to this literature are only meant to be indicative. They are by no means complete.

A closely related issue concerns the design of bankruptcy procedures, i.e., the legal framework that governs the breach of debt contracts. In the US, many features of the bankruptcy law, such as the automatic stay provision and debtor-in-possession financing, are structured to provide the debtor with a high probability of renegotiating the existing contract and continuing as a reorganized firm. The bankruptcy systems in the UK, Germany, and Japan are structured to allow the secured creditor to seize the assets on bankruptcy so that the renegotiation of the debt contract is not an important component of the insolvency code. (See, e.g., Franks, Nyborg, and Torous [8] or Kaiser [17].) As we have discussed in the Introduction, systems that favor renegotiation increase the probability of efficient continuations in the event of default, but at the cost of encouraging the occurrence of default. In this sense, the trade-offs involved in designing an optimal bankruptcy system are similar to those tackled in the debt-recontracting literature. However, one issue that has received relatively little attention is the impact of debt contract or insolvency code design on project choice itself, i.e., the nature of risk-shifting incentives that arise.

The emphasis in all of these areas on the impact of the feedback effects of recontracting on initial equilibrium outcomes is similar to our own, but the focus of these papers and the models employed are evidently very different from ours. Some of these differences bear highlighting here. The issue of pre-commitment vs. recontracting is not a central area of concern in debt contract design; rather, the emphasis is on the renegotiation process that minimizes ex-ante inefficiency. In contrast, the renegotiation process is not of primary concern to us: it is natural in our setting to allocate the right to reset the contract exclusively to the principal as the writer of the option. Moreover, pre-commitment to never resetting can also be credibly accomplished in our setting, by including a condition in the original contract that its terms are immutable. A second important difference concerns the models themselves. Moral hazard in our framework arises from the dependence of the firm's cash flow distribution on the effort-averse manager's actions. In much of the recontracting literature, the cash flow process is treated as exogeneous; moral hazard arises from the non-verifiability of the cash flows, that is, from the manager's ability to effect strategic defaults. Thus, the "shirking" or risk-shifting incentives of the renegotiation process are not examined.

3 The Model

We consider a two-period model of firm value with dates indexed by $t = 0, 1, 2$. Our model is intended to capture the impact of information revelation in the interim between inception of a compensation contract and its culmination. To this end, we assume that all payoffs in our model are received only at the terminal date $t = 2$. This enables the interim date $t = 1$ to serve purely as an information event concerning final outcomes that provides a basis for resetting the terms of the initial contract.

The specifics of the model we study are directly motivated by the popular binomial model of asset-pricing theory. It might help to refer to Figure 1 while going through the description below. The firm in our model belongs to an entrepreneur (the "principal") who employs a manager (the "agent") for the two periods. The initial investment in the firm is normalized to unity. There is a single liquidating cash flow from the firm at $t = 2$. This cash flow may have three possible values: H^2, $HL = LH$, and L^2, where $H > 1 > L$. The probabilities of these cash flows depend on the actions (effort levels) taken by the manager in each of the two periods. We elaborate on this below.

The manager's set of possible actions in each period is $A = [0, \bar{a}]$. In the first period, the manager takes an action $a \in A$. Subsequent to this action, a public signal $s \in \{H, L\}$ is observed concerning the terminal cash flows. If the signal H is observed, then terminal cash flows will be either H^2 or HL; if the signal is L, then terminal cash flows will be either LH or L^2. After observing the signal, the manager chooses his second-period action; we will denote by a_h the action following the signal H, and by a_l the action following the signal L.

The probabilities of the signals and of the final cash flows depend on the actions taken by the manager. Given the initial period action a, the signal H is observed with probability $p(a)$ and the signal L with probability $q(a) = 1 - p(a)$. If H occurs and the manager follows it up with the action a_h, then the terminal cash flow H^2 is realized with probability $p(a_h)$ and the cash flow HL with probability $q(a_h) = 1 - p(a_h)$. Similarly, if L occurs and the manager follows it with the action a_l, the cash flows LH and L^2 are observed with probabilities $p(a_l)$ and $q(a_l) = 1 - p(a_l)$, respectively. Throughout, it is assumed that $p(\cdot)$ is an increasing function, i.e., that higher actions result in superior cash flows.

Figure 1 describes in a diagram the evolution of information over the model's horizon and the final cash flows that result along the various paths together with their probabilities.

Taking the action a in any period also results in a cost or disutility to the manager of $c(a)$, where $c(\cdot)$ is an increasing function of a. The manager's compensation at the terminal node could depend on the path of firm value up to that point. Let $\mathcal{W} = (w_{hh}, w_{hl}, w_{lh}, w_{ll})$ denote a typical compensation profile for the manager, i.e., a typical vector of contingent payoffs at the four terminal nodes. The manager's objective is to choose an initial action a, and contingent continuation actions a_h and a_l at the nodes H and L, respectively, to maximize the discounted expected value of his compensation net of the costs of these actions.

As is usual, we assume the principal to be risk-neutral. The principal takes into account the manager's response to any initial offer, and selects a compensation profile that will maximize his own initial expected utility, viz., the discounted expected terminal value of the firm, net of the manager's compensation. We elaborate on both of these optimization problems below. To keep notation simple, we shall set all discount rates in the model to zero. We will also assume that the principal–manager relationship lasts the full two periods. This is a reasonable assumption in our framework, since ours is essentially a one-period model with an interim information event. Nonethless, in Section 7, we look at the impact of allowing either the principal or the manager to sever the relationship upon revelation of the interim information. We find that while this complicates exposition significantly, under very reasonable conditions it does not have an impact on the qualitative nature of our results.

3.1 Equilibrium

We describe the manager's best-response problem first. Let $\mathcal{W}$ be the compensation profile anticipated by the manager. Note the fundamental point that the anticipated compensation vector need not be the same as that offered by the principal at time $t = 0$ if the manager expects that resetting will take place at time $t = 1$ (this anticipation of future changes is precisely what causes the feedback effect of resetting); we will discuss the relation between the offered and anticipated compensations in greater detail below. Throughout the paper, we will require that compensation be non-negative in all states of the world.[3] Now, given $\mathcal{W}$ and any action vector $\mathcal{A} = (a, a_h, a_l)$, the manager's *continuation* utility from H, denoted U_h, is given by

$$U_h \;=\; p(a_h)w_{hh} + q(a_h)w_{hl} - c(a_h). \tag{3.1}$$

The manager's continuation utility U_l from L is analogously defined. Thus, the manager's initial expected utility from $\mathcal{W}$ and $\mathcal{A}$ is

$$U \;=\; p(a)U_h + q(a)U_l - c(a). \tag{3.2}$$

It is immediate from these expressions that in response to the anticipated offer $\mathcal{W}$, the manager's optimal actions at the nodes H and L, denoted a_h^* and a_l^*, say, must satisfy:

$$a_h^* \;=\; \arg\max_{a_h} U_h(a_h, w_{hh}, w_{hl}) \qquad a_l^* \;=\; \arg\max_{a_l} U_l(a_l, w_{lh}, w_{ll})$$

Therefore, letting $U_h^* = U_h(a_h^*, w_{hh}, w_{hl})$ and $U_l^* = U_l(a_l^*, w_{lh}, w_{ll})$, the optimal initial action a^* is defined by:

$$a^* \;=\; \arg\max_a U(a, U_h^*, U_l^*)$$

Now, given a compensation profile $\mathcal{W}$ and the manager's response $\mathcal{A} = (a, a_h, a_l)$ to it, the principal's continuation utility from H, denoted V_h, is given by

$$V_h \;=\; p(a_h)[H^2 - w_{hh}] + q(a_h)[HL - w_{hl}]. \tag{3.3}$$

The principal's continuation utility V_l from L is defined analogously. Therefore, the principal's initial expected utility (or *value*) V is

$$V \;=\; p(a)V_h + (1 - p(a))V_l. \tag{3.4}$$

[3]The effective assumption here is that the manager has finite wealth and cannot be made to pay the principal arbitrarily large sums of money as negative compensation; that is, his payoff in each state must be bounded from below. The choice of zero as lower bound is made for analytical convenience.

The principal chooses an initial offer $\mathcal{W}$ to maximize V taking into account the manager's reaction to $\mathcal{W}$. The latter depends, in turn, on the extent of resetting anticipated by the manager. There are at least three interesting cases to be considered in this regard.

Case 1. Pre–Commitment

The first case of interest is the analog of the situation where the corporation granting stock options commits to not changing the strike price of the options regardless of what may transpire during the option's life. In our model, this is equivalent to the principal offering an initial compensation vector $\mathcal{W}$ and committing to never resetting the contract. Under such pre-commitment, the manager's anticipated compensation vector $\mathcal{W}$ is precisely the initial one that is offered by the principal. Thus, for each initial offer $\mathcal{W}$, the manager's response $\mathcal{A}^*(\mathcal{W})$ is known, and the principal simply chooses $\mathcal{W}$ to maximize (3.4).

Case 2. Full Flexibility

At the other extreme is the situation where the principal fully retains the right to amend the terms of the compensation contract in any direction at $t = 1$. (Any offer at $t = 1$ is, of course, taken to be firm, that is, it cannot be altered at $t = 2$. The problem is trivial otherwise.) In this case, it is evident that at $t = 1$, the principal will choose a compensation contract for the continuation that maximizes his continuation payoff from that point, regardless of the initial ($t = 0$) offer that was made. Suppose, for example, the node H has been reached at $t = 1$. Given any offer (w_{hh}, w_{hl}) at this point, the manager chooses a_h^* to solve $\max_{a_h} U_h(a_h, w_{hh}, w_{hl})$. Taking into account the manager's response to any offer (w_{hh}, w_{hl}), the principal then solves for the offer at H that maximizes $V_h(a_h^*, w_{hh}, w_{hl})$. The solution at the node L is analogous. Thus, at time $t = 0$, the manager will regard any initial offer that does not coincide with these continuation offers as irrelevant, and will choose his initial action to maximize his expected utility taking these continuation offers as the anticipated compensation vector. This completely determines equilibrium outcomes.

Case 3. Reincentivization

A third case, of interest in its own right but especially relevant for us here, is motivated by the observation that resetting of previously-issued stock options in practice is overwhelmingly associated with *underwater* options; contract terms are almost never reset after good performance when options are in-the-money. The analog in our model is where the principal offers an initial compensation vector $\mathcal{W}$, and retains the right to revise the compensation "upwards" in the manager's favor at $t = 1$, i.e., to alter the contract provided the revision also benefits the manager by increasing his continuation utility. This case of partial flexibility corresponds precisely to a situation where the principal wishes to reset incentives for demotivated employees in order to improve continuation outcomes, but otherwise leaves the contract untouched; accordingly, we shall refer to it as the strategy of *reincentivization* or *resetting*.

The essential difference between reincentivization strategies and fully flexible ones may be put another way. The latter class of strategies effectively presumes that the principal can unilaterally alter the terms of the initial contract. The former, on the other hand, makes the more realistic assumption that the manager also has some bargaining power, and, in particular, can veto contract changes; equivalently, the principal cannot rescind the original contract except at substantial cost.

Solving for equilibrium outcomes under reincentivization is a little more complex than in the other two cases. Given an initial offer $\mathcal{W}$, we first solve for the manager's continuation utilities from H and L under $\mathcal{W}$. Then, from each node, we maximize the principal's expected continuation utility over feasible continuation compensation vectors taking as given the manager's optimal response to each offer, and subject to the constraint that the new offer must offer the manager at least as much continuation utility as $\mathcal{W}$. Of course, the principal's and manager's expected utilities in this solution depend on the continuation payoffs associated with the original offer $\mathcal{W}$; this provides us an expression for the initial expected utilities in terms of $\mathcal{W}$. We then maximize the principal's initial expected utility over all offers $\mathcal{W}$ to recover the initial equilibrium offer.

3.2 A Preliminary Observation

In the sections that follow, we compare equilibrium outcomes under these different regimes. One point of interest before proceeding with this analysis is a simple observation that reduces the cases we have to consider in the sequel. For the purpose of emphasis, we raise it to the level of a proposition.

Proposition 3.1 *From the principal's standpoint, equilibrium value under full flexibility is weakly dominated by both pre-commitment and reincentivization, i.e., the principal's value under full flexibility is never higher, and could be strictly smaller, than under the two alternatives.*

Proof Let $\mathcal{W}^* = (w^*_{hh}, w^*_{hl}, w^*_{lh}, w^*_{ll})$ be an equilibrium compensation vector under full flexibility. ($\mathcal{W}^*$ is the realized compensation vector that is obtained by solving for the principal's optimal continuations from H and L.) Then, $\mathcal{W}^*$ is a feasible initial offer under pre-commitment, but evidently need not be an optimal one. It is immediate that pre-commitment weakly dominates full flexibility from the principal's standpoint.

Under reincentivization, one possible strategy for the principal is to make an initial offer of $\mathcal{W}_0 = (0, 0, 0, 0)$, and then to revise it to $\mathcal{W}^*$ at time $t = 1$. (Revision to $\mathcal{W}^*$ is clearly an optimal continuation for the principal given the initial offer of $\mathcal{W}_0$.) Of course, the optimal initial offer for the principal must provide at least as much value as under the initial offer of $\mathcal{W}_0$, so reincentivization also weakly dominates full flexibility.

It remains to be shown that the principal's value in some situations may actually be *strictly* worse under full flexibility. This is easy. It may readily be checked, for example, that the linear model of Section 5.1 is one such instance. □

Proposition 3.1 is related to the result in Hart and Moore [12] that renegotiation-proof contracts in the buyer–seller game typically dominate outcomes under ex-post bargaining (i.e., where contracts are written only after interim information is realized). Appealing to this result, we shall only compare the principal's outcomes under pre-commitment and reincentivization strategies in the sequel.

4 Unrestricted Compensation Structures

As the first step in our analysis, we consider the situation where there are no restrictions on the compensation vector $\mathcal{W} \in \mathbb{R}^4_+$ that the principal may offer the agent. In Proposition 4.1, we show that the weak superiority of pre-commitment over resetting may be easily established in this case. We then show that, for suitable parameterizations, resetting may even be *strictly* dominated.

Proposition 4.1 *If $\mathcal{W}$ is unrestricted, then pre-commitment can never make the principal worse off ex-ante. That is, the principal's time–0 value in any equilibrium under pre-commitment is never less than the corresponding level under reincentivization.*

Proof Let $\mathcal{W}^*$ denote the realized payoffs to the manager at the terminal nodes in any equilibrium under reincentivization, and let V^* be the principal's initial expected utility in this equilibrium. Under pre-commitment, the principal can always make an initial offer of $\mathcal{W}^*$, thereby guaranteeing a utility level of V^*. The optimal pre-commitment strategy must do at least as well. □

A natural question that arises from Proposition 4.1 is whether the principal is *strictly* better off from pre-committing to a compensation structure. In general, the answer to this question is in the negative: it is a simple matter to construct examples where the principal's equilibrium payoffs under the two regimes coincide. (As may readily be checked, the linear model of Section 5.1 is an instance.) Of interest, however, is that there do exist robust parameterizations in which pre-commitment performs strictly better than retaining the right to reincentivize the manager at time $t = 1$. One such model, which we shall call the "linear/quadratic model," is described below.

The Linear/Quadratic Model

The linear/quadratic model takes the action space for the manager to be the interval $[0, \bar{a}]$ for some $\bar{a} < 1$, and uses the following specifications for the functions $p(\cdot)$ and $c(\cdot)$:

$$p(a) = a, \tag{4.1}$$

$$c(a) = \frac{1}{2}ka^2, \qquad k > 0. \tag{4.2}$$

essence of Proposition 4.1 is that the former effect must always dominate the latter, at least weakly.

5 Commonly-Used Compensation Structures

It is well known that equilibrium contracts in principal/agent models may, in general, involve a significantly higher degree of complexity in state-dependence than is commonly observed in reality. Indeed, in practice, such dependence is usually introduced using a relatively simple array of instruments such as equity and call options on equity (which are typically set at-the-money at the time of issue). The difference is non-trivial from a modeling standpoint. Consider the case where the manager's compensation may only take the form of call options on the firm's terminal value. By way of analogy with at-the-money options, assume that any options awarded at time $t = 0$ have a strike of unity; and that if any options are reset at H or L, the new strike prices that apply are H and L, respectively. Finally, assume for specificity that $HL \geq 1$ (the illustration is equally stark if $HL < 1$), and denote by Y^+, the term $\max\{Y, 0\}$. If the manager's initial contract awards him the right to purchase a fraction α of the firm at time $t = 2$, and the contract is not reset at any point, then his payoffs at the four terminal nodes are given by

$$\begin{array}{rcccl} w_{hh} & = & \alpha \cdot (H^2 - 1)^+ & = & \alpha(H^2 - 1) \\ w_{hl} & = & \alpha \cdot (HL - 1)^+ & = & \alpha(HL - 1) \\ w_{lh} & = & \alpha \cdot (LH - 1)^+ & = & \alpha(LH - 1) \\ w_{ll} & = & \alpha \cdot (L^2 - 1)^+ & = & 0 \end{array} \tag{5.1}$$

On the other hand, Table 1 illustrates that unrestricted equilibrium contracts will not typically involve equality between w_{lh} and w_{ll}; they may, for instance, use low values of w_{hl} (to provide appropriate continuation incentives at H), but higher values of w_{lh} (to ensure a high action at L). Equation (5.1) implies that such fine gradations are no longer possible if the manager's terminal payoffs are to be defined through call options. Of course, a similar conclusion obtains even if we allow the use of other instruments (e.g., salary, equity) in addition to the options; all we really require, in general, is that the permitted instruments are not, in combination, sufficient to span the space of uncertainty.

Two consequences follow immediately from this. First, under these circumstances, the ability to reset the contract and reincentivize the manager has real "bite," since it expands the space of terminal payoffs that may be generated. Suppose, for instance, in the example under consideration, we allow the principal to reset the options at L, by replacing the α initial options with β new calls with a strike of L. The manager's terminal payoffs are then

Table 1: Pre-commitment vs Reincentivization with Unrestricted Compensation structures

This table describes the structure of equilibrium payoffs and actions under both pre-commitment and resetting in the quadratic model of Section 4.2. The base parameters are fixed at $H = 1.50$, $L = 0.80$, and $\bar{a} = 0.80$. Three values are considered for the quadratic cost parameter k. The remaining notation in the table is taken from the text: (i) V and U are, respectively, the principal's and agent's expected utilities in equilibrium, (ii) the four values of w represent the compensation to the agent at the four terminal nodes, and (iii) the three values of a the actions taken by the agent at the three decision nodes.

$k = 0.70$									
Regime	V	U	w_{hh}	w_{hl}	w_{lh}	w_{ll}	a	a_h	a_l
Pre-commitment	1.1403	0.2247	0.9790	0	0.0975	0	0.789	0.800	0.139
Resetting	1.1149	0.2374	0.9800	0	0.2800	0	0.720	0.800	0.400

$k = 0.75$									
Regime	V	U	w_{hh}	w_{hl}	w_{lh}	w_{ll}	a	a_h	a_l
Pre-commitment	1.0992	0.2039	0.9865	0	0.1229	0	0.719	0.800	0.164
Resetting	1.0800	0.2200	0.9923	0	0.2800	0	0.669	0.800	0.373

$k = 0.80$									
Regime	V	U	w_{hh}	w_{hl}	w_{lh}	w_{ll}	a	a_h	a_l
Pre-commitment	1.0635	0.1872	0.9965	0	0.1418	0	0.661	0.800	0.177
Resetting	1.0486	0.2043	1.0044	0	0.2800	0	0.623	0.800	0.350

The derivation of the equilibrium under either regime in this model involves a considerable degree of algebraic detail. In the interests of expositional continuity, we present the details in Appendix A. For specific values of the parameters H, L, and $\bar{a}$, and a range of values of the cost parameter k, Table 1 describes the structure of equilibrium payoffs and actions that arise in the model.

Several features of the table are noteworthy; in particular, the table provides an excellent illustration of the trade-offs inherent in reincentivization. Note, first of all, that pre-commitment does *strictly* dominate resetting ex-ante from the principal's standpoint for the chosen parameter values; this establishes the claim made at the top of this section. Second, observe that, as one might anticipate, the superior performance under pre-commitment is enforced by threat of a poor continuation from L: in all cases in the table, the value of w_{lh} is lower under pre-commitment than under resetting. This has two consequences. On the one hand, there is the feedback effect on the initial action a: the value of a is, in all cases, lower under resetting than under pre-commitment. On the other hand, there is the reincentivization effect: the continuation action a_l at L is always higher under resetting. Of course, the given by

$$\begin{array}{lllll} w_{hh} & = & \alpha \cdot (H^2 - 1)^+ & = & \alpha(H^2 - 1) \\ w_{hl} & = & \alpha \cdot (HL - 1)^+ & = & \alpha(HL - 1) \\ w_{lh} & = & \beta \cdot (LH - L)^+ & = & \beta(LH - L) \\ w_{ll} & = & \beta \cdot (L^2 - L)^+ & = & 0 \end{array} \tag{5.2}$$

We now have $w_{lh} > w_{hl}$ if $\beta \geq \alpha$ (indeed, even if $\beta < \alpha$ as long as $\beta \geq \alpha(HL-1)/(HL-L)$).

Second, the proof of Proposition 4.1 (the weak dominance of pre-commitment) no longer holds, since—as we have just seen—not every terminal payoff structure that can be generated under a strategy that permits reincentivization is a feasible initial offer under pre-commitment. Of course, this does not, by itself, mean that the proposition is necessarily false. Although reincentivization does permit a larger class of terminal payoff structures for the manager, such strategies are, unlike pre-commitment, also constrained by the requirement of avoiding "incredible" continuation payoffs; the negative feedback effect this causes could outweigh the advantage of being able to reset in the continuation.

In this section, we reexamine the optimality of pre-commitment strategies when terminal payoffs may only be generated using a limited range of instruments.[4] We limit attention to the case where compensation may only take on the form of at-the-money call options. It should be clear that this is an assumption made only in the interests of analytical simplicity; similar conclusions should obtain as long as the admissible range of instruments does not span the space of uncertainty. However, incorporating multiple compensation instruments into our model will greatly reduce tractability: it increases the number of choice variables in the principal's optimization problem, and may necessitate an expansion of the number of terminal states to maintain the non-spanning condition. Secondly, also in the interests of analytical simplicity, we will make the assumption that $HL < 1$; this simplifies payoffs in (5.1)–(5.2) by ensuring that $w_{hl} = w_{lh} = 0$ in the first case, and $w_{hl} = 0$ in the second.[5] Finally, we assume that under pre-commitment no new options may be granted at time $t = 1$. This is consistent with the finding in Brenner, et al [6] that resetting does not appear to be a substitute for the granting of new options. It is also necessary for meaningful analysis since our model cannot formally distinguish between a new option grant at $t = 1$ and one that is reset.

Our analysis proceeds in two stages. In Subsection 5.1, we consider a "linear" family of models and show that for any parameter values in this class, a complete reversal of Proposition 4.1 takes place: pre-commitment strategies are now *strictly* dominated by those that

[4] Analogous restrictions have also been considered by other authors working in a principal–agent setting. See, e.g., Gorton and Grundy [11], who study the optimality of managerial entrenchment.

[5] The assumption that $HL \leq 1$ does not play an important role in obtaining our results. Qualitatively identical behavior emerged in the linear/quadratic model when we solved for equilibria using a numerical optimization package when $HL > 1$. However, closed-form solutions appear hard to obtain in this case, since the algebra becomes dense.

permit resetting! Although derived in a particular framework, the intuition driving this result extends more generally to situations where the manager's cost of effort is "small." We demonstrate this in Subsection 5.2 where we revisit the linear/quadratic model of Subsection 3.1, and show that for small values of the cost parameter, the optimality of resetting continues to obtain.

5.1 A Linear Model

Intuitively speaking, for reincentivization to dominate pre-commitment, we need a situation where the feedback effect of resetting is minimal, but where the effect of resetting on continuation payoffs is strong. Thus, we must identify a setting in which the manager's continuation utilities from resetting and not resetting do not differ widely (this will minimize the feedback effect); but where the manager's actions in the two cases differ substantially (so the principal gets the benefits of resetting). We describe in this subsection a model with linear payoffs for both players that meets these conditions, and show that reincentivization *strictly* dominates pre-commitment from the principal's standpoint.

We will take the space of feasible actions for the manager to be $[0, \bar{a}]$ for some $\bar{a} < 1$. As earlier, the function $p(\cdot)$ is taken to be $p(a) = a$. The "cost function" $c(\cdot)$ for the manager is also presumed to have a linear form: $c(a) = ka$ where $k > 0$. Finally, we will assume that $k < LH - L^2$. Without this restriction, the continuation from L is trivial since it will be unprofitable for the principal to ever offer a positive payoff to the manager. This completes the description of the model.

5.1.1 Equilibrium under Pre-Commitment

Let α be given. Then, the manager's terminal payoffs at the four nodes are given by (5.1). Therefore, at the node H, the manager's action a_h is determined as the solution to

$$\max_{a \in [0,\bar{a}]} [a \cdot \alpha(H^2 - 1) + (1 - a) \cdot 0 - ka].$$

It is immediate that a_h and the manager's continuation utility U_h from H are given by

$$a_h = \begin{cases} 0, & \text{if } \alpha(H^2 - 1) < k \\ \bar{a}, & \text{otherwise} \end{cases} \tag{5.3}$$

$$U_h = \begin{cases} 0, & \text{if } \alpha(H^2 - 1) < k \\ \bar{a}\alpha(H^2 - 1) - k\bar{a}, & \text{otherwise} \end{cases} \tag{5.4}$$

At L, regardless of the choice of α, the continuation payoffs for the manager are always zero. It follows trivially that a_l and U_l are given by

$$a_l = U_l = 0. \tag{5.5}$$

Finally, at the initial node, the manager solves $\max_{a \in [0,\bar{a}]} \{aU_h + (1-a)U_l - ka\}$. The optimal time–0 action, therefore, is

$$a = \begin{cases} 0, & \text{if } U_h - U_l < k \\ \bar{a}, & \text{otherwise} \end{cases} \tag{5.6}$$

Expressions (5.3)–(5.6) make clear the choices facing the principal. If the principal sets α so that $(U_h - U_l) < k$, then from (5.6), the node H is never reached, so from (5.5), the final outcome is L^2 with certainty. Thus, contingent on this case, the principal's best choice is to set $\alpha = 0$, which provides an initial expected utility to the principal of L^2.

On the other hand, suppose the principal sets α so that $U_h - U_l \geq k$. Since $k > 0$ and $U_l = 0$, this can happen only if $U_h > 0$, so U_h must be given by the second value in (5.4), i.e., $U_h = \bar{a}\alpha(H^2 - 1) - k\bar{a}$. Therefore, $(U_h - U_l) \geq k$ holds if and only if

$$\alpha \geq \frac{k(1+\bar{a})}{\bar{a}(H^2-1)}. \tag{5.7}$$

In addition, (5.4) implies that for U_h to be given by $\bar{a}\alpha(H^2 - 1) - k\bar{a}$, α must also satisfy $\alpha(H^2-1) \geq k$. Now, it is evidently in the principal's interest to have α as small as possible. An easy calculation shows that the least value of α that satisfies both of the required inequalities is when equality holds in (5.7). For this value of α, a further computation shows that the principal's initial expected utility is given by $[\bar{a}^2H^2 + \bar{a}(1-\bar{a})HL + (1-\bar{a})L^2 - k\bar{a}(1+\bar{a})]$. This is larger than L^2 if, and only if, $(\bar{a}H + L)(H - L) \geq k(1+\bar{a})$. But this last inequality always holds, since $k < HL - L^2$ by assumption, and $H > L$.

To sum up, therefore, the equilibrium under pre-commitment has the following values for α and the principal's initial expected utility V:

$$\alpha = \frac{k(1+\bar{a})}{\bar{a}(H^2-1)}. \tag{5.8}$$

$$V = \bar{a}^2H^2 + \bar{a}(1-\bar{a})HL + (1-\bar{a})L^2 - k\bar{a}(1+\bar{a}). \tag{5.9}$$

In this equilibrium, the manager takes the action $\bar{a}$ at the initial node and at the node H, but continues with $a_l = 0$ if the node L is reached.

5.1.2 The Superiority of Reincentivization

Under pre-commitment, the inability of the principal to reset the contract at L resulted in a continuation value of L^2 for the principal and zero for the manager. If resetting is possible, however, the principal may be able to induce a better action for the manager. Specifically, note that if the principal resets by offering β new at-the-money options, the manager's optimal action a_l in the continuation from L is

$$a_l = \begin{cases} 0, & \text{if } \beta(LH - L) < k \\ \bar{a}, & \text{otherwise} \end{cases}$$

It is evident that the optimal reset contract is either $\beta = 0$ or $\beta = k/(LH - L)$. If $\beta = 0$ (i.e., the principal does not reset), then the principal's continuation utility from L is, of course, $V_l = L^2$. On the other hand, if $\beta = k/(LH - L)$, we have $a_l = \bar{a}$, so the principal's continuation utility is

$$V_l = \bar{a}LH + (1 - \bar{a})L^2 - k\bar{a}. \tag{5.10}$$

This quantity is greater than L^2 under our assumption that $LH - L^2 > k$. Thus, it is optimal for the principal to reset at L (in particular, by setting $\beta = k/(LH - L)$), and this results in the continuation value (5.10) for the principal. The continuation value U_l for the manager is given by

$$U_l = \bar{a}\beta(LH - L) - k\bar{a} = 0. \tag{5.11}$$

Observe the important point that the manager's continuation utility from L in this case is the same as without resetting. This means that optimal resetting at L has no feedback effect on the manager's first period action.

Now, we have seen that the optimal initial offer when there is no resetting is given by

$$\alpha = \frac{k(1 + \bar{a})}{\bar{a}(H^2 - 1)}. \tag{5.12}$$

Suppose the principal were to make the initial offer (5.12) when resetting is permitted. We will show that the principal's time–0 expected utility from making this initial offer is strictly larger than his time–0 expected utility in the pre-commitment equilibrium. Since (5.12) is a feasible, but not necessarily optimal, initial offer in this case, the superiority of reincentivization over pre-commitment in this setting is proved.[6]

It is easy to check that if the principal makes the initial offer α as defined by (5.12), it is optimal for the principal to never reset contingent on reaching H, but to reset to $\beta = k/(LH - L)$ options with a strike of L if the node L is reached. As a consequence:

1. The principal's continuation utility V_h from H under this strategy is the same as in the pre-commitment equilibrium.

[6]In fact, it is not very hard to verify that (5.12) is also the equilibrium initial offer under resetting, and that the principal's value V in this equilibrium is given by $[\bar{a}H + (1 - \bar{a})L]^2 - 2\bar{a}k$. This is strictly greater than the corresponding pre-commitment level (5.9) as long as $LH - L^2 - k > 0$, which is a maintained hypothesis.

2. The principal's continuation utility V_l from L (given by (5.10)) is strictly higher than the continuation level of L^2 in the pre-commitment equilibrium.

3. Resetting at L does not change the manager's continuation utility U_l from L (see (5.11)), so the manager's first-period incentives are unaffected, and his first-period action continues to be given by $\bar{a}$.

It is immediate from this that the principal's time–0 value under reincentivization from the feasible initial offer α is strictly larger than that in the pre-commitment equilibrium. This completes the proof.

5.2 The Linear/Quadratic Model Revisited

Reincentivization proved superior to pre-commitment in the linear model because it was possible to change continuation behavior of the manager without affecting the manager's expected continuation utility. Of course, this may not be feasible in other settings; that is, resetting may have a non-trivial feedback effect that weakens initial incentives. In such situations, to restore the manager's incentives in the initial period, the initial offer would have to be raised, so that the manager receives a higher continuation value at H. Evidently, whether this is profitable or not for the principal depends on the amount by which the utility "spread" $U_h - U_l$ has to be raised to restore initial incentives. If a moderate increase in the utility spread has a substantial effect on the manager's actions, we would expect the principal to be able to profitably implement a change in the initial incentives, leading to resetting dominating pre-commitment.

Of course, the impact of a small change in the utility spread on initial actions depends ultimately on the manager's cost function; thus, when costs are "small" relative to their productivity impact, we would expect to resetting to be superior. In this subsection, we demonstrate this point in the context of the linear-quadratic model of Section 4;[7] of course, we work with the added proviso that compensation structures be defined as in (5.1)–(5.2).

Recall that in the linear–quadratic model, the functions $p(\cdot)$ and $c(\cdot)$ are given by $p(a) = a$ and $c(a) = \frac{1}{2}ka^2$, respectively. Under these parametrizations, Section B below describes in detail the derivation of equilibrium under both pre-commitment (Section B.1) and reincentivization (Section B.2). A priori, we would guess that if the parameter k of the cost function is sufficiently small, then it should be possible to make up for the feedback effect, since a small increase in the continuation utility at H should in this case have a large impact on the initial action. Thus, resetting should emerge as the dominant strategy for the principal. As k increases, however, ever-larger payouts are required to make up for the feedback effect, and we would expect pre-commitment to do better.

[7]The same result could also, obviously, be derived in an extension of the linear model of the last section in which the cost function has the form $c(a) = \ell a + ma^2$.

Table 2: Pre-commitment vs Reincentivization with Options-based Compensation

This table describes the structure of equilibrium payoffs and actions under both pre-commitment and resetting in the linear/quadratic model of Section 5.2. The base parameters are fixed at $H = 1.20$, $L = 0.833$, and $\bar{a} = 0.90$. Three values are considered for the quadratic cost parameter k. The remaining notation in the table is taken from the text: (i) V and U are, respectively, the principal's and agent's expected utilities in equilibrium, and (ii) α is the number of at-the-money options in the initial offer, and (iii) β is the number of at-the-money options offered under the reincentivization strategy when resetting at L.

$k = 0.050$				
Regime	V	U	α	β
Pre-commitment	1.2671	0.0203	0.165	0.000
Reincentivization	1.2723	0.0405	0.216	0.270

$k = 0.075$				
Regime	V	U	α	β
Pre-commitment	1.2378	0.0304	0.247	0.000
Reincentivization	1.2318	0.0608	0.324	0.405

$k = 0.100$				
Regime	V	U	α	β
Pre-commitment	1.2084	0.0405	0.330	0.000
Reincentivization	1.1913	0.0810	0.432	0.540

That this intuition is correct is borne out in Table 2. The table summarizes the structure of equilibrium payoffs and compensation offers for specified parameter values. Three values of k are considered, chosen to highlight the importance of this parameter in the choice between pre-commitment and resetting. For this range of parameter values, equilibrium values and option awards have the following form (C and R denote pre-commitment and resetting, respectively):

$$V_C = L^2 + \bar{a}[HL - L^2 + \bar{a}(H^2 - HL) - k\bar{a} - k\bar{a}^2/2]. \tag{5.13}$$

$$V_R = L^2 + 2\bar{a}\left[HL - L^2 - \bar{a}k\right] + \bar{a}^2(H - L)^2. \tag{5.14}$$

$$\alpha_C = 2k(2 + \bar{a})/[2(H^2 - 1)]. \tag{5.15}$$

$$\alpha_R = k(1 + \bar{a})/(H^2 - 1) \qquad \beta_R = (\bar{a}k)/(HL - L) \tag{5.16}$$

Since β_R is strictly positive, resetting is strictly preferable to not resetting in the continuation from L. Of course, this has an unfavorable feedback effect of weakening initial incentives by lowering the utility "spread" $(U_h - U_l)$ for the manager. To compensate for this, the initial value of α is substantially higher under resetting than under pre-commitment.

At low values of k, it is possible to use this higher value of α to compensate for the feedback effect, so resetting emerges clearly superior. (See, e.g., the equilibrium outcomes corresponding to $k = 0.050$ in the table.) As k increases, the gap between the regimes narrows, and the two are roughly equal from the principal's standpoint at the middle value of $k = 0.075$. At still higher values of k, pre-commitment becomes uniquely dominant.

6 Background Noise, Managerial Control, and Resetting

An issue often raised in the context of resetting is the influence of "macro" (economy-wide or industry-wide) factors on corporate performance and share prices. Such factors are, by definition, beyond the manager's control, and are sometimes cited as a justification for resetting. We examine the validity of this argument in this section. In a nutshell, we find that external factors play a significant role in determining the relative optimality of resetting strategies; in particular, that resetting may become more—not less—optimal as the impact of these factors increases.

To capture the effect of external factors on outcomes in our model in a simple and efficient manner, we will adopt the following specification for the function $p(\cdot)$:

$$p(a) = m + \xi a, \tag{6.1}$$

where m and ξ are non-negative constants.[8] The parameter m represents the influence of external (or "market") factors on firm returns: it places a lower bound on the probability of L and an upper bound on the probability of H. As such, it represents "background risk" for the manager that cannot be eliminated. A lower value of m increases this risk since it results, ceteris paribus, in a higher probability of L and a lower probability of H. The parameter ξ, on the other hand, measures the relative productivity of the manager in determining returns. When $\xi = 0$, the manager's action is irrelevant; returns are entirely determined by the market factors with m determining the relative likelihood of high states. As ξ increases, the manager's role becomes progressively more important relative to the market factors: other things being equal, a higher value of ξ results in a higher probability of H and a lower probability of L. Thus, the simple specification (6.1) offers a rich menu of overall possibilities.

The specification (6.1) is also particularly advatageous from an analytical standpoint. When the cost structure is quadratic, equilibria under (6.1) may be identified by essentially retracing the steps in Section B with a few marginal changes. To see this, consider node H (for example), and suppose that the manager will receive w_{hh} and w_{hl}, respectively, at the terminal nodes H^2 and HL. Then, when $p(a) = a$ (as was assumed in Section B), the manager picks $a \in [0, \bar{a}]$ to maximize $aw_{hh} + (1-a)w_{hl} - \frac{1}{2}ka^2$, or what is the same thing,

$$w_{hl} + a[w_{hh} - w_{hl}] - \frac{1}{2}ka^2. \tag{6.2}$$

Under (6.1), the manager maximizes $(m + \xi a)w_{hh} + (1 - m - \xi a)w_{hl} - \frac{1}{2}ka^2$, or, equivalently,

$$[mw_{hh} + (1-m)w_{hl}] + \xi a[w_{hh} - w_{hl}] - \frac{1}{2}ka^2. \tag{6.3}$$

Both (6.2) and (6.3) are quadratic optimization problems in a. The only differences in these exercises are trivial ones, viz., the size of the constant term (which is relevant only for computing the maximized value) and the scaling of the linear term in (6.3) by the factor ξ.

Given this, we will not repeat the details involved in identifying equilibria in this problem, focussing instead on the properties of equilibrium under pre-commitment and under resetting. Table 3 summarizes for a range of parameter values the equilibrium values of the principal's and agent's ex-ante expected utilities and the compensation contracts under either regime. The table considers three equally-spaced values for ξ ranging from 0.35 to 0.55, and seven equally-spaced values for m ranging from 0.250 to 0.400. For the parameter values in the table, equilibrium values and option awards are given by the following expressions (C and R denote pre-commitment and resetting):

$$\begin{aligned} V_C &= L^2 + m(HL - L^2) \\ &\quad + (m + \xi\bar{a})[(1-m)(HL - L^2) + (m + \xi\bar{a})(H^2 - HL) - k\bar{a}/\xi - k\bar{a}^2/2] \end{aligned} \tag{6.4}$$

[8]To avoid irrelevancies, it is implicit in what follows that m, ξ, and $\bar{a}$ always satisfy $m + \xi\bar{a} \leq 1$.

Table 3: The Effect of Background Risk on Equilibrium Outcomes

This table describes the structure of equilibrium payoffs and actions under both pre-commitment and resetting under the specifications of Section 6. The base parameters are fixed at $H = 1.20$, and $L = 0.833$. Three values are considered for the parameter ξ in (6.1): 0.35, 0.45, and 0.55. ξ is the measure of manager's influence to background noise in generating outcomes. The cost parameter is taken to be $k = 0.025$. The subscripts R and C refer to "resetting" and "pre-commitment," respectively. The remaining notation in the table is as in the text: (i) V and U are, respectively, the principal's and agent's expected utilities in equilibrium, (ii) α is the number of options in the initial offer; and, (iii) under resetting, β is the number of options in the reset offer.

Equilibrium Outcomes: $\xi = 0.35$							
m	0.250	0.275	0.300	0.325	0.350	0.375	0.400
V_R	1.010	1.026	1.042	1.058	1.075	1.091	1.108
V_C	1.000	1.018	1.038	1.058	1.079	1.099	1.119
U_R	0.052	0.056	0.059	0.062	0.065	0.068	0.072
U_C	0.026	0.028	0.029	0.031	0.033	0.034	0.036
α_R	0.405	0.394	0.384	0.374	0.366	0.358	0.350
α_C	0.299	0.287	0.275	0.264	0.254	0.245	0.237
β_R	0.386	0.386	0.386	0.386	0.386	0.386	0.386

Equilibrium Outcomes: $\xi = 0.45$							
m	0.250	0.275	0.300	0.325	0.350	0.375	0.400
V_R	1.087	1.104	1.122	1.139	1.157	1.175	1.193
V_C	1.070	1.092	1.113	1.135	1.157	1.179	1.201
U_R	0.045	0.048	0.050	0.053	0.055	0.058	0.060
U_C	0.023	0.024	0.025	0.026	0.028	0.029	0.030
α_R	0.287	0.281	0.275	0.269	0.264	0.259	0.255
α_C	0.209	0.201	0.194	0.187	0.181	0.175	0.170
β_R	0.300	0.300	0.300	0.300	0.300	0.300	0.300

Equilibrium Outcomes: $\xi = 0.55$							
m	0.250	0.275	0.300	0.325	0.350	0.375	0.400
V_R	1.163	1.182	1.200	1.219	1.238	1.257	1.276
V_C	1.148	1.171	1.194	1.217	1.240	1.264	1.288
U_R	0.041	0.043	0.045	0.047	0.049	0.051	0.053
U_C	0.020	0.021	0.022	0.023	0.024	0.025	0.027
α_R	0.218	0.214	0.210	0.206	0.203	0.200	0.197
α_C	0.156	0.151	0.146	0.141	0.137	0.133	0.130
β_R	0.245	0.245	0.245	0.245	0.245	0.245	0.245

$$V_R = L^2 + 2(m + \xi\bar{a})[HL - L^2 - \bar{a}k/\xi] + (m + \xi\bar{a})^2(H - L)^2. \tag{6.5}$$

$$\alpha_C = \bar{a}k(1 + \bar{a}\xi/2)/[\xi(m + \xi\bar{a})(H^2 - 1)]. \tag{6.6}$$

$$\alpha_R = \bar{a}k(1 + m + \bar{a}\xi)/[\xi(m + \xi\bar{a})(H^2 - 1)] \quad \beta_R = \bar{a}k/[\xi(HL - L)]. \tag{6.7}$$

Several characteristics of Table 3 stand out. We will first discuss the behavior of equilibirum outcomes as m changes, and then as ξ changes. Concerning the former, the principal's equilibrium values V_R and V_C display two strong monotonicity properties. First, V_R and V_C are each monotone *increasing* in m. Second, the *difference* $V_R - V_C$ between these values *decreases* monotonically as m increases: in all three panels, this difference is strictly positive for small values of m and strictly negative at larger values. The first property is intuitive; it obtains from the feature that, ceteris paribus, an increase in m raises the probability of H.

The second property is more interesting; in words, it states that the *relative* optimality of resetting increases as market factors become more important. To understand what might drive this behavior, it helps to think about the issue intuitively. An increase in background risk, in general, makes a risk-averse manager worse off. This means that conditional on resetting occurring at some node, an increase in background risk lowers the manager's continuation utility from that point. The lower continuation utility implies, in turn, that resetting has a smaller feedback effect. As a consequence, resetting is more likely to be optimal from an ex-ante standpoint. Put in our notation, this says that the relative importance of resetting may be greater, the lower the value of m, which is, of course, precisely the case in our model. Note that, as one might expect from this intuitive argument, the manager's equilibrium expected utility levels are lower when background risk is larger: in all three panels in Table 3, both U_R and U_C fall as m decreases. Similarly, the initial option awards α_R and α_C both increase as m decreases, reflecting the increased difficulty of incentivizing the manager as background risk increases.

Turning now to behavior in ξ, note that V_R and V_C are both increasing in this parameter. As with m, this monotonicity is intuitive: higher values of ξ mean, ceteris paribus, higher probabilities of H. Less intuitive at first sight is the fact that the manager's expected utility *decreases* as his productivity ξ increases, as do the sizes of the initial and continuation option awards. To see why this might occur, consider, e.g., the case of resetting. In the continuation from L, it is evidently easier to incentivize the agent if ξ is higher; consequently, the reset award sizes β_R are lower as ξ increases. These lower values of β_R may result in a lower continuation utility for the agent despite the higher productivity factor; this is, in fact, the case in our model. The lower continuation utilities result in a lower feedback effect. With a higher ξ and a lower feedback effect, incentivizing the agent in the first period is facilitiated, so the equilibrium values of α_R decline as ξ increases. This results in our model in lower ex-ante expected utility levels for the manager at higher productivity levels.

Similarly, the relative optimality of resetting $V_R - V_C$ is also not monotone in ξ. When background risk is large (i.e., m is small), this difference is positive and first increases, then decreases in ξ. At larger values of m, the pattern reverses: the difference is negative, and first decreases, then increases. This behavior is a consequence of the fact that the feedback effect depends on the interaction of two factors, m and ξ, and this interaction could be complex. For instance, at low values of m, a small increase in ξ contributes relatively more to increasing the probability of H than at large values of m. No general lesson may, therefore, be drawn concerning the relative optimality of resetting as managerial control over returns distributions increases.

7 Extensions of the Model

This section discusses extensions and modifications of our basic model, focusing on the impact such changes in the model structure may have on the qualitative nature of our results. We discuss three issues: (i) allowing for modification of only the strike price during resetting (and not also the number of options); (ii) allowing the principal to fire the manager at the interim time point $t = 1$; and (iii) allowing the manager to quit at the interim time point $t = 1$.

7.1 Changing only the Strike Price

In our model, we have assumed that the resetting process may change not only the strike price of the existing options, but also the number of options itself; that is, the new options do not have to be exchanged for the old options on a 1–for–1 basis. Although this does sometimes happen in practice,[9] it is more typically the case that only the parameters of the options are changed, and not the number held (Brenner, et al [6] report, for instance, that resetting left the number of options unchanged in 89% of their sample).

Requiring that resetting only involve changes to the options' characteristics and not their number has an obvious impact on what may be achieved under reincentivization strategies. In the linear model, for instance, it is no longer possible to guarantee that resetting has no feedback effect. Nonetheless, our results are not substantially affected by adding this constraint. Most importantly, it remains true that from the principal's viewpoint outcomes under resetting may, depending on the parameterizations, strictly dominate those under pre-commitment.

Table 4 illustrates this point. The table describes equilibrium outcomes in the linear/quadratic model with option-generated payoffs under the requirement that the number of options awarded be immutable. Qualitatively, even with the added constraint, the results are similar to those of Table 2. The principal prefers resetting to pre-commitment for "low" values of the cost parameter k, while pre-commitment emerges superior at high values; in all cases, the manager is again better off under resetting. And, once again on account of the

[9] For instance, IBM in 1993 offered its managers the opportunity to exchange their previously-issued options for new options with lower strikes at a 5:2 ratio.

Table 4: Pre-commitment v Reincentivization with Options-based Compensation

This table describes the structure of equilibrium payoffs and actions under both pre-commitment and resetting in the linear/quadratic model of Section 5.2 under the constraint that the number of options may not be altered in the resetting process. The base parameters are fixed at $H = 1.20$, $L = 0.833$, and $\bar{a} = 0.90$. Three values are considered for the quadratic cost parameter k. The remaining notation in the table is taken from the text: (i) V and U are, respectively, the principal's and agent's expected utilities in equilibrium, and (ii) α is the number of at-the-money options in the initial offer.

$k = 0.010$			
Regime	V	U	α
Pre-commitment	1.3141	0.0041	0.033
Reincentivization	1.3333	0.0119	0.054

$k = 0.080$			
Regime	V	U	α
Pre-commitment	1.2319	0.0324	0.264
Reincentivization	1.2336	0.0485	0.304

$k = 0.150$			
Regime	V	U	α
Pre-commitment	1.1497	0.0608	0.494
Reincentivization	1.1359	0.0909	0.570

feedback effect of resetting at L, the number of options initially awarded under resetting is significantly larger than that under pre-commitment.

7.2 Allowing Dismissal of the Manager

Our model presumes the principal/manager relationship lasts the full length of the horizon, in particular, that neither party may elect to terminate the relationship at $t = 1$. This is not an unreasonable assumption to make since our model is, in effect, a one-period model with an interim time point where information is received. Nonetheless, it seems worthwhile to examine the consequences of allowing a termination of the relationship, subsequent to the revelation of information. In this subsection, we examine the impact of allowing the principal to fire the manager at time–1; the subsection immediately following looks at the case where the manager can quit at this interim point. We argue in either case that, under reasonable assumptions, the addition of these features complicates our model but does not add anything essential to the reincentivization-vs-feedback issue at the heart of this paper.

So suppose that the principal may elect to dismiss the incumbent manager after one period. We first analyze the case where the dismissed manager is replaced with an ex-ante identical manager, and where this replacement process is *costless* for the principal. We will show that, under these conditions, the pre-commitment and reincentivization strategies are *equivalent* from the principal's viewpoint.

Take any strategy for the principal when resetting is allowed. Consider the strategy under pre-commitment which makes the same initial offer, and then proceeds as follows: at any node where the resetting strategy fires the manager, the pre-commitment strategy also fires the manager; and at any node where the resetting strategy alters the terms of an existing contract, the pre-commitment strategy fires the manager, and offers the new manager the reset contract. Then, it is easy to see that the continuation payoffs for the principal from any node are never worse under pre-commitment than under resetting. Moreover, the initial incentives are evidently no weaker under pre-commitment. It is immediate that pre-commitment cannot do worse than resetting.

Conversely, take any strategy under pre-commitment. Consider the strategy under resetting which makes the same initial offer and proceeds as follows. The strategy fires the manager at any node where either (a) the pre-commitment strategy fires the manager, or (b) a Pareto-improving resetting is possible, but would have a negative feedback effect. (If resetting would also have a positive feedback effect, the strategy does not fire and resets accordingly.) The initial incentives are then no weaker under resetting than under pre-commitment, and the continuation payoffs are never worse for the principal. Conversely, resetting must do at least as well as pre-commitment. Thus, the two must be equivalent in equilibrium.

This equivalence may appear troubling at first blush, but it is driven by a single assumption of the model, viz., that the manager may be replaced costlessly in mid-stream with no accompanying productivity losses. In effect, this assumption presents the principal with a situation in which superior continuation payoff patterns can be generated without weakening initial incentives through a feedback effect. In practice, however, many costs exist which may drive a wedge between the continuation values that may be realized using incumbent managers and those obtainable by replacement.[10] There may be explicit costs such as hiring costs or costs associated with terminating the original contract. There may be implicit costs (i.e., productivity losses) such as the presence of learning-by-doing effects on account of which the new manager will not initially be as productive as the one replaced. There may be adverse selection considerations on account of which untried managers may have uncertain productivity characteristics.

In the presence of such costs, the optimal resetting of an existing contract will result in a strictly higher continuation payoff than replacing the manager and offering the new manager an optimal contract for the continuation; and, of course, the "tighter" the human resource constraint (i.e., the higher the explicit or implicit costs of replacment), the greater

[10]The presence of such costs would also then explain what would otherwise be irrational: why corporations may prefer to retain and reincentivize existing managers than replace them and offer the replacements appropriate initial incentives.

will be this difference. Allowing for resetting, thus, provides for superior continuations, but—via the feedback effect—have a negative effect on initial incentives. Conversely, pre-committing to firing the manager at certain nodes will provide superior initial incentives but poor continuation payoffs at those nodes. These trade-offs are precisely the ones at the heart of the current paper.

7.3 Allowing the Manager to Quit

Corporations that have reset options have typically offered two reasons justifying their actions. One is the need to reincentivize employees who have become demotivated because of their underwater options; this point has, of course, formed the focus of our paper. A second reason is also commonly offered for resetting: that it serves as a device to help retain employees who might otherwise quit. This section examines the modeling of this second issue. As in Subsection 7.2, we will first show that if all managers are assumed a priori identical and there are no replacement costs, pre-commitment and resetting are *equivalent* strategies, but that this equivalence is broken, and the choice resembles the issues discussed in this paper, if more reasonable assumptions are made.

Some background discussion is, unfortunately, unavoidable here. Traditionally, models of principal/manager relationships in the literature make one of two assumptions (and, sometimes, both) that constrain the compensation contract the principal may offer the manager:

1. The manager's compensation is bounded below in each state; that is, the principal may not impose arbitrarily large penalties on the manager.

2. The contract must enable the manager to meet a reservation expected utility level.

The second assumption is, perhaps, more commonly employed, but the first has also been widely used (e.g., Radner [18],[19]). (Of course, the two are closely connected, since the lower bounds in the first assumption implicitly define a reservation utility level for the manager in the obvious way.) The current paper has also used the first formulation. This has enabled us to focus on the issue of reincentivizing existing employees without also worrying about meeting participation constraints. In order to capture concerns about employee retention, however, the model must necessarily incorporate explicit reservation utility levels for the manager at the various nodes; we may then assume that if these levels are not attainable under the contract offered by the principal, the manager leaves and must be replaced. It is this approach we shall take in this section.

For specificity, we confine attention to the binomial model of this paper. We retain the assumption of Section 5 that $HL \leq 1$; our statements below are also valid if $HL > 1$, but the algebra gets cumbersome. Finally, since the model with general payoffs may again be analyzed on the lines of Section 4 of this paper, we limit our attention to the framework of Section 5, where compensation is defined only through the use of at-the-money call options.

Concerning reservation utility levels, the following new notation is employed: $\bar{u}$ will denote the manager's initial reservation utility level, and $\bar{u}_h$, $\bar{u}_l$ the reservation utility levels at the nodes H and L, respectively. Let $\hat{u}$, $\hat{u}_h$, and $\hat{u}_l$ be the maximum utility levels the manager can attain from the initial node and nodes H and L, respectively, if the manager is offered zero compensation in all contingencies. For the reservation levels to have any bite, we must have $\bar{u} > \hat{u}$, $\bar{u}_h > \hat{u}_h$ and $\bar{u}_l > \hat{u}_l$. We shall presume all these inequalities hold.

Now, consider any initial offer α under resetting. At L, these options are worthless, so the continuation utility level for the incumbent manager under the original contract falls below his reservation level. There are two possibilities that arise at this stage. The incumbent manager can be retained and reincentivized by resetting the options at this stage. Alternatively, a new manager must be hired and incentivized anew. In either case, given that managers are ex-ante identical, the offers will be the same; let the new offer be β at-the-money options. One feasible strategy that can be followed under pre-commitment is to make the same initial offer of α, allow the incumbent manager to depart at L, and make the new manager an offer of β. This leads to exactly the same payoffs for the principal as under resetting.

The converse is also easy to see in this case that resetting cannot do worse than pre-commitment. We omit the details here. Thus, resetting and pre-commitment are, as in Subsection 7.2, identical from the principal's viewpoint.

Once again, though, the equivalence is driven by an implicit assumption that the incumbent manager may be costlessly replaced by a clone. Of course, as we have seen, a host of factors such as hiring or severance costs, learning-by-doing effects, or uncertainty about the productivity of untried employees, may upset this situation. In all such cases, continuation payoffs are strictly higher for the principal when the incumbent manager is retained by resetting his contract and pushing him above reservation levels, than when he is allowed to quit and is replaced. Of course, this means that the comparison between pre-commitment and resetting boils down to the trade-off between the superior initial incentive effects of pre-commitment and the better continuation prospects under resetting, the very issue we have studied in this paper. And once again, it is true that the tighter the human resource constraint (the greater the cost of replacing the incumbent manager), the more likely and profitable resetting will be in our model.

8 Conclusions

The resetting of the terms of executive stock options has become commonplace, yet its possible optimality and incentive effects have not, thus far, been addressed in the theoretical literature. This paper provides a model for analysis of this issue.

We find that in idealised circumstances, where no restrictions exist on the principal's ability to set contingent contracts, resetting can destroy, but never increase, shareholder value. Under more realistic circumstances, however, when some limits exist on the menu of contracts, resetting can and does emerge as a superior alternative. We demonstrate this first in the context of a class of linear models. Then, we show that the intuition extends more generally to models in which the manager's effort-aversion is "small" in an appropriate sense.

A justification sometimes cited for restting is the presence of "macro" (economy- or industry-wide) factors that are beyond managerial control. Our analysis of this question shows that the relative optimality of resetting may increase as such background risk factors become more important. This provides one possible explanation of the greater frequency of resetting amongst small firms.

We also examine extensions of our basic framework, most interestingly to settings where the principal or manager may sever their relationship when interim news becomes available on the "state of the world." This does little violence to our main conclusions. In particular, we find that the tighter the "human resource" constraint, i.e., the explicit or implicit (productivity-related) costs of replacing the incumbent manager, the more likely—and profitable—resetting will be as a compensation strategy.

In summary, our results suggest that the current criticism of the practice of resetting may be misguided, and that resetting may be a value-enhancing aspect of compensation contracts.

A Equilibrium in the Model of Section 4.2

This section describes the derivation of equilibrium in the linear/quadratic model of Section 4. Section A.1 handles the pre-commitment model, while Section A.2 looks at the reincentivization solution.

A.1 Equilibrium under Pre-Commitment

In any equilibrium, there are a number of boundary conditions that must be met: the actions a, a_h, and a_l must each lie in the interval $[0, \bar{a}]$, and the compensation amounts w_{hh}, w_{hl}, w_{lh}, and w_{ll} must each be non-negative. As our first step in identifying equilibria, we check if there is an "interior" equilibrium. To this end, we will solve the problem ignoring boundary conditions where they arise, and see if the candidate strategies that result from this process meet all the required conditions.

So let any compensation vector $\mathcal{W} = (w_{hh}, w_{hl}, w_{lh}, w_{ll})$ be given. At the node L, the agent solves

$$\max_{a_l \in [0,\bar{a}]} \; a_l w_{lh} + (1 - a_l) w_{ll} - \frac{1}{2} k a_l^2.$$

It is intuitively obvious that we must have $w_{lh} \geq w_{ll}$ in any equilibrium. (Otherwise, conditional on reaching L, the agent gets paid more for "shirking" and reducing firm value, which is absurd from the principal's standpoint.) Taking this as given, and solving for a_l yields

$$a_l \;=\; \min\{\lambda(w_{lh} - w_{ll}), \bar{a}\}, \tag{A.1}$$

where $\lambda = 1/k$. For the moment, we ignore the boundary solution; that is, we assume that our equilibrium will satisfy the condition $\lambda(w_{lh} - w_{ll}) \leq \bar{a}$. Some algebra now shows that the agent's continuation utility U_l and the principal's continuation utility V_l are given by

$$U_l \;=\; w_{ll} + \frac{\lambda}{2}(w_{lh} - w_{ll})^2 \tag{A.2}$$

$$V_l \;=\; a_l(LH - w_{lh}) + (1 - a_l)(L^2 - w_{ll}). \tag{A.3}$$

Analogous expressions for a_h, U_h, and V_h are easily derived (under the same caveat of ignoring the boundary condition now and checking for it later). These expressions are:

$$a_h \;=\; \lambda(w_{hh} - w_{hl}) \tag{A.4}$$

$$U_h \;=\; w_{hl} + \lambda(w_{hh} - w_{hl})^2/2 \tag{A.5}$$

$$V_h = a_h(H^2 - w_{hh}) + (1 - a_h)(HL - w_{hl}) \tag{A.6}$$

At time–0, therefore, the agent solves

$$\max_{a \in [0,\bar{a}]} aU_h + (1-a)U_l - \frac{1}{2}ka^2,$$

and this has the solution (again, ignoring the boundary)

$$a = \lambda(U_h - U_l). \tag{A.7}$$

Using (A.7), we can compute the principal's initial expected utility V as a function of $\mathcal{W}$:

$$V = aV_h + (1-a)V_l. \tag{A.8}$$

This expression must be maximized with respect to $\mathcal{W}$. Under the non-negativity restriction on $\mathcal{W}$, it is easy to see that in any solution, we must have $w_{ll} = 0$. Taking the first-order conditions with respect to the other three variables yields

$$0 = \frac{\partial V}{\partial w_{hh}} = \frac{\partial a}{\partial w_{hh}} \cdot (T_1 - T_2) + a \cdot \left(\frac{\partial (T_1 - T_2)}{\partial w_{hh}}\right), \tag{A.9}$$

$$0 = \frac{\partial V}{\partial w_{hl}} = \frac{\partial a}{\partial w_{hl}} \cdot (T_1 - T_2) + a \cdot \left(\frac{\partial (T_1 - T_2)}{\partial w_{hl}}\right), \tag{A.10}$$

$$0 = \frac{\partial V}{\partial w_{lh}} = \frac{\partial a}{\partial w_{lh}} \cdot (T_1 - T_2) + (1-a) \cdot \frac{\partial T_2}{\partial w_{lh}}, \tag{A.11}$$

where T_1 and T_2 are given by

$$T_1 = (HL - w_{hl}) + \lambda(w_{hh} - w_{hl})[H^2 - HL - w_{hh} + w_{hl}].$$

$$T_2 = L^2 + \lambda(LH - L^2)(w_{lh} - w_{ll}) - \lambda w_{lh}^2.$$

Adding the first-order conditions (A.9) and (A.10) yields $a = \lambda(T_1 - T_2)$, which from (A.7) implies $U_h - U_l = T_1 - T_2$. Substituting this in (A.9), we obtain

$$w_{hh} - w_{hl} = H^2 - HL. \tag{A.12}$$

From the definition of T_1, this means $T_1 = HL - w_{hl}$. Using this in the first-order conditions (A.9) and (A.11) results in a system of two quadratic equations in the two unknowns w_{hl}

and w_{lh}. Together with (A.12), this determines a candidate solution to the problem. Of course, we drop this case as a possibility if this candidate solution violates one or more of the boundary conditions. (For specific values of the parameters H, L, k, and $\bar{a}$, this is easy to check.)

Next, we identify possible boundary solutions. From an intuitive standpoint, the most likely boundary to be hit is $a_h \leq \bar{a}$; roughly speaking, providing suitable incentives in the first period requires increasing the size of the "spread" $(U_h - U_l)$, and this raises the possibility that the agent is "over-incentivized" at H.[11] Now, $a_h = \bar{a}$ occurs only if $\lambda(w_{hh} - w_{hl}) > \bar{a}$. Presuming this to hold, the continuation values U_h and V_h are given by

$$U_h = \bar{a}w_{hh} + (1-\bar{a})w_{hl} - \frac{1}{2}k\bar{a}^2 \tag{A.13}$$

$$V_h = \bar{a}(H^2 - w_{hh}) + (1-\bar{a})(HL - w_{hl}) \tag{A.14}$$

Using (A.13)–(A.14), we rework the solutions under the assumption that no other boundaries are hit. The details are not provided here; however, working through the problem shows that there are multiple values of w_{hh} and w_{hl} that solve the first-order conditions and which yield the same value of the objective function. (These solutions must all satisfy $V_h - V_l = U_h - U_l$.) Of course, we must again verify if the solutions meet the boundary conditions, in particular, the condition that $\lambda(w_{hh} - w_{hl}) > \bar{a}$.

Proceeding along these lines, we identify all the possible candidate solutions to the problem. Comparison of the values of the principal's ex-ante utility V at these candidate solutions then determines the equilibrium to the problem. □

A.2 Equilibrium under Reincentivization

Turning to the reincentivization case, note that given any anticipated payoff vector $\mathcal{W}$, the agent's reactions and the agent's and principal's continuation utilities are exactly as outlined above in (A.1)–(A.7). We will use these expressions to derive the optimal initial offer from the principal, as well as the reset offers at $t = 1$. Once again, we first examine if there is an interior equilibrium.

First consider the node L. Let (w'_{lh}, w'_{ll}) be the unconstrained optimal continuation from L for the principal (i.e., the pair that maximizes (A.3) given (A.1)). Some algebra reveals that V_l is maximized when

$$w'_{lh} = \frac{1}{2}(LH - L^2), \quad w'_{ll} = 0. \tag{A.15}$$

Let U'_l and V'_l denote the agent's and principal's continuation utilities from L, given (A.15).

[11] The numerical solutions in Table 1 are all of this form with a, a_l interior, and $a_h = \bar{a}$.

Now pick any pair (w_{hh}, w_{hl}) as continuation compensation from the node H. Given these values, a_h is evidently given by (A.4), so the continuation utilities U_h and V_h are given by (A.5) and (A.6). Given these continuation values, the agent picks his first-period action a' to solve $\max\{aU_h + (1-a)U_l' - ka^2/2\}$; ignoring boundary conditions, the solution is

$$a' = \lambda(U_h - U_l'). \tag{A.16}$$

Now, w_{hh}' and w_{hl}' are defined as the solutions to

$$\max_{(w_{hh}, w_{hl})} a'V_h + (1-a')V_l'.$$

Taking the first-order conditions with respect to w_{hh} and w_{hl}, some algebraic manipulation shows that we obtain the solutions:

$$w_{hh}' = H^2 - HL + w_{hl}', \tag{A.17}$$

$$w_{hl}' = \frac{1}{2}\left[(LH - L^2) - \frac{\lambda}{8}(LH - L^2)^2 - \frac{\lambda}{2}(H^2 - HL)^2\right]. \tag{A.18}$$

The value of the objective function in this solution is easily computed from these expressions.[12]

It remains to be shown that (i) $\mathcal{W}'$ is an optimal initial offer for the principal to make. and (ii) no resetting of this offer is optimal at time $t = 1$. Consider first the continuation from the node L. We will argue that it is suboptimal for the principal to make any initial (time–0) offer that gives the agent a continuation utility *larger* than U_l' from L. Indeed, if the principal were to lock himself into such an initial offer, it would make the principal worse off conditional on L being reached. Moreover, through the feedback effect, it would also decrease the first-period action of the agent (since the agent's utility "spread" $(U_h - U_l)$ would decrease). Thus, both the continuation and feedback effects are negative, establishing the desired result. Since it is clearly not credible to make an initial offer that provides the agent a continuation utility from L of *less* than U_l', it now easily follows that (w_{lh}', w_{ll}') is part of the equilibrium initial offer.

To complete the proof, we have to show that (w_{hh}', w_{hl}') is also part of an optimal initial offer from the principal's standpoint. This is easy. By construction, no other initial offer can increase the principal's ex-ante expected utility. Thus, we only need show that (w_{hh}', w_{hl}') is "credible" from H, that is, there is no way to reset it at H that makes the agent and principal both better off. Suppose such a resetting existed. Then, it would result in a higher value $\hat{U}_h$ for the agent in the continuation from h; this raises the "spread" $(U_h - U_l')$, thereby also

[12] It is possible—depending on the parameter values—that w_{hl}' may be negative in (A.18). In this case, we can rework the problem, setting w_{hl} to zero. Only one first-order condition need be considered now, and it results in a cubic equation for w_{hh}'.

increasing the agent's first-period action (i.e., it has a favorable feedback effect). Finally, by definition, it also increases the principal's continuation value from H. All of this means that the principal would have been better off making this offer at time–0 itself, contradicting the hypothesis of optimality of $\mathcal{W}'$ at time–0.

This completes the description of the candidate interior equilibrium. To proceed, we must check that the boundary conditions are all met in this solution (this is a trivial task for specific parameterizations); this solution is discarded as a possibility if any constraints are violated. Next, we identify possible candidate solutions when one or more boundaries are hit. Once again, it is best to first look at the situation where $a_h = \bar{a}$ (i.e., assume $\lambda(w_{hh} - w_{hl}) > \bar{a}$), and then at the case where $a \leq \bar{a}$ also holds with equality. Finally, we compare the values of the principal's utility at all the candidate solutions to identify the equilibrium under resetting. □

B Equilibrium in the Model of Section 5.2

This section derives equilibria in the linear/quadratic model of Section 5.2. Section B.1 looks at the pre-commitment game, while Section B.2 describes how equilibria may be identified when resetting is permitted.

B.1 Equilibrium under Pre-commitment

Let α be the number of call options (each with a strike of unity) awarded the agent at time–0. Contingent upon reaching the node H, the agent solves

$$\max_{a \in [0,\bar{a}]} \{a \cdot \alpha(H^2 - 1) + (1 - a) \cdot 0 - \frac{1}{2}ka^2\}.$$

This has the solution

$$a_h(\alpha) = \begin{cases} \alpha(H^2 - 1)/k, & \text{if } \alpha < \bar{a}k/(H^2 - 1) \\ \bar{a}, & \text{otherwise} \end{cases} \tag{B.19}$$

Thus, the agent's and principal's continuation utilities $U_h(\alpha)$ and $V_h(\alpha)$ from the node H are given by

$$U_h(\alpha) = a_h(\alpha)\alpha(H^2 - 1) - \frac{1}{2}k[a_h(\alpha)]^2. \tag{B.20}$$

$$V_h(\alpha) = a_h(\alpha)[H^2 - \alpha(H^2 - 1)] + (1 - a_h(\alpha))HL. \tag{B.21}$$

At node L, the options are guaranteed to finish out of the money, so we trivially have $a_l = U_l = 0$ and $V_l = L^2$. At the initial node, now, the agent solves

$$\max_{a\in[0,\bar{a}]} [aU_h(\alpha) + (1-a)U_l - \frac{1}{2}ka^2].$$

Using $U_l = 0$, the optimal first-period action for the agent is

$$a(\alpha) = \begin{cases} U_h(\alpha)/k, & \text{if } U_h(\alpha) \leq \bar{a}k \\ \bar{a}, & \text{otherwise} \end{cases} \tag{B.22}$$

Taking into account the agent's optimal response (B.19)–(B.22) to an initial offer of α, the principal now picks α to maximize his initial expected utility:

$$\max_{\alpha\geq 0} [a(\alpha)V_h(\alpha) + (1-a(\alpha))V_l]. \tag{B.23}$$

Our goal is to identify the value of α that solves (B.23). For notational simplicity, we will suppress dependence on α in the sequel. There are four possibilities that could be induced by α in equilibrium: (i) $a_h < \bar{a}$, $a < \bar{a}$; (ii) $a_h < \bar{a}$, $a = \bar{a}$; (iii) $a_h = \bar{a}$, $a < \bar{a}$; and (iv) $a_h = a = \bar{a}$. We look at each of these in turn to see if such equilibria exist.

Case 1 $a_h < \bar{a}$, $a < \bar{a}$.

The inequalities $a_h < \bar{a}$ and $a < \bar{a}$ can hold only if $a_h = \alpha(H^2-1)/k$ and $a = U_h/k$. Of course, for these to hold, α must, in turn, satisfy $\alpha < \bar{a}k/(H^2-1)$ and $U_h(\alpha) < \bar{a}k$. We will assume for the moment that α satisfies these conditions, solve for the optimal value of α, and see whether our assumptions were justified at this optimal value. If so, the solution qualifies as a candidate equilibrium initial offer; if not, equilibria of this form evidently do not exist.

Under the presumed hypotheses, we have $U_h = \alpha^2(H^2-1)^2/2k$ and $V_h = HL + [\alpha(H^2-1)(H^2-HL) - \alpha^2(H^2-1)^2]/k$. Substituting these expressions into (B.23) and maximizing with respect to α results in a quadratic in $\alpha(H^2-1)$. Solving this quadratic yields

$$\alpha = \frac{-m + \sqrt{m^2 - 4ln}}{2l}, \tag{B.24}$$

where

$$\begin{aligned} l &= 2(H^2-1)^2/k \\ m &= -3(H^2-1)(H^2-HL)/2k \\ n &= -(HL-L^2) \end{aligned}$$

Expression (B.24) is retained as a candidate equilibrium solution is it satisfies the two assumptions under which it was derived. (This is easy to check for any given specific values of the parameters.) If either inequality is violated, then no equilibria of the desired form exist under the chosen parameters.

Case 2 $a_h < \bar{a}$, $a = \bar{a}$.

A simple set of computations using (B.19)–(B.22) shows that these inequalities can hold together only if $\bar{a} > 2$. Since this is impossible, we discard this case.

Case 3 $a_h = \bar{a}$, $a < \bar{a}$.

In this case, the continuation utilities from H are given by

$$U_h = \bar{a}\alpha(H^2 - 1) - \frac{1}{2}k\bar{a}^2. \tag{B.25}$$

$$V_h = \bar{a}[H^2 - \alpha(H^2 - 1)] + (1 - \bar{a})HL. \tag{B.26}$$

Thus, the agent chooses a to solve

$$\max_{a \in [0, \bar{a}]} \{a[\bar{a}\alpha(H^2 - 1) - \frac{1}{2}k\bar{a}^2] - \frac{1}{2}ka^2\}.$$

Since we are assuming the interior solution for a, we have $a = U_h/k$. Using this, we seek the value of α that maximizes (B.23). The solution is easily seen to be

$$\alpha = \frac{1}{2\bar{a}(H^2 - 1)}\left[\bar{a}H^2 + (1 - \bar{a})HL - L^2 + \frac{1}{2}k\bar{a}^2\right]. \tag{B.27}$$

Once again, this solution is discarded if it violates either of the presumed hypotheses that $\alpha > k\bar{a}/(H^2 - 1)$ or $U_h \leq \bar{a}k$.

Case 4 $a_h = \bar{a}$, $a = \bar{a}$.

Now, we must have $\alpha \geq \bar{a}k/(H^2 - 1)$ and $U_h \geq \bar{a}k$. It is apparent that, in this case, it is in the principal's interest to choose the smallest value of α that guarantees these outcomes; this value may be seen to be

$$\alpha = \frac{k(2 + \bar{a})}{2(H^2 - 1)}. \tag{B.28}$$

Having identified potential solutions of all four forms, it is now a trivial matter, given any set of values for the parameters H, L, $\bar{a}$ and k, to identify the set of candidate solutions. Comparison of the value of the objective function at these solutions (and at the point $\alpha = 0$) establishes the optimal value of α under pre-commitment. □

B.2 Equilibrium under Reincentivization

When reincentivization is possible, equilibria are a little harder to identify because of the possibility of the constrained resetting at H and L. We proceed in three steps. First, we identify equilibrium resetting at L. Then, we identify the problem whose solution yields the equilibrium initial offer α in this problem, taking into account the possibility of resetting at both H and L. Finally, we discuss deriving the solution to this problem.

Step 1: Equilibrium Resetting at L

For any value of the initial offer α, the initial options are worthless at L. Thus, if no resetting of the initial contract is made, the agent's optimal response in the continuation is $a_l = U_l = 0$, which gives the principal a continuation utility of $V_l = L^2$. However, if a new award of β at-the-money options is made, then the agent solves

$$\max_{a\in[0,\bar{a}]} \{a\beta(HL - L) - \frac{1}{2}ka^2\}.$$

This has the solution $a_l(\beta) = \min\{\bar{a}, \beta(HL - L)/k\}$. The equilibrium reset contract is the one which maximizes the principal's continuation utility from L:

$$\max_{\beta\in[0,1]} \{a_l(\beta)(HL - \beta(HL - L)) + (1 - a_l(\beta))L^2\}.$$

Some computation shows that the solution to this problem is given by[13]

$$\beta = \begin{cases} (H - L)/[2(H - 1)], & \text{if } L(H - L) \le 2\bar{a}k \\ k\bar{a}/(HL - L), & \text{otherwise} \end{cases}$$

As a consequence, the continuation values U_l and V_l for the principal and agent are given by

$$U_l = \begin{cases} L^2(H - L)^2/8k, & \text{if } L(H - L) \le 2\bar{a}k \\ k\bar{a}^2/2, & \text{otherwise} \end{cases} \tag{B.29}$$

$$V_l = \begin{cases} L^2 + L^2(H - L)^2/4k, & \text{if } L(H - L) \le 2\bar{a}k \\ \bar{a}HL + (1 - \bar{a})L^2 - k\bar{a}^2, & \text{otherwise} \end{cases} \tag{B.30}$$

Note that in the first case (when $L(H - L) \le 2\bar{a}k$), it is clearly optimal to reset the contract at L since the continuation value is strictly larger than L^2; this also holds in the

[13]We must also ensure that $\beta \le 1$. This is satisfied whenever $\bar{a}k \le (HL - L)$, an assumption we shall make here and in our numerical calculations in Table 2.

second case provided $L(H-L) > k\bar{a}$. In the sequel, we continue with only the first case. The second is easily handled analogously.

Step 2: The Equilibrium Initial Offer α^*

Pick any value of α and define the continuation action $a_h(\alpha)$ and the continuation values $U_h(\alpha)$ and $V_h(\alpha)$ as in (B.19)–(B.21). With U_l given by (B.29), let $a(\alpha)$ be the solution to

$$\max_{a\in[0,\bar{a}]} \{aU_h(\alpha) + (1-a)U_l - \frac{1}{2}ka^2\}. \tag{B.31}$$

Finally, with V_l given by (B.30), let α^* be the optimum value of α in the problem

$$\max_{\alpha\in[0,1]} \{a(\alpha)V_h(\alpha) + (1-a(\alpha))V_l\}. \tag{B.32}$$

In words, α^* is the optimal initial offer to make for the principal if resetting will occur at L but not at H. Of course, the principal cannot commit himself a priori to not resetting at H. Nonetheless, we will show that (i) α^* is an optimal initial offer to make under resetting, and (ii) if $a(\alpha^*) > 0$, then there will be no resetting at the node H under the offer α^*. The following lemma will help establish these claims:

Lemma B.1 *In any solution to (B.32), it is the case that either $a(\alpha^*) = 0$ or $V_h(\alpha^*) \geq V_l$.*

Proof Suppose we had $a(\alpha^*) > 0$ and $V_h(\alpha^*) < V_l$. Then, of course, we must have

$$V_l \; > \; a(\alpha^*)V_h(\alpha^*) + (1-a(\alpha^*))V_l. \tag{B.33}$$

Now, the principal can always achieve the value V_l in (B.32) by using $\alpha = 0$, since this guarantees the agent's first-period action will be $a = 0$. Together with (B.33), this implies α^* cannot maximize (B.32), a contradiction. □

We return to the proof of the claim. We will first show that if the initial offer α^* is made and $a(\alpha^*) > 0$, then it cannot be optimal to reset at H. Suppose to the contrary that under these conditions, a Pareto-improving continuation exists from H that leaves the principal strictly better off. For specificity, suppose this continuation involves issuing γ new options each with a strike of H to replace the existing α^* options. We will show that this means α^* does not solve (B.32), a contradiction.

Let $U_h(\gamma)$ and $V_h(\gamma)$ represent the continuation payoffs from H under γ. By hypothesis, $U_h(\gamma) \geq U_h(\alpha^*)$ and $V_h(\gamma) > V_h(\alpha^*)$. Now consider the effect of setting $\alpha = \gamma H/(H+1)$ in (B.32). Under α, the payoffs to the agent and the principal at the nodes H^2 and HL are the same as under γ; therefore, we must have $U_h(\alpha) = U_h(\gamma)$ and $V_h(\alpha) = V_h(\gamma)$, and this implies in turn

$$U_h(\alpha) \geq U_h(\alpha^*), \qquad V_h(\alpha) > V_h(\alpha^*).$$

The first inequality states that the offer α does not decrease the "spread" $(U_h - U_l)$, and so from (B.31) the action $a(\alpha)$ it induces must satisfy $a(\alpha) \geq a(\alpha^*)$. Combining this with the second inequality and the inequality $V_h(\alpha^*) \geq V_l$ (which must hold by Lemma B.1), we have

$$a(\alpha)V_h(\alpha) + (1 - a(\alpha))V_l > a(\alpha^*)V_h(\alpha^*) + (1 - a(\alpha^*))V_l.$$

But this means α does better than α^* in (B.32), a contradiction. This completes the proof that resetting cannot be optimal at H if the initial offer is α^*.

Finally, suppose that α^* is not an optimal initial offer under resetting; specifically, suppose there is another initial offer $\hat{\alpha}$ that does strictly better. Then, $\hat{\alpha}$ must involve resetting at H; if it did not, it could not do better than α^*, since α^* solves (B.32). Let the resetting at H be γ at-the-money options. Define $U_h(\gamma)$ and $V_h(\gamma)$ as earlier, and denote by $a(\gamma)$ the first period action induced by γ. Note that the initial expected utility of the principal under $\hat{\alpha}$ is then $[a(\gamma)V_h(\gamma) + (1 - a(\gamma))V_l]$, which, by hypothesis, is strictly larger than $a(\alpha^*)V_h(\alpha^*) + (1 - a(\alpha^*))V_l$.

Consider now setting $\alpha = \gamma H/(H+1)$ in (B.32). This offer induces the same endgame payoffs as γ at the nodes H^2 and HL, so we clearly have $U_h(\alpha) = U_h(\gamma)$ and $V_h(\alpha) = V_h(\gamma)$; and, as a consequence, $a(\alpha) = a(\gamma)$. Summing up:

$$a(\alpha)V_h(\alpha) + (1 - a(\alpha))V_l = a(\gamma)V_h(\gamma) + (1 - a(\gamma))V_l.$$

But this means α does better than α^* in (B.32), contradicting the definition of the latter. This establishes the claim.

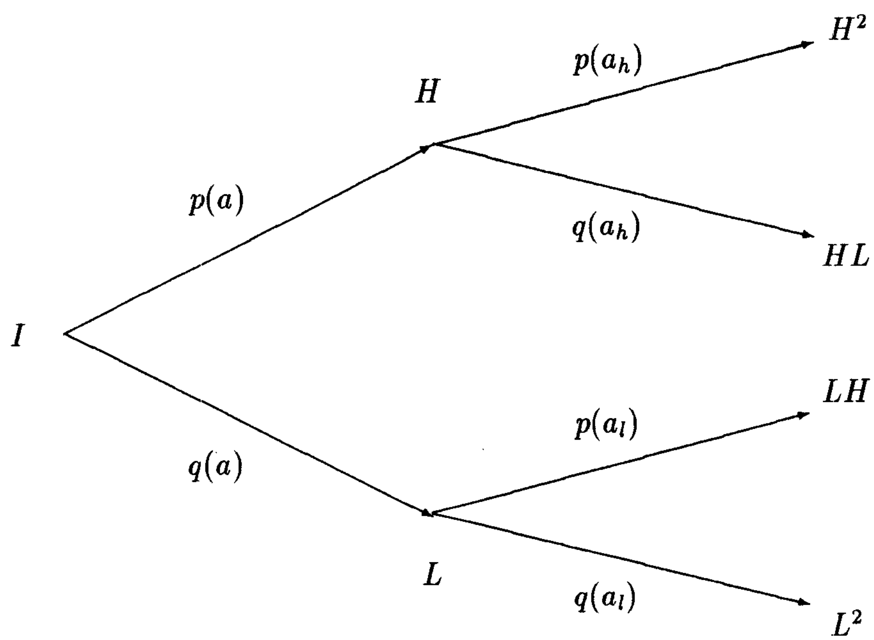
Step 3: Solving for the Optimal Initial Offer α^*

To solve for α^*, we must solve (B.32). This is completely analogous to the procedure for solving for the pre-commitment equilibrium in (B.23). There are again four cases to consider: where α^* induces (i) $a_h < \bar{a}$, $a < \bar{a}$; (ii) $a_h < \bar{a}$, $a = \bar{a}$; (iii) $a_h = \bar{a}$, $a < \bar{a}$; and (iv) $a_h = a = \bar{a}$. The derivation of potential equilibria of each sort may be carried out as earlier. For example, it may be verified that if an equilibrium α^* exists which induces $a_h < \bar{a}$ and $a < \bar{a}$, then α^* must satisfy the equation

$$(V_h - V_l)\lambda^2\alpha(H^2 - 1)^2 + a[\lambda(H^2 - 1)(H^2 - HL) - 2\lambda\alpha(H^2 - 1)^2] = 0.$$

(Once again, of course, to qualify as a candidate solution, it must be verified that α^* so defined meets the assumptions under which it was derived.) Proceeding as we did earlier, we identify all the possible solutions. Comparison of the value of the objective function at all feasible candidate solutions then delivers the equilibrium. □

Figure 1: Evolution of Information and Distribution of Terminal Cash Flows



References

[1] Aghion, P. and P. Bolton (1992) An Incomplete Contracts Approach to Financial Contracting, *Review of Economic Studies* 59, 473–494.

[2] Aghion, P., M. Dewatripont, and P. Rey (1990) On Renegotiation Design, *European Economic Review* 34, 322–329.

[3] Bolton, P. (1990) Renegotiation and the Dynamics of Contract Design, *European Economic Review* 34, 303–310.

[4] Bolton, P. and D. Scharfstein (1989) A Theory of Predation Based on Agency Problems in Financial Contracting, *American Economic Review* 80, 94–106.

[5] Bolton, P. and D. Scharfstein (1996) Optimal Debt Structure and the Number of Creditors, *Journal of Political Economy* 104(1), 1–25.

[6] Brenner, M., R. Sundaram, and D. Yermack (1998) Altering the Terms of Executive Stock Options, Working Paper, Department of Finance, Stern School of Business.

[7] Chance, D., R. Kumar, and R. Todd (1997) The "Repricing" of Executive Stock Options, mimeo, Department of Finance, Virginia Tech.

[8] Franks, J., K. Nyborg, and W. Torous (1996) A Comparison of US, UK, and German Insolvency Codes, *Financial Management* 25(3), 86–101.

[9] Gale, D. and M. Hellwig (1989) Repudiation and Renegotiation: The Case of Sovereign Debt, *International Economic Review* 30(1).

[10] Gilson, S. and M. Vetsuypens (1993) CEO Compensation in Financially Distressed Firms: An Empirical Analysis, *Journal of Finance* 48, 425–458.

[11] Gorton, G. and B. Grundy (1997) Executive Compensation and the Optimality of Managerial Entrenchment, Working Paper, Wharton School, University of Pennsylvania.

[12] Hart, O. and J. Moore (1988) Incomplete Contracts and Renegotiation, *Econometrica* 56(4), 755–785.

[13] Hart, O. and J. Moore (1994) A Theory of Debt based on the Inalienability of Human Capital, *Quarterly Journal of Economics* 109, 841–880.

[14] Hart, O. and J. Moore (1995) Debt and Seniority: An Analysis of the Role of Hard Claims in Constraining Management, *American Economic Review* 85, 567–585.

[15] Hart, O. and J. Moore (1998) Default and Renegotiation: A Dynamic Model of Debt, *Quarterly Journal of Economics* 113(1), 1–41.

[16] Hart, O. and J. Tirole (1988) Contract Renegotiation and Coasian Dynamics, *Review of Economic Studies* 55.

[17] Kaiser, K. (1996) European Bankruptcy Laws: Implications for Corporations facing Financial Distress, *Financial Management* 25(3), 67–85.

[18] Radner, R. (1981) Repeated Principal–Agent Games with Discounting, *Econometrica* 53, 1173–97.

[19] Radner, R. (1998) Dynamic Games in Organization Theory, in *Organizations with Incomplete Information: Essays in Economic Analysis* (M. Majumdar, Ed.), Cambridge University Press, Cambridge and New York.

[20] Rogerson, W. (1985) Repeated Moral Hazard, *Econometrica* 53, 69-77.

[21] Saly, P.J. (1994) Repricing Executive Stock Options in a Down Market, *Journal of Accounting and Economics* 18, 325–356.