# Effects of Accounting Conservatism on Investment Efficiency and Innovation*

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July 19, 2017

ABSTRACT: We study how biases in financial reporting affect managers' incentives to spend effort searching for innovative projects, and to make appropriate investment decisions once they have uncovered a new project. Holding the manager's earnings-based payoffs exogenously fixed, a move to more conservative accounting (i) reduces the manager's temptation to invest in risky projects, which can either reduce overinvestment or increase underinvestment, and (ii) weakens his incentive to search for innovative ideas ex ante. These effects are broadly consistent with informal arguments developed in the extant literature. When incentive contracts are endogenous, however, more conservative accounting (i) always reduces overinvestment incentives (and does not create underinvestment incentives) and (ii) leads to stronger, not weaker, managerial incentives to search for innovative projects.
Keywords: Innovation, accounting conservatism, executive compensation.

*We thank Jeremy Bertomeu, Robert Goex, Paul Newman, Raghu Venugopalan, and seminar participants at the University of Miami, University of Houston, University of Zuerich, and UT Arlington for their valuable comments.

# 1 Introduction

This paper studies the role of conservative financial reporting on investment efficiency and innovation in corporations. Conservative accounting practices and innovation seem to conflict with one another. Innovation requires an environment that encourages risk-taking and provides protection from failure (Manso 2011; Reis 2011). Conservative reporting practices, however, impose stricter verification standards for recognizing good news relative to bad news (Basu 1997; Watts 2003), which increases the chances that risky investments translate into unfavorable earnings reports. Conservatism may thereby foster prudence and risk avoidance, inhibiting innovation.

What is missing from this intuition, however, is the role of incentive contracting. Corporate boards will adjust the incentives provided to managers when the reporting system changes. We show that under optimal contracting, conservative accounting practices do not impede but increase innovation in corporations.

We consider a model that captures the following key features of innovation: (i) the manager has to spend costly effort to uncover innovative investment ideas, (ii) if the manager uncovers an innovation, he chooses whether to implement it based on private information about the innovation's success probability, (iii) implementing the innovation is more risky than maintaining the status quo and (iv) the innovation delivers results in the long run.

Due to the long-term nature of innovation, the firm's board links the manager's compensation to an interim accounting report that is informative about the economic performance of the firm. Similar to the extant analytical literature (e.g., Gigler et al. 2009), we assume that conservative accounting reduces the frequency of favorable earnings signals but increases the information content of those signals. The manager will invest in a newly discovered innovation only when investment yields a higher expected compensation than maintaining the status quo, which is the case if the innovation's success probability lies above a certain threshold, referred to as the investment threshold. The bias in the accounting system affects the likelihood that risky investments translate into favorable performance reports and thus influence the manager's investment choices.

We first study the role of accounting conservatism in a setting where the payments to the manager are exogenously held fixed. Fixing payments helps clarify some of the casually argued links between accounting conservatism, investment efficiency, and innovation. Conservative accounting reduces the probability that risky investments yield favorable earnings reports, and hence renders innovation less attractive. This effect not only increases the manager's investment threshold once he has uncovered a new innovation, but also weakens his incentive to search for innovative ideas in the first place. Overall, conservatism reduces the probability that the manager innovates, consistent with the informal argument developed in Chang et al. (2015). Although conservatism reduces the probability of innovation, the effect on firm value is ambiguous. For very low levels of conservatism, the manager overinvests in new projects (that is, implements some negative NPV projects) and a move to more conservative accounting helps alleviate this problem. But if the accounting system is already highly conservative, the manager underinvests in new projects (that is, foregoes some positive NPV projects) and a further increase in conservatism aggravates the underinvestment problem. This argument is consistent with Roychowdhury (2010) who points out that conservatism is no panacea because it can alleviate as well as aggravate investment inefficiencies.

While the above arguments are intuitive, they only apply when the manager's payments are given exogenously. But boards design incentive pay plans to control management's actions and the optimal pay plan will change when the bias in the measurement system changes. A key conflict in our setting is that the optimal pay plan that induces the manager to search for innovations subsequently encourages him to invest in a newly uncovered idea even when it is less promising than the status quo. Adjusting the incentive contract to eliminate the temptation for overinvestment is possible but not optimal as it leaves the manager with excessive rents. Thus, in environments where innovation plays an important role for the future success of the firm, the relevant incentive problem is to counteract overinvestment (not underinvestment) and conservatism is indeed a useful tool to address this problem, consistent with arguments in Ball (2001), Watts (2003), and Ball and Shivakumar (2005). We show that conservative accounting practices allow the board to provide the manager with strong incentives to search for innovations without creating excessive incentives for overinvestment. As a result, conservatism does not reduce the manager's incentive to discover innovations, as is the case with exogenous contracts, but leads to optimal contracts that strengthen incentives. In sum, a shift to more conservative accounting reduces the inclination for overinvestment, and increases innovation effort and expected firm value.

We are aware of only one empirical study that examines the link between conservative accounting and innovation. Using the number of patents and patent citations as a proxy for the level of innovation, Chang et al. (2015) find a negative relation between conservatism and innovation in organizations. The number of patents, however, is unlikely to capture the type of innovation we have in mind. Firms that continue business as usual and firms that are truly innovative and venture out into new and uncharted territory will likely both generate patents. But the important difference is that the latter type of firm is more likely to generate patents for ideas that are ultimately not pursued to completion. After all, innovations are highly risky and not all ideas are worthwhile pursuing. In our model, conservative accounting practices lead to optimal contracts that encourage managers to search for innovative ideas and reject those ideas that are relatively unpromising. Our model therefore predicts that conservative accounting increases the number of new ideas and patents that eventually end up in the drawer and are not adopted by the firm. We hope our theory will stimulate further interest in empirically examining the relation between accounting practices and innovation.

Our paper fuses two streams of the analytical conservatism literature. The first stream studies the role of conservatism for investment efficiency (Gigler et al. 2009; Li 2013; Nan and Wen 2014; Caskey and Laux 2016). In this literature, the principal (e.g., the board of directors or the lender) makes an investment or abandonment decision based on a public accounting report that is informative about the profitability of the project. A conservative reporting system reduces the probability that the principal invests in a failing project (Type II error) but increases the probability that she foregoes a profitable project (Type I error). If the expected cost of Type II errors exceeds (is exceeded by) the expected cost of Type I errors, the principal optimally designs an accounting system with a conservative (aggressive) bias. In contrast, in our study, the manager is in charge of the investment decision and he bases this decision not on a public accounting report but on private information. The bias in the accounting system nevertheless matters for the manager's investment choice because, ceteris paribus, conservative accounting reduces the likelihood that risky investments will translate into favorable future reports, which reduces the manager's willingness to take risks ex ante.

The second stream of literature focuses on the role of conservatism for contracting under moral hazard and limited liability (e.g., Kwon et al. 2001; Kwon 2005; Bertomeu et al. 2016). These studies show that conservatism reduces the expected bonus required to induce the manager to take a certain effort level. The driver behind this result is that conservatism renders a high report more informative about the manager's effort (that is, the likelihood ratio of the high report increases).[1] In contrast, in our setting, if the only problem was to induce the manager to search for new projects, the bias in the reporting system would have no effect on the effort incentive problem. This follows because implementing an innovation increases both the probability of success and failure. It is the combination of both the moral

[1] Gigler and Hemmer (2001) find that aggressive accounting can reduce the cost of inducing effort in a setting in which the manager is not protected by limited liability but instead is risk averse.

hazard and the adverse selection problems that creates a role for the accounting bias in our setting.[2] We contribute to the extant literature by providing a formal discussion of how conservative accounting relates to optimal contracting, investment efficiency, and innovation.

The remainder of this paper proceeds as follows. In Section 2 we outline the model and in Section 3 we discuss the incentive constraints and the board's optimization problem. In Section 4 we analyze how conservatism affects managerial behavior, holding the payoffs to the manager fixed. In Sections 5 and 6 we derive the optimal contract and examine how conservatism affects the contract and equilibrium behavior. In Section 7 we offer empirical implications and discuss the extant empirical literature. Section 8 concludes. All proofs are in appendix B.

# 2 Model

We consider a model with two risk neutral players: shareholders, represented by a benevolent board of directors, and a manager. The manager is responsible for the dual task of searching for new investment opportunities and deciding whether to invest in the new opportunity based on a privately observed signal. After the manager makes the investment decision, the accounting system generates a public report that is informative about firm performance. The details and the timeline of the model follow.

**Timing:** There are five dates. At date 1, the board hires the manager and offers him an incentive contract, which we describe further below. At date 2, the manager expends effort to search for new investment ideas. At date 3, the manager privately observes the success probability of the investment idea and decides whether to implement it or whether to continue business as usual. At date 4, the accounting system generates a public report

[2] Other papers that study the dual problem of inducing effort and appropriate interim decisions include, e.g., Lambert (1986), Levitt and Snyder (1997), and Laux (2008). However, these papers do not consider biases in the performance measurement system.

that is informative of the long-term cash flows of the firm. Long-term cash flows, denoted by $X$, are realized at date 5 after the contract with the manager expires; hence, $X$ cannot be used for contracting purposes.

**Innovation effort:** If he rejects the contract, the manager gets nothing. If he accepts the incentive contract, the manager privately chooses to expend innovation effort $a \in [0, 1)$, for a personal cost equal to $0.5ka^2$, where $k > 0$ is a constant.[3] Conditional on effort $a$, the manager discovers a viable investment idea with probability $a$ and a nonviable idea with probability $1 - a$. The viable idea has a success probability of $\theta$, which is drawn from a distribution $F(\theta)$, with density $f(\theta)$ and full support over the interval $[0, 1]$. The nonviable investment opportunity has a success probability of zero, $\theta = 0$. The manager privately learns the profitability $\theta$ of the new idea before he makes the investment decision. In Appendix D we consider a more general setting in which $\theta$ is distributed according to a distribution $F_2$ with probability $a$ and $F_1$ with probability $1 - a$, where the distribution $F_2$ first order stochastically dominates $F_1$. We show that our results are robust to this modeling change.

**Project choice:** Once the manager has observed the profitability $\theta$ of the new investment idea, he decides whether to implement it or whether to continue business as usual. If the manager invests in the new project, the project succeeds with probability $\theta$, yielding a future cash flow of $X_h$, or fails with probability $1-\theta$, yielding a future cash flow of $X_l$. If the manager continues business as usual, cash flow is $X_m > 0$. Assume that $X_l < X_m < X_h$; hence, innovation makes cash flows more volatile. The first-best investment decision is to implement the innovation if and only if $\theta \geq \theta_{FB}$, where $\theta_{FB}$ is defined by $\theta_{FB}X_h + (1 - \theta_{FB})X_l = X_m$. Also note that the first-best innovation effort level is given by

$$a_{FB} = \frac{1}{k} \int_{\theta_{FB}}^{1} (\theta X_h + (1 - \theta)X_l - X_m) f(\theta) d\theta. \tag{1}$$

[3] We assume the parameter $k$ is sufficienctly large to ensure an interior solution with $a < 1$.

**Accounting signal:** The firm's accounting system produces a contractible signal $S \in \{S_h, S_m, S_l\}$ that is related to the firm's future cash flow $X$. If the manager continues business as usual, there is no uncertainty, and the signal is $S = S_m$, representing cash flows $X_m$. If the manager implements the risky project, the accounting signal is either high ($S = S_h$) or low ($S = S_l$). Let $p_{ij} \equiv p(S_i|X_j)$ be the probability that the measurement system generates signal $S_i$ when cash-flows are $X_j$, with $i, j \in \{h, l\}$.[4] The probability $p_{ij}$ is a function of the level of conservatism, denoted $c \in [\underline{c}, \overline{c}]$, where a higher (lower) $c$ implies a higher degree of conservative (aggressive) accounting. All players observe $c$, and $p_{ij}$ is twice differentiable with respect to $c$. Conservative accounting imposes stricter verification requirements for recognizing good news than for recognizing bad news (Basu 1997). We adopt the statistical framework from Gigler et al. (2009), which captures the core intuition behind Basu (1997) through a series of axioms on the accounting system[5]:

(A1) For any given $c$, the likelihood ratio $\frac{p(S|X_h)}{p(S|X_l)}$ is increasing in $S$: $\frac{p_{hh}}{p_{hl}} > 1 > \frac{p_{lh}}{p_{ll}}$.

(A2) For each outcome $X \in \{X_l, X_h\}$, the probability of a low report is increasing in $c$: $\frac{dp_{lh}}{dc} > 0$ and $\frac{dp_{ll}}{dc} > 0$.

(A3) The likelihood ratios $\frac{p_{hh}}{p_{hl}}$ and $\frac{p_{lh}}{p_{ll}}$ increase in $c$.

(A1) guarantees that the report is informative about $X$, where $S_h$ represents good news and $S_l$ represents bad news. Thus, the posterior probability of a high (low) cash flow given a high (low) signal exceeds the prior probability: $p(X_h|S_h, \theta) > \theta$ and $p(X_l|S_l, \theta) > (1 - \theta)$. (A2) implies that a move to more conservative accounting increases the probability that both

[4]Because the outcome and signal spaces are binary, $p_{hh} + p_{lh} = 1$ and $p_{hl} + p_{ll} = 1$. This will simplify the analysis throughout the paper.

[5]Several papers on conservatism use the parameterization $\Pr(S_h|X_h) = \lambda + \delta$ and $\Pr(S_l|X_l) = 1 - \delta$, where $\delta$ reflects a reduction in conservatism (e.g., Venugopalan 2004; Chen et al. 2007; Li 2013; Drymiotes and Hemmer 2013; Nan and Wen 2014; Bertomeu et al. 2016). This parameterization is a special case of the assumptions (A1)-(A3).

high and low cash flows lead to low rather than high signals. (A3) implies that conservative accounting increases the information content of the high signal but reduces the information content of the low signal:

$$\frac{dp(X_h|S_h,\theta)}{dc} > 0 \text{ and } \frac{dp(X_l|S_l,\theta)}{dc} < 0. \tag{2}$$

**Contracting:** In the beginning of the game, the board offers the manager a contract that specifies his payments contingent on the signal $S$. Specifically, the contract is given by $W = (w_h, w_m, w_l)$, where $w_i$ denotes the payment if $S = S_i$. The manager has a reservation utility of zero and is protected by limited liability such that payments must be nonnegative; that is, $w_i \geq 0$ for each $i = h, m, l$. This assumption implies that the manager's participation constraint is always satisfied and can be ignored. Since the manager is privately informed about the profitability $\theta$ of the new project, the board grants the manager the authority to make the investment decision. We show in Appendix A that restricting attention to this simple contract is without loss of generality. To show this, we consider a contract in which the board retains investment authority and designs a general direct revelation mechanism that induces the manager to truthfully reveal his private information $\theta$ and demonstrate that this revelation mechanism cannot outperform the simple contract we consider.

Figure 1 depicts the game tree of the model.

# 3 Managerial Actions and Incentive Problem

In this section, we solve for the manager's effort and investment behavior given contract $W$ and determine the board's optimization problem. After the manager observes the profitability $\theta$ of the new investment idea, he decides whether to implement it or whether to continue business as usual.

Let

$$E[w|X_h, c] = p_{hh}w_h + p_{lh}w_l, \tag{3}$$

$$E[w|X_l, c] = p_{hl}w_h + p_{ll}w_l, \tag{4}$$

denote the manager's expected compensation when future cash flows are high, $X_h$, and when future cash flows are low $X_l$, respectively. Conditional on $\theta$ and the level of conservatism $c$, the manager's expected compensation when he implements an innovation is then:

$$w_I(\theta, c) \equiv \theta E[w|X_h, c] + (1 - \theta)E[w|X_l, c].$$

We refer to $w_I(\theta, c)$ as the manager's innovation compensation.

The manager invests in the new project rather than continue business as usual if and only if:

$$w_I(\theta, c) \geq w_m. \tag{5}$$

Note when $E[w|X_l, c] > w_m$, the manager would implement the innovation even when he knows that the innovation will fail with certainty ($\theta = 0$). In the other extreme, when $w_m > E[w|X_h, c]$, the manager would reject the innovation even when he knows that it will succeed with certainty. The optimal contract therefore always specifies payments such that

$$E[w|X_h, c] > w_m > E[w|X_l, c], \tag{6}$$

is satisfied, which implies that $w_h > w_m > w_l$.

Given (6), the left hand side of (5) is continuously increasing in $\theta$ and there is a unique interior threshold, $\theta_T$, that satisfies

$$w_I(\theta_T, c) = w_m. \tag{7}$$

The manager therefore implements the innovation for all $\theta \geq \theta_T$ and continues business as usual for all $\theta < \theta_T$.

At date 2, the manager chooses innovation effort $a$ to maximize his ex ante payoff

$$U_M = a\left(\int_{\theta_T}^{1} w_I(\theta, c) f(\theta) d\theta + w_m F(\theta_T)\right) + (1-a) w_m - 0.5ka^2. \tag{8}$$

The first-order condition for a maximum satisfies:

$$a = \frac{1}{k}\int_{\theta_T}^{1} \left(w_I(\theta, c) - w_m\right) f(\theta) d\theta. \tag{9}$$

Figure 2 illustrates the manager's incentives graphically. We assume in the figure (and in all figures that follow) that the profitability $\theta$ of a viable project follows a uniform distribution over the interval $[0, 1]$. The $x$-axis is the profitability $\theta$ of the new project and the $y$-axis is the manager's expected pay. The manager's investment threshold $\theta_T$ is determined by the intersection between the expected pay he receives when implementing the project, $w_I(\theta, c)$, and the pay $w_m$ he receives when continuing business as usual. The manager implements the innovation if $\theta \geq \theta_T$ and continues business as usual otherwise. The manager receives no rents from the marginal project $\theta_T$, but positive rents on the inframarginal projects $\theta > \theta_T$.

Region A in Figure 2 represents the increase in the manager's ex ante compensation if he discovers a viable project and hence determines his effort incentive. Since the figure considers a uniform distribution, the manager's innovation effort incentive is $a = A/k$. The larger the region $A$, the larger is the expected reward for discovering a viable project and the higher is the manager's incentive to expend innovation effort.

Given the manager's effort and investment choices from (9) and (7), the firm's ex ante cash flows are:

$$CF = a\left(\int_{\theta_T}^{1} (\theta X_h + (1-\theta)X_l)\, f(\theta)d\theta + F(\theta_T)X_m\right) + (1-a)X_m, \qquad (10)$$

and the manager's expected compensation is

$$V = a\left(\int_{\theta_T}^{1} w_I(\theta, c) f(\theta)d\theta + w_m F(\theta_T)\right) + (1-a)w_m. \qquad (11)$$

The board's problem is now to maximize shareholders' payoffs

$$\max_{(a,\theta_T)} U_B = CF - V, \qquad (12)$$

subject to the manager's incentive constraints (7) and (9), and the non-negativity constraint $w_h,\ w_m,\ w_l \geq 0$. Due to the limited liability assumption, the manager's participation constraint $U_M \geq 0$ is always slack and thus can be ignored.[6]

# 4 Benchmark: Effects of Conservatism when Contracts are Exogenous

We start the analysis with a benchmark case in which the manager's payments $(w_h, w_m, w_l)$ are exogenously given, with $E[w|X_h, c] > w_m > E[w|X_l, c]$, and consider how changes in the accounting measurement system affect managerial decisions and firm value. Fixing managerial payoffs helps clarify some of the casually argued links between accounting conservatism,

[6] More generally, the participation constraint could take the form $U_m \geq \bar{u}$, where $\bar{u}$ is sufficiently small that there is still an agency problem between the manager and the board.

investment efficiency, and innovation.

The next proposition establishes how an increase in conservative accounting affects the manager's effort $a$ devoted to searching for viable innovations, his investment threshold $\theta_T$, his expected pay $V$ and firm value $U_B$.

**Proposition 1** *Holding the contract $W$ fixed, an increase in conservatism $c$:*

*(i) increases the investment threshold $\theta_T$ and hence reduces the probability that a viable innovation is implemented;*

*(ii) reduces the manager's innovation effort $a$ and hence the probability that a viable innovation is discovered;*

*(iii) reduces the expected payments $V$ to the manager;*

*(iv) either increases or decreases firm value $U_B$.*

From Assumption (A2) an increase in conservatism reduces the chances that risky innovations will result in a favorable earnings report, which renders investment less attractive for the manager. Specifically, using (3) and (4) and recognizing that $p_{ll} = (1 - p_{hl})$ and $p_{lh} = (1 - p_{hh})$, the manager's innovation compensation can be written as

$$w_I(\theta, c) = (\theta p_{hh} + (1 - \theta)p_{hl})(w_h - w_l) + w_l,$$

which decreases in conservatism for all $\theta$ since $dp_{hh}/dc < 0$ and $dp_{hl}/dc < 0$ and $w_h > w_l$.

As a consequence, conservatism reduces the probability that the manager invests in a viable innovation ($\theta_T$ increases), and renders the manager less eager to spend effort to uncover a viable innovation ex ante ($a$ declines). The finding that conservatism stifles innovation in organizations is consistent with the view put forth in Chang, et al. (2015).

Figure 3 illustrates these effects graphically. An increase in conservatism from $c$ to $c'$ increases the manager's investment threshold from $\theta_T$ to $\theta'_T$, and reduces his incentive to expand innovation effort from $a = (A + B)/k$ to $a' = A/k$.

Whether an increase in conservatism improves or worsens investment efficiency depends on whether the investment threshold $\theta_T$ initially lies below or above the first-best level $\theta_{FB}$. For marginal changes in conservatism, there are two cases to consider.

Case 1: $\theta_T < \theta_{FB}$. The manager initially overinvests in the project for all $\theta \in [\theta_T, \theta_{FB})$ in the sense that he implements the new project even though it has a negative NPV. Increasing the level of conservatism increases the investment threshold and hence reduces the overinvestment region.

Case 2: $\theta_{FB} < \theta_T$. The manager initially underinvests in the project for all $\theta \in (\theta_{FB}, \theta_T]$ in the sense that he rejects the project although its NPV is positive. Here, an increase in conservatism further increases the underinvestment region and worsens investment efficiency.

Empirical studies and informal discussions take the manager's temptation for over or underinvestment as exogenously given and assume that the level of conservatism is the only tool to counteract misaligned incentives.[7] Watts (2003), for example, argues that managers are typically prone to overinvestment and that conservatism is a useful governance mechanism to counteract this temptation and to induce more efficient investments.[8] This view is built on the premise that most firms are characterized by case 1 above. Roychowdhury (2010) raises the point that conservatism can not only reduce overinvestment incentives, but can also aggravate underinvestment incentives. That is, Roychowdhury recognizes that there is also the potential for case 2.

Even if we accept the assumption that an increase in conservatism improves investment efficiency (case 1 is the relevant case), an increase in conservatism does not necessarily improve shareholder value. This follows because more conservative accounting reduces the manager's incentive to search for promising projects ex ante. The effect of greater conser-

[7] See, e.g., Watts (2003), Roychowdhury (2010), and Garcia Lara et al. (2016).

[8] For similar arguments see Francis and Martin (2010), Ball (2001), Ball and Shivakumar (2005).

vatism on firm value $U_B$ is therefore ambiguous even when conservatism improves ex post investment efficiency.

While the discussion in this section serves as a useful benchmark, we are ultimately interested in the question of how conservatism affects managerial behavior and firm value when contracts are endogenous. Allowing for optimal contracting demonstrates three key results. A higher degree of conservatism (i) always leads to more efficient investment decisions, (ii) leads to stronger (not weaker) incentives for the manager to search for viable innovations, and (iii) always increases firm value $U^B$.

# 5 Optimal Contracting

In this section, we determine the optimal pay plan and in Section 6 we analyze how conservative accounting affects the manager's behavior and firm value when contracts are chosen optimally. The approach in determining the optimal contract follows Grossman and Hart (1983), which occurs in two steps. First, we fix the effort and investment levels $(a, \theta_T)$ and determine the cheapest contract that implements this combination. The second step is to solve for the optimal $(a^*, \theta_T^*)$ combination, given that the board will choose the least costly contract for any $(a, \theta_T)$. Proposition 2 presents the results from the first step.

**Proposition 2** *Let* $\{w_i^*(\theta_T, a)\}_{i=h,m,l}$ *denote a contract that elicits innovation effort* $a$ *and the investment threshold* $\theta_T$ *at the lowest cost. Then,*

$$w_h^*(\theta_T, a) = \frac{ak}{(p_{hh} - p_{hl}) \left( \int_{\theta_T}^1 (\theta - \theta_T) f(\theta) d\theta \right)}, \tag{13}$$

$$w_m^*(\theta_T, a) = \left( \theta_T + \frac{p_{hl}}{p_{hh} - p_{hl}} \right) \frac{ak}{\int_{\theta_T}^1 (\theta - \theta_T) f(\theta) d\theta}, \tag{14}$$

$$w_l^*(\theta_T, a) = 0, \tag{15}$$

*and the expected compensation* $V(\theta_T, a)$ *and the manager's rent* $U_M$ *are*

$$V(\theta_T, a) = ka^2 + w_m^*(\theta_T, a), \quad (16)$$

$$U_M(\theta_T, a) = 0.5ka^2 + w_m^*(\theta_T, a). \quad (17)$$

The payments $w_h$ and $w_m$ each serve a specific role. The bonus $w_h$ rewards the manager for high reported performance and hence provides him with incentives to search for viable innovations. The pay $w_m$ rewards the manager for continuing business as usual and ensures that he does not implement the innovation when its success probability $\theta$ is low. Otherwise, if $w_m = 0$, the manager would always invest in the innovation even when the probability of success $\theta$ is close to zero. To further curb the manager's temptation to pursue innovations that have low success probabilities, the optimal contract does not reward him for poor reported performance; that is, $w_l^* = 0$.

Observe that

$$w_m^* = \theta_T(p_{hh} - p_{hl})w_h^* + p_{hl}w_h^* \quad (18)$$

$$= [\theta_T p_{hh} + (1 - \theta_T)p_{hl}]\, w_h^* \quad (19)$$

In principle, by choosing relatively high values of $w_h$ and $w_m$, the board can induce first-best investment, $\theta_T = \theta_{FB}$, and first-best innovation effort, $a = a_{FB}$. However, as the next proposition shows, doing so is not optimal because it is too costly.

**Proposition 3** *For any level of conservatism* $c \in [\underline{c}, \overline{c}]$*, relative to first-best, the optimal contract induces the manager*

*(i) to underprovide innovation effort,* $a^* < a_{FB}$*, and*

*(ii) overinvest in a viable project,* $\theta_T^* < \theta_{FB}$*.*

In the optimal solution, the manager's actions are distorted relative to first-best: the manager chooses insufficient innovation effort, and once he discovers a viable innovation, he implements it too frequently.

To see the intuition behind why the optimal contract induces overinvestment, consider a contract ($w_h^o > 0$, $w_m^o > 0$, $w_l^o = 0$) that induces an investment threshold $\theta_T^o$ below the first-best level, $\theta_{FB}$. Let $w_I^o(\theta, c)$ be the innovation compensation based off $(w_h^o, w_m^o, w_l^o)$. Given this contract, the manager overinvests in the innovation for all $\theta \in (\theta_T^o, \theta_{FB}]$. To reduce the overinvestment region, the board has to render continuing business as usual more attractive for the manager by specifying a greater pay $w_m$. As depicted in Figure 4, an increase in $w_m$, say to $w_m'$, increases the investment threshold from $\theta_T^o$ to $\theta_T'$.

However, the larger pay $w_m$ involves two costs: it increase the manager's compensation $V$, and it reduces the manager's incentive to search for viable innovations. In Figure 4, the increase in $w_m$ reduces the manager's effort incentive from $a^o = (A + B)/k$ to $a' = A/k$.

The board can now counteract the decline in innovation effort by increasing the bonus $w_h$. Assume the board increases $w_h$ to restore the effort level to the initial level, $a = a^o$. The new bonus is denoted by $w_h'$ in Figure 5. The new innovation compensation is $w_I'(\theta, c)$. The new effort level is now determined by $a = (A + C)/k$, which equals the initial level $a^o = (A + B)/k$ because $w_h'$ is chosen such that $B = C$.

The increase in $w_h$ comes again at two costs: it further increases the total expected compensation $V$ and reduces the manager's investment threshold from $\theta_T'$ to $\theta_T''$ (see Figure 5). However, the new threshold $\theta_T''$ is still higher than the initial one $\theta_T^o$.

In sum, the move from ($w_m^o$, $w_h^o$) to $(w_m', w_h')$ increases the investment threshold from $\theta_T^o$ to $\theta_T''$, did not change the innovation effort $a = a^o$, and increased the expected compensation $V$ by $w_m' - w_m^o$ (see (16)). In the example in the figure, the increase in the manager's compensation cost outweighs the benefits of more efficient investments, so the contract ($w_m^o$, $w_h^o$)

dominates $(w'_m, w'_h)$. In fact, contract $(w^o_m, w^o_h)$ is the optimal contract given the parameters used in the figures.

The discussion shows that the board designs a contract that implements an investment threshold below the first-best level, $\theta^o_T < \theta_{FB}$, to economize on the manager's compensation. Similar arguments can be used to explain why the optimal contract induces an innovation effort level below the first-best level, $a^o < a_{FB}$.

# 6 Effects of Conservatism

Having established the optimal contract and its equilibrium actions, we now study how changes in the measurement system changes these actions as well as firm value $U_B$. The next proposition presents the results.

**Proposition 4** *An increase in the degree of conservative accounting c,*

*(i) increases the investment threshold* $\theta^*_T$ *and reduces the overinvestment range* $(\theta^*_T, \theta_{FB})$*,*

*(ii) increases innovation effort* $a^*$*, and*

*(iii) increases shareholder value* $U_B$*.*

It is instructive to compare these results with the results from Section 3, where we treat the contract as exogenous. Under exogenous payments, conservatism has an ambiguous effect on investment efficiency because it can either reduce overinvestment or increase underinvestment. In contrast, under optimal contracting, conservative accounting always leads to more efficient investments. Further, with exogenous payments, a shift to more conservative accounting renders risky innovations less attractive for the manager and reduces his incentive to search for new ideas. With optimal contracting, the result flips and conservatism always leads to more –not less– innovation effort. Finally, whereas with exogenous payments an increase in conservatism can increase or decrease firm value, with endogenous payments, conservatism always increases firm value.

To explain these results we assume that $c = c^o$ and start with the optimal contract $w_m^o = w_m^*(c^o)$ and $w_h^o = w_h^*(c^o)$. Figure **??** revisits the effects of an increase in conservatism from $c^o$ to $c'$, holding the pay plan constant.[9]

Similar to the discussion in Section 3, the increase in conservatism (while keeping payments constant) increases the investment threshold from $\theta_T^o$ to $\theta_T'$, reduces the manager's incentive to expand innovation effort from $a^o = (A + B)/k$ to $a' = A/k$, and reduces the manager's expected total compensation $V$ by $k(a^{o2} - a'^2)$ (see (16)). Different to Section 3, the increase in $\theta_T$ is now unambiguously desirable since it alleviates the overinvestment problem. Given these three effects, an isolated increase in conservative accounting can either increase or decrease shareholder value. For the parameter values used in Figure **??**, the increase in conservatism reduces shareholder value.

The board, however, will now respond to the change in accounting conservatism by adjusting the pay plan. To counteract the decline in innovation effort, the board increases the bonus $w_h$. Assume for now that the board increases $w_h$ just to restore the effort level to the initial level, $a = a^o$. The new bonus that restores effort incentives is denoted by $w_h'$. The dotted line in Figure **??** shows the new innovation compensation $w_I'(\theta, c')$ given conservatism $c'$ and the bonus $w_h'$.

The increase in the bonus from $w_h^o$ to $w_h'$ not only restores innovation effort incentives but also reduces the investment threshold from $\theta_T'$ to $\theta_T''$ (see Figure **??**), and hence worsens investment efficiency. The important point here, however, is that the investment threshold $\theta_T''$ is still higher than the initial threshold $\theta_T^o$. As a consequence, the shift from $(c^o, w_h^o)$ to $(c', w_h')$ increases the investment threshold from $\theta_T^o$ to $\theta_T''$ and reduces the overinvestment

[9] To ease exposition, Figure **??** assumes $\frac{\partial p_{hh}}{\partial c} = \frac{\partial p_{hl}}{\partial c}$, so changes to $c$ only affect the intercept of $w_I(\theta, c)$, not its slope.

region, while keeping the level of innovation effort $a^o$ unchanged.

We now have to check if and how the move to $(c', w'_h)$ affects the manager's ex ante pay $V$. From (16), we know that $V = ka^2 + w_m$, which is increasing in the implemented effort level and the pay $w_m$. Since neither $a$ nor $w_m$ has changed, the ex ante pay under $(c', w'_h)$ is the same as in the initial situation with $(c^o, w^o_h)$. Thus, the shift from $(c^o, w^o_h)$ to $(c', w'_h)$ leads to a higher threshold $\theta_T$ and hence more efficient investments, but does not change the level of effort $a$ or the total compensation $V$.

The key driver underlying this result is as follows. As shown in Figure **??**, more conservative accounting combined with a higher bonus $w_h$ shifts the manager's innovation compensation $w_I(\theta, w_h)$ downwards and increases its slope. Consequently, the manager's innovation compensation becomes more sensitive to the success probability $\theta$ of the innovation but the overall expected compensation $V$ does not change. The advantage of a greater pay sensitivity is not that it encourages greater innovation effort. After all, stronger effort incentives can also be provided simply by reducing the level of conservatism which does not change the slope of $w_I(\theta, w_h)$ in the example in the figure. Instead, the benefit of a greater pay sensitivity is that it induces the manager to search for viable projects and simultaneously dampen his temptation to overinvest in new projects. Figure **??** illustrates this effect graphically. For the case with $(c^o, w^o_h)$ the manager's effort incentive is determined by the area $A+B+D$. Here, projects with intermediate $\theta$ values are relatively attractive to the manager which provides incentives to search for viable projects but also creates strong incentives for overinvestment. Instead, for the case with $(c', w'_h)$, effort incentives are determined by $A+B+C$. Relative to the previous case $(c^o, w^o_h)$, innovations that have a success probability $\theta$ below $\widehat{\theta}_T$ become less attractive to the manager, but projects that have a success probability $\theta$ above $\widehat{\theta}_T$ become more attractive (see Figure **??**). This shift does not change the manager's innovation effort incentive nor his expected pay because $C = D$, but implements a higher investment threshold $\theta_T$.

From this discussion it immediately follows that a shift to more conservative accounting increases firm value. Whereas in the case with fixed payments, an increase in conservatism involves a trade off between ex post investment efficiency and ex ante effort incentives (as shown in Figure **??**), there is no such trade off when pay is adjusted optimally. An increase in $c$ combined with an increase in $w_h$ enables the board to implement a greater investment efficiency without sacrificing innovation effort incentives and without increasing the manager's expected compensation.

The board will not stop here, however. Since more conservative accounting allows the implementation of greater innovation effort without causing excessive overinvestment, the optimal contract under $c'$ will induce an effort level above $a^o$. The end result is that the increase in conservatism from $c^o$ to $c'$ leads to a contract that implements a higher innovation effort level, a higher investment threshold, and a higher firm value relative to the initial levels, that is, $\theta_T^*(c') > \theta_T^o = \theta_T^*(c^o)$, $a^*(c') > a^o = a^*(c^o)$, and $U_B(c') > U_B(c^o)$.

# 7 Discussion and Empirical Implications

Our model predicts that adopting more conservative accounting will lead to stronger incentives for management to search for innovative ideas, and simultaneously increases the hurdle above which managers will implement a newly discovered idea. A higher hurdle implies that managers are less likely to invest in new innovations that have a negative net present value. A large empirical literature studies the effects of conservative accounting on corporate investments and finds evidence of a negative relation between conservatism and overinvestment, consistent with our model (Francis and Martin 2010; Bushman et al. 2011; Ball and Shivakumar 2005; Garcia Lara et al. 2016).

To the best of our knowledge, Chang et al. (2015) is the only empirical study that examines the association between conservatism and innovation in organizations. Using the number of patents and patent citations as a proxy for the level of innovation, Chang et al. (2015) find a negative relation between conservatism and innovation. They argue that managers are under pressure to meet short-term performance targets and conservative accounting adds to this pressure, causing managers to forego investments in innovation (similar to the intuition behind real earnings management). The empirical findings in Chang et al. (2015) do not contradict our theory as the number of patents and patent citations are unlikely to capture the type of innovation we have in mind. In our model, the manager incurs costly effort to come up with new investment opportunities and ideas. These ideas, if implemented, can change the direction of the firm and are highly risky. For example, a consumer electronics company can continue "business as usual," which may lead to the development of new and improved gadgets, or can seek to venture out into new technologies, products, and markets that depart from their existing business model (think of Apple developing the iphone). Although firms that continue business as usual and firms that search for ways to venture out into new areas will both generate patents, the difference is that the latter type of firm will be more likely to generate patents for products and technologies that are ultimately not pursued. After all, these new inventions and ideas are highly risky and managers will only pursue them to completion if they have reason to believe they will likely be successful. Our model therefore predicts that conservatism increases the number of new ideas and patents that eventually end up in the drawer and are not pursued, and simultaneously increases shareholder value.[10] As far as we know, there is no empirical study that tests this prediction.

[10] Formally, conservatism increases $a\int_0^{\theta_T} f(\theta)d\theta$, which is the probability that the manager develops new ideas that are ultimately not implemented. From Proposition 4, conservatism also increases shareholder value.

# 8 Conclusion

Innovation and conservatism seem to be conflicting concepts. Innovation involves risk taking and discovery. Conservatism embodies caution and risk avoidance. In this paper, we argue that conservatism and innovation can reinforce rather than conflict with one another. Our model of innovation involves a manager who must first exert costly effort to discover potential innovations and then decide whether to implement the innovation based on private information about its success probability. Due to the long-term nature of innovation, the manager is paid based on an interim accounting signal that is informative about the economic performance of the firm. Once the manager uncovers an innovation, he chooses to implement it if and only if its probability of success exceeds a certain threshold.

We first discuss the effects of accounting biases on managerial behavior assuming that the manager's pay plan is exogenously fixed. A move to more conservative accounting reduces the manager's willingness to take risks and thus (i) increases the threshold above which he invests in the innovation once he has uncovered one and (ii) weakens his incentive to spend effort searching for innovations in the first place. Although conservatism reduces the probability of innovation, the effect on firm value is ambiguous. When the accounting system is initially aggressive, the manager overinvests in newly discovered projects and more conservative accounting reduces the manager's temptation for overinvestment. However, if the accounting system is highly conservative, the manager underinvests in newly discovered projects, and a further increase in conservatism aggravates this underinvestment problem.

We then discuss the case of main interest in which incentive contracts are endogenous. We show that the optimal contract that induces the manager to search for innovative ideas induces him to overinvest in the new idea once he has uncovered one. The relevant incentive problem is therefore to combat overinvestment (not underinvestment), and conservative accounting is useful in this regard. Conservative accounting practices enable the board to provide strong incentives for innovation effort without encouraging excessive overinvestment. As a result, the board responds to heightened conservatism by boosting managerial incentives to uncover new ideas. In short, under endogenous contracting, conservatism does not hinder but promotes innovation in firms.

Though we focus on the specific question of how conservatism affects innovation, our broader goal is to highlight potential problems that can emerge when accounting practices are viewed in a vacuum. Boards have multiple tools to control managerial behavior and one important tool is incentive contracting. We show that although conservatism impedes innovation when incentive contracts are exogenously given, the result flips when contracts are endogenous. This result demonstrates the dangers of considering changes in the financial reporting environment in isolation from other governance tools.

# Appendix A

In this appendix, we consider a direct revelation mechanism, where the investment decision and payments to the manager are contingent on the manager's report $\widehat{z}$. If the manager uncovers a new project, he learns $\theta \in [0,1]$. The manager's private information is therefore $z \in \{z_0\} \cup [0,1]$, where $z_0$ represents the case in which the manager fails to uncover a new project. At the beginning of the game, the board commits to a menu of contracts $M = (I(\widehat{z}), w_h(\widehat{z}), w_l(\widehat{z}), w_m(\widehat{z}))$. By sending his report $\widehat{z}$, the manager selects a contract from the menu. The parameter $I(\widehat{z}) \in \{0,1\}$ is an indicator variable that denotes whether the new investment idea is pursued. If $I = 1$ the project is implemented and if $I = 0$ the project is rejected. $w_h(\widehat{z})$ or $w_l(\widehat{z})$ are the payments to the manager if the project is implemented and the accounting report is high or low, respectively. $w_m(\widehat{z})$ is the pay if the project is rejected. By the revelation principle, we can restrict attention to contracts that induce the manager to truthfully report his private information. In the optimal mechanism, for any two reports $\widehat{z}_i$ and $\widehat{z}_j$ for which the board rejects the project, $I(\widehat{z}_i) = I(\widehat{z}_j) = 0$, the manager must receive the same pay $w_m(\widehat{z}_i) = w_m(\widehat{z}_j) \geq 0$. Otherwise, if $w_m(\widehat{z}_i) > w_m(\widehat{z}_j)$ and $I(\widehat{z}_i) = I(\widehat{z}_j) = 0$, the manager would announce $\widehat{z}_i$ even when $z_j$ is true. Equivalently, since the optimal contract does not reward the manager for poor performance, $w_l = 0$, the manager must receive $w_H(\widehat{z}_i) = w_H(\widehat{z}_j)$ for all $\widehat{z}_i, \widehat{z}_j$ for which $I(\widehat{z}_i) = I(\widehat{z}_j) = 1$.

Further, the optimal mechanism involves a cutoff $\theta_T$ such that $I = 0$ if $\widehat{z} \in \{z_0\} \cup [0, \theta_T)$ and $I = 1$ if $\widehat{z} \in [\theta_T, 1]$. This follows because if $I(\theta_i) = 1$, then it must be that $I(\theta_j) = 1$ for all $\theta_j > \theta_i$. Suppose to the contrary that $I(\theta_i) = 1$, $I(\theta_j) = 0$, and $\theta_j > \theta_i$. The incentive compatibility for truthtelling requires that $(\theta_i p_{hh} + (1-\theta_i) p_{hl})\, w_H \geq w_m$ and $w_m \geq (\theta_j p_{hh} + (1-\theta_j) p_{hl})\, w_h$. If the first condition is satisfied, the second is violated and vice versa, since $\theta_j > \theta_i$ and $p_{hh} > p_{hl}$.

As a consequence, the mechanism $M$ can be replicated by the simple contract $(w_h, w_m, w_l)$, where payments are independent of the manager's report $\widehat{z}$ and where the manager makes the investment decision (rather than sending a report that determines the investment decision).

# Appendix B

**Proof of Proposition 1:** Combine (3) and (4) with (7) to get

$$\theta_T p_{hh} + (1-\theta_T)p_{hl} = \frac{w_m - w_l}{w_h - w_l}. \tag{20}$$

Using the implicit function theorem generates

$$\frac{\partial \theta_T}{\partial c} = -\frac{\theta_T \frac{dp_{hh}}{dc} + (1-\theta_T)\frac{dp_{hl}}{dc}}{p_{hh} - p_{hl}} > 0, \tag{21}$$

since $\frac{dp_{hh}}{dc} < 0$ and $\frac{dp_{hl}}{dc} < 0$ from (A2).

Using (9) and (3) and (4), we obtain

$$\begin{aligned} \frac{da}{dc} &= -\frac{1}{k}\left(\theta_T E[w|X_h] + (1-\theta_T)E[w|X_l] - w_m\right) f(\theta_T)\frac{d\theta_T}{dc} \\ &\quad +\frac{1}{k}\int_{\theta_T}^{1}\left(\theta\frac{dp_{hh}}{dc} - (1-\theta)\frac{dp_{ll}}{dc}\right)(w_h - w_l)\, f(\theta)d\theta \\ &< 0. \end{aligned} \tag{22}$$

The first line in (22) is zero since the manager's optimal choice of $\theta_T$ solves (7) and the second line in (22) is negative since $\frac{dp_{hh}}{dc} < 0$ and $\frac{dp_{ll}}{dc} > 0$ from (A2).

Using (3) and (4), we can write (11) as

$$V = a\int_{\theta_T}^{1}\left(\theta\left(p_{hh}w_h + p_{lh}w_l\right) + (1-\theta)\left(p_{hl}w_h + p_{ll}w_l\right) - w_m\right) f(\theta)d\theta + w_m.$$

Taking the first derivative with respect to $c$ yields:

$$\begin{aligned}\frac{dV}{dc} &= \frac{da}{dc}\int_{\theta_T}^{1}\left(\theta\left(p_{hh}w_h+p_{lh}w_l\right)+(1-\theta)\left(p_{hl}w_h+p_{ll}w_l\right)-w_m\right)f(\theta)d\theta \\ &\quad -a\left(\theta_T\left(p_{hh}w_h+p_{lh}w_l\right)+(1-\theta_T)\left(p_{hl}w_h+p_{ll}w_l\right)-w_m\right)f(\theta_T)\frac{d\theta_T}{dc} \\ &\quad +a\left(w_h-w_l\right)\int_{\theta_T}^{1}\left(\theta\frac{dp_{hh}}{dc}+(1-\theta)\frac{dp_{hl}}{dc}\right)f(\theta)d\theta.\end{aligned} \tag{23}$$

The second line in (23) is zero from condition (7). The first line is negative since we just established that $\frac{da}{dc} < 0$ and the third line is negative since $\frac{dp_{hh}}{dc} < 0$ and $\frac{dp_{hl}}{dc} < 0$ from (A2). Using (9) we can simplify (23) to

$$\frac{dV}{dc} = \frac{da}{dc}ka + a\left(w_h - w_l\right)\int_{\theta_T}^{1}\left(\theta\frac{dp_{hh}}{dc}+(1-\theta)\frac{dp_{hl}}{dc}\right)f(\theta)d\theta, \tag{24}$$

and using (22), we obtain

$$\frac{dV}{dc} = 2\frac{da}{dc}ka < 0. \tag{25}$$

■

**Proof of Proposition 2**: The pay $w_m$ is determined by the investment condition (7) and is given by

$$w_m = \theta_T E[w|X_h] + (1-\theta_T)E[w|X_l]. \tag{26}$$

Substituting (26) into the effort constraint (9) yields

$$a = \frac{1}{k}\int_{\theta_T}^{1}\left(\theta-\theta_T\right)\left(E[w|X_h]-E[w|X_l]\right)f(\theta)d\theta. \tag{27}$$

After inserting (3) and (4) and rearranging we obtain

$$(w_h - w_l) = \frac{ak}{(p_{hh} - p_{hl}) \int_{\theta_T}^{1} (\theta - \theta_T) f(\theta) d\theta}. \tag{28}$$

Substituting (28) into (26) yields

$$w_m = \frac{\theta_T + \frac{p_{hl}}{p_{hh} - p_{hl}}}{\left( \int_{\theta_T}^{1} (\theta - \theta_T) f(\theta) d\theta \right)} ak + w_l. \tag{29}$$

Substituting (9) and (29) into the expected cost of compensation (11) yields

$$V = a^2 k + \frac{\theta_T + \frac{p_{hl}}{p_{hh} - p_{hl}}}{\left( \int_{\theta_T}^{1} (\theta - \theta_T) f(\theta) d\theta \right)} ak + w_l. \tag{30}$$

From (30) it is obvious that setting $w_l = 0$ is optimal. Using (29) and setting $w_l = 0$ we obtain (16). ■

**Proof of Proposition 3:** Substituting the compensation cost (16) into the board's objective function (12) yields:

$$U_B = a \left( \int_{\theta_T}^{1} (\theta X_h + (1 - \theta) X_l - X_m) f(\theta) d\theta \right) + X_m - ka^2 - w_m^*(\theta_T, a). \tag{31}$$

Taking the first-order conditions for $\theta_T$ and $a$ yields:

$$\begin{aligned} \frac{\partial U_B}{\partial \theta_T} &= 0 = -(\theta_T X_h + (1 - \theta_T) X_l - X_m) f(\theta_T) \\ &\quad - \frac{k}{\int_{\theta_T}^{1} (\theta - \theta_T) f(\theta) d\theta} \left( 1 + \int_{\theta_T}^{1} f(\theta) d\theta \frac{\left( \theta_T + \frac{p_{hl}}{(p_{hh} - p_{hl})} \right)}{\left( \int_{\theta_T}^{1} (\theta - \theta_T) f(\theta) d\theta \right)} \right), \end{aligned} \tag{32}$$

and

$$\frac{\partial U_B}{\partial a} = 0 = \int_{\theta_T}^{1} \left(\theta X_h + (1-\theta)X_l - X_m\right) f(\theta) d\theta - \left(2a + \frac{\theta_T + \frac{p_{hl}}{(p_{hh}-p_{hl})}}{\int_{\theta_T}^{1}(\theta-\theta_T)f(\theta)d\theta}\right) k. \tag{33}$$

Since $\theta_{FB}X_h + (1-\theta_{FB})X_l = X_m$ by definition, equation (32) implies $\theta_T^* < \theta_{FB}$. Equation (33) implies

$$a^* = 0.5\left(\frac{1}{k}\int_{\theta_T^*}^{1} \left(\theta X_h + (1-\theta)X_l - X_m\right) f(\theta)d\theta - \frac{\theta_T^* + \frac{p_{hl}}{p_{hh}-p_{hl}}}{\left(\int_{\theta_T^*}^{1}(\theta-\theta_T^*)f(\theta)d\theta\right)}\right), \tag{34}$$

where $(a^*, \theta_T^*)$ are the optimal actions.

Since $a_{FB} = \frac{1}{k}\int_{\theta_{FB}}^{1}(\theta X_h + (1-\theta)X_l - X_m)f(\theta)d\theta$, we obtain

$$a^* = 0.5\left(a_{FB} + \frac{1}{k}\int_{\theta_T}^{\theta_{FB}} \left(\theta X_h + (1-\theta)X_l - X_m\right) f(\theta)d\theta - \frac{\theta_T + \frac{p_{hl}}{p_{hh}-p_{hl}}}{\left(\int_{\theta_T}^{1}(\theta-\theta_T)f(\theta)d\theta\right)}\right). \tag{35}$$

Since $\left(\int_{\theta_T}^{\theta_{FB}} \left(\theta X_h + (1-\theta)X_l - X_m\right) f(\theta)d\theta\right) < 0$, we have $a^* < 0.5a_{FB}$.

The second-order conditions for a maximum is satisfied if

$$\frac{\partial^2 U_B}{\partial \theta_T^2}\frac{\partial^2 U_B}{\partial a^2} - \left(\frac{\partial^2 U_B}{\partial \theta_T \partial a}\right)^2 > 0, \tag{36}$$

$$\frac{\partial^2 U_B}{\partial a^2} < 0, \tag{37}$$

where $\frac{\partial^2 U_B}{\partial\theta_T\partial a} = 0$, $\frac{\partial^2 U_B}{\partial a^2} = -2k$ and

$$\begin{aligned}\frac{\partial^2 U_B}{\partial\theta_T^2} &= -(X_h - X_l) f(\theta_T) - (\theta_T X_h + (1-\theta_T)X_l - X_M) \frac{df(\theta_T)}{d\theta_T} \\ &\quad - \frac{2k\int_{\theta_T}^1 f(\theta)d\theta}{\left(\int_{\theta_T}^1 (\theta-\theta_T) f(\theta)d\theta\right)^2}\left(1 + \frac{\left(\theta_T + \frac{p_{hl}}{p_{hh}-p_{hl}}\right)\int_{\theta_T}^1 f(\theta)d\theta}{\int_{\theta_T}^1(\theta-\theta_T)f(\theta)d\theta}\right) \\ &\quad + \frac{\left(\theta_T + \frac{p_{hl}}{p_{hh}-p_{hl}}\right) f(\theta_T)k}{\left(\int_{\theta_T}^1(\theta-\theta_T)f(\theta)d\theta\right)^2}.\end{aligned} \tag{38}$$

We assume that $(X_h - X_l)$ is sufficiently large such that $\frac{\partial^2 U_B}{\partial\theta_T^2} < 0$. ■

**Proof of Proposition 4:** Differentiating the first-order condition (32) with respect to $c$ yields:

$$\frac{\partial^2 U_B}{\partial\theta_T^2}\frac{\partial\theta_T^*}{\partial c} + \frac{\partial^2 U_B}{\partial\theta_T\partial a}\frac{\partial a^*}{\partial c} + \frac{\partial^2 U_B}{\partial\theta_T\partial c} = 0,$$

where $\frac{\partial^2 U_B}{\partial\theta_T\partial a} = 0$ and

$$\frac{\partial^2 U_B}{\partial\theta_T\partial c} = \frac{\frac{d\frac{p_{hh}}{p_{hl}}}{dc}\int_{\theta_T}^1 f(\theta)d\theta}{\left(\frac{p_{hh}}{p_{hl}}-1\right)^2\left(\int_{\theta_T}^1(\theta-\theta_T)f(\theta)d\theta\right)^2}k > 0, \tag{39}$$

which is positive because $\frac{d\frac{p_{hh}}{p_{hl}}}{dc} > 0$ from Assumption (A3) and $\frac{p_{hh}}{p_{hl}} > 1$ from Assumption (A1). Further, $\frac{\partial^2 U_B}{\partial\theta_T^2} < 0$ is given by (38), which is the second-order condition for a maximum.

Differentiating the first-order condition (33) with respect to $c$ yields:

$$\frac{\partial^2 U_B}{\partial a^2}\frac{\partial a^*}{\partial c} + \frac{\partial^2 U_B}{\partial a\partial\theta_T}\frac{\partial\theta_T^*}{\partial c} + \frac{\partial^2 U_B}{\partial a\partial c} = 0, \tag{40}$$

where

$$\frac{\partial^2 U_B}{\partial a^2} = -2k, \text{ and } \frac{\partial^2 U_B}{\partial a \partial c} = \frac{\frac{d\frac{p_{hh}}{p_{hl}}}{dc}k}{\left(\frac{p_{hh}}{p_{hl}} - 1\right)^2 \int_{\theta_T}^{1} (\theta - \theta_T) f(\theta) d\theta} > 0, \text{ and}$$

The first-order condition (32) implies that $\frac{\partial^2 U_B}{\partial a \partial \theta_T} = 0$. Since $d\frac{p_{hh}}{p_{hl}}/dc > 0$ from Assumption (A3) and $\frac{p_{hh}}{p_{hl}} > 1$ from Assumption (A1), $\frac{\partial^2 U_B}{\partial a \partial c} > 0$. We therefore obtain

$$\frac{\partial \theta_T^*}{\partial c} = -\frac{\frac{\partial^2 U_B}{\partial \theta_T \partial c}}{\frac{\partial^2 U_B}{\partial \theta_T^2}} > 0 \text{ and } \frac{\partial a^*}{\partial c} = -\frac{\frac{\partial^2 U_B}{\partial a \partial c}}{\frac{\partial^2 U_B}{\partial a^2}} > 0.$$

In the optimal solution, shareholder value is

$$U_B(a, \theta_T, c) = CF(a, \theta_T) - V(a, \theta_T, c),$$

where the levels of $a$ and $\theta_T$ satisfy the first-order conditions (32) and (40). The expected cash flow $CF$ is given in (10) and is independent from $c$. From Proposition 2, the expected compensation is

$$V(\theta_T, a, c) = ka^2 + \left(\theta_T + \frac{p_{hl}}{p_{hh} - p_{hl}}\right) \frac{ak}{\int_{\theta_T}^{1} (\theta - \theta_T) f(\theta) d\theta}.$$

By the envelope theorem,

$$\frac{dU_B(c)}{dc} = \left.\frac{\partial U_B(\theta_T, a, c)}{\partial c}\right|_{\substack{\theta_T = \theta_T^*(c) \\ a = a^*(c)}} \tag{41}$$

where $\theta_T^*(c)$ and $a^*(c)$ are the optimal solutions for any $c$. We now obtain

$$\frac{dU_B(c)}{dc} = -\left.\frac{\partial V(\theta_T, a, c)}{\partial c}\right|_{\substack{\theta_T=\theta_T^*(c) \\ a=a^*(c)}} > 0, \tag{42}$$

where $\frac{\partial V(\theta_T,a,c)}{\partial c} = -\frac{d\frac{p_{hh}}{p_{hl}}}{dc} \frac{1}{\left(\frac{p_{hh}}{p_{hl}}-1\right)^2} \frac{ak}{\int_{\theta_T}^1 (\theta-\theta_T) f(\theta) d\theta}$ is negative since $\frac{d\frac{p_{hh}}{p_{hl}}}{dc} > 0$ from (A3). ■

OLD proof

Using (32) and (40), we obtain

$$\frac{d\theta_T}{dc} = -\frac{\frac{\partial^2 U_B}{\partial\theta_T \partial c}}{\frac{\partial^2 U_B}{\partial \theta_T^2}} = -\frac{\frac{k\int_{\theta_T}^1 f(\theta)d\theta}{\left(\int_{\theta_T}^1 (\theta-\theta_T)f(\theta)d\theta\right)^2} \frac{d\frac{p_{hh}}{p_{hl}}}{dc}}{\frac{\partial^2 U_B}{\partial \theta_T^2}\left(\frac{p_{hh}}{p_{hl}} - 1\right)^2} > 0, \tag{43}$$

$$\frac{da}{dc} = -\frac{\frac{\partial^2 U_B}{\partial a \partial c}}{\frac{\partial^2 U_B}{\partial a^2}} = \frac{0.5\frac{d\frac{p_{hh}}{p_{hl}}}{dc}}{\left(\frac{p_{hh}}{p_{hl}} - 1\right)^2 \left(\int_{\theta_T}^1 (\theta - \theta_T) f(\theta) d\theta\right)} > 0, \tag{44}$$

which are both positive because (A3) implies $\frac{d\frac{p_{hh}}{p_{hl}}}{dc} > 0$ and (A1) implies $\frac{p_{hh}}{p_{hl}} > 1$ (and assuming that the second-order conditions for a maximum are satisfied, which requires that $\frac{\partial^2 U_B}{\partial \theta_T^2} < 0$).

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