Effects of Accounting Conservatism on Investment Efficiency and Innovation*

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ABSTRACT: We study how biases in financial reporting affect managers' incentives to develop innovative projects and to make appropriate investment decisions. Conservative reporting practices impose stricter verification standards for recognizing good news, and reduce the chance that risky innovations will lead to favorable future earnings reports. Holding all else constant, more conservative reporting therefore weakens the manager's incentive to work on innovative ideas, consistent with informal arguments in the extant literature. However, all else does not stay constant because the manager's pay plan will change in response to changes in the accounting system. We show that under optimal contracting, more conservative accounting does not stifle innovation in organizations, but rather increases incentives for innovation.

Keywords: Optimal contracting, Innovation, Accounting conservatism, Investment efficiency.

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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. On the one hand, innovation requires an environment that protects managers from failure and encourages risk-taking (Manso 2011; Reis 2011). On the other hand, conservative reporting practices impose stricter verification standards for recognizing good news relative to bad news (Basu 1997; Watts 2003), and reduce the chance that risky investments will translate into favorable earnings reports. Conservatism may thereby foster prudence and risk avoidance, and inhibit innovation in organizations.

What is missing from this intuition, however, is the role of incentive contracting. Corporate boards design optimal incentive pay plans to control managements' actions, and these incentive plans will change when the reporting system changes. The aim of this manuscript is to examine how conservative accounting practices affect innovation in organizations taking into account optimal incentive contracting. We find that contrary to conventional wisdom, more conservative accounting does not impede innovation, but instead fosters innovation. Understanding the relation between conservative accounting rules and incentives for innovation is important, as innovation is vital for the continued growth of the economy.

We consider a model that captures the following key features of innovation: (i) the manager must spend costly effort to develop innovative ideas, and more effort increases the probability that his idea is viable; (ii) after the manager has worked on the innovation, he privately observes a signal about its success probability and chooses to either implement the innovation or continue with the status quo; (iii) pursuing the innovation is more risky than maintaining the status quo; and (iv) the innovation generates results in the long run.

Due to the long-term nature of innovation, the manager's compensation is linked to an interim earnings report that is informative about the firm's economic performance. We define the firm's accounting system as being more conservative when the verification requirements for issuing a favorable report are more stringent. More conservative accounting policies therefore render the firm less likely to issue a favorable report, but if it does issue a favorable report, it is a more accurate indicator that firm performance is indeed high.

The extant informal accounting literature evaluates conservative accounting by how it *directly* affects innovation and investment efficiency, taking other governance tools, such as incentive contracting, as exogenously fixed. Our model generates results that are similar to the arguments presented in the literature if we also view the manager's pay plan as exogenous. Specifically, since a shift to more conservative accounting reduces the probability that risky investments translate into favorable future earnings reports, conservatism weakens the manager's incentive to spend effort developing innovative ideas, consistent with arguments in Chang et al. (2015). Conservatism not only affects the manager's ex ante effort incentive, but also his decision whether to invest in the new idea ex post based on his private information about its profitability. More conservative accounting renders investing in the innovation less attractive for the manager, which improves investment efficiency if the manager is inclined to overinvest in the innovation, but aggravates investment efficiency if he is inclined to underinvest in the innovation, consistent with arguments in Roychowdhury (2010). Given these effects, more conservative accounting can either reduce or increases firm value.

While these arguments are intuitive, the desirability of conservative accounting should be evaluated in a broader framework that takes into account that contracts are chosen optimally and that they will be adjusted when the reporting environment changes. When designing the optimal pay plan, the board must address two incentive problems: motivate the manager to spend effort on developing innovative ideas, and induce him to make an efficient investment decision based on his private information about the innovation's success probability. These two incentive problems, however, conflict with each other. The optimal contract that encourages the manager to work hard on developing innovative ideas induces him to invest in an innovation even when its success probability is relatively low. Due to this tension, the optimal contract implements two types of inefficiencies: insufficient innovation effort and overinvestment in the innovation relative to first-best.

The question now is, how does an increase in conservative accounting affect these agency frictions, and hence the manager's equilibrium actions? As discussed earlier, holding all else equal, an increase in conservatism reduces the probability that risky investments lead to favorable future earnings reports, and hence weakens the manager's incentive to work on innovative ideas. All else does not stay equal, however. We find that the board responds to an increase in conservatism by offering the manager stronger incentives to innovate. As a result, conservatism does not impair, but fosters, innovation in organizations. The intuition for this result is as follows. By imposing stricter verification requirements for issuing a favorable report, conservative accounting increases the probability that a favorable report is an accurate representation of firm performance. This feature of conservatism allows the board to design incentive contracts that tie the manager's pay more closely to the profitability of the innovation. Offering a pay plan that is more sensitive to the innovation's profitability is beneficial not just because it induces the manager to work harder on developing innovative ideas. Rather, the advantage of a higher pay-performance sensitivity is that it induces higher innovation effort *without* creating excessive incentives to subsequently overinvest in the innovation. In short, more conservative accounting enables the board to better tackle the twin problems of inducing effort and efficient investment, and thus reduces contracting frictions.

As long as an increase in conservative accounting renders favorable reports more indicative of high performance (which permits the board to offer contracts with a higher pay-performance sensitivity), an increase in conservatism (1) increases the manager's incentive to work on innovative ideas, (2) reduces the manager's incentive to overinvest in an innovation, and (3) ultimately increases firm value. Overall, our results indicate that conservative accounting does not discourage innovation in organizations, as is typically argued, but instead encourages innovation.

Due to the aforementioned effects, the optimal accounting system is characterized by strict verification requirements that minimize the risk that a high report is an incorrect representation of firm performance. This characteristic of the optimal accounting system is consistent with the conservatism principle embedded in many accounting rules. For example, strict revenue recognition standards, expensing of R&D costs, and the lower of cost or market approach all have in common that if there is uncertainty, firms must play it safe and rather understate than overstate firm performance. As a consequence, these rules minimize the risk that firms portray their financial situation as too rosy, consistent with the optimal accounting system in our model.

Our paper fuses two streams of the analytical conservatism literature. The first stream examines the effect of conservatism on investment efficiency (Gigler et al. 2009; Li 2013; Nan and Wen 2014; Caskey and Laux 2017). 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 earnings, 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. 2017). 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 accounting 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 spend effort developing an innovation, the bias in the accounting system would be irrelevant. It is the combination of both the effort moral hazard problem and the investment adverse selection problem that creates a role for conservative accounting. We contribute to the literature on conservatism by providing a formal discussion of how conservative accounting relates to optimal contracting, investment efficiency, and innovation.

Other papers that study the dual problems of inducing effort and efficient interim decisions include, e.g., Lambert (1986), Levitt and Snyder (1997), and Laux (2008). These studies show that providing the manager with effort incentives comes at the cost of encouraging inefficient interim actions, such as overinvestment or CEO entrenchment. However, these papers do not study the effects of conservative accounting policies. We show that more conservative accounting allows the board to design contracts that can better address the dual problems of inducing effort and efficient investment. Conservative accounting therefore results in contracts that lead to greater innovation effort, more efficient investment, and higher firm value.

[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.

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 tasks of developing new investment opportunities and deciding whether to invest in the new opportunity based on a privately observed signal about its profitability. The board's task is to set up the firm's financial reporting system and to design the incentive contract for the manager. The timeline and the details of the model follow.

Timing: There are five dates. At date 1, the board designs the accounting system and the incentive contract. At date 2, the manager expends effort to work on new investment ideas. At date 3, the manager privately observes the success probability of the investment idea and decides whether to implement it or continue with business as usual. At date 4, the accounting system generates a public report 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 has expired. Hence, X cannot be used for contracting purposes.

Innovation effort: The manager has an investment idea that is either viable or nonviable. The viable idea succeeds with probability θ, where θ is drawn from a distribution $F(\theta)$, with density $f(\theta)$ and full support over the interval $[0, 1]$. The nonviable idea has a success probability of zero, $\theta = 0$. As will become apparent below, the manager always prefers to reject a nonviable investment idea since it fails with certainty. The manager can take a costly and unobservable action $a \in [0, 1]$ to increase the probability that his idea is viable. Specifically, with probability a the idea is viable, and with probability $(1 - a)$ it is nonviable.[2] The manager's personal cost of effort a is $0.5ka^2$, where $k > 0$ is a constant. We

[2] An alternative modeling approach is to assume that the project's probability of success θ is drawn from a distribution $f(\theta|a)$ and that a higher effort level a shifts the probability distribution to the right in the sense of first-order stochastic dominance. This setting becomes intractable quickly, but is solvable when the effort choice is binary, $a \in \{a_L, a_H\}$. Similar to the present model, an increase in conservatism allows the board to better tackle the dual problems of inducing effort and efficient investment. An increase in conservatism

assume the parameter k is sufficiently large to ensure an interior solution with $a < 1$.

Project choice: After choosing effort, the manager privately learns the profitability θ of the new investment idea and decides whether to implement it or continue with business as usual. If the manager invests in the new project, the project succeeds with probability θ, 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 with business as usual, cash flow is $X_m > 0$. Assume that $X_l < X_m < X_h$; hence, innovation renders cash flows more volatile.

Accounting report: The firm issues a contractible report $R \in \{R_h, R_m, R_l\}$ that is informative about the future cash flow X. If the manager continues with business as usual, there is no uncertainty, and the report is $R = R_m$, representing cash flows X_m. If the manager implements the risky innovation, the accounting report is either high ($R = R_h$) or low ($R = R_l$).[3] The mapping from the output $X \in \{X_h, X_l\}$ to the report $R \in \{R_h, R_l\}$ follows a two-step process (see, e.g., Kwon et al. (2001), Dye (2002), and Gao (2015)). In the first step, evidence $e = X + \varepsilon$ about the outcome is generated, where ε is drawn from a distribution with density $f(\varepsilon)$ and positive support over $(-L, L)$. Let $f(e|X)$ denote the probability density of e conditional on output X. See Figure 1 for a graphical illustration of the probability densities.

We denote $e_1 \equiv X_h - L$ and $e_2 \equiv X_l + L$ and assume that $e_2 > e_1$. Thus, any evidence e below e_1 indicates a low output, $X = X_l$; any evidence above e_2 indicates a high output,

therefore leads to more efficient investment and higher firm value. Proofs are available upon request.

[3] We can modify our model so that the board cannot infer the manager's investment decision from the report R. Specifically, suppose that implementing a viable project leads to a risky outcome with probability $\beta_I < 1$, in which case the outcome is high, X_h, with probability θ and low, X_l, with probability $(1 - \theta)$. However, with probability $(1 - \beta_I)$ the outcome is safe and $X = X_m$. In contrast, if the manager continues with business as usual, the outcome is risky with probability β_N, where $\beta_N < \beta_I$, in which case the high and low outcome are equally likely. With probability $(1-\beta_N)$ the outcome is safe and $X = X_m$. The assumption $\beta_I > \beta_N$ captures the notion that investing in an innovation is more risky than continuing with business as usual. We can show that as long as the probability of generating a high cash flow X_h is higher when the manager invests in an innovation than when he continues with business as usual, our qualitative results continue to hold. Details are available upon request.

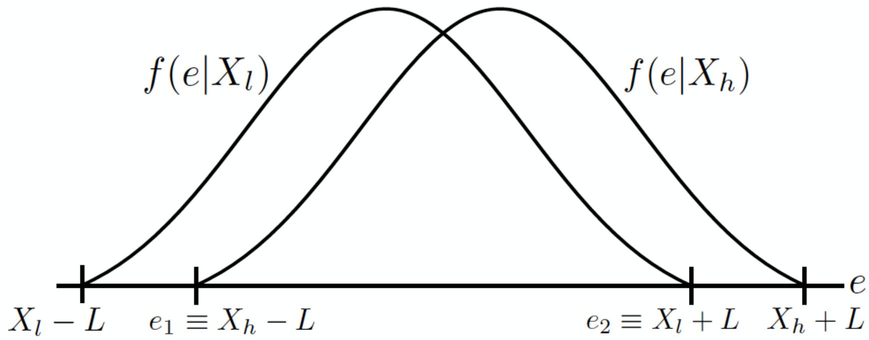

Figure 1

$X = X_H$; and evidence in the range (e_1, e_2) is inconclusive about X. We make the standard assumption that the likelihood ratio $f(e|X_h)/f(e|X_l)$ is increasing in e for all $e \in [e_1, e_2]$, that is, the monotone likelihood ratio property (MLRP) holds. This property implies that higher evidence e is good news since it indicates that the output is more likely high.

In the second step, the accounting system partitions evidence e into a binary report $R \in \{R_h, R_l\}$. Specifically, there is a threshold c such that the report is low, $R = R_l$, when $e < c$, and high, $R = R_h$, when $e \geq c$. The threshold c is observable to all players. Letting $p_{ij} \equiv \Pr(R_i|X_j)$ denote the probability that the accounting system generates report R_i when cash flow is X_j, with $i, j \in \{h, l\}$, we obtain:

$$p_{hh} = \int_c^{X_h+L} f(e|X_h)de \text{ and } p_{hl} = \int_c^{X_l+L} f(e|X_l)de, \tag{1}$$

$$p_{lh} = \int_{X_h-L}^{c} f(e|X_h)de \text{ and } p_{ll} = \int_{X_l-L}^{c} f(e|X_l)de. \tag{2}$$

The threshold c reflects a summary measure of the set of conditions that must be satisfied to issue a favorable report. An accounting system is more conservative when the requirements for a favorable report are more stringent, that is, when c is higher. This characterization is consistent with Basu (1997) and Watts (2003), who define conservative reporting practices as imposing stricter verification standards for recognizing good news than for recognizing bad news.

In practice, the degree of conservatism in a firm is determined collectively by the measurement principles the firm applies when it recognizes revenues, expenses or capitalizes development costs, impairs assets, recognizes loss contingencies, and values inventory. In general, when there is business uncertainty, more conservative accounting practices require the use of methods that are more likely to understate, rather than overstate, financial performance.

Contracting: At date 1, the board offers the manager a contract that specifies his payments contingent on the accounting report R. Specifically, the contract is given by $W = (w_h, w_m, w_l)$, where w_i denotes the manager's payment if $R = R_i$. The manager is protected by limited liability in the sense that payments must be nonnegative; that is, $w_i \geq 0$ for each $i = h, m, l$. The limited liability constraint restricts the board's ability to use punishments as a means to provide incentives. The board therefore has to rely solely on rewards as an incentive tool, which allow the manager to enjoy a positive utility. To guarantee contracting frictions, we make the standard assumption that the manager's reservation utility is below a certain threshold, denoted $\underline{U}_T$ (where $\underline{U}_T > 0$ is specified in the appendix). This assumption implies that the rewards that induce the second-best actions yield the CEO an expected utility that exceed his reservation utility; that is, the manager reaps an economic rent. The board therefore faces a trade-off between the costs of granting the manager larger rents and the benefits of inducing more efficient actions.[4]

[4] As is typical in limited liability settings, if the manager's reservation utility is very high, the board can implement the first-best actions without leaving the manager any rents. In this case, there are no contracting frictions and the level of conservatism plays no role. However, this is only the case if the manager's reservation utility is so high that he must receive most of the output just to ensure his participation, leaving the shareholders only with X_l. Let $\underline{U}_F$ denote the reservation utility that leads to the first-best actions and note that $\underline{U}_F > \underline{U}_T$. If $\underline{U}$ lies between $\underline{U}_T$ and $\underline{U}_F$, the board cannot implement first-best actions without leaving the manager rents and induces the highest actions that keep him at his reservation utility $\underline{U}$; that is, the manager's participation constraint determines the optimal actions. Assuming that $\underline{U} \in (\underline{U}_T, \underline{U}_F)$ does not change our main results that more conservative accounting leads to a higher innovation effort level and higher firm value (under optimal contracting). Proofs are available upon request.

Since the manager is privately informed about the profitability θ of the new project, the board grants the manager the authority to make the investment decision. We show in Appendix B 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 θ. This revelation mechanism does not outperform the simple contract we study.

Figure 2 depicts the game tree of the model.

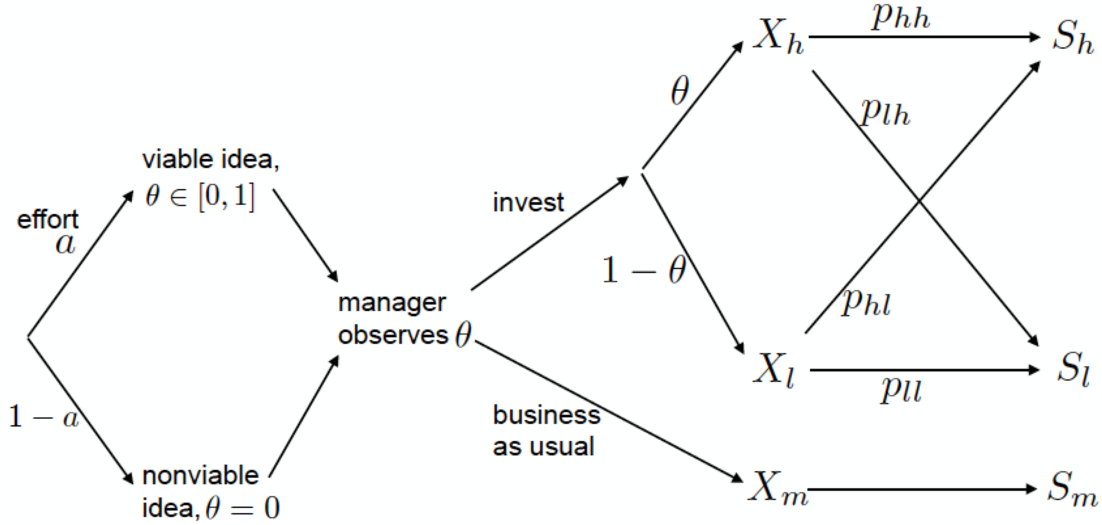

Figure 2

3 Definition of Conservatism

The firm's accounting system is more conservative when the requirements for a favorable report are more stringent, that is, when c is larger. This is consistent with the definition of conservatism in Gigler et al. (2009). Specifically, for any threshold $c \in [e_1, e_2]$, our setting satisfies Gigler et al.'s (2009) conditions (A1)-(A3). Translated into our setting, these conditions are as follows[5]:

(A1) The likelihood ratio $\frac{\Pr(R|X_h)}{\Pr(R|X_l)}$ is increasing in R: $\frac{p_{hh}}{p_{hl}} > 1 > \frac{p_{lh}}{p_{ll}}$.

(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) implies that the accounting report is informative about X, where R_h represents good news and R_l represents bad news. Thus, the posterior probability of a high (low) cash flow given a high (low) report exceeds the prior probability: $\Pr(X_h|R_h, \theta) > \theta$ and $\Pr(X_l|R_l, \theta) > (1 - \theta)$.

(A2) implies that more conservative accounting increases the probability that both X_h and X_l lead to a low rather than high accounting report. Intuitively, an increase in the threshold c strengthens the requirements that must be satisfied for a favorable report, and hence reduces the probability of a favorable report.

(A3) implies that conservative accounting increases the information content of the high report but reduces the information content of the low report:

$$\frac{d\Pr(X_h|R_h, \theta)}{dc} > 0 \text{ and } \frac{d\Pr(X_l|R_l, \theta)}{dc} < 0. \tag{3}$$

As the requirements for issuing a high report become more stringent (c increases), the high report becomes a better indicator of high output X_h and the low report becomes a weaker indicator of low output X_l.

When the threshold c reaches e_2, the requirements for issuing a high report are so stringent that the high report becomes a clear indicator that the firm's economic performance is high,

[5] We show in Appendix C that conditions (A1)-(A3) follow from (1) and (2).

$\Pr(X_h|R_h) = 1$. Any further increase in c above e_2 does not change the information content of R_h but reduces the information content of R_l (since p_{lh} increases with c). Similarly, when c reaches e_1, the requirements for reporting good news are so weak that a low report becomes a clear indicator that economic performance is indeed grim, $\Pr(X_l|R_l) = 1$. Reducing c below e_1 does not change the information content of R_l, but reduces the information content of R_h (since p_{hl} increases as c decreases). It is therefore without loss of generality to focus on the intermediate values $c \in [e_1, e_2]$ in what follows.

4 Managerial Actions

In this section, we solve for the manager's effort and investment choices given contract W and determine the board's optimization problem. After the manager observes the profitability θ of the new investment idea, he decides whether to implement it or continue with business as usual. Conditional on θ, the manager's expected compensation if he implements the innovation is

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

where

$$E[w|X_h] = p_{hh}w_h + p_{lh}w_l, \tag{4}$$

$$E[w|X_l] = p_{hl}w_h + p_{ll}w_l, \tag{5}$$

are the manager's expected pay when future cash flows are high, X_h, and low, X_l, respectively. We refer to $\Omega(\theta)$ as the manager's innovation compensation.

The manager invests in the innovation rather than continues business as usual if and only if:

$$\Omega(\theta) \geq w_m. \tag{6}$$

As will become clear later, the optimal contract W is such that

$$E\left[w|X_h\right] > w_m > E\left[w|X_l\right] \tag{7}$$

is satisfied. The first inequality in (7) implies that the manager's payoff is higher if he implements an innovation that succeeds with certainty than if he continues with the status quo, and the second inequality implies that the manager's payoff is lower if he implements an innovation that fails with certainty than if he continues with the status quo.

Given (7), there is a unique interior threshold, θ_T, that satisfies

$$\Omega(\theta_T) = w_m, \tag{8}$$

so that the manager implements the innovation if its profitability θ exceeds θ_T, and continues with business as usual if θ is below θ_T.

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

$$U = \Psi - 0.5ka^2, \tag{9}$$

where

$$\Psi = a\left(\int_{\theta_T}^{1} \Omega(\theta)f(\theta)d\theta + F(\theta_T)w_m\right) + (1-a)w_m \tag{10}$$

is his expected compensation. With probability a, the innovation is viable and the manager implements it if $\theta \geq \theta_T$, yielding him $\Omega(\theta)$, and continues with the status quo if $\theta < \theta_T$, yielding him w_m. With probability $(1-a)$, the innovation is nonviable and the manager

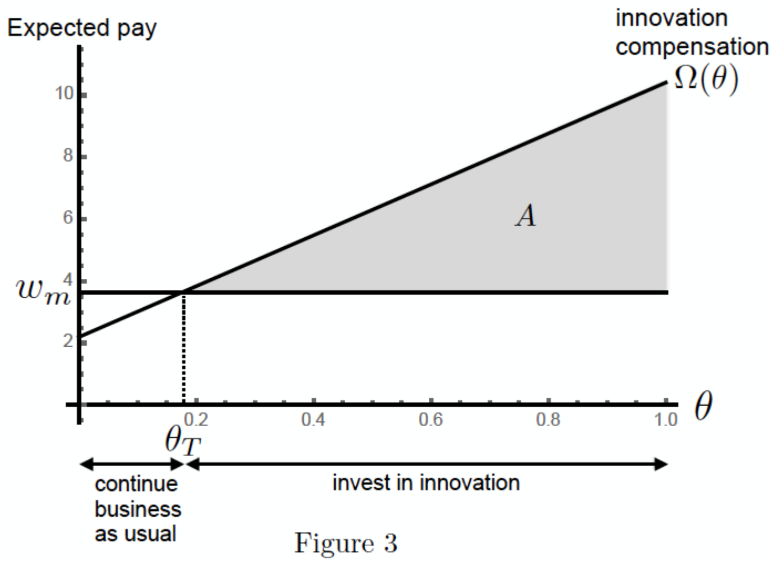

Figure 3

continues with the status quo. Taking the first-order condition for a maximum yields:

$$a = \frac{1}{k} \int_{\theta_T}^{1} \left(\Omega(\theta) - w_m\right) f(\theta) d\theta. \tag{11}$$

Figure 3 illustrates the manager's incentives graphically. We assume in the figure (and in all figures that follow) that the profitability θ of a viable project follows a uniform distribution over the interval $[0, 1]$. The x-axis is the profitability θ of the new project and the y-axis is the manager's expected pay. The manager's investment threshold θ_T is determined by the intersection between the expected pay he receives when pursuing the innovation, $\Omega(\theta)$, and the pay w_m he receives when continuing with business as usual.

Region A in Figure 3 represents the increase in the manager's ex ante compensation if he develops a viable idea, and hence determines his innovation effort incentive. Since the figure considers a uniform distribution, the manager's effort choice is $a = A/k$. The larger the region A, the larger is the expected reward for developing a viable innovation and the higher is the manager's incentive to expend innovation effort.

Given the manager's effort and investment choices, the firm's ex ante cash flow is:

$$CF = a\left(\int_{\theta_T}^{1} (\theta X_h + (1-\theta)X_l)\, f(\theta)d\theta + F(\theta_T)X_m\right) + (1-a)X_m. \tag{12}$$

The board's problem is now to maximize the expected firm value

$$\max_{(a,\theta_T)} \; V = CF - \Psi, \tag{13}$$

subject to the manager's incentive constraints (8) and (11), his participation constraint $U \geq \underline{U}$, and the limited liability constraints w_h, w_m, $w_l \geq 0$. To ensure that the board's optimization problem is concave, we assume that the marginal cost of effort, k, is sufficiently high.[6]

As a reference, note that the first-best actions solve

$$\max_{(a,\theta_T)} \; CF - 0.5ka^2.$$

The first-best investment decision is to implement the innovation if and only if $\theta \geq \theta_{FB}$, where θ_{FB} is defined by

$$\theta_{FB}X_h + (1-\theta_{FB})X_l = X_m \tag{14}$$

and the first-best innovation effort is

$$a_{FB} = \frac{1}{k}\int_{\theta_{FB}}^{1} (\theta X_h + (1-\theta)X_l - X_m)\, f(\theta)d\theta. \tag{15}$$

[6] See the proof of Proposition 2 for details.

5 Benchmark: Effects of conservatism when the pay plan is exogenous

We start the analysis with a benchmark case in which the manager's pay plan W is given with $E[w|X_h] > w_m > E[w|X_l]$ (see (7)), and consider how changes in the accounting system affect the manager's actions and firm value. Fixing the contract replicates some of the casually argued links between accounting conservatism, investment efficiency, and innovation made in the literature.

The next proposition establishes how an increase in conservative accounting affects the manager's effort a devoted to innovation effort, his investment threshold θ_T, his expected pay Ψ, and firm value V. All proofs are in the Appendix.

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

(i) increases the investment threshold θ_T above which the manager implements the innovation;

(ii) reduces the manager's innovation effort a;

(iii) reduces the manager's expected compensation Ψ;

(iv) either increases or decreases firm value V.

When the accounting system is more conservative, investing in a risky innovation is less likely to result in a favorable earnings report. The manager's expected innovation compensation $\Omega(\theta)$ is therefore lower when the accounting system is more conservative for any given θ.[7] Figure 4 depicts the decline in the manager's expected innovation compensation when

[7]Formally, using (4) and (5) and recognizing that $p_{ll} = (1 - p_{hl})$ and $p_{lh} = (1 - p_{hh})$, the manager's innovation compensation can be written as

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

which decreases with c for all θ since $dp_{hh}/dc < 0$, $dp_{hl}/dc < 0$, and $w_h > w_l$.

conservatism increases from c to c'.[8]

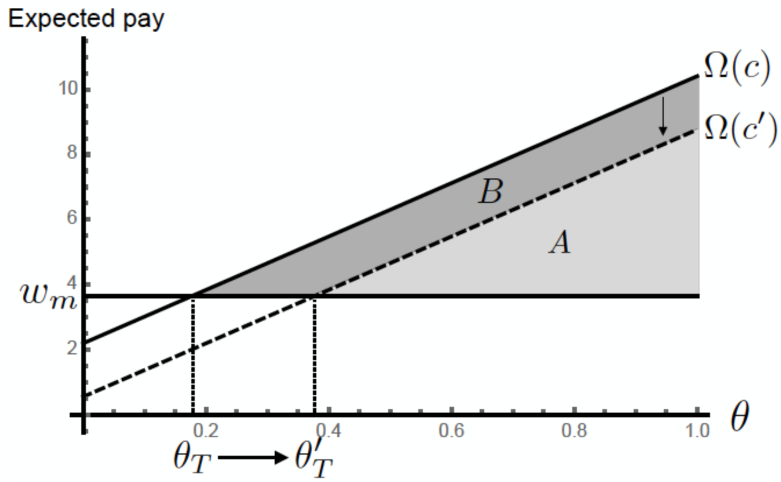

Figure 4

The decline in the innovation compensation Ω associated with an increase in c renders the manager less eager to work hard on developing innovative ideas. The manager's innovation effort choice therefore declines from $a = (A + B)/k$ to $a' = A/k$ in Figure 4. This result is consistent with the view put forth by Chang et al. (2015), who argue that conservative accounting stifles innovation in organizations.

Further, the degree of conservatism affects the manager's investment decision once he has made his effort choice. Specifically, the decline in Ω reduces the manager's incentive to invest in the innovation, and hence increases the investment threshold from θ_T to θ'_T in Figure 4. Whether an increase in the threshold θ_T improves or worsens investment efficiency depends on whether the investment threshold θ_T initially lies below or above the first-best level θ_{FB}. If $\theta_T < \theta_{FB}$, the manager overinvests in the innovation for all $\theta \in [\theta_T, \theta_{FB})$, in the sense that he implements the new idea even though continuing the status quo is optimal for shareholders. More conservative accounting then reduces the manager's overinvestment incentive and pushes θ_T closer to θ_{FB}. The opposite is true when $\theta_{FB} < \theta_T$. In this case,

[8] To ease exposition, Figure 4 (and all figures that follow) assumes $\partial p_{hh}/\partial c = \partial p_{hl}/\partial c$, so that an increase in c reduces the intercept of the innovation compensation Ω but not its slope.

the manager underinvests in the innovation for all $\theta \in (\theta_{FB}, \theta_T]$ and more conservative accounting aggravates the manager's underinvestment incentive. These findings are consistent with Roychowdhury (2010), who points out that conservatism is no panacea because it can alleviate as well as aggravate investment inefficiencies.

Coupling these effects, an increase in conservatism can increase or decrease firm value, as stated in part (iv) of Proposition 1.

6 Optimal Contracting

We now take into account that incentive contracts are chosen endogenously and that they will be adjusted in response to changes in the accounting system. Allowing for optimal contracting leads to conclusions that differ significantly from those in the benchmark section. Specifically, we find that more conservative accounting practices do not result in weaker managerial incentives to work on innovative projects, but result in stronger innovation effort incentives. Further, conservatism always leads to more efficient investment and higher firm value.

Our analysis proceeds in two steps. In Section 6.1 we show that the optimal pay plan that motivates the manager to work on an innovation induces him to subsequently overinvest in the innovation. Due to this tension, the optimal effort level and investment threshold lie below the first-best levels, $a^* < a_{FB}$ and $\theta_T^* < \theta_{FB}$. We then show in Section 6.2 that more conservative accounting alleviates the tension between inducing effort and inducing efficient investment, and thus results in less overinvestment, greater innovation effort, and higher firm value.

6.1 Tension between inducing effort and efficient investment

When designing the contract W the board has to address two incentive problems: motivate the manager to work hard on developing a viable innovation, and induce him to make an efficient investment decision based on his private information about the innovation's profitability θ. These two incentive problems conflict with one another. To show why, consider Figure 5A and suppose the pay plan (w_h, w_m, w_l) depicted there implements actions that are below first-best, $\theta_T < \theta_{FB}$ and $a < a_{FB}$.[9]

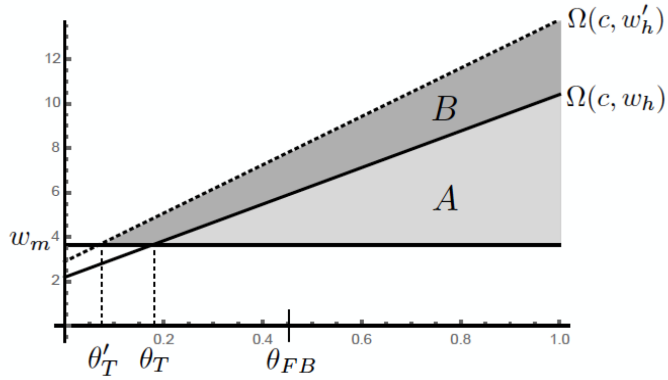

Figure 5A

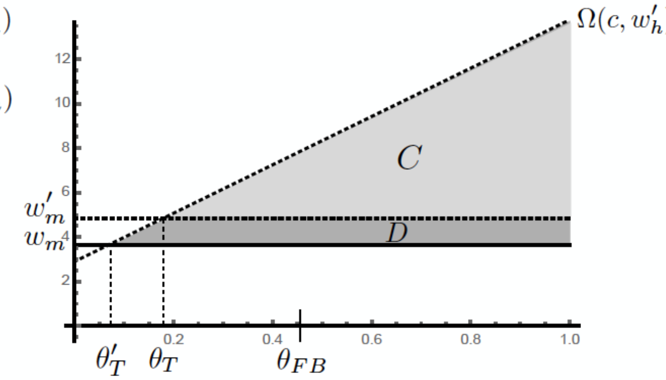

Figure 5B

If the board wishes to boost the manager's incentive to work on an innovation, it can do so by increasing the manager's bonus w_h for a high accounting report, say to w_h'. The higher bonus increases the innovation compensation from $\Omega(c, w_h)$ to $\Omega(c, w_h')$, and hence the manager's effort level from $a = A/k$ to $a' = (A + B)/k$, as depicted in Figure 5A. The higher bonus, however, has two drawbacks: First, it increases the manager's expected compensation, and second, it boosts the manager's incentive to overinvest in a viable innovation, reducing the investment threshold from θ_T to θ_T'. The board's goal of inducing effort therefore conflicts with its goal of inducing efficient investment.

[9] The contract (w_h, w_m, w_l) depicted in Figure 5A is actually the optimal contact when $k = 5$, $X_h = 110$, $X_l = 0$, $X_m = 50$, and $p_{hh}(c) = 0.95$, $p_{hl}(c) = 0.2$.

The board can of course counteract the manager's increased incentive for overinvestment by offering a greater reward for continuing business as usual, w_m. When w_m increases to w_m', as depicted in Figure 5B, the manager's investment threshold increases back to the initial level θ_T. But rewarding the manager for doing business as usual increases the manager's pay, and also weakens his incentive to innovate. The manager's innovation effort incentive therefore declines from $(C + D)/k$ to C/k in Figure 5B. To preserve incentives for innovation effort, an increase in w_m must be combined with an increase in the bonus w_h, which further increases the cost of the incentive system, and so on.

Due to these interactions and costs, the optimal contract implements actions that lie below the first-best levels, $\theta_T^* < \theta_{FB}$ and $a^* < a_{FB}$, as stated in the next proposition. The optimal pay plan (w_h, w_l, w_m) that implements the optimal actions can be found in the appendix.

Proposition 2 *For any level of conservatism c, the optimal contract induces the manger*

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

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

relative to the first-best levels.

6.2 The value of conservative accounting

We are now ready to study the benefits of conservative accounting practices. The analysis proceeds as follows. We first show that conservatism alleviates the contracting tensions that we discussed in the previous subsection. We then show that more conservative accounting leads to contracts that implement greater innovation effort and more efficient investment, and ultimately increases firm value.

We know from Section 6.1 that offering the manager a higher bonus w_h spurs his incentive to work on the innovation, but has the downside of creating stronger incentives for overinvestment. Proposition 3 shows that an increase in both w_h and c allows the board to boost the manager's innovation effort incentive without increasing his incentive for overinvestment.

Proposition 3 *For all* $c \in [e_1, e_2]$*, a higher level of conservatism alleviates the tension between inducing effort and inducing efficient investment. Specifically, as* c *increases, the board can offer a larger bonus* w_h *to:*

(i) increase the level of innovation effort, a*, without increasing incentives for overinvestment (*θ_T *stays constant), or*

(ii) reduce overinvestment incentives (increase θ_T*) without reducing the level of innovation effort (effort* a *stays constant).*

The intuition behind the result in Proposition 3(i) can be best explained with the help of Figure 6A, which depicts the change in innovation compensation Ω when the bonus and the level of conservatism increase from (w_h, c) to (w_h', c').

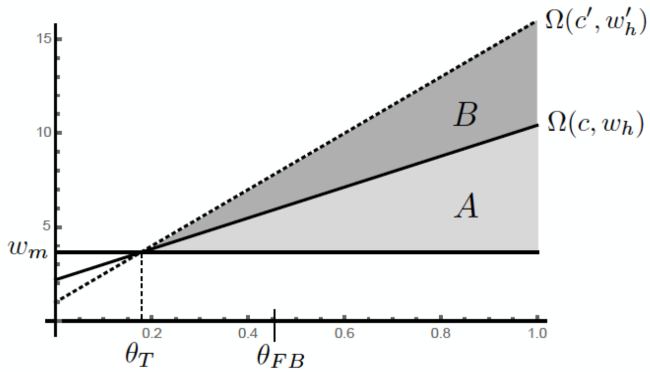

Figure 6A

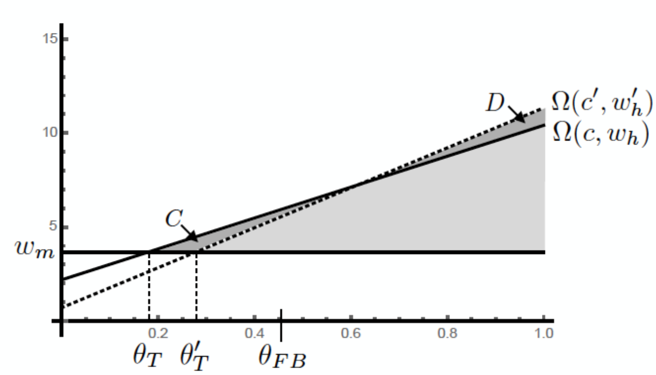

Figure 6B

More conservative accounting shifts the manager's innovation compensation Ω downward and the higher bonus w_h increases the slope of Ω. As a result, the innovation compensation Ω becomes more sensitive to the innovation's success probability θ. The advantage of the higher pay-performance sensitivity is not just that it increases the manager's incentive to work on the innovation from A/k to $(A+B)/k$ (see Figure 6A). Rather, the advantage is that it increases innovation effort incentives *without* increasing the manager's incentive to overinvest in low profitability projects, that is, the manager's investment threshold θ_T remains unchanged. As long as more conservative accounting renders the high report more informative of high performance (that is, $d\frac{p_{hh}}{p_{hl}}/dc > 0$), the board can exploit an increase in c to tie the manager's innovation pay closer to θ. This is the case until conservatism reaches $c = e_2$. Increasing c above e_2 does not further increase the information content of the high report, and hence has no effect on contracting.

Alternatively, the board can respond to an increase in c by adjusting the bonus w_h so that the manager's overinvestment incentive declines but his incentive for innovation effort remains constant (as stated in part (ii) of Proposition 3). This case is depicted in Figure 6B, where the shift from (w_h, c) to (w_h', c') increases the investment threshold from θ_T to θ_T' but leaves effort incentives unchanged, since $C = D$. The steeper performance sensitivity of Ω implies that the manager's incentive for innovation effort now comes mainly from highly profitable innovations. Thus, the manager is less inclined to overinvest in an innovation while his incentive to spend innovation effort remains unchanged.

Both cases demonstrate that more conservative accounting permits the board to better tackle the twin problems of encouraging the manager to work on innovative ideas and make efficient investment decisions. Since conservative accounting reduces agency frictions, a higher degree of conservatism results in more efficient actions and higher firm value, as stated in Proposition 4.

Proposition 4 *For all $c \in [e_1, e_2]$, a higher level of conservatism*

(i) increases the investment threshold θ_T^* and reduces overinvestment,

(ii) increases innovation effort a^*, and

(iii) increases firm value V.

It is instructive to compare these results with the results from Section 4, where we treat the contract as exogenous. With exogenously fixed payments, conservatism renders risky innovations less attractive for the manager and reduces his incentive to work on new ideas. With optimal contracting, the result flips and conservatism always leads to more -not less- innovation effort.

Further, with exogenous payments, the effect of more conservative accounting on investment efficiency is ambiguous, because it can lead to either less overinvestment or more underinvestment, depending on whether $\theta_T < \theta_{FB}$ or $\theta_T > \theta_{FB}$. In contrast, under optimal contracting, conservative accounting always leads to more efficient investment decisions.

Finally, whereas with exogenous payments an increase in conservatism can increase or decrease firm value, with endogenous payments, conservatism always increases firm value.

7 Optimal Accounting System

From Proposition 4 we know that more conservative accounting reduces contracting frictions and yields a higher firm value until c reaches e_2. This result immediately leads to the next corollary.

Corollary 1 *The level of conservatism that maximizes firm value is $c^* = e_2$.*

When the level of conservatism is chosen optimally, $c = e_2$, the requirements for issuing a high report R_h are so stringent that the firm can only report R_h if the evidence e clearly supports the good news (that is, $e \geq e_2$). Thus, if there is uncertainty about the output, the firm has to play it safe and understate, rather than overstate, financial performance. The optimal level of conservatism therefore minimizes the risk that the firm issues a high report when output is in fact low.

These characteristics of the optimal accounting system are consistent with the conservatism principle embedded in many accounting rules. For example, under conservative revenue recognition principles, firms must anticipate possible future losses but can only recognize revenues when they are assured of being received. Further, generally accepted accounting principles (GAAP) require that R&D costs must be expensed as incurred rather than capitalized, because the future economic benefits of those costs are uncertain. As another example, U.S. GAAP uses a lower of cost or market (LCM) approach to determine the value of assets such as inventory. Under this rule, if the firm believes the expected market price is below the acquisition cost, it must write down the value of the asset. The firm cannot write up the value of the asset, however, if it believes the expected market price exceeds the acquisition cost. The LCM rule therefore ensures that the book value of the asset never exceeds the true value. These accounting rules have in common that if there is uncertainty, firms have to play it safe and use methods that understate, rather than overstate, financial performance. As a consequence, these rules minimize the risk that firms portray their financial situation as too rosy. These features are consistent with the properties of the accounting system in our model when $c = e_2$.

We next determine the optimal pay plan and equilibrium actions when conservatism is chosen optimally. To do so, note that for $c = e_2 \equiv X_l + L$, the conditional probabilities in (1) and (2) change to

$$p_{hh} = \int_{X_l+L}^{X_h+L} f(e|X_h)de \text{ and } p_{hl} = 0, \tag{16}$$

$$p_{lh} = \int_{X_h-L}^{X_l+L} f(e|X_h)de \text{ and } p_{ll} = 1. \tag{17}$$

Substituting these probabilities into (24), (25), (35), (36), and (46) in Appendix A yields the optimal pay plan, managerial actions, and firm value.

Three observations are useful. First, when the level of conservatism is chosen optimally, $c = e_2$, the incentive problems discussed in Section 6.1 still prevail but are less severe relative to the case in which $c < e_2$. Thus, the first-best solution cannot be achieved and the optimal contract implements an investment threshold and an innovation effort level below the first-best levels, $\theta_T^* < \theta_{FB}$ and $a^* < a_{FB}$.[10]

Second, the fact that the contract can only be contingent on the earnings report R but not on the long-term output X does not negatively affect firm performance when the level of conservatism is chosen optimally (but does reduce firm value if c is suboptimal). Thus, for $c = e_2$, the optimal contract studied here leads to the same equilibrium actions and firm value that would result if the firm were able to write contracts that are directly contingent on long-term output. The reason is that the optimal earnings-based contract rewards the manager only for a high report, and the high report is a clear indicator of high firm performance when $c = e_2$.[11]

Finally, since for $c = e_2$ the firm can achieve the same performance as if the long-term outcome X were contractible, linking the manager's pay to an interim stock price cannot further improve contracting. This follows because the stock price cannot provide more information about X than X itself. To be sure, the stock price may very well reflect more information about firm performance than a conservative earnings report. For example, R&D expenditures are expensed as incurred for accounting purposes, but are reflected in the market valuation of the firm. However, the very fact that conservative reporting does

[10] Formally, this can be seen by substituting $c = e_2$ into the first-order conditions for θ_T^* and a^* given in (35) and (36) and comparing these first-order conditions with the first-best actions determined in (14) and (15).

[11] To obtain the optimal solution when X is contractible, we do not need to redo the analysis, but merely have to set $p_{hh} = 1$ and $p_{ll} = 1$, because the report R is then a one-to-one mapping of the outcome X. When the board contracts on R and chooses c, it can never achieve $p_{hh} = 1$ and $p_{ll} = 1$, as is apparent from (1) and (2). Instead, the optimal level of conservatism, $c = e_2$, leads to $p_{ll} = 1$ and $p_{hh} < 1$, which implies that only the high report, but not the low report, is a perfect indicator of output X. Inspection of (24), (25), (35), and (36) shows that the optimal contract and actions are determined by $\frac{p_{hl}}{p_{hh} - p_{hl}}$. Since $c = e_2$ achieves $p_{hl} = 0$, the optimal earnings-based contract replicates the optimal output-based contract.

not reflect certain information is the reason why contracting based on conservative reports is optimal in our setting. Conservative reporting practices ensure that the firm reports good news only when the underlying information satisfies strict verification standards. In contrast, the stock price reflects any information that is performance relevant, even when it does not satisfy these standards.

8 Discussion and Empirical Implications

Our model predicts that adopting more conservative accounting practices will lead to (i) stronger managerial incentives to develop innovative ideas, and (ii) weaker incentives to invest in new ideas 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; see, e.g., Francis and Martin 2010, Bushman et al. 2011, Ball and Shivakumar 2005, and Garcia Lara et al. 2016.

To the best of our knowledge, the working paper by 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, which causes 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 either continues with business as usual or implements an innovation.

For example, a consumer electronics company can venture out into new technologies, products, and markets that depart from their existing business model (think of Apple creating the iPhone). This type of innovation changes the direction of the firm and is highly risky and disruptive. Alternatively, the firm can continue with business as usual, which will likely lead to improvements of existing products and services (think of Apple's yearly update of the iPhone). Since both types of activities generate patents, the number of patents is not a useful proxy for the type of innovation our model addresses. Balsemier et al. (2017) have developed new, more refined measures of innovation to distinguish between exploration of new technologies and exploitation of well-known technologies. For example, they argue that patents that cite other patents owned by the same company are based on existing knowledge, while patents that do not cite other patents are more explorative. These more refined measures of innovation could be used to test our theory, and we encourage empirical researchers to do so.

9 Conclusion

Innovation and conservatism seem to be conflicting concepts: Innovation involves risk taking and discovery, while conservatism embodies caution and risk avoidance. In this paper, we argue that conservatism and innovation can actually reinforce one another. Our model of innovation involves a manager who must first exert costly effort to develop a viable innovation 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 report that is informative about the economic performance of the firm.

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 practices reduces the probability that risky investments yield high earnings reports, and therefore weakens the manager's incentive to spend effort developing new ideas ex ante. Further, conservatism increases the profitability threshold above which the manager invests in a new idea, which either increases or decreases investment efficiency, depending on whether the manager is initially tempted to overinvest or underinvest in the innovation. The effect of conservatism on firm value is therefore ambiguous. These findings are broadly consistent with informal arguments in the literature.

Corporate boards, however, design optimal incentive pay plans, and these plans change when the accounting system changes. When designing the optimal contract, the board faces the challenge of providing the manager with incentives to spend effort on innovative ideas without inducing him to subsequently overinvest in a new idea. We find that conservative accounting alleviates the tension between inducing innovation effort and inducing efficient investment, and hence leads to more efficient actions. As a result, in equilibrium, more conservative accounting (i) increases the manager's incentive to work on innovative ideas, (ii) reduces his incentive to overinvest in an innovation, and (iii) increases firm value. These results stand in contrast to the standard arguments offered in the literature.

Our model highlights the dangers of evaluating changes in accounting practices in isolation from other governance instruments. Boards have multiple tools to control managerial behavior, and one important tool is incentive contracting. Although conservatism impedes innovation when all else is held constant, we find that this result flips when one takes into account that incentive contracts are optimally adjusted in response to changes in the reporting environment. This demonstrates that changes in accounting practices should not be evaluated in a vacuum, but in conjunction with other governance tools.

Appendix A: Proofs

Proof of Proposition 1: Combine (4) and (5) with (8) to get

$$\theta_T p_{hh} + (1-\theta_T)p_{hl} = \frac{w_m - w_l}{w_h - w_l}. \tag{18}$$

Using the implicit function theorem generates

$$\frac{\partial \theta_T}{\partial c} = -\frac{\theta_T \frac{dp_{hh}}{dc} + (1-\theta_T)\frac{dp_{hl}}{dc}}{p_{hh} - p_{hl}} > 0, \tag{19}$$

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

Using (11), we obtain

$$\begin{aligned} \frac{da}{dc} &= -\frac{1}{k}\left(\theta_T E[w|X_h] + (1-\theta_T)E[w|X_l] - w_m\right) f(\theta_T)\frac{d\theta_T}{dc} \\ &\quad + \frac{1}{k}\int_{\theta_T}^{1}\left(\theta\frac{dp_{hh}}{dc} - (1-\theta)\frac{dp_{ll}}{dc}\right)(w_h - w_l)\, f(\theta)d\theta < 0. \end{aligned} \tag{20}$$

The first line in (20) is zero since the manager's optimal choice of θ_T solves (8), and the second line in (20) is negative since $\frac{dp_{hh}}{dc} < 0$ and $\frac{dp_{ll}}{dc} > 0$ from (A2).

Using (4) and (5), we can write (10) as

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

Taking the first derivative with respect to c yields:

$$\begin{aligned}\frac{d\Psi}{dc} &= \frac{da}{dc}\int_{\theta_T}^{1}\left(\theta\left(p_{hh}w_h+p_{lh}w_l\right)+(1-\theta)\left(p_{hl}w_h+p_{ll}w_l\right)-w_m\right)f(\theta)d\theta \\ &\quad -a\left(\theta_T\left(p_{hh}w_h+p_{lh}w_l\right)+(1-\theta_T)\left(p_{hl}w_h+p_{ll}w_l\right)-w_m\right)f(\theta_T)\frac{d\theta_T}{dc} \\ &\quad +a\left(w_h-w_l\right)\int_{\theta_T}^{1}\left(\theta\frac{dp_{hh}}{dc}+(1-\theta)\frac{dp_{hl}}{dc}\right)f(\theta)d\theta.\end{aligned} \tag{21}$$

The second line in (21) is zero from condition (8). 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 (11), we can simplify (21) to

$$\frac{d\Psi}{dc}=\frac{da}{dc}ka+a\left(w_h-w_l\right)\int_{\theta_T}^{1}\left(\theta\frac{dp_{hh}}{dc}+(1-\theta)\frac{dp_{hl}}{dc}\right)f(\theta)d\theta, \tag{22}$$

and using (20), we obtain

$$\frac{d\Psi}{dc}=2\frac{da}{dc}ka<0. \tag{23}$$

Proof of Proposition 2: To determine the equilibrium actions, we proceed in two steps. In the first, we specify the least costly contract that implements a certain effort level and investment threshold combination (a,θ_T). In the second step, we solve for the optimal (a^*,θ_T^*) combination, given that the board will choose the least expensive contract for any (a,θ_T). The next lemma presents the results from the first step.

Lemma 1 *Let $\{w_i^*(\theta_T,a)\}_{i=h,m,l}$ denote the least costly contract that elicits innovation effort* *a and the investment threshold* θ_T. *Then,*

$$\begin{aligned} w_h^*(\theta_T, a) &= \frac{ak}{(p_{hh} - p_{hl}) \left(\int_{\theta_T}^1 (\theta - \theta_T) f(\theta) d\theta \right)}, & (24) \\ w_m^*(\theta_T, a) &= (\theta_T p_{hh} + (1 - \theta_T) p_{hl}) w_h^* \text{ and } w_l^*(\theta_T, a) = 0, & (25) \end{aligned}$$

and the expected compensation $\Psi(\theta_T, a)$ *and the manager's utility* $U(\theta_T, a)$ *are*

$$\begin{aligned} \Psi(\theta_T, a) &= ka^2 + w_m^*(\theta_T, a), & (26) \\ U(\theta_T, a) &= 0.5ka^2 + w_m^*(\theta_T, a). & (27) \end{aligned}$$

Proof: The pay w_m is determined by the investment condition (8), and is given by

$$w_m = \theta_T E[w|X_h] + (1 - \theta_T) E[w|X_l]. \tag{28}$$

Substituting (28) into the effort constraint (11) yields

$$a = \frac{1}{k} \int_{\theta_T}^1 (\theta - \theta_T) (E[w|X_h] - E[w|X_l]) f(\theta) d\theta. \tag{29}$$

After inserting (4) and (5) and rearranging, we obtain

$$(w_h - w_l) = \frac{ak}{(p_{hh} - p_{hl}) \int_{\theta_T}^1 (\theta - \theta_T) f(\theta) d\theta}. \tag{30}$$

Substituting (30) into (28) yields

$$w_m = \frac{\theta_T + \frac{p_{hl}}{p_{hh} - p_{hl}}}{\left(\int_{\theta_T}^1 (\theta - \theta_T) f(\theta) d\theta \right)} ak + w_l. \tag{31}$$

Substituting (11) and (31) into (10) yields the manager's expected compensation when the board implements (a, θ_T)

$$\Psi = a^2 k + \frac{\theta_T + \frac{p_{hl}}{p_{hh} - p_{hl}}}{\left(\int_{\theta_T}^{1} (\theta - \theta_T) f(\theta) d\theta\right)} ak + w_l. \tag{32}$$

From (32) it immediately follows that $w_l = 0$ is optimal (given the limited liability constraint $w_l \geq 0$). Using (31) and setting $w_l = 0$, we obtain (26).

Step 2: Substituting (26) into the board's utility function (13), we can write the board's problem as:

$$\begin{aligned} \max_{a, \theta_T, w_l} V \equiv\ & a \left(\int_{\theta_T}^{1} (\theta X_h + (1 - \theta) X_l) f(\theta) d\theta + F(\theta_T) X_m \right) + (1 - a) X_m \\ & - \left(ka^2 + \frac{\theta_T + \frac{p_{hl}}{p_{hh} - p_{hl}}}{\int_{\theta_T}^{1} (\theta - \theta_T) f(\theta) d\theta} ka \right), \end{aligned} \tag{33}$$

subject to the manager's participation constraint

$$U = 0.5ka^2 + \frac{\theta_T + \frac{p_{hl}}{p_{hh} - p_{hl}}}{\left(\int_{\theta_T}^{1} (\theta - \theta_T) f(\theta) d\theta\right)} ka \geq \underline{U}. \tag{34}$$

As discussed in Section 2, the limited liability constraints imply that the board has to rely on rewards to provide incentives (and cannot use punishments), which yields the manager a positive utility. If the manager's reservation utility is not larger than a certain threshold, denoted $\underline{U}_T$, he enjoys an economic rent, that is, the participation constraint is slack. In what follows, we assume that this is the case and determine $\underline{U}_T$ below.

Taking the first-order conditions for θ_T and a yields

$$\begin{aligned}\frac{\partial V}{\partial \theta_T} &= -\left(\theta_T X_h + (1-\theta_T)X_l - X_m\right) f(\theta_T) \qquad (35)\\ &\quad - \frac{k}{\int_{\theta_T}^1 (\theta-\theta_T) f(\theta)d\theta}\left(1 + \int_{\theta_T}^1 f(\theta)d\theta \frac{\left(\theta_T + \frac{p_{hl}}{(p_{hh}-p_{hl})}\right)}{\left(\int_{\theta_T}^1 (\theta-\theta_T) f(\theta)d\theta\right)}\right) = 0,\end{aligned}$$

and

$$\begin{aligned}\frac{\partial V}{\partial a} &= \int_{\theta_T}^1 \left(\theta X_h + (1-\theta)X_l - X_m\right) f(\theta)d\theta \qquad (36)\\ &\quad - \left(2a + \frac{\theta_T + \frac{p_{hl}}{(p_{hh}-p_{hl})}}{\int_{\theta_T}^1 (\theta-\theta_T) f(\theta)d\theta}\right) k = 0.\end{aligned}$$

Since $\theta_{FB}X_h + (1-\theta_{FB})X_l = X_m$ by definition, equation (35) implies $\theta_T^* < \theta_{FB}$. Equation (36) implies

$$a^* = 0.5\left(\frac{1}{k}\int_{\theta_T^*}^1 \left(\theta X_h + (1-\theta)X_l - X_m\right) f(\theta)d\theta - \frac{\theta_T^* + \frac{p_{hl}}{p_{hh}-p_{hl}}}{\left(\int_{\theta_T^*}^1 (\theta-\theta_T^*) f(\theta)d\theta\right)}\right), \qquad (37)$$

where (a^*, θ_T^*) are the optimal actions. Using

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

we obtain

$$a^* = 0.5\left(a_{FB} + \frac{1}{k}\int_{\theta_T^*}^{\theta_{FB}} \left(\theta X_h + (1-\theta)X_l - X_m\right) f(\theta)d\theta - \frac{\theta_T + \frac{p_{hl}}{p_{hh}-p_{hl}}}{\left(\int_{\theta_T^*}^1 (\theta-\theta_T^*) f(\theta)d\theta\right)}\right). \qquad (38)$$

Since $\left(\int_{\theta_T^*}^{\theta_{FB}} \left(\theta X_h + (1-\theta)X_l - X_m\right) f(\theta)d\theta\right) < 0$, it follows that $a^* < 0.5a_{FB}$. The result that $a^* < 0.5a_{FB}$ is an artifact of the quadratic effort cost function, the limited liability assumption, and the fact that the board has to deal with the dual problems of inducing effort and inducing efficient investment.

The second-order conditions for a maximum are satisfied if

$$\frac{\partial^2 V}{\partial \theta_T^2}\frac{\partial^2 V}{\partial a^2} - \left(\frac{\partial^2 V}{\partial \theta_T \partial a}\right)^2 > 0, \tag{39}$$

$$\frac{\partial^2 V}{\partial a^2} < 0, \tag{40}$$

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

$$\begin{aligned}\frac{\partial^2 V}{\partial \theta_T^2} = & -(X_h - X_l)\, f(\theta_T) - (\theta_T X_h + (1-\theta_T)X_l - X_M)\,\frac{df(\theta_T)}{d\theta_T} \\ & -\frac{k\left(\theta_T + \frac{p_{hl}}{p_{hh}-p_{hl}}\right)}{\left(\int_{\theta_T}^1 (\theta-\theta_T) f(\theta) d\theta\right)^2}\left[\frac{2\left(\int_{\theta_T}^1 f(\theta)d\theta\right)^2 - f(\theta_T)\int_{\theta_T}^1(\theta-\theta_T)f(\theta)d\theta}{\int_{\theta_T}^1(\theta-\theta_T)f(\theta)d\theta}\right] \\ & -\frac{2k\int_{\theta_T}^1 f(\theta)d\theta}{\left(\int_{\theta_T}^1(\theta-\theta_T)f(\theta)d\theta\right)^2}.\end{aligned} \tag{41}$$

Conditions (39) and (40) are therefore satisfied when $\frac{\partial^2 V}{\partial \theta_T^2} < 0$. We obtain $\frac{\partial^2 V}{\partial \theta_T^2} < 0$, for example, when the marginal cost of effort, k, is sufficiently high, because the term in square brackets in (41) is positive.

Using (34), the manager's participation constraint is indeed slack (as initially assumed) when his reservation utility $\underline{U}$ is not larger than

$$\underline{U}_T \equiv 0.5ka^{*2} + \frac{\theta_T^* + \frac{p_{hl}}{p_{hh}-p_{hl}}}{\left(\int_{\theta_T^*}^1(\theta-\theta_T^*)f(\theta)d\theta\right)}ka^*,$$

where θ_T^* and a^* are determined by the first-order conditions (35) and (36). Substituting

(36) into $\underline{U}_T$ yields

$$\underline{U}_T = \left(a^* \int_{\theta_T^*}^{1} \left(\theta X_h + (1-\theta) X_l - X_m\right) f(\theta) d\theta - 0.5 k a^{*2} \right) - k a^{*2}. \tag{42}$$

The term in parentheses in (42) is the total surplus associated with innovation effort, that is, the increase in expected cash flows from the manager's innovation effort a^* minus his personal cost of effort.

Proof of Proposition 3: We first show that an increase in c and w_h allows the board to increase the manager's incentive to work on the innovation without increasing his incentive to overinvest in the innovation; that is, a increases but θ_T remains unchanged. Solving the investment constraint (8) for w_h and setting $w_l = 0$ yields

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

As c increases, the bonus $w_h(\theta_T)$ must increase to maintain the investment threshold θ_T. Inserting $w_h(\theta_T)$ into the effort constraint (11) and setting $w_l = 0$ yields, after some rearranging,

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

Taking the first derivative shows that an increase in c increases the effort level a:

$$\frac{da}{dc} = \frac{d\frac{p_{hh}}{p_{hl}}}{dc} \frac{\int_{\theta_T}^{1} (\theta - \theta_T) f(\theta) d\theta}{k\left(\theta_T \frac{p_{hh}}{p_{hl}} + (1-\theta_T)\right)^2} w_m > 0,$$

since $\frac{d\frac{p_{hh}}{p_{hl}}}{dc} > 0$. Thus, an increase in c (and the subsequent increase in w_h that is required to keep the investment threshold θ_T unchanged) increases the manager's incentive to work on the innovation.

Alternatively, the board can increase c and w_h to reduce the manager's incentive to overinvest in the innovation without reducing his incentive to work on the innovation; that is, θ_T increases but a remains unchanged. Solving effort constraint (11) for w_h and setting $w_l = 0$ yields

$$w_h(a) = \frac{ka + w_m \int_{\theta_T}^{1} f(\theta)d\theta}{\int_{\theta_T}^{1} (\theta p_{hh} + (1-\theta)p_{hl}) f(\theta)d\theta}. \tag{43}$$

Note that as c increases, the bonus $w_h(a)$ must increase to maintain the effort level a. Substituting (43) into the investment constraint (8) with $w_l = 0$ and rearranging yields

$$Q \equiv \left(\theta_T \frac{p_{hh}}{p_{hl}} + (1-\theta_T)\right) \frac{ka + w_m \int_{\theta_T}^{1} f(\theta)d\theta}{\int_{\theta_T}^{1} \left(\theta \frac{p_{hh}}{p_{hl}} + (1-\theta)\right) f(\theta)d\theta} - w_m = 0. \tag{44}$$

Using the implicit function theorem, we obtain:

$$\frac{d\theta_T}{dc} = -\frac{dQ/dc}{dQ/d\theta_T},$$

where

$$\frac{dQ}{dc} = -\frac{\left(ka + w_m \int_{\theta_T}^{1} f(\theta)d\theta\right)\left(\int_{\theta_T}^{1} (\theta - \theta_T) f(\theta)d\theta\right)}{\left(\int_{\theta_T}^{1} \left(\theta \frac{p_{hh}}{p_{hl}} + (1-\theta)\right) f(\theta)d\theta\right)^2} \frac{d\frac{p_{hh}}{p_{hl}}}{dc} < 0,$$

and

$$\begin{aligned} \frac{dQ}{d\theta_T} &= \left(\frac{p_{hh}}{p_{hl}} - 1\right) \frac{ka + w_m \int_{\theta_T}^{1} f(\theta)d\theta}{\int_{\theta_T}^{1} \left(\theta \frac{p_{hh}}{p_{hl}} + (1-\theta)\right) f(\theta)d\theta} \\ &+ \left(\theta_T \frac{p_{hh}}{p_{hl}} + (1-\theta_T)\right) f(\theta_T) \frac{\left(\theta_T \frac{p_{hh}}{p_{hl}} + (1-\theta_T)\right)\left(ka + w_m \int_{\theta_T}^{1} f(\theta)d\theta\right)}{\left(\int_{\theta_T}^{1} \left(\theta \frac{p_{hh}}{p_{hl}} + (1-\theta)\right) f(\theta)d\theta\right)^2} \\ &+ \left(\theta_T \frac{p_{hh}}{p_{hl}} + (1-\theta_T)\right) \frac{-w_m f(\theta_T)}{\int_{\theta_T}^{1} \left(\theta \frac{p_{hh}}{p_{hl}} + (1-\theta)\right) f(\theta)d\theta}, \end{aligned}$$

which using (44) simplifies to

$$\frac{dQ}{d\theta_T} = \left(\frac{p_{hh}}{p_{hl}} - 1\right) \frac{ka + w_m \int_{\theta_T}^1 f(\theta)d\theta}{\int_{\theta_T}^1 \left(\theta \frac{p_{hh}}{p_{hl}} + (1-\theta)\right) f(\theta)d\theta} > 0.$$

These calculations show that $\frac{d\theta_T}{dc} > 0$, implying that an increase in c (and the subsequent increase in w_h required to preserve effort incentives) increases the manager's investment threshold θ_T.

Proof of Proposition 4: Differentiating the first-order condition (35) with respect to c yields:

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

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

$$\frac{\partial^2 V}{\partial \theta_T \partial c} = \frac{\frac{d\frac{p_{hh}}{p_{hl}}}{dc}\int_{\theta_T}^1 f(\theta)d\theta}{\left(\frac{p_{hh}}{p_{hl}} - 1\right)^2 \left(\int_{\theta_T}^1 (\theta - \theta_T) f(\theta)d\theta\right)^2} k > 0, \tag{45}$$

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

Differentiating the first-order condition (36) with respect to c yields:

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

where

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

Since $d\frac{p_{hh}}{p_{hl}}/dc > 0$ from (A3) and $\frac{p_{hh}}{p_{hl}} > 1$ from (A1), $\frac{\partial^2 V}{\partial a \partial c} > 0$. We therefore obtain

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

In the optimal solution, firm value is

$$V(a, \theta_T, c) = CF(a, \theta_T) - \Psi(a, \theta_T, c), \tag{46}$$

where the levels of a and θ_T satisfy the first-order conditions (35) and (36). The expected cash flow CF is given in (12). From Proposition 1, the expected compensation is

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

By the envelope theorem,

$$\frac{dV(c)}{dc} = \left.\frac{\partial V(\theta_T, a, c)}{\partial c}\right|_{\substack{\theta_T = \theta_T^*(c) \\ a = a^*(c)}} \tag{47}$$

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

$$\frac{dV(c)}{dc} = -\left.\frac{\partial \Psi(\theta_T, a, c)}{\partial c}\right|_{\substack{\theta_T = \theta_T^*(c) \\ a = a^*(c)}} > 0, \tag{48}$$

where

$$\frac{\partial \Psi(\theta_T, a, c)}{\partial c} = -\frac{d\frac{p_{hh}}{p_{hl}}}{dc} \frac{ak}{\left(\frac{p_{hh}}{p_{hl}} - 1\right)^2 \int_{\theta_T}^{1} (\theta - \theta_T) f(\theta) d\theta}$$

is negative since $d\frac{p_{hh}}{p_{hl}}/dc > 0$ from (A3).

Appendix B: Communication

In this appendix, we consider a direct revelation mechanism, in which the investment decision and payments to the manager are contingent on the manager's message $\widehat{\theta}$. After the manager exerts effort a, he learns $\theta \in [0,1]$. At the beginning of the game, the board commits to a menu of contracts $M = (I(\widehat{\theta}), w_h(\widehat{\theta}), w_l(\widehat{\theta}), w_m(\widehat{\theta}))$. By sending his message $\widehat{\theta}$, the manager selects a contract from the menu. The parameter $I(\widehat{\theta}) \in \{0,1\}$ 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. $w_h(\widehat{\theta})$ or $w_l(\widehat{\theta})$ are the payments to the manager if the project is implemented and the accounting report is high R_h or low R_l, respectively. $w_m(\widehat{\theta})$ is the pay if the project is rejected. By the revelation principle, we can restrict attention to contracts that induce the manager to truthfully reveal his private information. In the optimal mechanism, for any two messages $\widehat{\theta}_i$ and $\widehat{\theta}_j$ for which the board rejects the project, $I(\widehat{\theta}_i) = I(\widehat{\theta}_j) = 0$, the manager must receive the same pay $w_m(\widehat{\theta}_i) = w_m(\widehat{\theta}_j) \geq 0$. Otherwise, if $w_m(\widehat{\theta}_i) > w_m(\widehat{\theta}_j)$ and $I(\widehat{\theta}_i) = I(\widehat{\theta}_j) = 0$, the manager would announce $\widehat{\theta}_i$ even when $\widehat{\theta}_j$ is true. Equivalently, since the optimal contract does not reward the manager for poor performance, $w_l = 0$, the manager must receive $w_H(\widehat{\theta}_i) = w_H(\widehat{\theta}_j)$ for all $\widehat{\theta}_i, \widehat{\theta}_j$ for which $I(\widehat{\theta}_i) = I(\widehat{\theta}_j) = 1$.

Further, the optimal mechanism involves a cutoff θ_T such that $I = 0$ if $\widehat{\theta} \in [0, \theta_T)$ and $I = 1$ if $\widehat{\theta} \in [\theta_T, 1]$. This follows because if $I(\widehat{\theta}_i) = 1$, then it must be that $I(\widehat{\theta}_j) = 1$ for all $\widehat{\theta}_j > \widehat{\theta}_i$. Suppose to the contrary that $I(\widehat{\theta}_i) = 1$, $I(\widehat{\theta}_j) = 0$, and $\widehat{\theta}_j > \widehat{\theta}_i$. 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), in which payments are independent of the manager's message $\widehat{\theta}$ and the manager makes the investment decision (rather than sending a message that determines the investment decision).

Appendix C

We prove that the conditional probabilities in (1) and (2) imply properties (A1) to (A3). Rewriting the conditional probability p_{hl} from (1) as $p_{hl} = \int_{c+X_h-X_l}^{X_h+L} f(e|X_h)de$ and the conditional probability p_{ll} from (2) as $p_{ll} = \int_{X_h-L}^{c+X_h-X_l} f(e|X_h)de$ shows that

$$p_{hh} = \int_{c}^{X_h+L} f(e|X_h)de > p_{hl}$$

and

$$p_{ll} > p_{lh} = \int_{X_h-L}^{c} f(e|X_h)de,$$

implying (A1).

Taking the first derivatives of the conditional probabilities in (1) and (2) yields $\frac{dp_{lh}}{dc} = f(e|X_h) > 0$ and $\frac{dp_{ll}}{dc} = f(e|X_l) > 0$, implying (A2).

Finally, using (1) and (2), we obtain

$$\begin{aligned} \frac{d\frac{p_{hh}}{p_{hl}}}{dc} &= \frac{-f(c|X_h)}{\int_c^{X_l+L} f(e|X_l)de} + f(c|X_l)\frac{\int_c^{X_h+L} f(e|X_h)de}{\left(\int_c^{X_l+L} f(e|X_l)de\right)^2} \\ &= \frac{\int_c^{X_l+L}\left(f(c|X_l)\left(\frac{f(e|X_h)}{f(e|X_l)} - \frac{f(c|X_h)}{f(c|X_l)}\right)f(e|X_l)\right)de + f(c|X_l)\int_{X_l+L}^{X_h+L} f(e|X_h)de}{\left(\int_c^{X_l+L} f(e|X_l)de\right)^2}. \end{aligned}$$

Due to the MLRP ($d\frac{f(e|X_h)}{f(e|X_l)}/de \geq 0$ for $e \in [e_1, e_2]$) and due to $c < X_l + L$, the term $\int_c^{X_l+L} f(c|X_l)\left(\frac{f(e|X_h)}{f(e|X_l)} - \frac{f(c|X_h)}{f(c|X_l)}\right) f(e|X_l)de$ is nonnegative. Hence, $d\frac{p_{hh}}{p_{hl}}/dc > 0$. The proof that $d\frac{p_{lh}}{p_{ll}}/dc > 0$ is equivalent and hence is omitted. This establishes (A3).

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