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Managerial compensation as a double-edged sword: Optimal incentives under misreporting

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ABSTRACT

A well-known prescription in corporate governance is that high-powered incentive contracts such as performance bonuses are an optimal mechanism for aligning managers with shareholders on an efficient investment policy. However, if managers are able to manipulate profits in order to obtain the bonuses, such contracts become a double-edged sword. An agency model is proposed to analyze how compensation plans should be designed to counteract these perverse incentives while preserving the primary managerial incentives to select optimal investment projects. Implications of the results for real-world executive incentive plans are discussed and an analysis is conducted of regulatory policies such as penalties and bonus caps.

1. Introduction

A conventional prescription in corporate governance is that performance pay contracts are an effective mechanism for aligning the objectives of top management with those of dispersed shareholders. However, several accounting scandals over the last two decades have highlighted the ability of managers to manipulate the information used to evaluate and reward their performance, thus revealing the undesirable side effects high-powered incentive structures can generate. In addition to this anecdotal experience, a growing body of empirical research has provided more systematic evidence of an association between this class of executive compensation plans and managerial malpractices such as accounting misrepresentation, stock price manipulation and even corporate fraud.[1]

The conclusion arising from all this evidence is that when misreporting is a possible outcome, executive compensation schemes can turn out to be a double-edged sword, that is, a trade-off between two contradictory forces. On the one hand, in order to mitigate the moral hazard problem involved in the selection by a manager of the most profitable investment projects, the compensation scheme should be increasing and convex, such as a performance bonus. This is a standard result in the contract theory literature, and follows

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[1] For empirical evidence of a relationship between managerial compensation plans and earnings management, see Gayle and Miller (2015), Bergstresser and Philippon (2006), Burns and Kedia (2006), Denis, Hanouna, and Sarin (2006), Veenman, Hodgson, van Praag, and Zhang (2011), Kadan and Yang (2016), Healey and Wahlen (1998), Ke (2004), Gao and Shrieves (2002), Cheng and Warfield (2005), Efendi, Srivastava, and Swanson (2007), and Zhao, Zhou, Zhao, and Zhou (2019). On the links between executive pay structures and accounting fraud the results are mixed, with evidence of such a relationship in some studies (Johnson, Ryan, & Tian, 2009; Peng & Röell, 2008) and no consistent evidence in others (Dechow, Sloan, & Sweeney, 1996; Erickson, Hanlon, & Maydew, 2006). See also Bruner, McKee, and Santore (2008), who provide experimental evidence on how greater equity compensation can lead to fraudulent behavior.

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from assuming a monotonically increasing relationship between profits (observable) and the selected project (unobservable). On the other hand, a compensation plan increasing in profits may tempt the manager to manipulate the firm's accounting statements if costs and penalties (reputational, ethical, or legal) are sufficiently low.

Therefore, it is not obvious a priori how optimal incentive schemes should balance these two counteracting effects in order to induce top management to adopt both an efficient investment policy and honest accounting system. To investigate the theoretical implications of this trade-off, we propose an agency model that analyzes the characteristics an optimal incentive scheme should possess in order to align the manager with shareholders on two objectives: (i) the adoption of a value-maximizing investment policy, and (ii) the implementation of a truthful reporting system.

Our analysis generates three main results. First, it implies that an optimal managerial compensation scheme should balance the two above-mentioned counteracting objectives by offering pay structures that are *increasing* in profits to ensure an efficient investment policy but with *lower*-powered incentives than structures prescribed as optimal in an environment with no misreporting. This suggests that although performance bonuses or stock-based plans can be optimal arrangements, in practice the convexity of such incentive schemes should be moderated in order to dissuade fraud and episodes of earnings management.

Second, our analysis suggests some conditions under which it may be impossible to write a contract that induces management to select profitable investment projects while also implementing a fully honest accounting system. This failure to achieve both desirable outcomes is particularly likely when there are (i) large private benefits associated with the project selection process (e.g., highly entrenched managers), (ii) low costs of implementing a misreporting system (e.g., weak managerial ethical principles or accounting principles that allow considerable managerial discretion), and (iii) investment projects with low success rates (e.g., highly risky and innovative ventures).

Third, the framework we develop has a number of policy oriented implications regarding some mechanisms the regulator may adopt to improve corporate governance systems and deter managerial misconduct. Our analysis highlights the importance of improving the effectiveness and independence of external auditors, strengthening the level of legal protection for outside investors, and increasing the degree of corporate liability for fraud episodes. Moreover, we theoretically identify situations in which imposing a cap on executive bonuses could be a social efficiency-enhancing measure. Interestingly, we are also able to show that in the context of our setup, a regulation of this type may not only deter misreporting but also guarantee a value-maximizing private investment policy.

One of the major contributions of the present paper has to do with the way in which misreporting is modeled. As will be discussed further in Section 2, most of the previous literature assumes that the manager chooses whether or not to manipulate profits (or how much to manipulate them) at an *intermediate* stage, i.e., *after* observing the true level of profits. This implies that reporting is modeled as a revelation or signaling game, the aim of these studies thus being to characterize conditions for a separating equilibrium (truthful reporting) or a pooling equilibrium (misreporting). By contrast, in our framework the manager chooses a reporting rule ex ante i.e., *before* observing the true profits, given our assumption that implementing such a rule involves setup costs. An appealing aspect of this formulation is that it allows us to model *both* the choice of a productive action (in our setup, an investment project) and the implementation of a reporting system as moral hazard problems. The result is a general model incorporating both decisions.

In terms of results, this model reveals that whereas reported profits have an increasing statistical relationship with the productive action, they have a decreasing relationship with misreporting. This in turn enables us to characterize how this statistical duality ends up shaping the optimal incentive scheme, a point not examined by the extant literature.[2]

The remainder of this paper is organized as follows. Section 2 presents a comparative analysis with previous theoretical research, highlighting what is novel in the proposed approach. Section 3 presents a general model in which the manager chooses both investment projects and the reporting system. Section 4 examines the effects of misreporting on the optimal management incentive scheme. To isolate the source of the effects, the equilibrium is determined for each of two polar setups (investment project selection only and reporting system election only), and based on the results, the solution to the general model is developed. Section 5 contains some extensions of our framework which are used to analyze corporate governance regulatory policies aimed at deterring accounting manipulation and fraud. Finally, Section 6 concludes with a summary of the general model's implications for real-world executive compensation plans. Technical proofs of the main results are collected in the Appendix.

2. Related literature

This paper is related to previously published works on optimal compensation structures and incentive power when management is able to manipulate the measure used to evaluate and reward its own performance. However, there are several important differences. First, existing studies generally limit the optimal arrangement a priori to a specific scheme such as restricted stock, stock option compensation or bonuses (Andergassen, 2008, 2010 and, 2016; Baglioni & Colombo, 2009, 2011; Wu, 2011; Wilson & Wu, 2014; Santore & Tackie, 2013; Peng & Röell, 2008; Goldman & Slezak, 2006; Robinson & Santore, 2011; Crocker & Slemrod, 2007). By contrast, our approach is more general in that we characterize optimal managerial incentives without assuming a given functional form for such a scheme.

Second, much of the extant literature adopts a multiperiod setup in order to explore the discrepancy between the horizons of shareholders and managers, and thereby illustrate the perverse effects of performance pay structures (Andergassen, 2008, 2016; Goldman & Slezak, 2006; Peng & Röell, 2014; Wu, 2011). Here, however, we model the twofold nature of high-powered incentives in a

[2] Capponi, Cvitanic, and Yolcu (2013) also study the effects of two sources of moral hazard (effort and misreporting) on the optimal pay-for-performance sensitivity. Contrary to our setting, however, they assume misreporting to be *beneficial* to shareholders.

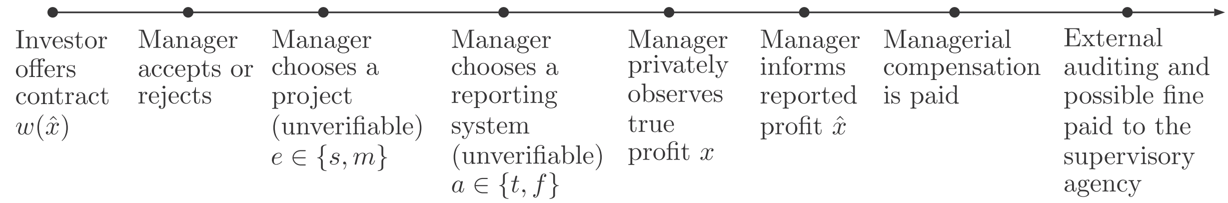

Fig. 1. Timeline of events.

one-period setting where the temptation for the manager to manipulate profits arises from the fact that such misbehavior is unobservable.

Third, some papers consider misreporting but not a productive activity (Capponi, Cvitanic, & Yolcu, 2012; Loyola & Portilla, 2018). These studies differ from our framework of two managerial decisions –investment project selection and reporting system implementation– which allows us to draw conclusions on how the possibility of earning management affects optimal incentive power.

Last but not least, a crucial distinction between our approach and the existing literature concerns the way misreporting is modeled. One strand of this literature models reporting as a signaling/reporting game in which the manager privately learns his/her type (high or low profits, for instance), and only then chooses whether or not to make a truthful report. The goal of this analysis is therefore to characterize the conditions for a separating or a pooling equilibrium (Andergassen, 2010 and 2016) or the conditions for the existence of an optimal incentive scheme encouraging both value enhancing effort and honest reporting (Baglioni & Colombo, 2011; Crocker & Slemrod, 2007; Evans & Sridhar, 1996).

Another strand of the literature assumes that the source of asymmetric information is the inability of shareholders to verify any of the following: (i) the cost to management of manipulating the stock price (Peng and Röell, 2008, 2014), (ii) the extent of the manipulation (Andergassen, 2008; Santore & Tackie, 2013; Wilson & Wu, 2014; Wu, 2011), (iii) the probability of detecting the manipulation (Robinson & Santore, 2011), and (iv) the amount of resources diverted by management to influence a third-party monitor's report (Goldman & Slezak, 2006). All these approaches assume, however, that management chooses *simultaneously* an optimal level of value-enhancing effort and an optimal reporting bias, and thus does not get access to private information on true profits.

Although in our model, management reports profits *after* observing privately their true value, we assume, contrary to all the previous literature, that the decision on whether or not to report truthfully is taken *before* that event. Implicit in this timeline is the idea that earnings manipulation is not an improvised action but rather requires the prior implementation of a misreporting system that involves a costly setup process. This approach allows us to model misreporting as a second managerial hidden action (in addition to project selection) and thereby to explore how the *dual* statistical relationship between the observable variable (reported profits) and the two unobservable actions (project selection and reporting system implementation) helps explain the property of managerial incentives as a double-edged sword.

3. The model

Consider the following agency model of a single owner of a company called the investor (she) and a manager (he) hired to run the business. First, the investor makes the manager a take-it-or-leave-it offer of a wage w that may be contingent on verifiable outcomes. If the manager accepts the offer, he must make two binary decisions. The first one concerns an investment project $e \in \{s, m\}$ that the investor cannot verify. Project s implies zero private benefits for the manager and a profit profile described by

$$x = \begin{cases} x_2 & \text{with prob } p \\ x_1 & \text{with prob } 1-p \end{cases},$$

where $x_2 > x_1 > 0$ and $p \in (0,1)$. By contrast, project m produces for the manager a private benefit $B > 0$ and the certainty of a failure profit $x = x_1$. The two projects require the same initial investment, which is assumed to be exogenous and is therefore normalized to zero for simplicity.

The manager's second decision is the action he takes to implement a reporting system $a \in \{t, f\}$ also not verifiable by the investor. Action t represents the implementation of a *truthful* reporting system, at no cost to him, while action f represents the implementation of a *misreporting* system as described below, with a setup cost to him of $c > 0$. After implementing one of these two accounting systems, the manager privately observes x, the *true* profits of the company, which are distributed in accordance with the investment project previously selected.

The manager then discloses to the investor through the company's financial statements a level of *reported* profit $\hat{x}$ depending on the reporting system a the manager had previously chosen. If $a = t$, the manager always reports the true level of profit (i.e., $\hat{x} = x$) but if $a = f$, the manager always reports the success profit (i.e., $\hat{x} = x_2$) even when its true value is the failure profit x_1. That is, conditional on $x = x_1$, the misreporting system allows the manager to overstate the reported profit by an amount $\Delta_x \equiv x_2 - x_1$.

Next, the manager is paid as specified in the optimal contract previously designed by the investor. Lastly, an external auditor verifies the financial statements and detects with probability $\theta \in (0,1)$ whether the reported profit is equal to the true profit. If it is not, the company must pay a fine $\varphi > 0$ to a supervisory agency that is sufficiently high to dissuade the investor from inducing the manager to implement a misreporting system.

A timeline showing the order of events in this game is presented in Fig. 1.

A comment on the feasibility of the game if earnings management occurs is in order here. If there is a gap Δ_x between inflated and real profit, the question arises as to what is the source of funds to pay the investor and the manager. The answer is that we link the earnings manipulation practice to a *fraud*, assuming that the manager convinces outside investors (e.g., bondholders) to fund a false project with an initial investment of Δ_x. We further assume that the potential penalty φ paid by the company can be transferred to these outside investors as legal compensation if they successfully sue the company for fraud.[3] For simplicity, we suppose that once the external auditor detects inflated reporting, the lawsuit is certain to be successful. Therefore, when inflating company profit the manager is in fact betting that there will be a positive probability $1 - \theta$ the external audit will fail, the fraud will go unpunished, and consequently the outside investors will receive no compensation.

Note also that in our framework, whether the penalty is paid by the company or the investor is of no importance because the investor is the sole shareholder. However, assuming that the company pays the fine allows us to analyze the role played by the level of *corporate liability* in deterring and detecting a fraud. In particular, we are interested in analyzing the possibility of a *tacit* collusion of the manager with the investor to commit fraud, which will be implemented through an incentive scheme sufficiently tempting for the manager. Consequently, in Section 5 we relax the assumption that the penalty φ is sufficiently large and explore conditions under which it may be in the investor's best interest to induce the manager to implement a non-truthful reporting system.

It is worthy to note that in our baseline model we restrict the nature of c as a setup cost, that is, a cost borne by the manager before disclosing profits. Implicit in this assumption is the fact that committing earnings management and fraud is not an improvisation given that implementing a misreporting system requires the manager to carry out several activities involving a significant amount of time and resources in advance. These costly activities include to adopting an accounting system that gives the manager large degrees of discretion when elaborating the financial statements so that the false story invented by him looks credible. Also, the manager must spend resources to camouflage this falsification, including the cooperation of or the collusion with other executives and internal auditors, and strategies to avoid that accounting manipulations are detected by external auditors. Although an expected penalty to be paid by him in case of detecting misreporting could also be considered as part of c, we decided in the baseline model to focus exclusively on the role played by the ex ante setup cost and abstract from any managerial costs that are ex post to a potential detection.[4] In section 5, however, we relax this assumption and develop an extension of the model in which the manager faces an expected misreporting penalty that is optimally designed by the investor.

In addition, we adopt the following assumptions: (A1) there is universal risk neutrality; (A2) the investor has zero reservation payoff and the manager's reservation payoff is given by $\underline{U} \in (0, (1-p)x_1)$; (A3) the investor and the manager both have limited liability, i.e., $0 \le w \le \widehat{x}$, and zero initial wealth; (A4) $\frac{B}{p} < c < \frac{(1-p)\underline{U}}{p}$; and (A5) $\Delta_x > \frac{\underline{U}}{p}$.

Assumption A1 (risk neutrality) allows us to skip the traditional analysis of the trade-off between risk-sharing and incentives faced by the investor when designing the optimal management pay structure, meaning we can concentrate exclusively on the trade-off involved in defining the pay structure when misreporting is possible. This implies in turn that the task confronting the investor is to offer incentives inducing the manager to pursue an efficient investment policy while deterring him from acting perversely.

Assumptions A4 and A5 guarantee that the expected social NPV of the project associated with the pair of decisions (s,t) is higher than that associated with the combination (m,t), i.e., $E(x|s,t) > E(x|m,t) + B$. Since we assume that the company is subject to a sufficiently high expected penalty in the case where a misreporting system is implemented, (m,f) and (s,f) are also dominated in social terms. It can be shown that all of the foregoing ensures that the best combination from the investor's standpoint is also (s,t).[5]

4. The results

To examine how the possibility of misreporting can affect the power of optimal incentives, we break this part of our analysis into two stages. In the first stage we study separately two polar cases resulting from the general model presented above: (i) the traditional moral hazard model in which the manager is exclusively concerned with project selection, and (ii) a model in which the manager is only concerned with the implementation of a reporting system. Then, in the second stage, we solve our general model and analyze its main implications based on the insights gained from a comparison of the two polar cases.

In all of the setups we examine, the optimal managerial incentive scheme is described by

$$w^*(\widehat{x}) = \begin{cases} w_2^* & \text{if} \quad \widehat{x} = x_2 \\ w_1^* & \text{if} \quad \widehat{x} = x_1 \end{cases}.$$

We then define $\Delta w^* \equiv w_2^* - w_1^*$, the *optimal power of incentives*, which will be useful for our subsequent analysis.

[3] The outside investors can be interpreted more broadly as stakeholders different from the shareholders. In this sense, the link between earnings management and the defrauding of the stakeholders resembles some recent real-world accounting scandals such as the Wells Fargo case. Since this scandal involved the opening by company executives of fake bank and credit cards accounts, among the main stakeholders ultimately affected were the customers who were charged unnecessary fees on these unsolicited accounts (*The New York Times*, August 4, 2017).

[4] Other cost elements that may be part of this c are ethical regret and reputational losses for the manager. Whereas the former is a managerial cost borne ex ante, the latter is an expected cost due to the possible detection of misreporting and fraud.

[5] See Corollary 1.

4.1. Project selection only

We begin with a classical model of moral hazard with binary actions. The sole decision the manager must make is assumed to be the project selection decision e. This implies that profits are always honestly disclosed so that $\hat{x} = x$.

Then, if the investor prefers $e = s$ to $e = m$, the optimal incentive scheme solves the problem[6]

$$\min_{w_1, w_2} p w_2 + (1-p) w_1 \tag{1}$$

subject to

$$p w_2 + (1-p) w_1 \geq \underline{U} \tag{2}$$

$$p w_2 + (1-p) w_1 \geq w_1 + B \tag{3}$$

$$w_1, w_2 \geq 0 \tag{4}$$

$$w_1 \leq x_1, \quad w_2 \leq x_2, \tag{5}$$

where (2) is the manager's participation constraint (PC), (3) is the incentive-compatibility constraint (IC), and (4) and (5) are the limited liability conditions (LLC) for the manager and the investor, respectively.

Proposition 1. *When the moral hazard problem only concerns the investment project selection, there is a continuum of optimal incentive schemes represented by all the pairs* (w_1^*, w_2^*) *satisfying the following conditions*:

(i) $w_1^* \in [0, \underline{U} - B]$, (*ii*) $w_2^* \in \left[\underline{U} + \frac{(1-p)B}{p}, \frac{\underline{U}}{p}\right]$,

(iii) $p w_2^* + (1-p) w_1^* = \underline{U}$.

Proof. *See the Appendix.*

To expose the solution in a more friendly fashion, we plot all the equations of the above program in Fig. 2, including the isocost line representing the minimum cost level.

From this figure, we confirm that there is a continuum of optimal incentive schemes characterized by the three conditions above described.

Thus, the optimal incentive power interval is such that

$$\Delta w^* \in \left[\frac{B}{p}, \frac{\underline{U}}{p}\right].$$

We therefore conclude that optimal incentive schemes must always be increasing in profits, since by assumption $\frac{B}{p} > 0$. This result holds because in a setup with a truthful accounting system, high reported profits are more informative than low reported profits in revealing that the manager has selected investment project s instead of m. Technically, this follows from assuming that the profit probability distribution satisfies the increasing monotone likelihood ratio property (IMLRP) with respect to the managerial investment selection process.

To confirm this property in formal terms, let us define, in the context of a setup with a truthful reporting system, the likelihood ratio of outcome x as follows:

$$LR_x \equiv \frac{\Pr(\hat{x} = x | s, t)}{\Pr(\hat{x} = x | m, t)},$$

from which it is straightforward to check that

$$LR_{x_2} > 1 - p = LR_{x_1}$$

as $LR_{x_2} \to \infty$, and thus that the likelihood ratio is monotonically increasing in reported profits.

Two additional properties of the optimal scheme can be described by examining the bounds of the interval containing Δw^*. First, since the lower bound of the interval is increasing with private benefits B, our model suggests that as the moral hazard involved in the investment policy becomes more severe, the optimal scheme should either remain unchanged or offer higher-powered incentives. Second, given that the lower and upper bounds of the interval containing Δw^* are decreasing with the success probability p, our setup indicates that an increase in the (exogenous) motivation of investment project s may prompt the investor to reduce the power of the (endogenous) incentives.

[6] Notice that $\Pr(\hat{x} = x_2 | s, t) = p$ and $\Pr(\hat{x} = x_2 | m, t) = 0$. It can be shown that the investor does indeed prefer project s instead of m, which is guaranteed by assumptions A4 and A5. The proof of this result is available from the authors upon request.

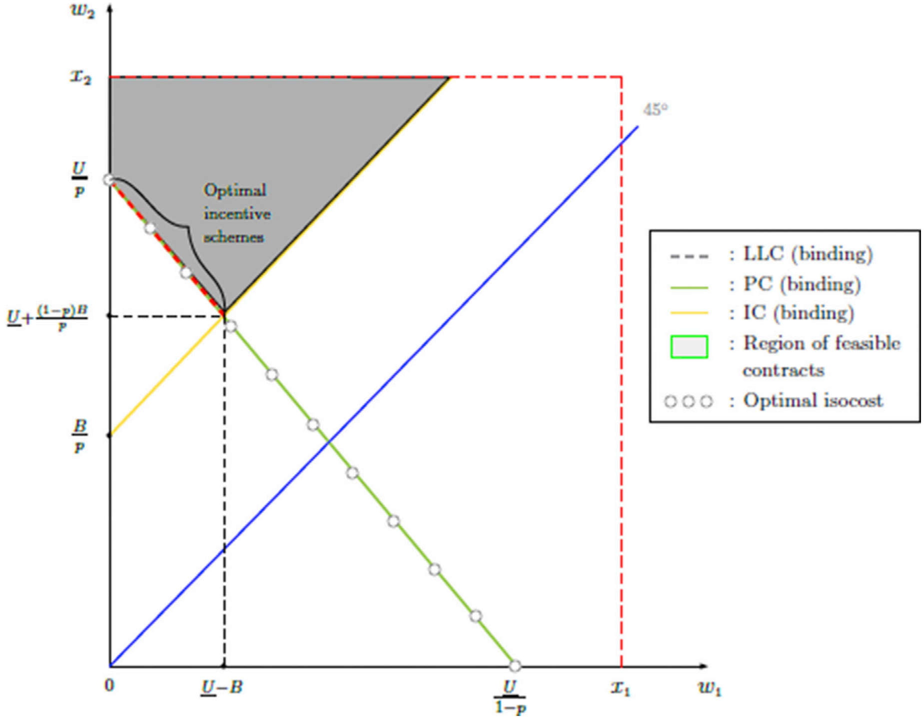

Fig. 2. Optimal incentive schemes with project selection only. Since the isocost line overlaps the binding participation constraint, there is a continuum of solutions (w_1^*, w_2^*) such that $w_1^* \in [0, \underline{U} - B]$, $w_2^* \in \left[\underline{U} + \frac{(1-p)B}{p}, \frac{\underline{U}}{p}\right]$ and $pw_2^* + (1-p)w_1^* = \underline{U}$.

We end this subsection with some comments on the robustness of our findings. Although a multiplicity of optimal contracts emerges because of assumption A4 (as well as risk-neutrality), neither the increasing nature of the optimal arrangement nor its existence depends on that assumption. In particular, if $B > \underline{U}$, it can be shown that there is a unique optimal incentive scheme $(w_1^*, w_2^*) = \left(0, \frac{B}{p}\right)$, and hence, $\Delta w^* = \frac{B}{p} > 0$. In addition, the conditions for the existence of an optimal contract are $x_2 \geq \underline{U} + \frac{(1-p)B}{p}$ and $px_2 + (1-p)x_1 \geq \underline{U}$, both of which are guaranteed in our model by the stronger condition imposed by assumption A5.

4.2. Reporting system only

We next analyze a model in which the only decision the manager must make is on the reporting system a to be implemented, thus assuming that project s has already been chosen. Then, if the investor prefers $a = t$ to $a = f$, the optimal incentive scheme solves the problem[7]

$$\min_{w_1, w_2} pw_2 + (1-p)w_1 \tag{6}$$

subject to

$$pw_2 + (1-p)w_1 \geq \underline{U} \tag{7}$$

$$pw_2 + (1-p)w_1 \geq w_2 - c \tag{8}$$

$$w_1, w_2 \geq 0 \tag{9}$$

$$w_1 \leq x_1, \quad w_2 \leq x_2, \tag{10}$$

where (7) is the manager's participation constraint, (8) is a truthful reporting constraint (TR), and (9) and (10) are the limited liability conditions to be satisfied by the optimal contract.

[7] Note that $\Pr(\widehat{x} = x_2 | s, t) = p$ and $\Pr(\widehat{x} = x_2 | s, f) = 1$.

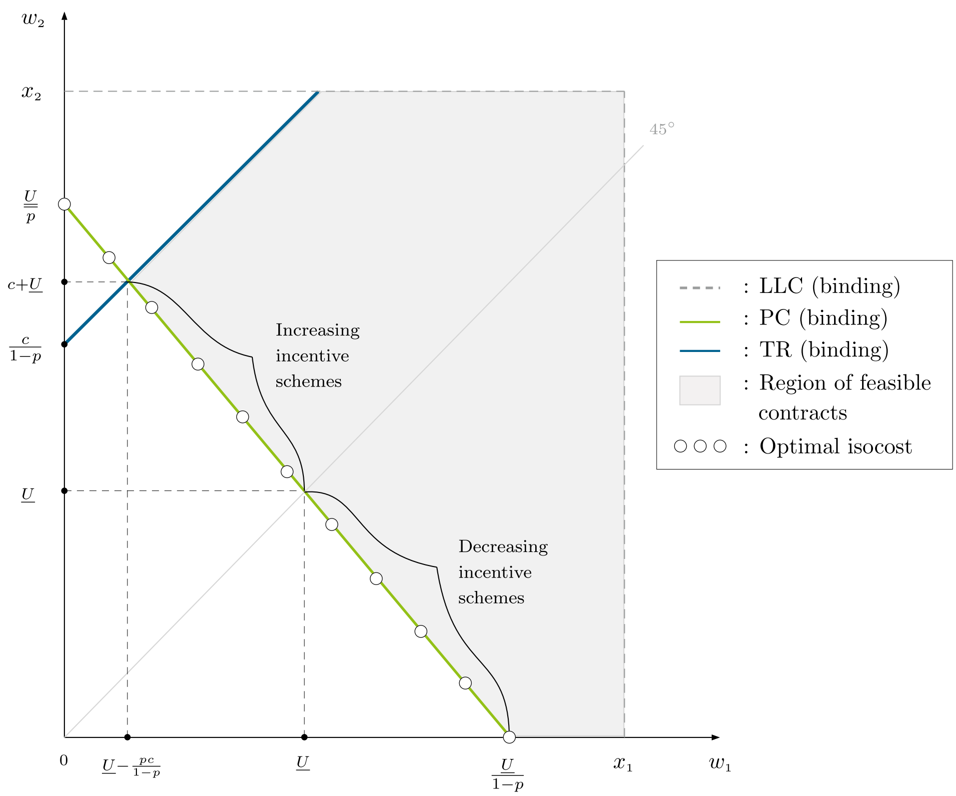

Fig. 3. Optimal incentive schemes with reporting system election only. Since the isocost line overlaps the binding participation constraint, there is a continuum of solutions $(w_1^*,\ w_2^*)$ such that $w_1^* \in \left[\underline{U} - \frac{pc}{1-p},\ \frac{\underline{U}}{1-p}\right]$, $w_2^* \in [0, \underline{U} + c]$ and $pw_2^* + (1-p)w_1^* = \underline{U}$. The decreasing incentive scheme interval contains all the pairs $(w_1^*,\ w_2^*)$ such that.$w_2^* < w_1^*$

Proposition 2. *When the moral hazard problem only concerns the reporting system implementation, there is a continuum of optimal incentive schemes represented by all the pairs* (w_1^*, w_2^*) *satisfying the following conditions:*

(i) $w_1^* \in \left[\underline{U} - \frac{pc}{1-p}, \frac{\underline{U}}{1-p}\right]$,

(ii) $w_2^* \in [0, \underline{U} + c]$,

(iii) $pw_2^* + (1-p)w_1^* = \underline{U}$.

Proof. *See the Appendix.*

Upon plotting all the equations in the above program (Fig. 3), we observe that there is indeed a continuum of optimal incentive schemes given by all the pairs (w_1^*, w_2^*) satisfying the three conditions described in Proposition 2.

Hence, the optimal incentive power interval is such that

$$\Delta w^* \in \left[-\frac{\underline{U}}{1-p}, \frac{c}{1-p}\right].$$

Fig. 4 illustrates how the optimal interval varies under different environments, where the ordered set operator $\succ$ indicates the investor's preference as between two choices.

Upon comparing the interval for a reporting decision only (i.e., $t \succ f$) with that for a project selection only (i.e., $s \succ m$), some interesting results emerge. First, there is a subset of high-powered incentive contracts consisting of all the Δw^* belonging to the subinterval $\left(\frac{c}{1-p}, \frac{\underline{U}}{p}\right]$ that are no longer optimal.[8] Second, there is a new subset of lower-powered incentive contracts consisting of all the Δw^* within the subinterval $\left[-\frac{\underline{U}}{1-p}, \frac{B}{p}\right)$ that are now optimal. And third, this new subset includes a segment where optimal incentive schemes

[8] The indicated subinterval is nonempty due to the r.h.s. of assumption A4.

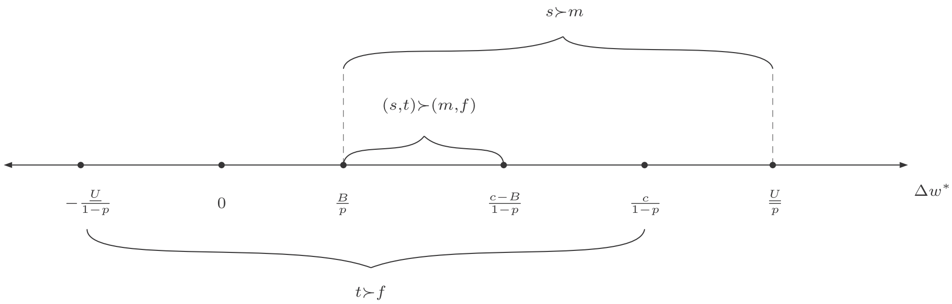

Fig. 4. Intervals containing the optimal incentive power Δw^* under different environments.

can be *decreasing* in profits, consisting of all the Δw^* belonging to $\left[-\frac{\underline{U}}{1-p}, 0\right)$ (at zero the contract is flat).

The intuition behind this last result is as follows. From (8), it is evident that at the optimal contract the truth-telling condition reduces to $c \geq (1-p)\Delta w^*$, which implies that when deciding whether or not to deviate to a misreporting system, the manager performs a cost-benefit analysis that considers (i) the incremental cost c, and (ii) the incremental expected benefit $(1-p)\Delta w^*$. If c is positive, the investor is then indifferent between offering an increasing and a decreasing incentive scheme since the fact that it is costly for the manager to implement a misreporting system is enough to align his decision with the investor's preferences. However, if c approaches zero, the incentive power interval reduces to a subinterval in which compensation schemes are always decreasing, i.e., $\left[-\frac{\underline{U}}{1-p}, 0\right]$.[9] In other words, if implementing a misreporting system has no cost at all, the investor is forced to use the compensation plan as a mechanism to dissuade the manager from choosing such a system. The investor can achieve this with a managerial incentive scheme that rewards low profits and punishes (in relative terms) high ones. This counterintuitive property holds because in our setup, low reported profits are a better signal that the manager has not chosen a system allowing overstatement of earnings.

In statistical terms, this last result follows from the assumption that the probability distribution of reported profits satisfies the decreasing monotone likelihood ratio property (DMLRP) with respect to the managerial decision to implement a truthful reporting system. More formally, in the context of a setup with an efficient investment policy, the likelihood ratio of outcome x is defined as

$$LR_x \equiv \frac{\Pr(\widehat{x} = x|s,t)}{\Pr(\widehat{x} = x|s,f)},$$

from which it is simple to check that

$$LR_{x_2} = p < LR_{x_1}$$

since

$$LR_{x_1} \to \infty.$$

The results of this subsection suggest, therefore, that if the aim of the compensation scheme is limited to avoiding a misreporting system, the incentives should in general be *less* powered than those implemented when the goal is confined to aligning management with an efficient investment policy.

The extent to which the results of this subsection are sensitive to our assumptions merits a brief discussion. The existence of a multiplicity of optimal contracts is due strictly to assumption A1 (risk neutrality). For instance, it can be shown that if the r.h.s. of assumption A4 is relaxed (i.e., $c > \frac{(1-p)\underline{U}}{p}$), we still obtain a continuum of solutions that may be either increasing or decreasing schemes. This solution consists of all the pairs (w_1^*, w_2^*) such that the participation constraint is binding, and thus, $\Delta w^* \in \left[-\frac{\underline{U}}{1-p}, \frac{\underline{U}}{p}\right]$. From this last interval, we can establish how robust are our main results regarding the comparison of the incentive power of models with and without potential misreporting. In the case of the result that lower-powered incentive contracts are also optimal, this is robust to assumption A4 because the lower bound of Δw^* continues to be $-\frac{\underline{U}}{1-p}$. By contrast, since the upper bound of Δw^* changes to $\frac{\underline{U}}{p}$, i.e., the same value found in the project-selection-only model, the result that higher-powered incentive contracts are no longer optimal turns out to be sensitive to assumption A4.

As regards the conditions ensuring the existence of an optimal contract, they are $x_1 \geq \underline{U} - \frac{pc}{1-p}$ and $px_2 + (1-p)x_1 \geq \underline{U}$, which in our model are guaranteed by the stronger conditions imposed by assumptions A2 and A5, respectively. Lastly, assumption A2 also allows optimal incentive schemes decreasing in profits to be affordable.

[9] This is just a hypothetical exercise since by assumption, $c > 0$.

4.3. Project selection and reporting system

Finally, we characterize the optimal incentives in our general model where the manager's decision-making process involves both project selection e and reporting system implementation a. If the investor prefers (s,t) instead of either (s,f), (m,t) or (m,f), the optimal incentive scheme must solve the program

$$\min_{w_1,w_2} pw_2 + (1-p)w_1 \tag{11}$$

subject to

$$pw_2 + (1-p)w_1 \geq \underline{U} \tag{12}$$

$$pw_2 + (1-p)w_1 \geq w_1 + B \tag{13}$$

$$pw_2 + (1-p)w_1 \geq w_2 - c \tag{14}$$

$$pw_2 + (1-p)w_1 \geq w_2 + B - c \tag{15}$$

$$w_1, w_2 \geq 0 \tag{16}$$

$$w_1 \leq x_1, \quad w_2 \leq x_2, \tag{17}$$

where (12) is the manager's participation constraint, (13) is the incentive-compatibility constraint, (14) is the truthful reporting constraint, (15) is a mixed incentive-truthtelling constraint (IC-TR); and (16) and (17) are the program's limited liability conditions.

Notice that the mixed constraint (15) is needed to prevent a managerial deviation from the decision pair (s,t) to (m,f), namely a joint deviation in both project selection and reporting system implementation. This is because the presence of both constraints (13) and (14) is not enough to avoid a deviation of this nature, as each of these constraints only prevents separated deviations in either project selection or reporting system, respectively, but they do not capture the mixed effects generated by a joint deviation in these two

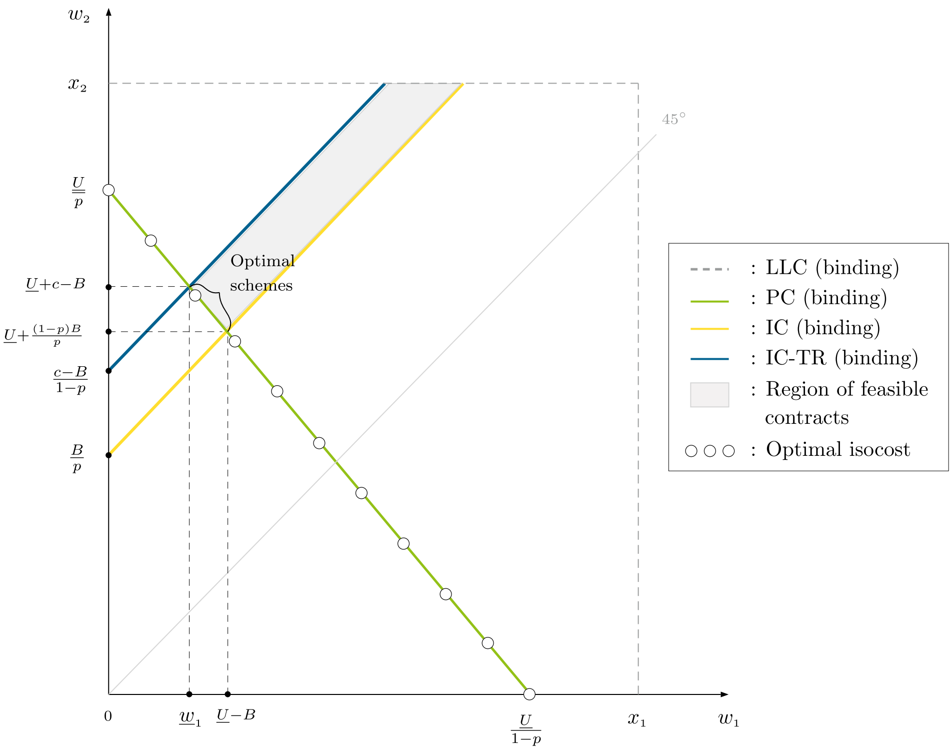

Fig. 5. Optimal incentive schemes with both project selection and reporting system election. Since the isocost line overlaps the binding participation constraint, there is a continuum of solutions (w_1^*, w_2^*) such that $w_1^* \in [\underline{w}_1, \underline{U}-B]$, $w_2^* \in \left[\underline{U}+\frac{(1-p)B}{p}, \underline{U}+c-B\right]$ and $pw_2^* + (1-p)w_1^* = \underline{U}$, where $\underline{w}_1 \equiv \underline{U}+\frac{p(B-c)}{1-p}$.

dimensions.

A manifestation of this property is that in fact the mixed constraint is stronger than the truthful reporting constraint: since $B > 0$, it is easy to check that (15) is a sufficient condition for (14) and hence the last constraint can be removed from the original program.

Proposition 3. *When the moral hazard problem concerns both the project selection and the reporting system implementation, there is a continuum of optimal incentive schemes represented by all the pairs* (w_1^*, w_2^*) *satisfying the following conditions:*

(i) $w_1^* \in \left[\underline{U} + \frac{p(B-c)}{1-p}, \underline{U} - B\right]$,

(ii) $w_2^* \in \left[\underline{U} + \frac{(1-p)B}{p}, \underline{U} + c - B\right]$,

(iii) $pw_2^* + (1-p)w_1^* = \underline{U}$.

Proof. *See the Appendix.*

The existence of this continuum of optimal incentive schemes is illustrated by Fig. 5, in which we have plotted all the remaining equations of the program after removing constraint (14).

Hence, the optimal incentive power interval is such that

$$\Delta w^* \in \left[\frac{B}{p}, \frac{c-B}{1-p}\right].$$

This general model can be contrasted with project selection only (i.e., $s \succ m$) in Fig. 4. The comparison reveals that the optimal incentive power interval when there exist two managerial decisions exhibits two properties. First, the lower bounds of the interval are the same, implying that despite the existence of a potential for misreporting, an efficient investment policy requires that managerial incentive schemes continue to be always increasing in profits. Second, the upper bound of the interval for Δw^* is now smaller. Thus, there is a subset of high-powered incentive contracts consisting of all of the $\Delta w^* \in \left(\frac{c-B}{1-p}, \frac{\underline{U}}{p}\right]$ that are no longer optimal when constraints demanding a truthful reporting must also be verified.

Considered jointly, these two results suggest that executive compensation schemes should optimally balance two objectives: (i) to preserve the primary incentives for an efficient investment policy, and (ii) to counteract the collateral misreporting incentives generated by the compensation scheme itself. Our model suggests that this desirable equilibrium can be achieved by means of compensation structures that are increasing in profits, but with *lower*-powered incentives than those adopted when their only alignment role is to select the most profitable investment project.

Three additional properties of the optimal incentives scheme can be derived from an analysis of the bounds of the interval containing Δw^*. First, the upper bound of the interval is increasing in parameter c. This suggests that as the cost of implementing a reporting system allowing more discretion to the manager increases, companies should base their compensation schemes more closely on earnings so as to strengthen the manager's motivation to pursue an efficient investment policy. Evidence consistent with this prediction is reflected in the passage by the United States government of the Sarbanes-Oxley Act in the wake of a series of accounting scandals at the turn of the present century. Among other things, this reform aimed at strengthening corporations' internal control systems and improving their ethical standards through a code of ethics for executives and officers. Both provisions in the context of our model setup can be interpreted as increasing cost c. Our prediction is further supported by evidence given in Carter, Lynch, and Zechman (2009) and Cohen, Dey, and Lys (2013) showing that after the implementation of these legal provisions, firms did in fact respond by either increasing bonus compensation or placing more weight on earnings in bonus-like schemes.

The second additional property is that there is clearly an ambiguous relationship between incentive power and B given that the lower bound of the interval is increasing with private benefits while the upper bound is decreasing. This contrasts with the traditional moral hazard model (such as our project-selection-only setup in Subsection 4.1), which suggests that if the investment policy agency problem intensifies, the optimal scheme will either remain unchanged or require greater incentive power.

Finally, the third additional property is that there is also an ambiguous relationship between incentive power and p because the optimal power interval's lower bound is decreasing while its upper bound is increasing with the success probability. Again, this contrasts with the traditional moral hazard model in Subsection 4.1, since now when misreporting is a concern we cannot assert that there will necessarily exist a kind of substitution between the exogenous motivation of the investment project s (the success probability) and the endogenous motivation of the optimal incentive scheme.

We end this section by showing formally that the premise behind program (11)–(17), namely that combination (s, t) is the optimal solution from the investor's viewpoint, is indeed true.

Corollary 1. *When the moral hazard problem concerns both the project selection and the reporting system implementation, the pair* (s, t) *is the investor's optimal decision.*

Proof. *See the Appendix.*

5. Extensions

In this section we discuss four extensions: (i) the conditions for the non-existence of an optimal contract that implements a profitable investment project, (ii) the role played by certain corporate governance policies aimed at dissuading financial misreporting and fraud, (iii) a potential problem of time consistency, and (iv) the possibility of an optimal managerial penalty.

5.1. Non-existence of an optimal contract

In our general model (Subsection 4.3) the investor's ability to write an optimal contract implementing a profitable investment project (with or without a truthful reporting system) depends crucially on the l.h.s. of assumption A4. Indeed, if this assumption is not satisfied, then $c < \frac{B}{p}$, which is equivalent to $\frac{c-B}{1-p} < \frac{B}{p}$. By simple inspection it can be seen that when this inequality holds, the optimal incentive power interval in the general model is empty. There would therefore be no contract that satisfies the constraints of the program described by equations (11)–(17), meaning in turn that the pair (s, t) could not be implemented.

Note also that from the manager's standpoint, the decision pair (s, f) is strictly dominated by (m, f).[10] The profitable investment project s thus could not be implemented even if the investor (i) was willing to accept a misreporting system because the expected fine for misreporting and fraud was sufficiently low, or (ii) overlooked the possibility of managerial misreporting when designing the top executive compensation plans.

To better understand when a profitable investment project cannot be implemented, we rearrange the inverse of the l.h.s. of the interval in assumption A4 to obtain

$$c < (1-p)\frac{B}{p} + B. \tag{18}$$

This expression means that a sufficient condition for the inability to write an optimal contract involves a manager's evaluation of his incentives when deciding whether or not to deviate from (s, t) to (m, f). This condition in fact illustrates an incremental cost-benefit analysis. On the cost side there is c, i.e., the cost of implementing a misreporting system, while on the benefit side there is the sum of two terms: (i) the *minimum* incremental expected bonus the manager receives for choosing reporting system f instead of t, and (ii) the private benefits of selecting project m instead of s.[11]

Therefore, from condition (18) our analysis predicts that in three specific circumstances the agency relationship might collapse, in which case a profitable project will not be undertaken. The three circumstances are: (i) the moral hazard problem associated with project selection is too serious (large B), which may arise in companies with highly entrenched management; (ii) the cost of implementing a misreporting system is sufficiently low (small c) because, for example, of the manager's weak ethical principles or the adoption of accounting principles giving management too much discretion in the preparation of financial statements; and (iii) the success probability of the project s is too low (small p), which may be true for highly risky and innovative ventures.

Note that this source of the inability to design an optimal contract is a novel result absent from the classical model with project selection only. It emerges solely because of the presence of a mixed incentive-truthtelling constraint, which in turn is a consequence of possible misreporting.[12]

5.2. Corporate liability and bonus cap

In this subsection we explore some corporate governance regulatory policies aimed at dissuading financial statement misrepresentation and fraud. In particular, we consider regulations that: (i) make external audits more effective and independent, (ii) impose higher penalties for such misconduct on firms, and (iii) place caps on convex pay-for-performance schemes such as bonuses and stock-based compensation structures.

We therefore relax our assumption of a sufficiently high penalty φ to the company and explore the conditions under which, from the investor's perspective, it would be advantageous to implement a non-truthful reporting system. As was discussed earlier, the manager prefers (m, f) to (s, f), making it impossible for the investor to design a contract that would induce the manager to choose the second decision pair. This being the case, we need only analyze the situation in which it is in the investor's best interest to implement (m, f).

We begin by defining $\psi \equiv \theta\varphi$ as the expected fine to be paid by the company when management selects the less profitable project and adopts a misreporting system. Since we have assumed that the investor prefers the pair (m, f) to either (m, t), (s, t) or (s, f), the optimal incentive scheme solves the program[13,14]

[10] This is so because the r.h.s. of (15) is larger than the r.h.s. of (14).

[11] If the manager deviates from (s, t) to (m, f), he would receive a minimum bonus $\Delta w^* = \frac{B}{p}$ even if the project s fails, which occurs with probability $1-p$.

[12] Baglioni and Colombo (2011) also characterize the possible non-existence of an optimal contract under misreporting, but in their setup the source of this result is the presence of an imperfect auditing technology.

[13] We omit the constraint imposing that the manager prefers (m, f) to (s, f) because, as pointed out above, from the manager's standpoint the first pair of decisions strictly dominates the second one.

[14] Recall that $\Pr(\hat{x} = x_2 | m, f) = 1$.

$$\max_{w_1,w_2} x_2 - w_2 - \psi \tag{19}$$

subject to

$$w_2 + B - c \geq \underline{U} \tag{20}$$

$$w_2 + B - c \geq w_1 + B \tag{21}$$

$$w_2 + B - c \geq p w_2 + (1-p) w_1 \tag{22}$$

$$w_1, w_2 \geq 0 \tag{23}$$

$$w_1 \leq x_1, \quad w_2 \leq x_2, \tag{24}$$

where the objective function includes the expected penalty ψ to be paid by the company if it is found guilty of misreporting and fraud. Using a graphical analysis similar to that applied in the preceding sections, it can be shown that from the above program we can derive a continuum of optimal incentive schemes represented by all the pairs (w_1^*, w_2^*) satisfying the following conditions:

(i) $w_1^* \in \left[0, \underline{U} + \frac{p(B-c)}{1-p}\right]$,

(ii) $w_2^* = \underline{U} + c - B$.

Hence, the optimal incentive power interval is such that[15]

$$\Delta w^* \in \left[\frac{c-B}{1-p}, \underline{U} + c - B\right].$$

5.2.1. External audit and corporate liability

To explore the role played by the size of the penalty φ and the audit success level θ, we compare the investor's expected payoff evaluated at the optimal contract when her best decision pair is (s,t) (subsection 4.3) and when it is (m,f) (the present subsection). Let us denote these payoffs as $EV^*(s,t)$ and $EV^*(m,f)$, respectively, such that

$$EV^*(s,t) = px_2 + (1-p)x_1 - pw_2^* - (1-p)w_1^* = px_2 + (1-p)x_1 - \underline{U} \tag{25}$$

and

$$EV^*(m,f) = x_2 - w_2^* - \psi = x_2 - \underline{U} - c + B - \psi. \tag{26}$$

From the comparison between (25) and (26), it follows that the investor will prefer to adopt a misreporting system (and not undertake the profitable project) if

$$\psi < (1-p)\Delta_x + B - c \equiv \overline{\psi}. \tag{27}$$

Therefore, as long as the expected penalty imposed on the company is sufficiently low (i.e., lower than the threshold $\overline{\psi}$), it will be in the investor's best interest to induce management to implement a misreporting and fraud scheme.[16] Since $\psi \equiv \theta\varphi$, condition (27) highlights the role played by three external corporate governance mechanisms in dissuading such misconduct. First, regarding parameter θ, this result underlines the importance of external auditors able to act effectively and with independence in detecting accounting manipulations and reporting misstatements. Our analysis thus provides a justification for certain regulatory provisions introduced in the United States by the Sarbanes-Oxley Act and other related reforms (listing standards in NYSE and NASDAQ) intended to improve external auditing such as the creation of the Public Company Accounting Oversight Board (for certifying audit quality) and the adoption of fully independent audit committees.

Second, as regards parameter φ, condition (27) brings out the importance of raising the degree of corporate liability and enhancing the level of legal protection for the agents ultimately affected by a fraud, who in our setup are the outside investors. More specifically, it illustrates how expanding the liability of directors in case of misreporting –as was done with the passage of the SOX Act– should reduce the likelihood of such fraudulent acts.

Third, in the case of parameter c, condition (27) also predicts a positive effect for other provisions of the SOX Act requiring (i) disclosure regarding the firm's code of ethics for senior financial officers, and (ii) disclosure of its internal controls and an assessment of their adequacy.

[15] The r.h.s. of assumption A4 ensures that this interval is nonempty.

[16] In our model this is an admissible scenario since assumptions A4 and A5 ensure that this threshold is strictly positive.

Interestingly, Carter et al. (2009) support all of our predictions, providing evidence that the implementation of the SOX Act and other related reforms has in fact led to a decrease in earnings management.

Note further that condition (27) also illustrates the role played by idiosyncratic firm characteristics in attaining an equilibrium that implements the decision pair (m,f). More specifically, the likelihood of this undesirable equilibrium will be greater, the greater is (i) the risk level of the profitable investment project (low p and high Δ_x), and (ii) the severity of the project selection agency problem (high B).

5.2.2. Bonus cap

In the analysis that follows we assume that the expected penalty ψ satisfies condition (27) and thus the best option for the investor is to induce the manager to adopt the decision pair (m,f). In this scenario, another deterrent the regulator could adopt as an alternative to raising the investor's degree of liability is to impose an upper bound on the size of performance bonuses. In our model, this means bounding from above the set of possible incentive power levels Δw available to the investor when designing the optimal compensation scheme.

This is done by comparing the two intervals containing Δw^* obtained under the assumptions that the best choice for the investor is (s,t) (subsection 4.3) and (m,f) (the present subsection), respectively. This comparison suggests that imposing a cap $\overline{\Delta w}$ on bonuses such that

$$\Delta w < \overline{\Delta w} = \frac{c-B}{1-p}$$

would make it impossible for the investor to induce the manager to choose (m,f). This is indeed the case since in the program (19)–(24), constraint (22) evaluated at the optimum can be restated as

$$\Delta w^* \geq \frac{c-B}{1-p}.$$

We must now show that when (m,f) is no longer implementable for the investor because of the bonus cap, the second-best choice for the investor is in fact (s,t). That is, we have to demonstrate that (s,t) dominates both (s,f) and (m,t). The first step is to note that since (s,f) is strictly dominated by (m,f) from the manager's standpoint, by transitivity it will also be impossible for the investor to align him with the first pair of decisions.[17] Then, applying Corollary 1, we can conclude that the assumptions of our model guarantee that $EV^*(s,t) > EV^*(m,t)$. It therefore follows that from the investor's perspective, it is better to optimally implement (s,t) than (m,t).[18]

We next consider another situation in which the bonus cap may be a useful regulatory policy to discourage managerial misreporting. This occurs when the investor *disregards* –because of ignorance, carelessness or naivety– the possibility that the manager may implement a misreporting system when designing his optimal pay structure. Observe that this differs from the situation studied above in which the investor *deliberately* designs a compensation scheme that induces the manager to implement an untruthful reporting system. Here, we suppose that the investor induces the manager to choose $e = s$ instead of $e = m$ but is completely unaware of the existence of another managerial decision $a \in \{t,f\}$ regarding the truthfulness of the accounting system. Thus, the investor solves the program described by equations (1)-(5) in Section 4, with the interval for Δw^* then given by $\left[\frac{B}{p}, \frac{\underline{U}}{p}\right]$.

The particular question we want to explore is whether, under this contract interval, the manager has incentives to exploit the ignorance of the investor and deviate from (s,t) to (m,f).[19] To that end, we must find the critical success wage for which the manager is indifferent between these two decision pairs, that is, the value of w_2 for which the manager's expected payoff when choosing (m,f) is equal to his expected payoff evaluated under the optimal contract when choosing (s,t). If EU denotes the manager's expected payoff, we then solve the following equation:

$$EU(m,f) = EU^*(s,t),$$

or equivalently,

$$w_2 + B - c = \underline{U},$$

from which we find that the cut-off value of the success wage is given by $w_2 = \underline{U} + c - B$. The cut-off value for the failure wage is then $w_1 = \underline{U} - \frac{p(c-B)}{1-p}$, which in turn means the critical incentive power level is $\Delta w = \frac{c-B}{1-p}$. We therefore conclude that for all Δw^* belonging to the subinterval $\left[\frac{c-B}{1-p}, \frac{\underline{U}}{p}\right]$, it will be profitable for the manager to deviate from (s,t) to (m,f).

The foregoing implies that an alternative policy the regulator could adopt to avoid this possible managerial wrongdoing would be to set a cap on bonuses equal to $\overline{\Delta w} = \frac{c-B}{1-p}$. The new interval of available bonuses for the investor when designing compensation then becomes $\left[\frac{B}{p}, \frac{c-B}{1-p}\right]$.[20] This regulatory policy has clear social benefits as it not only eliminates the possibility of misreporting and fraud but

[17] Alternatively, it can be seen in Fig. 4 that from the investor's standpoint $(s,t) \succ (s,f)$ to the left of $\frac{c-B}{1-p}$.

[18] From Corollary 1, one can infer that in the case in which the best investor's decision is (m,t), $\Delta w^* \in \left[B - \underline{U}, \frac{B}{p}\right]$. Since $\frac{B}{p} < \frac{c-B}{1-p}$, the bound $\overline{\Delta w}$ does not affect, therefore, the optimal scheme in that case.

[19] Recall that from the manager's standpoint, (s,f) is strictly dominated by (m,f).

[20] Interestingly, this cap level coincides with that proposed above to prevent the investor from *intentionally* inducing the manager to choose (m,f).

also guarantees that the more profitable investment project will always be undertaken. In the former case, the elimination of misreporting prevents fraud against outside investors and avoids imposition of the expected penalty ψ on company's owners; in the latter case, social benefits are given by

$$E(x|s,t) - E(x|m,f) - B = p\Delta_x + B > 0,$$

where the last inequality holds due to assumptions A4 and A5.

We end this subsection by noting that the analysis developed here gives partial support to some proposals made by American and European Union authorities in the wake of the last financial crisis that were aimed at moderating executive compensation plans. These proposals included:

(i) capping total compensation,
(ii) restricting performance-based components,
(iii) capping the ratio of variable compensation to total compensation, and
(iv) giving differential tax treatment to certain components of the compensation package.

A major concern with this class of policies, however, is whether the regulator would have the information needed to set these caps optimally, which according to our model should include a fair estimate of

(i) the private benefits B,
(ii) the investment project success probability p, and
(iii) the cost c of implementing a misreporting system.

This concern is especially significant in the case of B and p, which are highly idiosyncratic characteristics of the firms, making it unlikely that the setting of a bonus cap could be achieved through a one-size-fits-all regulation.

5.3. A potential problem of time consistency

One critical feature of the model is that the decision about the reporting system is taken ex ante, i.e., *before* the manager observes the true profits. However, this raises a concern about time consistency because once the manager has observed the true profits, he may have an ex post incentive to deviate from the truthful reporting rule.[21] This fact deserves then some comments.

First, it is worthy to note that the timing we assume is based on the idea that earning manipulation is not an improvised action, but that it requires to previously implement an accounting system that offers the management degrees of discretion and several mechanisms to credibly camouflage his false story and avoid its detection by internal or external audits (see Section 3 for a more detailed discussion on the nature of setup costs c). Since all these mechanisms are costly to be implemented, one way to solve a potential problem of time consistency is to assume that the cost of implementing a misreporting system strongly increases as long as the date in which profits must be officially announced gets closer. In particular, we can assume that the cost c of implementing a misreporting system after observing the true profits would increase by an amount Δc sufficiently large, making therefore unprofitable any deviation from a truthful reporting system.

In order to compute this lower bound for Δc, we incorporate into the program (11)–(17) the following ex post truthful-reporting constraints

$$w_1 \geq w_2 - (c + \Delta c) \tag{28}$$

$$w_2 \geq w_2 - (c + \Delta c), \tag{29}$$

where (28) and (29) guarantee that the manager will prefer not to deviate from the truthful reporting system to the misreporting system after observing that true profit x is x_1 and x_2, respectively.[22] Using a methodology similar to that adopted in the previous sections, it is possible to establish the following results.

Case 1. If $\Delta c \geq \frac{pc-B}{1-p}$, there is a continuum of ex post optimal incentive schemes consisting of all the pairs (w_1^*, w_2^*) satisfying the following conditions:

(i) $w_1^* \in \left[\underline{U} + \frac{p(B-c)}{1-p}, \underline{U} - B\right]$,

(ii) $w_2^* \in \left[\underline{U} + \frac{(1-p)B}{p}, \underline{U} + c - B\right]$,

[21] We are grateful to an anonymous referee for raising this concern.

[22] Constraint (29) is always satisfied since it implies that $c + \Delta c \geq 0$, which is true by assumption. Thus, only constraint (28) becomes relevant for the problem, which is the result that the manager only faces a temptation to inflate the true profit when the project has failed.

(iii) $pw_2^* + (1-p)w_1^* = \underline{U}$.

Hence, the optimal incentive power interval is such that

$$\Delta w^* \in \left[\frac{B}{p}, \frac{c-B}{1-p}\right].$$

Case 2. If $\Delta c < \frac{pc-B}{1-p}$, there is a continuum of ex post optimal incentive schemes consisting of all the pairs (w_1^*, w_2^*) satisfying the following conditions:

(i) $w_1^* \in [\underline{U} - p(c+\Delta c), \underline{U} - B]$,

(ii) $w_2^* \in \left[\underline{U} + \frac{(1-p)B}{p}, \underline{U} + (1-p)(c+\Delta c)\right]$,

(iii) $pw_2^* + (1-p)w_1^* = \underline{U}$.

Hence, the optimal incentive power interval is such that

$$\Delta w^* \in \left[\frac{B}{p}, c+\Delta c\right].$$

These results can be contrasted with those of the model with only ex ante optimality studied in Section 4.3. On the one hand, in Case 1, the comparison reveals that the set of optimal incentive schemes is the same, which means that when the incremental cost of implementing ex post a misreporting system is large enough, all the contracts characterized in Section 4.3 are optimal not only ex ante, but also ex post. Therefore, in that case the time consistency concern can be completely ruled out.

On the other hand, notice that in Case 2 the upper bound of the interval for Δw^* is now smaller than that found in Section 4.3. Thus, there is a subset of high-powered incentive contracts consisting of all of the $\Delta w^* \in \left(c+\Delta c, \frac{c-B}{1-p}\right]$ that are no longer optimal when constraints demanding an ex post truthful reporting must also be verified. However, there is still a subset of original contracts represented by all $\Delta w^* \in \left[\frac{B}{p}, c+\Delta c\right]$ that survive to this additional constraint. This implies that when the incremental cost of implementing ex post a misreporting system is relatively low, ex post truthful reporting works like a *refinement criterion* that imposes a more stringent property on the set of solutions derived in Section 4.3. We conclude, therefore, that in this case ex post optimality improves our previous analysis, but it does not invalidate at all the conclusions coming from our baseline model.

5.4. *Managerial penalty*

In this subsection we incorporate the possibility that the manager also incurs a penalty in case misreporting is detected.[23] In particular, we assume now that the investor chooses optimally a managerial penalty $\rho > 0$ at a total cost $k\rho$ with $k > 0$. The values of both penalty ρ and wage pair (w_1, w_2) are known by the manager when he decides if accepting or not to run the business. One possible interpretation of this penalty is a clawback provision, a clause that in real-world executive compensation contracts allows the company to recover a bonus paid in excess when a misconduct is detected such as earning manipulation or fraud.

In order to explore the role played by that penalty, we must modify assumption A2. In particular, we replace it by the condition $\underline{U} > x_1 + \frac{(1-p)c}{p}$, which we will call assumption A2-B.[24] Under this new assumption, we first characterize the optimal incentive scheme (w_1^*, w_2^*) when the manager only cares about the project selection, which gives us a benchmark solution. Then, we characterize the optimal augmented incentive scheme (w_1^*, w_2^*, ρ^*) in an environment in which the manager must decide about both project selection and reporting system implementation. We then compare the two incentive schemes in order to analyze how an optimal joint arrangement of managerial penalty and compensation can deter misreporting.

5.4.1. *Project selection only*

If the investor prefers $e = s$ to $e = m$, the optimal incentive scheme solves the program (1)–(5) described in Subsection 4.1. Following a similar methodology to that used in that subsection, it can be shown formally that, under assumption A2-B, there is a continuum of optimal incentive schemes represented by all the pairs (w_1^*, w_2^*) satisfying the following conditions:

[23] We thank an anonymous referee for suggesting this extension of the baseline model. A related issue that may also be studied under our framework is the role played by the directors' and officers' (D&O) liability insurances on executive compensation plans and earnings management (see Weng, Chen, & Chi, 2017; and; Wang & Chen, 2016).

[24] If assumption A2-B is not verified, the optimal penalty becomes zero. An intuitive analysis of this property is discussed later on. The formal proof of this result is available from the authors upon request.

(i) $w_1^* \in [0, x_1]$,

(ii) $w_2^* \in \left[\frac{\underline{U}-(1-p)x_1}{p}, \frac{\underline{U}}{p}\right]$,

(iii) $pw_2^* + (1-p)w_1^* = \underline{U}$.

Thus, the optimal incentive power interval is such that $\Delta w^* \in \left[\frac{\underline{U}-x_1}{p}, \frac{\underline{U}}{p}\right]$.

5.4.2. Project selection and reporting system

If the investor prefers (s, t) instead of either (s, f), (m, t) or (m, f), the optimal incentive scheme (w_1^*, w_2^*, ρ^*) must solve the program

$$\min_{w_1, w_2, \rho} pw_2 + (1-p)w_1 + k\rho \tag{30}$$

subject to

$$pw_2 + (1-p)w_1 \geq \underline{U} \tag{31}$$

$$pw_2 + (1-p)w_1 \geq w_1 + B \tag{32}$$

$$pw_2 + (1-p)w_1 \geq w_2 - c - \theta(1-p)\rho \tag{33}$$

$$pw_2 + (1-p)w_1 \geq w_2 + B - c - \theta(1-p)\rho \tag{34}$$

$$w_1, w_2 \geq 0 \tag{35}$$

$$w_1 \leq x_1, \quad w_2 \leq x_2 \tag{36}$$

$$0 \leq \rho \leq w_2, \tag{37}$$

where the right-hand-side of the truthful reporting constraint (33) and the mixed incentive-truthtelling constraint (34) consider the expected penalty to be paid by the manager if misreporting is detected by the external auditor.

Following a similar problem-solving approach to that adopted so far, it can be formally shown that the optimal augmented incentive scheme (w_1^*, w_2^*, ρ^*) is unique and given by:

(i) $w_1^* = x_1$,

(ii) $w_2^* = \frac{\underline{U}-(1-p)x_1}{p}$,

(iii) $\rho^* = \frac{1}{\theta}\left(\frac{\underline{U}-x_1}{p} + \frac{B-c}{1-p}\right)$.

Thus, the optimal incentive power is given by $\Delta w^* = \frac{\underline{U}-x_1}{p}$.

The comparison between the optimal incentive schemes of the two environments characterized reveals two important properties. First, when truthful constraints are incorporated into the problem, the set of optimal incentive schemes shrinks to the lowest-powered scheme represented by the lower bound $\Delta w^* = \frac{\underline{U}-x_1}{p}$. Consequently, the high-powered incentive contracts consisting of all the $\Delta w^* \in \left(\frac{\underline{U}-x_1}{p}, \frac{\underline{U}}{p}\right]$ are no longer optimal. This property is similar to that already identified in Section 4, in the sense that the incentives should be less powered when there exists a possibility of misreporting, although this effect here is much more dramatic.

Second, this less incentive power is not, however, enough to deter misreporting because $\Delta w^* = \frac{\underline{U}-x_1}{p}$ is yet too high and tempting for the manager. Thus, a complementary corporate governance mechanism like a penalty is also needed to prevent a deviation in the two choice dimensions, namely project selection and reporting system. To grasp a better intuition of this property, rearrange the mixed constraint (34) evaluated at the optimal solution such that it emerges the following condition:

$$\Delta w^* \leq \frac{c}{1-p} - \frac{B}{1-p} + \theta\rho^*. \tag{38}$$

Therefore, if $\Delta w^* \leq \frac{c}{1-p} - \frac{B}{1-p}$ (i.e., the power of incentives is sufficiently low), it would not be necessary for the investor to use a costly penalty to align the manager and ρ^* should thus be zero. However, this is not the case because our modified assumption A2-B implies that indeed the opposite is true since

$$\Delta w^* = \frac{\underline{U} - x_1}{p} > \frac{c}{1-p} - \frac{B}{1-p},$$

which in turn implies that a positive penalty ρ^* is needed to guarantee condition (38) to be satisfied, and thereby, to prevent a deviation from (s,t) to (m,f).

6. Conclusions

An agency model was proposed that examines how executive compensation schemes should be designed to provide the right incentives for an efficient investment policy while at the same time discouraging collateral incentives generated by the possibility of misreporting. Our analysis formally shows that, as compared to a conventional model with investment project selection only, the set of contracts exhibiting these properties reduces to one in which only the lowest-powered incentive schemes are still optimal. Furthermore, under certain circumstances this subset may even be empty, reflecting the fact that accounting manipulations have the potential to render a profitable investment project unimplementable.

Our findings have normative and positive implications. In the first case, the main implication of our results for real-world executive compensation practices is that, although increasing schemes such as performance bonuses and stock-based plans can be suitable, they should moderate their convexity in order to mitigate the manager's temptation to inflate profits. In the same vein, our analysis illustrates under which conditions two regulatory policies, such as imposing high corporate penalties and setting a bonus cap, may be helpful to both prevent the possibility of misreporting and ensure the undertaking of the most profitable investment projects.

As for its positive implications, our framework provides an economic rationale for the empirical evidence of lower managerial pay-for-performance sensitivity than that predicted by conventional models of moral hazard (Jensen & Murphy, 1990; Murphy, 1999), in the sense that the possibility of accounting manipulation generates less convex optimal compensation schemes. Our setup may also explain why the use of stock-option schemes in the almost two decades since the great accounting scandals in the United States at the turn of the century have increasingly given way to less convex schemes such as restricted stocks and other long-term incentive plans (see the evidence cited in Baglioni & Colombo, 2011 and Andergassen, 2008).

Finally, this study identified at the theoretical level certain elements that are common to what at first glance appear to be different cases of corporate accounting fraud. These elements should therefore be useful in predicting such fraud in real-world situations. In particular, our model suggests that the implementation of a misreporting system is more likely when highly convex incentive schemes are combined with an environment that includes: (i) external auditors with low degrees of independence, (ii) low corporate liability and weak legal protection of outside investors, (iii) high potential for a moral hazard problem in investment policy such as empire building and managerial entrenchment strategies, and (iv) low costs to managers implementing a misleading financial reporting system due either to weak internal control procedures, accounting standards allowing wide discretion or an organizational culture with loose ethical norms.

CRediT authorship contribution statement

Gino Loyola: Formal analysis. **Yolanda Portilla:** Formal analysis.

Declaration of competing interest

None.

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Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.iref.2020.04.007.

7. Appendix

7.1. Preliminary definitions

Before to demonstrate propositions 1, 2 and 3 we need to define the following functions:

$$h_0(w_2, w_1) = pw_2 + (1-p)w_1,$$

$$h_1(w_2, w_1) = pw_2 + (1-p)w_1 - \underline{U},$$

$$h_2(w_2, w_1) = pw_2 - pw_1 - B,$$

$$h_3(w_2, w_1) = (1-p)(w_1 - w_2) + c,$$

$$h_4(w_2, w_1) = (1-p)(w_1 - w_2) + c - B.$$

The Lagrangian of the most general program (11)–(17) is thus given by

$$L(w_2, w_1, \boldsymbol{\lambda}) = -h_0(w_2, w_1) + \lambda_1 h_1(w_2, w_1) + \lambda_2 h_2(w_2, w_1) + \lambda_3 h_3(w_2, w_1)$$

$$+\lambda_4 h_4(w_2, w_1) + \lambda_5 w_1 + \lambda_6 w_2 + \lambda_7(x_1 - w_1) + \lambda_8(x_2 - w_2), \tag{39}$$

where λ_i is the Lagrange multiplier of the constraint i of this program.

7.2. Proofs of main results

Proof of Proposition 1. In this model the program (1)–(5) is consistent with the Lagrangian given by (39), but in which the fourth and fifth terms of the r.h.s. of this equation are absent. We then characterize conditions (a)-(d), which are the Khun-Tucker conditions this problem must satisfy.

(a) First-order conditions

These are given by:

$$\frac{\partial L}{\partial w_2} = p(\lambda_1 - 1) + \lambda_2 p + \lambda_6 - \lambda_8 = 0, \tag{40}$$

$$\frac{\partial L}{\partial w_1} = (1-p)(\lambda_1 - 1) - \lambda_2 p + \lambda_5 - \lambda_7 = 0. \tag{41}$$

From (40) and (41) we obtain, respectively,

$$\lambda_1 = 1 - \lambda_2 + \frac{\lambda_8 - \lambda_6}{p}, \tag{42}$$

and

$$\lambda_1 = 1 + \lambda_2 \frac{p}{1-p} + \frac{\lambda_7 - \lambda_5}{1-p}. \tag{43}$$

(b) Dual feasibility. $\lambda_1, \lambda_2, \lambda_5, \lambda_6, \lambda_7, \lambda_8 \geq 0$.

(c) Complementary slackness.
- (c1) $\lambda_1 h_1(w_2, w_1) = 0$
- (c2) $\lambda_2 h_2(w_2, w_1) = 0$
- (c3) $\lambda_5 w_1 = 0$
- (c4) $\lambda_6 w_2 = 0$
- (c5) $\lambda_7(x_1 - w_1) = 0$, and
- (c6) $\lambda_8(x_2 - w_2) = 0$.

(d) Primal feasibility.
- (d1) $h_1(w_2, w_1) \geq 0$
- (d2) $h_2(w_2, w_1) \geq 0$
- (d3) $w_1 \geq 0$
- (d4) $w_2 \geq 0$
- (d5) $x_1 - w_1 \geq 0$, and
- (d6) $x_2 - w_2 \geq 0$.

We now establish two auxiliary results.

Lemma 1. From the couple of multipliers λ_5 and λ_7, at least one of them must be zero.
The same occurs with the couple λ_6 and λ_8.

Proof. Notice that it is not possible a situation in which $\lambda_5, \lambda_7 > 0$ because in that case by (c3) and (c5), we would obtain $w_1 = 0$ and $w_1 = x_1$, which is a contradiction. Therefore, at least one of these two multipliers must be zero. It is easy to check that a similar contradiction can be attained with λ_6 and λ_8 with respect to w_2.

Lemma 2. In the model with project selection only, the participation constraint is binding at the optimal solution, i.e., $h_1(w_2^*, w_1^*) = 0$.

Proof. We show this statement by contradiction. Then, suppose that the participation constraint is not binding, i.e., $h_1(w_2, w_1) > 0$, which by (c1) implies that $\lambda_1 = 0$. Substituting this value into (43) yields

$$\frac{\lambda_5 - \lambda_7}{1-p} = 1 + \lambda_2 \frac{p}{1-p}.$$

Since $\lambda_2 \geq 0$ and $p \in (0,1)$ then the r.h.s. of the last equation is strictly greater than zero. According to Lemma 1, the l.h.s of this equation is also strictly positive only if $\lambda_5 > \lambda_7 = 0$. Using the value of the multipliers so far derived, from equations (42) and (43) we obtain

$$\frac{\lambda_8 - \lambda_6}{p} = \frac{\lambda_2}{1-p} - \frac{\lambda_5}{1-p}. \tag{44}$$

From (44), we then analyze two cases: **(A)** $\lambda_2 = 0$, and **(B)** $\lambda_2 > 0$.

Case A: Since $\lambda_2 = 0$, equation (44) becomes

$$\frac{\lambda_8 - \lambda_6}{p} = -\frac{\lambda_5}{1-p}. \tag{45}$$

It is clear that the r.h.s. of the last equation is strictly negative, and thereby, its l.h.s. must also be smaller than zero. According to Lemma 1, this is possible only if $\lambda_6 > \lambda_8 = 0$. By (c3), if $\lambda_5 > 0$ then $w_1 = 0$, and by (c4), if $\lambda_6 > 0$ then $w_2 = 0$. This combination of wages contradicts, however, a nonbinding participation constraint, i.e., that $h_1(w_2, w_1) > 0$.

Case B: $\lambda_2 > 0$. In that case, by (c2) it is verified that $h_2(w_2, w_1) = 0$. Since $\lambda_5 > 0$, it follows from (c3) that $w_1 = 0$, which from $h_2(w_2, w_1) = 0$ yields $w_2 = \frac{B}{p}$. This combination of wages implies that $h_1(w_2, w_1) = B - \underline{U}$, which is strictly negative by assumption A4 and contradicts, therefore, condition (d1).

We next solve the program (1)–(5) using Lemma 2. Since the participation constraint is binding, we have

$$w_2 = \frac{\underline{U}}{p} - \frac{1-p}{p} w_1. \tag{46}$$

After substituting the bounds imposed over w_1 by the limited liability constraints (4) and (5) into (46), we define the following upper and lower bounds for w_2:

$$\overline{w}_2 = \frac{\underline{U}}{p}, \tag{47}$$

$$\underline{w}_2 = \frac{\underline{U}}{p} - \frac{1-p}{p} x_1. \tag{48}$$

The combination of these bounds and the limited liability constraints (4) and (5) for w_2 yields the following constraint:

$$\max\left\{0, \underline{w}_2\right\} \leq w_2 \leq \min\{x_2, \overline{w}_2\},$$

which by assumptions A2 and A5 reduces to

$$0 \leq w_2 \leq \overline{w}_2. \tag{49}$$

After replacing the binding participation constraint into the original program described by equations (1)–(5), and using expression (49), we can rewrite such a program as follows:

$$\min_{w_2} \underline{U} \tag{50}$$

subject to

$$w_2 \geq \underline{U} + \frac{(1-p)B}{p} \tag{51}$$

$$0 \leq w_2 \leq \overline{w}_2. \tag{52}$$

Since the objective function does not depend on w_2, the solution is defined by the relevant constraints of the problem. Since $0 < \underline{U} + \frac{(1-p)B}{p} < \overline{w}_2$ because the assumptions of the model guarantee that $0 < B < \underline{U}$, the interval of solutions for w_2^* becomes

$$\underline{U}+\frac{(1-p)B}{p}\leq w_2^*\leq\frac{\underline{U}}{p}.$$

Substituting the lower and upper bounds of this interval into the binding participation constraint we find that the interval of solutions for w_1^* is given by

$$0\leq w_1^*\leq\underline{U}-B,$$

which completes the proof.

Proof of Proposition 2. In this model the program (6)–(10) is consistent with the Lagrangian given by equation (39), but in which the third and fifth terms of the r.h.s. of this equation are absent. We then characterize the Khun-Tucker conditions this problem must satisfy.

(a) **First-order conditions.** These are given by:

$$\frac{\partial L}{\partial w_2}=p(\lambda_1-1)+\lambda_3(1-p)+\lambda_6-\lambda_8=0, \tag{53}$$

$$\frac{\partial L}{\partial w_1}=(1-p)(\lambda_1-1)+\lambda_3(1-p)+\lambda_5-\lambda_7=0. \tag{54}$$

From (53) and (54) we obtain, respectively,

$$\lambda_1=1+\lambda_3\frac{1-p}{p}+\frac{\lambda_8-\lambda_6}{p}, \tag{55}$$

and

$$\lambda_1=1-\lambda_3+\frac{\lambda_7-\lambda_5}{1-p}. \tag{56}$$

(b) Dual feasibility. $\lambda_1,\lambda_3,\lambda_5,\lambda_6,\lambda_7,\lambda_8\geq 0$
(c) Complementary slackness. (c1) $\lambda_1 h_1(w_2,w_1)=0$, (c2) $\lambda_3 h_3(w_2,w_1)=0$, (c3) $\lambda_5 w_1=0$, (c4) $\lambda_6 w_2=0$, (c5) $\lambda_7(x_1-w_1)=0$, and (c6) $\lambda_8(x_2-w_2)=0$.
(d) Primal feasibility. (d1) $h_1(w_2,w_1)\geq 0$, (d2) $h_3(w_2,w_1)\geq 0$, (d3) $w_1\geq 0$, (d4) $w_2\geq 0$, (d5) $x_1-w_1\geq 0$, and (d6) $x_2-w_2\geq 0$.

We now establish the following auxiliary result.

Lemma 3. In the model with reporting system only, the participation constraint is binding at the optimal solution, i.e., $h_1(w_2^*,w_1^*)=0$.

Proof. We show this statement by contradiction. Then, suppose that the participation constraint is not binding, i.e., $h_1(w_2,w_1)>0$, which by (c1) implies that $\lambda_1=0$. Substituting the value of this multiplier into equation (55) yields

$$\frac{\lambda_6-\lambda_8}{p}=1+\lambda_3\frac{1-p}{p}, \tag{57}$$

where the r.h.s. is greater than zero because $\lambda_3\geq 0$ and $p\in(0,1)$. According to Lemma 1, the l.h.s. of (57) is also strictly positive only if $\lambda_6>\lambda_8=0$. From equations (55) and (56) we then obtain

$$-\frac{\lambda_6}{p}+\frac{\lambda_3}{p}=\frac{\lambda_7-\lambda_5}{1-p}. \tag{58}$$

From (58), we then analyze two cases: **(A)** $\lambda_3=0$, and **(B)** $\lambda_3>0$.

Case A: Since $\lambda_3=0$, equation (58) becomes

$$\frac{\lambda_7-\lambda_5}{1-p}=-\frac{\lambda_6}{p}, \tag{59}$$

where the r.h.s. is smaller than zero. According to Lemma 1, the l.h.s. of equation (59) is also strictly negative only if $\lambda_5>0$ and $\lambda_7=0$. By (c3), if $\lambda_5>0$ then $w_1=0$, and by (c4), if $\lambda_6>0$ then $w_2=0$. This combination of wages contradicts, however, a nonbinding participation constraint, i.e., that $h_1(w_2,w_1)>0$.

Case B: $\lambda_3>0$. In that case, by (c2) it is verified that $h_3(w_2,w_1)=0$. Since $\lambda_6>0$, by (c4) it follows that $w_2=0$, which because $h_3(w_2,w_1)=0$ implies that $w_1=-\frac{c}{1-p}<0$, contradicting thus condition (d3). □

We next solve the program (6)–(10) using Lemma 3. Since the participation constraint is binding, we have

$$w_2 = \frac{\underline{U}}{p} - \frac{1-p}{p} w_1. \tag{60}$$

After substituting the bounds imposed over w_1 by the limited liability constraints (9) and (10) into (60), we define the following upper and lower bounds for w_2:

$$\overline{w}_2 = \frac{\underline{U}}{p}, \tag{61}$$

$$\underline{w}_2 = \frac{\underline{U}}{p} - \frac{1-p}{p} x_1. \tag{62}$$

The combination of these bounds and the limited liability constraints (9) and (10) for w_2 yields the following constraint:

$$\max\left\{0, \underline{w}_2\right\} \leq w_2 \leq \min\{x_2, \overline{w}_2\},$$

which by assumptions A2 and A5 simplifies to

$$0 \leq w_2 \leq \overline{w}_2. \tag{63}$$

After replacing the binding participation constraint into the original program described by equations 6–10, and using expression (63), this program can be rewritten as follows:

$$\min_{w_2} \underline{U} \tag{64}$$

subject to

$$w_2 \leq \underline{U} + c \tag{65}$$

$$0 \leq w_2 \leq \overline{w}_2. \tag{66}$$

Since the objective function does not depend on w_2, the solution is defined by the relevant constraints of the problem. Since $\underline{U} + c < \overline{w}_2$ because assumption A4 guarantees that $c < \frac{(1-p)\underline{U}}{p}$, the interval of solutions for w_2^* becomes

$$0 \leq w_2^* \leq \underline{U} + c.$$

The substitution of the lower and upper bounds of this interval into the binding participation constraint yields the following interval of solutions for w_1^*:

$$\underline{U} - \frac{pc}{(1-p)} \leq w_1^* \leq \frac{\underline{U}}{1-p},$$

which completes the proof.

Proof of Proposition 3. In this model the program (11)–(17) is consistent with the Lagrangian given by equation (39), but in which we omit the fourth term of its r.h.s. We do that because since $B > 0$, it follows that (15) is a sufficient condition for (14), and hence, the last constraint can be removed from the original program. We then characterize the Khun-Tucker conditions this problem must satisfy.

(a) **First-order conditions.** These are given by:

$$\frac{\partial L}{\partial w_2} = p(\lambda_1 - 1) + \lambda_2 p - \lambda_4(1-p) + \lambda_6 - \lambda_8 = 0, \tag{67}$$

$$\frac{\partial L}{\partial w_1} = (1-p)(\lambda_1 - 1) - \lambda_2 p + \lambda_4(1-p) + \lambda_5 - \lambda_7 = 0. \tag{68}$$

From (67) and (68) we obtain, respectively,

$$\lambda_1 = 1 - \lambda_2 + \lambda_4 \frac{1-p}{p} + \frac{\lambda_8 - \lambda_6}{p}, \tag{69}$$

and

$$\lambda_1 = 1 + \lambda_2 \frac{p}{1-p} - \lambda_4 + \frac{\lambda_7 - \lambda_5}{1-p}. \tag{70}$$

(b) Dual feasibility .$\lambda_1, \lambda_2, \lambda_4, \lambda_5, \lambda_6, \lambda_7, \lambda_8 \geq 0$.

(c) Complementary slackness. (c1) $\lambda_1 h_1(w_2,w_1) = 0$, (c2) $\lambda_2 h_2(w_2,w_1) = 0$, (c3) $\lambda_5 w_1 = 0$, (c4) $\lambda_6 w_2 = 0$, (c5) $\lambda_7(x_1 - w_1) = 0$, and (c6) $\lambda_8(x_2 - w_2) = 0$, (c7) $\lambda_4 h_4(w_2,w_1) = 0$.
(d) Primal feasibility. (d1) $h_1(w_2,w_1) \geq 0$, (d2) $h_2(w_2,w_1) \geq 0$, (d3) $w_1 \geq 0$, (d4) $w_2 \geq 0$, (d5) $x_1 - w_1 \geq 0$, and (d6) $x_2 - w_2 \geq 0$, (d7) $h_4(w_2,w_1) \geq 0$.

We establish the following auxiliary result.

Lemma 4. In the model with project selection and reporting system, the participation constraint is binding at the optimal solution, i.e., $h_1(w_2^*,w_1^*) = 0$.

Proof. We show this statement by contradiction. Then, suppose that the participation constraint is not binding, i.e., $h_1(w_2,w_1) > 0$, which by (c1) implies that $\lambda_1 = 0$. We then analyze two pertinent families of cases: **(A)** $\lambda_4 = 0$, and **(B)** $\lambda_4 > 0$.

Case A: When$\lambda_4 = 0$, we identify two additional subcases: (A.1) $\lambda_2 > 0$, and (A.2) $\lambda_2 = 0$. Notice that whereas subcase A.1 is similar to case A in the model with only project selection, subcase A.2 is similar to Case B of the same model. The proof of these two subcases is thus omitted here.

Case B: $\lambda_4 > 0$ implies by (c7) that $h_4(w_2,w_1) = 0$. We analyze two additional subcases: **(B.1)** $\lambda_2 = 0$, and **(B.2)** $\lambda_2 > 0$.

Subcase B.1: Since $\lambda_2 = 0$, equation (69) becomes

$$\frac{\lambda_6 - \lambda_8}{p} = 1 + \lambda_4 \frac{1-p}{p} > 0, \tag{71}$$

where the inequality follows because $\lambda_4 > 0$ and $p \in (0,1)$. From this and Lemma 1, the l.h.s. of equation (71) is then positive as long as $\lambda_6 > \lambda_8 = 0$. By (c4), if $\lambda_6 > 0$ then $w_2 = 0$, value which after being substituted into $h_4(w_2,w_1) = 0$ yields $w_1 = \frac{B-c}{1-p}$. This failure wage is negative by assumption A4, which contradicts condition (d3).

Subcase B.2: $\lambda_2 > 0$. On the one side, by (c2) it is verified that $h_2(w_2,w_1) = 0$, which implies that $w_2 = w_1 + \frac{B}{p}$. On the other side, $h_4(w_2,w_1) = 0$ yields $w_2 = w_1 + \frac{c-B}{1-p}$. These two values for w_2 produce a contradiction because $\frac{B}{p} < c$ according to assumption A4.

We next solve the program (11)–(17) using Lemma 4. Since the participation constraint is binding, we have

$$w_2 = \frac{\underline{U}}{p} - \frac{1-p}{p} w_1. \tag{72}$$

After substituting the bounds imposed over w_1 by the limited liability constraints (16) and (17) into (72), we define the following upper and lower bounds for w_2:

$$\overline{w}_2 = \frac{\underline{U}}{p}, \tag{73}$$

$$\underline{w}_2 = \frac{\underline{U}}{p} - \frac{1-p}{p} x_1. \tag{74}$$

The combination of these bounds and the limited liability constraints (16) and (17) for w_2 yields the following constraint:

$$\max\left\{0, \underline{w}_2\right\} \leq w_2 \leq \min\{x_2, \overline{w}_2\},$$

which by assumptions A2 and A5 becomes

$$0 \leq w_2 \leq \overline{w}_2. \tag{75}$$

After replacing the binding participation constraint into the original program described by equations 11–17, and using expression (75), we can rewrite such a program as follows:

$$\min_{w_2} \underline{U} \tag{76}$$

subject to

$$w_2 \geq \underline{U} + \frac{(1-p)B}{p} \tag{77}$$

$$w_2 \leq \underline{U} + c - B \tag{78}$$

$$0 \leq w_2 \leq \overline{w}_2. \tag{79}$$

Since the objective function does not depend on w_2, the solution is defined by the relevant constraints of the problem. First, notice that $\underline{U} + \frac{(1-p)B}{p} > 0$. Second, it is verified that $\underline{U} + c - B < \overline{w}_2$ because assumption A4 guarantees that $c < \frac{(1-p)\underline{U}}{p} + B$. Third, notice that $\underline{U}+$

$\frac{(1-p)B}{p} < \underline{U} + c - B$ since assumption A4 ensures that $\frac{B}{p} < c$. Therefore, the interval of solutions for w_2^* becomes

$$\underline{U} + \frac{(1-p)B}{p} \le w_2^* \le \underline{U} + c - B.$$

Substituting the lower and upper bounds of this interval into the binding participation constraint we find that the interval of solutions for w_1^* is given by

$$\underline{U} + \frac{p(B-c)}{(1-p)} \le w_1^* \le \underline{U} - B,$$

which completes the proof.

Proof of Corollary 1. To find what is the best decision pair from the investor's standpoint, we first evaluate her expected payoff at the optimal contract assuming that each of the four pairs is her best decision. Then, we show formally that this expected payoff takes its highest value when pair (s,t) is assumed to be her best decision.

Let us thus denote generically this payoff as $EV^*(e,a)$ with $e \in \{s,m\}$ and $a \in \{t,f\}$. In the case of (s,t), we use the fact that the optimal contract characterized in Proposition 3 is such that the participation constraint is binding, and hence

$$EV^*(s,t) = px_2 + (1-p)x_1 - pw_2^* - (1-p)w_1^* \tag{80}$$

$$= px_2 + (1-p)x_1 - \underline{U}.$$

In the case of (m,t), we must first find what is the optimal contract assuming that this pair is the investor's best decision. Then, if the investor prefers (m,t) instead of either (s,f), (s,t) or (m,f), the optimal incentive scheme must solve the program[25]

$$\min_{w_1,w_2} w_1 \tag{81}$$

subject to

$$w_1 + B \ge \underline{U} \tag{82}$$

$$w_1 + B \ge pw_2 + (1-p)w_1 \tag{83}$$

$$w_1 + B \ge w_2 - c \tag{84}$$

$$w_1 + B \ge w_2 + B - c \tag{85}$$

$$w_1, w_2 \ge 0 \tag{86}$$

$$w_1 \le x_1, \quad w_2 \le x_2, \tag{87}$$

where (82) is the manager's participation constraint, (83) is the incentive-compatibility constraint, (84) is the truthful reporting constraint, (85) is a mixed incentive-truthtelling constraint; and (86) and (87) are the program's limited liability conditions. Since $B > 0$ and assumption A4, it is possible to show that constraint (83) is a sufficient condition for both (85) and (84) and hence the last two constraints can be removed. Using a graphical approach with the remaining equations like that adopted in the main text to expose the results, it is possible to show that there is a continuum of optimal incentive schemes consisting of all the pairs (w_1^*, w_2^*) satisfying the following conditions:

(i) $w_1^* = \underline{U} - B$,

(ii) $w_2^* \in \left[0, \underline{U} + \frac{(1-p)B}{p}\right]$,

Substituting this optimal contract into the investor's expected payoff we obtain

$$EV^*(m,t) = x_1 - w_1^* = x_1 - \underline{U} + B. \tag{88}$$

From the comparison between (80) and (88), it follows that the investor indeed prefers (s,t) to (m,t) since

[25] Note that $\Pr(\hat{x} = x_1 | m,t) = 1$.

$$EV^*(s,t) > EV^*(m,t) \Leftrightarrow \Delta_x > \frac{B}{p},$$

where the inequality holds true because assumptions A4 and A5.

Finally, to show that decision pair (s,t) dominates pairs (s,f) and (m,f) from the investor's standpoint, we do not need to find what are the specific optimal contracts in the two latter cases. This is the case given our assumption that the company incurs a penalty sufficiently high when the external auditor detects misreporting, which deters the investor to induce the manager from not implementing a truthful accounting system. Thus, irrespective of the values taken by (w_1^*, w_2^*) in cases (s,f) and (m,f), the value of the fine φ guarantees by assumption that

$$EV^*(a,f) = x_2 - w_2^* - \theta\varphi$$

$$< px_2 + (1-p)x_1 - \underline{U}$$

$$= EV^*(s,t)$$

for $a \in \{s,m\}$, which completes the proof.

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