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Real versus accounting earnings management: The effect of performance measure timing constraints

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Abstract
We study the influence of stricter rules for determining performance measures for compensation contracts on managers' choice between real and accounting earnings management. Constraints, like accounting regulation or corporate governance, limit managers' influence on performance measures. We find that tighter constraints intensify real earnings manipulation, because they reduce incentives for managers to supply effort on investment activities. In turn, discretion allows managers to anticipate future benefits of investment and reduces real earnings management. The results hold when contracts include forward-looking information and suggest that constraints on managers' influence on performance measures drive the choice between accounting and real earnings management.

1 | INTRODUCTION

In this paper, we study the influence of stricter rules for determining performance measures, such as tighter accounting regulation or corporate governance, on earnings management. Managerial compensation is often tied to accounting measures of performance in an attempt to induce managers to act in the long-term interest of the firm. This gives managers the incentive to manipulate earnings in order to increase their short-run compensation. Conventional wisdom suggests that stricter rules for determining these performance measures will reduce earnings manipulation (e.g., Christensen et al., 2013). However, literature has found that managers use accounting and real earnings management interchangeably (e.g., Cohen et al., 2008; Kothari et al., 2016).

Real earnings management (REM) describes managers' tendency to affect current earnings by real activities manipulation (Edmans et al., 2012; Zhao et al., 2012). REM comes in multiple forms, particularly to reduce the discretionary spending on R&D, advertising, maintenance, and so on (Graham et al., 2005). This has been found to be detrimental for the firms' future prospects (e.g., Bereskin et al., 2018). In contrast, accounting earnings management (AEM) relates to the use of discretion in applying accounting standards or other rules for determining performance measures used to evaluate and compensate managers. We study the influence of managerial compensation on the trade-off between earnings manipulation via AEM or REM. The principal–agent approach provides a theory for analyzing opportunistic relationships under asymmetric information and divergent objectives. Because earnings management is a genuinely opportunistic act of managers for private gain, agency theory is ideal to study our research question.

AEM involves the manipulation of accruals that determine performance measures over time. Accounting standards and other rules and regulations, such as auditing and enforcement, constrain the mangers' ability to manipulate the timing of the accruals (Christensen et al., 2013). In particular, standard setters and regulatory bodies try to restrict AEM by stricter rules (such as the Sarbanes–Oxley Act [SOX]). Moreover, Boards of Directors and compensation committees set rules for the definition of the performance measures that are used to determine managerial compensation (Bloomfield et al., 2021; Potepa, 2020). The aim is to incentivize managers to make investments for the long-term benefit of the firm. For example, performance measures sometimes exclude strategic expenditures such as research and development, advertising or special items related to restructuring. Relative performance evaluation (RPE) is another way to adjust performance measures (e.g., Du & Shen, 2018). Since these rules determine the accruals and performance measures over time, we term these constraints affecting the definition of performance measures “timing constraints.”

However, managers have an influence on how performance measures are determined, for example, by exerting power (Abernethy et al., 2015). Dikolli et al. (2018) show that powerful managers can distort performance measures and that this leads to common risk not being efficiently reduced. Likewise, Infuehr (2022) finds that firms are less likely to rely on RPE when it is easier for managers to misreport. We contribute to this literature by analyzing how constraints on the managers' ability to manipulate performance measures will influence their investment decisions, that is, their use of REM.

Prior empirical studies provide evidence that tighter accounting regulation will increase the use of REM (Chan et al., 2015; Cohen et al., 2008). The extant analytical literature on earnings management has focused on the expected capital market reactions to financial reporting as the basis for incentives to manipulate (Ewert & Wagenhofer, 2005; Königsgruber, 2012). However, this prior literature has not analyzed the influence of managerial compensation, which is often tied to accounting measures of performance that are subject to both AEM and REM.

We examine a two-period agency model in which the manager's efforts in Period 1 have short- and long-term consequences (operational and strategic effort). Think for instance of the operational effort as being spent on tasks like short-run promotion or immediate cost reduction, whereas strategic effort may be spent on advertising activities, investing in the development of new products, and so on (Sliwka, 2002). We interpret strategic effort as an investment decision for which its consequences only materialize in the second period. Performance measures used in the compensation contracts are derived from accounting earnings. In an extension, we allow for forward-looking performance measures, such as customer satisfaction, to be included in the compensation contract of the first period.

Our results suggest that timing constraints affect the management's choice between REM and AEM. In particular, tighter timing constraints increase incentives for managers to engage in REM and hence intensify underinvestment problems. In turn, AEM and investment levels increase when managers have more discretion on performance measures. The reason for this result is twofold.

First, AEM implies that the bonus coefficients on the performance measures in each period are partial substitutes. Thus, both bonus coefficients can be used to incentivize the manager to supply effort on investment activities. The principal can thus use the first-period performance measure to increase investment incentives, even when the benefits of the investment only materialize in the second period.

Second, discretion in defining performance measures allows managers to anticipate future benefits of investment decisions in contemporaneous performance measures. However, the extent to which managers include future benefits in contemporaneous performance measures depends on constraints imposed on the manager when influencing performance measures. AEM involves personal costs, for example costs arising in the auditing process for the verification and explanation of certain transactions. Tighter constraints increase the personal costs for the manager to engage in AEM and hence reduce incentives for the manager to invest. This is consistent with the empirical result that stricter regulation leads to increased REM because the latter does not result in such personal costs, that is, is “harder to detect” (Cohen et al., 2008, p. 759).

Our results are robust even when compensation contracts include forward-looking performance measures. The reason is that bonus coefficients on the first-period accounting performance measure and the forward-looking performance measure are not perfect substitutes. Hence, the principal can still augment incentives to supply effort on investment activities by accepting reporting discretion for the manager, even when forward-looking information is available for contracting. Moreover, the optimal weight placed on the forward-looking variable in an optimal compensation contract depends on the extent the manager can affect performance measures. Tighter performance measure timing constraints increase the relevance of forward-looking performance measures to mitigate REM activities.

Our results provide a theoretical explanation for the incentives behind the choice between AEM and REM. We contribute to the debate on the effects of weaker versus tighter accounting regulation by showing that tighter accounting regulation has real economic consequences in intensifying underinvestment problems. Our results provide direct empirical predictions. For example, managers in jurisdictions with tighter accounting regulation are expected to rely more strongly on REM activities, for example, reduced R&D, which is consistent with extant empirical findings (e.g., Cohen et al., 2008; Kalyta, 2009).

Our results extend theoretical explanations for the substitution of REM and AEM due to tighter timing constraints in the context of investment incentives. Prior literature (e.g., Ewert & Wagenhofer, 2005) has focused on the capital market effects and abstracts from agency problems. In contrast, we identify a substitution effect that holds valid in a more general setting than signaling on the capital market. It is not restricted to accounting regulation but comprises constraints relating to corporate governance and other restrictions. For instance, our results imply that tighter rules that restrict AEM, such as clawback provisions, will come at the cost of increased REM, which is consistent with empirical findings (Chan et al., 2015). Regarding RPE, our results imply that a higher degree of discretion allowed for managers to affect the performance measures underlying their compensation reduces underinvestment problems.

We also contribute to the debate on the relevance of forward-looking information in managerial compensation contracts when managers have a shorter time horizon than the firm (e.g., Reichelstein, 1997; Rogerson, 1997). In particular, Dikolli (2001) and Dikolli and Vaysman (2006) show that the relevance of forward-looking information in optimal compensation contracts increases when the manager's employment horizon decreases. While this literature typically assumes the forward-looking information to be a contractible variable, we allow the manager to integrate forward-looking information in contemporaneous performance measures depending on performance measure timing constraints. This allows us to analyze the manager's incentive to include forward-looking information in current performance measures when additional forward-looking performance measures are not available for contracting. Our results confirm the relevance of forward-looking information in managerial compensation contracts. That is, the manager's incentive to supply effort on investment activities increases in the extent to which the manager can include forward-looking information in contemporaneous performance measures. This finding is also consistent with the empirical observation that income smoothing improves earnings informativeness because managers include private information on future investment benefits in current earnings (Tucker & Zarowin, 2006).

The remainder of the paper is organized as follows: The next section provides our model framework and the benchmark results. Section 3 examines the interplay between the time horizon of managers, performance measure timing constraints, and management's choice between AEM and REM. We extend the analysis in Section 4 by assuming that a forward-looking variable is available for contracting. We conclude with a summary. All proofs are in the Appendix.

2 | THE MODEL

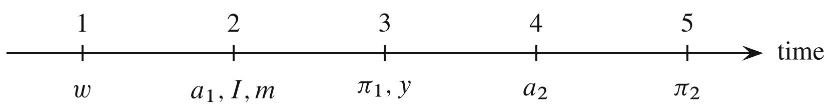
We examine a two-period LEN model, that is, contracts are linear, utility functions are exponential, and noise terms are normally distributed. The setup is as follows: A manager works for a firm in two consecutive periods $t=1,2$. In the first period, he exerts two types of effort, one on an operational activity a_1 and one on a strategic activity (investment decision) I. In the second period, he only supplies operational effort a_2. The principal cannot observe the manager's actions. While operational effort only affects the firm's profit in the respective period, the effects of the investment decision only materialize in the second period. Operational efforts may be spent on short-run promotion or immediate cost reductions, whereas strategic efforts may be spent on advertising or the development of new products (Sliwka, 2002). Underinvestment in such activities is a typical form of REM.

In Section 3, we analyze the interplay between time preferences, the design of performance measures and the manager's choice regarding AEM and REM when only accounting performance measures are available. In Section 4, we extend this to include forward-looking performance measures.

We assume that accounting performance measures can be affected by the manager via AEM, depending on the degree of accounting regulation, corporate governance, and other factors that limit his influence. Given these constraints, he has discretion over the accruals m. We assume that the effects of his reporting strategy balance out over time. A higher reported accounting profit in Period 1 will hence subsequently lead to a lower profit in Period 2. In line with Christensen et al. (2013), accruals are associated with the long-term decision I. Christensen et al. (2013) assume that m is specified by the principal which implies that mI reflects non-discretionary accruals. In contrast, we assume that m is determined by the manager and therefore reflects discretionary accruals. To highlight their influence, we assume zero non-discretionary accruals. Think for instance of a long-term project whose cash flows θI materialize only in Period 2. We assume the marginal return of the investment θ to be normalized to $[0;1]$. Then, $m \in [0;\theta]$ reflects the portion of investment benefits that can be realized in Period 1. In particular, the case $m=0$ implies cash accounting and $m=\theta$ implies fair value accounting. The accrual mI is reversed in Period 2 so that the cash benefit is recognized in both periods.

The manager's personal costs are $c_1 = \frac{1}{2}\left(a_1^2 + I^2 + \lambda m^2\right)$ in Period 1 and $c_2 = \frac{1}{2}a_2^2$ in Period 2. The effect of tighter performance measure timing constraints are captured by $\lambda \geqq 1$. Tighter timing constraints make AEM more costly for the manager. Such costs can for instance stem from negotiations with the auditor (e.g., Ewert & Wagenhofer, 2005; Marquardt & Wiedman, 2004).

The performance measures are $\pi_1 = a_1 + mI + \varepsilon_1$ and $\pi_2 = a_2 + (\theta - m)I + \varepsilon_2$, where ε_1 and ε_2 are random variables. We assume ε_1 and ε_2 to be stochastically independent and normally distributed with zero mean and variance σ^2. Since investments are deterministic, π_1 and π_2 are stochastically independent. The linear contract applied in Section 3 specifies a fixed wage α_t and an incentive rate β_t for each period, resulting in the compensation $w_t = \alpha_t + \beta_t \pi_t$. We assume that the principal does not lease the firm to the manager. She also does not discount, while the manager discounts at the rate $\delta \in (0;1]$. His planning horizon is shorter than that of the firm if $\delta < 1$. According to the LEN assumptions, the manager has the utility function $u(x) = -\exp(-rx)$ with constant absolute risk aversion r, where x is the present value of his compensation net of personal costs. In contrast, the risk-neutral principal maximizes the expected present value of her profits after compensating, $\Pi = \pi_1 + \pi_2 - w_1 - w_2$. Figure 1 depicts the sequence of events; the forward-looking performance measure y will be introduced in Section 4.



Date 1: The principal determines the compensation contract w.

Date 2: The manager decides on Period 1 effort a_1, investments I and reporting strategy m.

Date 3: The Period 1 accounting performance measure π_1 and the forward-looking performance measure y are observed.

Date 4: The manager decides on Period 2 effort a_2.

Date 5: The Period 2 accounting performance measure π_2 is observed.

FIGURE 1 Sequence of events.

As a benchmark, we determine the first-best operational efforts, investment and report by maximizing the expected sum of profits minus the manager's personal costs, that is, $a_1+a_2+\theta I-\frac{1}{2}\left(a_1^2+a_2^2+I^2+\lambda m^2\right)$, with respect to a_1, a_2, I, and m. This yields $a_1^{FB}=a_2^{FB}=1, I^{FB}=\theta$ and $m^{FB}=0$, where superscript "FB" denotes first-best values. There is no AEM in this case as AEM would increase the manager's personal costs (and hence his compensation) without providing any benefits for the principal compared to a forcing contract.

3 | CONTRACTING BASED ON ACCOUNTING PERFORMANCE MEASURES

We start with the solution to the principal's contracting problem when the compensation contract is solely contingent on accounting performance measures. Due to the LEN assumptions, in each period t the manager maximizes the certainty equivalent $\text{CE}_t(x)=\text{E}(x)-\frac{1}{2}r\text{Var}(x)$ of his compensation net of personal costs. In Period 1, this certainty equivalent is

$$\begin{aligned}\text{CE}_1(w_1+\delta w_2-c_1-\delta c_2) &= \text{E}(w_1+\delta w_2)-c_1-\delta c_2-\frac{1}{2}r\text{Var}(w_1+\delta w_2) \\ &= \alpha_1+\delta\alpha_2+\beta_1[a_1+mI]+\delta\beta_2[a_2+(\theta-m)I] \\ &\quad -\frac{1}{2}\left[a_1^2+I^2+\lambda m^2+\delta a_2^2+\left(\beta_1^2+\delta^2\beta_2^2\right)r\sigma^2\right].\end{aligned} \quad (1)$$

That is, the manager takes into account the effects on the performance measure in Period 2 when making decisions in Period 1. In Period 2, he supplies operational effort to maximize

$$\text{CE}_2(w_2-c_2)=\alpha_2+\beta_2\left[a_2+(\theta-\hat{m})\hat{I}\right]-\frac{1}{2}\left(a_2^2+\beta_2^2 r\sigma^2\right), \quad (2)$$

given his decisions on investment $\hat{I}$ and reporting strategy $\hat{m}$ in Period 1. Applying backward induction, we first maximize (2) with respect to a_2. The respective first-order condition reveals that the optimal operational effort is $\hat{a}_2=\beta_2$. Obviously, this is not affected by the first-period decisions $\hat{a}_1, \hat{I}$, and $\hat{m}$. Similarly, $\hat{a}_1=\beta_1$ maximizes (1) with respect to a_1. The first-order conditions regarding investment and reporting require more attention as they result in the system of equations

$$\hat{I}=\delta\beta_2\theta+(\beta_1-\delta\beta_2)\hat{m} \text{ and } \hat{m}=\frac{1}{\lambda}(\beta_1-\delta\beta_2)\hat{I}. \quad (3)$$

As $m \geqq 0$ requires $\beta_1-\delta\beta_2 \geqq 0$, increasing investments $\hat{I}$ increase accruals $\hat{m}$ and vice versa. The solution of (3) is given by

$$\hat{I}=\frac{\lambda\delta\beta_2\theta}{\lambda-(\beta_1-\delta\beta_2)^2} \text{ and } \hat{m}=\frac{\delta\beta_2\theta(\beta_1-\delta\beta_2)}{\lambda-(\beta_1-\delta\beta_2)^2}. \quad (4)$$

Note that both incentive rates affect investments although investment benefits only materialize in Period 2.

When designing the contract, the principal must meet the manager's participation constraint $\text{CE}_t(\cdot) \geqq 0$ in each period. Similarly, she must realize at least a reservation utility of zero in each period, that is, $w_t \leqq \pi_t$ (e.g., Casadesus-Masanell, 2004). The optimal incentive rates are summarized in the following lemma:

Lemma 1. *The incentive rates $\hat{\beta}_1$ and $\hat{\beta}_2$ in the optimal linear contract are*

$$\hat{\beta}_1=\frac{1+\theta\hat{m}-\delta\hat{\beta}_2\hat{m}(\theta-\hat{m})}{1+\hat{m}^2+r\sigma^2} \text{ and } \hat{\beta}_2=\frac{1+\delta(\theta-\hat{\beta}_1\hat{m})(\theta-\hat{m})}{1+\delta^2(\theta-\hat{m})^2+r\sigma^2}. \quad (5)$$

Note that (5) is an implicit characterization of the optimal incentive rates as $\hat{\beta}_1$ depends on $\hat{\beta}_2$ and vice versa. Although it would be possible to solve (5) for $\hat{\beta}_1$ and $\hat{\beta}_2$, the resulting formulas would still be implicit as they also depend on (4) via $\hat{m}$. Explicit solutions cannot be stated as the simultaneous solution of (4) and (5) involves polynomials of degree five. However, they are not necessary to state our results. Regarding the range of values, note that $\hat{\beta}_1$ and $\hat{\beta}_2$ also serve to incentivize operational efforts and thus need to be greater than zero. Furthermore, they cannot be greater than one as this would violate the principal's participation constraint. Therefore, the principal transfers a positive share of the performance measure to the manager in each period.

When the manager partially engages in AEM (i.e., $0<\hat{m}<\theta$), $\hat{\beta}_1$ and $\hat{\beta}_2$ interact in a rather complex way. In the special cases $\hat{m}=0$ and $\hat{m}=\theta$ as well as in the limit case of a myopic manager who does not account for Period 2 when deciding in Period 1 (i.e., $\delta \to 0$), the incentive effects of $\hat{\beta}_1$ and $\hat{\beta}_2$ are separable. We hence briefly comment on these cases below. When the manager accounts for Period 2 and partially engages in AEM, these effects overlap, making $\hat{\beta}_1$ and $\hat{\beta}_2$ partial substitutes.

In the case $\hat{m}=0$, that is, when the manager does not realize any investment benefits in Period 1, $\hat{\beta}_1$ simplifies to the incentive rate $\hat{\beta}^\circ=1/(1+r\sigma^2)$ familiar from standard moral hazard models (e.g., Holmström & Milgrom, 1991). It incentivizes operational effort only. In contrast, $\hat{\beta}_2$ simplifies to $(1+\delta\theta^2)/(1+\delta^2\theta^2+r\sigma^2)$, which depends on both the investment benefits and the discount factor δ, but not on $\hat{\beta}_1$. That is, both incentive rates are independent of each other. One cause for $\hat{m}=0$ is tight timing constraints ($\lambda \to \infty$) that make AEM too costly for the manager; see (3).

In the case of fair value accounting ($\hat{m}=\theta$), $\hat{\beta}_2$ simplifies to $\hat{\beta}^\circ$ that induces operational effort only. The reason is that fair value accounting brings all investment benefits forward to Period 1, rendering investment incentives in Period 2 obsolete. The corresponding incentive rate for Period 1 is $\hat{\beta}_1=(1+\theta^2)/(1+\theta^2+r\sigma^2)$. It increases with θ because more investment benefits make it more attractive to incentivize investments.

In the case of a myopic manager ($\delta \to 0$), $\hat{\beta}_2$ again simplifies to $\hat{\beta}^\circ$ that incentives operational effort only. This is because the myopic manager forces the firm to provide all investment incentives already in Period 1. At first sight, the corresponding incentive rate is $\hat{\beta}_1 = (1+\theta\hat{m})/(1+\hat{m}^2+r\sigma^2)$. However, the myopic manager does not consider the investment benefits when making decisions in Period 1 as these benefits materialize only in Period 2. Consequently, he will not invest ($\hat{I} \to 0$ as $\delta \to 0$; see 4) which renders pure cash accounting optimal ($\hat{m} \to 0$; see also 4). Therefore, $\hat{\beta}_1$ further reduces to $\hat{\beta}^\circ$. Taken together, a myopic manager fails to invest and the optimal contract only incentives operational efforts in both periods.

In general, that is, when the manager is not myopic and partially engages in AEM, the effects discussed above overlap. Then, both $\hat{\beta}_1$ and $\hat{\beta}_2$ affect investments and thus are partial substitutes. Investments are also affected by the tightness of the performance measure timing constraints. The following proposition summarizes our findings in this regard.

Proposition 1. *When only accounting performance measures are available, the following applies*:

(a) *Tighter timing constraints reduce investments*.
(b) *Tight timing constraints ($\lambda \to \infty$) imply underinvestment compared to the first-best level*.
(c) *Weak timing constraints ($\lambda = 1$) also imply underinvestment, but less pronounced than under tight timing constraints*.

To comprehend the forces driving Proposition 1, note that the manager's second-best investment decision is

$$I^{SB} = \frac{\lambda\delta\hat{\beta}_2}{\lambda - \left(\hat{\beta}_1 - \delta\hat{\beta}_2\right)^2} \cdot I^{FB}. \tag{6}$$

Proposition 1 (a) states that I^{SB} decreases as the manager's costs λ of AEM increases. This is because increases in λ make it more attractive for him to engage in REM, that is, to reduce investments. In contrast, weaker timing constraints allow him to anticipate future investment benefits and thus increase investment incentives.

Regarding Proposition 1 (b), note that when timing constraints are tight ($\lambda \to \infty$), (6) approaches the limit $\delta\hat{\beta}_2 I^{FB}$ which falls below I^{FB}. First-best investments would require $\delta = 1$ and $\hat{\beta}_2 = 1$. However, $\hat{\beta}_2$ also provides incentives for operational effort in Period 2. Hence, higher $\hat{\beta}_2$ would impose more risk on the manager who in turn requires higher risk premia. The principal therefore needs to limit the manager's risk exposure by setting $\hat{\beta}_2 < 1$. Nevertheless, even $\hat{\beta}_2 = 1$ would not induce first-best investments as long as the manager is impatient ($\delta < 1$) and thus dampens $\hat{\beta}_2$ when deciding in Period 1. Note that tight timing constraints make investments independent of $\hat{\beta}_1$. This is because both incentive rates are independent when AEM is ruled out.

Finally, Proposition 1 (c) addresses the case of weak timing constraints ($\lambda = 1$). Considering part (a), it is obvious that investments are higher than under tight timing constraints. However, underinvestment persists even then. To see this, consider the corresponding investment decision, $I^{SB} = \delta\hat{\beta}_2 I^{FB} / \left[1 - \left(\hat{\beta}_1 - \delta\hat{\beta}_2\right)^2\right]$. As both incentive rates provide investment incentives, I^{SB} increases in both $\hat{\beta}_1$ and $\hat{\beta}_2$. The highest level of investment would therefore be induced when setting $\hat{\beta}_1 = \hat{\beta}_2 = 1$. Of course, the principal will not do so, as this would involve prohibitively high risk premia. However, even if she did, the investment decision of an impatient manager (with $\delta < 1$) would fall below I^{FB} because he dampens the Period 2 investment incentives when deciding in Period 1. Efficient investments would require to lease the firm to a patient manager (i.e., $\delta = \hat{\beta}_1 = \hat{\beta}_2 = 1$) or to compensate an impatient manager with more than 100% of the performance measures (i.e., $\delta < 1, \hat{\beta}_1, \hat{\beta}_2 > 1$). However, the principal will set both incentive rates lower than 1 in order to avoid excessive risk premia. Consequently, even weak timing constraints induce underinvestment.

Note that AEM and REM act as substitutes. Tighter timing constraints intensify underinvestment problems, while weaker timing constraints allow the manager to anticipate future investment benefits. Hence, discretionary accruals may convey forward-looking information. Since our model is not limited to accounting performance measures, different time preferences can also be addressed by including forward-looking performance measures. Dikolli (2001) and Dikolli and Vaysman (2006) show that the relevance of such information in optimal linear compensation contracts increases when the manager's employment horizon decreases. As AEM causes personal costs for the manager, it becomes less attractive when additional forward-looking performance measures are available. This raises the question whether the substitution effect between AEM and REM remains valid.

4 | CONTRACTING BASED ON FORWARD-LOOKING PERFORMANCE MEASURES

We now consider contracts that include forward-looking performance measures, such as non-financial information like customer satisfaction, the number of new product launches or the number of patents awarded. Prior literature has found that such performance measures provide incentives for long-term investments (Dikolli, 2001).

Let the forward-looking performance measure be $y = \nu I + \varepsilon_y$, where $\nu \geqq 0$ reflects its sensitivity to the investment decision and ε_y is a random variable. Obviously, y would help to reduce risk premia if it had a smaller variance than the profit in Period 1. To avoid such motives, we make ε_y noisier than ε_1 by assuming $\varepsilon_y = \varepsilon_1 + \tau$, where τ is normally distributed with zero mean and variance σ_τ^2. Furthermore, we assume ε_t and τ to be stochastically independent. Similar assumptions can be found in Dikolli (2001) or Sliwka (2002).

Compared to the situation discussed in Section 3, compensation in Period 1 now also depends on y, that is, $w_1 = \alpha_1 + \beta_1\pi_1 + \gamma y$, where γ is the weight on the forward-looking performance measure. The compensation in Period 2 remains unchanged. The certainty equivalent of the manager's compensation net of his personal costs in Period 1 is then

$$\begin{aligned}&\mathrm{CE}_1(w_1+\delta w_2-c_1-\delta c_2)\\&=\mathrm{E}(w_1+\delta w_2)-c_1-\delta c_2-\frac{1}{2}r\mathrm{Var}(w_1+\delta w_2)\\&=\alpha_1+\delta\alpha_2+\beta_1[a_1+ml]+\gamma\nu l+\delta\beta_2[a_2+(\theta-m)l]\\&\quad-\frac{1}{2}\left[a_1^2+l^2+\lambda m^2+\delta a_2^2+(\beta_1^2+2\beta_1\gamma+\gamma^2+\delta^2\beta_2^2)r\sigma^2+\gamma^2 r\sigma_\tau^2\right],\end{aligned}\tag{7}$$

while his certainty equivalent in Period 2 is as in (2). Hence, his decision $\hat{a}_2=\beta_2$ in Period 2 also remains unaltered. Similarly, $\hat{a}_1=\beta_1$ maximizes (7) with respect to a_1. The first-order conditions regarding investment and reporting result in the system of equations

$$\hat{l}=\delta\beta_2\theta+(\beta_1-\delta\beta_2)\hat{m}+\gamma\nu \text{ and } \hat{m}=\frac{1}{\lambda}(\beta_1-\delta\beta_2)\hat{l}.\tag{8}$$

At first glance, y does not affect the manager's reporting strategy $\hat{m}$. However, investment activities $\hat{l}$ are more strongly incentivized since the sensitivity ν of y to investment decisions also provides incentives. This, in turn, affects discretionary accruals, because $\hat{m}$ depends on $\hat{l}$ and vice versa. The effect of y on $\hat{m}$ becomes evident when considering the solution of (8),

$$\hat{l}=\frac{\lambda(\delta\beta_2\theta+\gamma\nu)}{\lambda-(\beta_1-\delta\beta_2)^2} \text{ and } \hat{m}=\frac{(\delta\beta_2\theta+\gamma\nu)(\beta_1-\delta\beta_2)}{\lambda-(\beta_1-\delta\beta_2)^2}.\tag{9}$$

Comparing (4) and (9) (and taking $\lambda\geqq 1,\beta_1-\delta\beta_2\geqq 0$ into account) it becomes apparent that y strengthens both investment activities and discretionary accruals as long as it is informative regarding investments (i.e., $\nu>0$; otherwise, y just adds noise) and enters the manager's compensation (i.e., $\gamma>0$). This suggests that the principal should utilize forward-looking information. Lemma 2 summarizes our findings in this regard.

Lemma 2. *The incentive rates $\hat{\beta}_1,\hat{\beta}_2$, and $\hat{\gamma}$ in the optimal linear contract are*

$$\begin{aligned}\hat{\beta}_1&=\frac{1+\theta\hat{m}-\delta\hat{\beta}_2\hat{m}(\theta-\hat{m})-\hat{\gamma}(\nu\hat{m}+r\sigma^2)}{1+\hat{m}^2+r\sigma^2},\\\hat{\beta}_2&=\frac{1+\delta(\theta-\hat{\beta}_1\hat{m}-\hat{\gamma}\nu)(\theta-\hat{m})}{1+\delta^2(\theta-\hat{m})^2+r\sigma^2}, \text{ and}\\\hat{\gamma}&=\frac{\theta\nu-\hat{\beta}_1(\nu\hat{m}+r\sigma^2)-\delta\hat{\beta}_2\nu(\theta-\hat{m})}{\nu^2+r(\sigma^2+\sigma_\tau^2)}.\end{aligned}\tag{10}$$

Lemma 2 reveals that the incentive rates $\hat{\beta}_1,\hat{\beta}_2$ on the accounting performance measures remain partial substitutes even when forward-looking information is available. Since investments depend on $\hat{\gamma}$, all three coefficients incentivize investments and thus are partial substitutes. We discuss their substitution effects below. Explicit solutions cannot be stated as the simultaneous solution of (9) and (10) involves polynomials of degree nine. However, explicit solutions are not necessary to state our results.

Regarding the substitution effects between $\hat{\beta}_1,\hat{\beta}_2$, and $\hat{\gamma}$, note that their rates of substitution differ. While the substitution of $\hat{\beta}_1$ and $\delta\hat{\beta}_2$ is driven by the extent of AEM ($\hat{m}(\theta-\hat{m})$), the substitution of $\hat{\beta}_1$ and $\hat{\gamma}$ depends on the informativeness of the forward-looking performance measure ($\nu\hat{m}$) as well as on the risk premia induced by systematic risk ($r\sigma^2$). As systematic risk σ^2 affects both π_1 and y, the weights on these performance measures need to be balanced. Furthermore, the more informative y is, the more it incentivizes investments, making $\hat{\beta}_1$ and $\hat{\gamma}$ more pronounced substitutes. Similar arguments apply to the rate of substitution between $\delta\hat{\beta}_2$ and $\hat{\gamma}$ ($\nu(\theta-\hat{m})$). However, this rate does not depend on systematic risk (since π_2 and y are stochastically independent), but on the extent of AEM.

We now consider how the forward-looking information affects the interplay of the incentive rates in the special cases discussed in the context of Lemma 1. We reconsider the cases of no AEM ($\hat{m}=0$), fair value accounting ($\hat{m}=\theta$) and the case of a myopic manager ($\delta\to 0$).

Similar to the case without forward-looking information, tight timing constraints ($\lambda\to\infty$) drive out AEM ($\hat{m}\to 0$; see 8) as it is too costly for the manager. The incentive rates then simplify to

$$\hat{\beta}_1=\frac{1-\hat{\gamma}r\sigma^2}{1+r\sigma^2}, \hat{\beta}_2=\frac{1+\delta\theta^2-\hat{\gamma}\nu\theta}{1+\delta^2\theta^2+r\sigma^2}, \text{ and } \hat{\gamma}=\frac{\nu\theta-\hat{\beta}_1 r\sigma^2-\delta\hat{\beta}_2\nu\theta}{\nu^2+r(\sigma^2+\sigma_\tau^2)}.$$

Without AEM, $\hat{\beta}_1$ again incentivizes operational effort in Period 1 only. However, $\hat{\gamma}$ provides investment incentives in Period 1. As this imposes risk on the manager, the principal needs to adjust $\hat{\beta}_1$ accordingly to limit the manager's exposure to (systematic) risk. Consequently, $\hat{\beta}_1$ falls below the standard incentive rate $\hat{\beta}^\circ=1/(1+r\sigma^2)$. The interpretation of $\hat{\beta}_2$ does not significantly differ from the corresponding case in Section 3. Again, $\hat{\beta}_2$ does not depend on $\hat{\beta}_1$ and simplifies to $\hat{\beta}^\circ$ when there are no investment benefits ($\theta=0$). However, incentivizing investments via $\hat{\gamma}$ requires adjustments in $\hat{\beta}_2$ since both are partial substitutes. The rate of substitution $\nu\theta$ is driven by the impact of both incentive rates on investments: (8) reveals that investment earnings θ strengthen the impact of $\delta\hat{\beta}_2$, while the informativeness ν of the forward-looking performance measure strengthens the impact of $\hat{\gamma}$. Hence, increases in both θ and ν reinforce the substitution effect.

Next, consider the case of fair value accounting ($\hat{m}=\theta$). The incentive rates then simplify to

$$\hat{\beta}_1=\frac{1+\theta^2-\hat{\gamma}(\nu\theta+r\sigma^2)}{1+\theta^2+r\sigma^2}, \hat{\beta}_2=\frac{1}{1+r\sigma^2}, \text{ and } \hat{\gamma}=\frac{\nu\theta-\hat{\beta}_1(\nu\theta+r\sigma^2)}{\nu^2+r(\sigma^2+\sigma_\tau^2)}.$$

As in the case without forward-looking information, $\hat{\beta}_2$ simplifies to $\hat{\beta}^\circ$. It only induces operational effort, since fair value accounting eliminates investment incentives in Period 2. In Period 1, however, investment incentives are provided by both $\hat{\beta}_1$ and $\hat{\gamma}$, making them partial substitutes. Their rate of substitution $\nu\theta+r\sigma^2$ reveals that both increases in the value of the forward-looking information ($\nu\theta$) and increases in systematic risk make $\hat{\beta}_1$ and $\hat{\gamma}$ more pronounced substitutes. Furthermore, more investment benefits θ strengthen investment incentives. While increasing θ clearly translates into a higher weight $\hat{\gamma}$ on the forward-looking information, the effect on $\hat{\beta}_1$ is ambiguous: If θ is sufficiently high, both incentive rates increase as θ increases. Otherwise, the substitution effect between $\hat{\beta}_1$ and $\hat{\gamma}$ may prevail the positive effect of θ on $\hat{\beta}_1$, resulting in a weakened incentive rate $\hat{\beta}_1$.

The case of a myopic manager ($\delta \to 0$) is quite different compared to the situation in Section 3. While in the latter case the manager fails to invest, the incentive rates

$$\hat{\beta}_1 = \frac{1+\theta\hat{m} - \hat{\gamma}(\nu\hat{m} + r\sigma^2)}{1+\hat{m}^2 + r\sigma^2}, \hat{\beta}_2 = \frac{1}{1+r\sigma^2}, \text{ and } \hat{\gamma} = \frac{\theta\nu - \hat{\beta}_1(\nu\hat{m} + r\sigma^2)}{\nu^2 + r(\sigma^2 + \sigma_\tau^2)},$$

in the model with forward-looking information now induce investments. Again, $\hat{\beta}_2$ only incentivizes operational effort, because the myopic manager solely reacts to investment incentives in Period 1. However, forward-looking information brings investment benefits forward to Period 1, enabling $\hat{\beta}_1$ and $\hat{\gamma}$ to incentivize investments despite the manager's myopia. How investments react to them can be seen by evaluating (9): $\hat{I} = \lambda\hat{\gamma}\nu/(\lambda - \hat{\beta}_1^2)$. It becomes apparent that increases in both $\hat{\beta}_1$ and $\hat{\gamma}$ enhance investments, making them partial substitutes. The rate of substitution is $\nu\hat{m} + r\sigma^2$. Again, both increases in the value of the forward-looking information and increases in systematic risk make $\hat{\beta}_1$ and $\hat{\gamma}$ more pronounced substitutes.

Finally, let us comment on the specific risk σ_τ^2 associated with the forward-looking performance measure. According to (10), the only incentive rate directly affected by this type of risk is $\hat{\gamma}$. Of course, σ_τ^2 also influences the other incentive rates as they react to $\hat{\gamma}$ via the substitution effects. The larger σ_τ^2, the smaller $\hat{\gamma}$ becomes. The reason is that more specific risk and thus higher risk premia associated with the forward-looking information counteract its informational benefits ν. In the extreme case $\sigma_\tau^2 \to \infty$, prohibitively high specific risk premia force the principal to forgo the forward-looking performance measure completely by placing zero weight on it ($\hat{\gamma} = 0$). Then, the incentive rates $\hat{\beta}_1, \hat{\beta}_2$ on the accounting performance measures in Lemma 2 simplify to their counterparts in Lemma 1. The trade-off between specific risk and informational benefits inherent in forward-looking information thus may result in neglecting such performance measures.

Proposition 1 found underinvestment even under weak timing constraints, with tighter timing constraints exacerbating this problem. The following proposition summarizes our findings regarding the suitability of forward-looking information to mitigate or even eliminate underinvestment.

Proposition 2. *When forward-looking performance measures are also available, the following applies*:

(a) *Risk neutrality ($r = 0$) implies efficient investments.*
(b) *Managerial risk aversion ($r > 0$) implies underinvestment compared to the first-best level.*
(c) *Tighter timing constraints reduce investments.*

Hence, only risk-neutral managers invest efficiently in our model, while risk-averse managers underinvest even when forward-looking information is incorporated and timing constraints are weak. Tighter timing constraints exacerbate this problem. In this respect, Proposition 2 confirms Proposition 1. Forward-looking performance measures may mitigate underinvestment but cannot completely eliminate it as long as the manager is risk-averse.

However, Proposition 2 (a) shows that forward-looking information can induce first-best investments when the manager is risk-neutral. The principal can then exploit the informational benefits of forward-looking performance measures at no cost (in terms of risk premia). Therefore, she can set the incentive rates to induce efficient investments. However, this does not apply when the manager is risk-averse; see Proposition 2 (b). Then, incentives that induce efficient investments would involve prohibitively high risk premia. As a result, the principal is forced to dampen incentive rates, resulting in lower investments. Since investments under risk neutrality are efficient but decrease under risk aversion, they fall below the efficient level. Hence, risk aversion induces underinvestment, regardless of how tight the timing constraints are.

Note that the result of efficient investments under risk neutrality cannot be established without forward-looking performance measures. The discussion of Proposition 1 (b) reveals that investments approach $\delta\hat{\beta}_2 I^{FB}$ under tight timing constraints. Investments fall below the first-best level even when the principal leases the firm to the manager (i.e., $\hat{\beta}_2 = 1$). This is because the manager discounts his compensation in Period 2 when deciding on investments in Period 1. In the extreme case $\delta \to 0$, he does not invest at all. AEM can help mitigate underinvestment by transferring a part $\hat{m}$ of the investment earnings to Period 1. However, this is associated with personal costs $\frac{1}{2}\lambda\hat{m}^2$ to the manager, who therefore does not report enough earnings in Period 1 to make investments efficient. In contrast, forward-looking performance measures do not suffer from these limitations. They are already available in Period 1 and do not cause additional personal costs to the manager apart from additional risk premia. However, the latter are irrelevant when the manager is risk-neutral. This is why forward-looking performance measures assure efficient investments under risk neutrality.

Proposition 2 (c) confirms Proposition 1 (a) when forward-looking performance measures are available for contracting. To understand why tighter timing constraints reduce investments even then, note that forward-looking performance measures not only strengthen investment incentives but also induce a higher level of discretionary accruals; see (9). This makes investments more sensitive to increases in λ.

The principal can enhance investment incentives by placing more weight on the first-period accounting performance measure and giving the manager discretion in reporting. However, AEM results in additional personal costs to the manager, which the principal has to compensate. Alternatively, the principal can place more weight on the forward-looking performance measure. However, this imposes additional risk on the manager who in turn requires higher risk premia. Therefore, the principal faces a trade-off between accepting AEM and paying higher risk premia. Consequently, forward-looking information becomes more relevant for incentivizing investments when the principal gives the manager less discretion in reporting. This is confirmed by Corollary 1.

Corollary 1. *Tighter timing constraints increase the incentive rate on the forward-looking performance measure.*

Tightening timing constraints makes AEM more costly for the manager. He therefore engages more in REM, which negatively affects investments. To counteract, the principal must provide stronger investment incentives by placing more weight on the forward-looking performance measure.

Overall, our results from Section 3 are robust to the incorporation of forward-looking information: an impatient and risk-averse manager underinvests. AEM can mitigate but not eliminate this problem. However, efficient investments are possible provided the manager is risk-neutral. Furthermore, tighter rules for determining performance measures make forward-looking information more relevant for incentivizing investments.

5 | EMPIRICAL IMPLICATIONS AND CONCLUSION

In this paper, we examine the question whether managerial influence over accounting performance measures will affect the choice between REM and AEM. Our results suggest that tighter constraints on the manager's ability to affect performance measures reduce AEM but increase underinvestment problems in the form of REM. Hence, our model addresses the question whether it is optimal for the principal to accept reporting discretion for the manager.

Our study provides several implications. Our results reveal that investment incentives increase when managers are less constrained over how they can affect performance measures. The manager can influence contemporaneous performance measures based on which he is evaluated and compensated. Against conventional belief, this influence is not necessarily detrimental. Our study reveals that reporting discretion increases incentives for the manager to supply effort on investment activities.

From the perspective of accounting regulation, we conclude that more reporting discretion positively affects managers' investment activities. Discretion for the manager over performance measures allows managers to anticipate the future benefits of their investment decisions in their current performance measure. More reporting discretion for managers hence implies that contemporaneous performance measures will convey more forward-looking information. This result is consistent with the idea of managers using the option to capitalize R&D to include future benefits of these investments in current performance, as was found in empirical studies (e.g., Ahmed & Falk, 2006).

Our results imply that the extent to which managers choose REM critically depends on the underlying degree of accounting regulation or corporate governance. For equal managerial employment horizons and time preferences, managers in jurisdictions with tighter accounting regulation are expected to rely more strongly on REM activities, for example, significantly reduce discretionary spending on R&D. Our paper also reveals that the extent to which managers are shielded from certain expenditures affects the choice between AEM and REM.

One limitation of our results is that this paper assumes that higher supplied effort by the manager in investment activities is always beneficial to the firm. Hence, this paper neglects situations in which over-investment may be a problem.

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CONFLICT OF INTEREST STATEMENT

The authors have no conflicts of interest to declare that are relevant to the content of this article.

DATA AVAILABILITY STATEMENT

We do not analyze or generate any datasets, because our work proceeds within a theoretical and mathematical approach.

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APPENDIX

PROOFS

Proof of Lemma 1. The principal maximizes the expected present value of the firm after compensating, $\mathrm{E}(\Pi) = \mathrm{E}(\pi_1+\pi_2) - \mathrm{E}(w_1+w_2)$, subject to the manager's incentive compatibility and participation constraints. It is straightforward to see that the latter hold in equality, that is, $\mathrm{CE}_1(\cdot) = \mathrm{CE}_2(\cdot) = 0$. Therefore, the expected wage must compensate the manager for his personal costs and the risk premium in each period. Given (1) and (2), this results in

$$\begin{aligned} &\mathrm{E}(w_1)+\delta\mathrm{E}(w_2) = \frac{1}{2}\left[a_1^2 + I^2 + \lambda m^2 + \delta a_2^2 + \left(\beta_1^2 + \delta^2\beta_2^2\right)r\sigma^2\right] \text{ and} \\ &\mathrm{E}(w_2) = \frac{1}{2}\left(a_2^2 + \beta_2^2 r\sigma^2\right). \end{aligned} \tag{A1}$$

These participation constraints implicitly determine $\hat{\alpha}_1$ and $\hat{\alpha}_2$, such that the principal needs to maximize $\mathrm{E}(\Pi)$ with respect to β_1 and β_2 only. The incentive compatibility constraints are captured by the first-order conditions $a_1 = \hat{a}_1, a_2 = \hat{a}_2, I = \hat{I}$, and $m = \hat{m}$. Hence, the principal's program is

$$\begin{aligned} &\mathrm{E}(\pi_1+\pi_2) - \mathrm{E}(w_1+w_2) \to \max_{\beta_1,\beta_2} \text{ subject to } a_1 = \beta_1,\ a_2 = \beta_2, \\ &I = \frac{\lambda\delta\beta_2\theta}{\lambda - (\beta_1-\delta\beta_2)^2},\ m = \frac{\delta\beta_2\theta(\beta_1-\delta\beta_2)}{\lambda-(\beta_1-\delta\beta_2)^2}, \\ &\mathrm{E}(w_1)+\delta\mathrm{E}(w_2) = \frac{1}{2}\left[a_1^2 + I^2 + \lambda m^2 + \delta a_2^2 + \left(\beta_1^2+\delta^2\beta_2^2\right)r\sigma^2\right], \\ &\mathrm{E}(w_2) = \frac{1}{2}\left(a_2^2+\beta_2^2 r\sigma^2\right). \end{aligned}$$

From the incentive compatibility and participation constraints, it follows that $\mathrm{E}(\pi_1+\pi_2) = \beta_1+\beta_2+\theta\hat{I}$ as well as $\mathrm{E}(w_1+w_2) = \frac{1}{2}\left[\beta_1^2+\beta_2^2+\hat{I}^2+\lambda\hat{m}^2+\left(\beta_1^2+\beta_2^2\right)r\sigma^2\right] = \frac{1}{2}\left[\hat{I}^2+\lambda\hat{m}^2+\left(\beta_1^2+\beta_2^2\right)(1+r\sigma^2)\right]$. Together with $\hat{I} = \delta\beta_2\theta + (\beta_1-\delta\beta_2)\hat{m}$ according to (3), we arrive at

$$\mathrm{E}(\Pi) = \beta_1+\beta_2+\delta\beta_2\theta^2+(\beta_1-\delta\beta_2)\theta\hat{m} - \frac{1}{2}[\delta\beta_2\theta+(\beta_1-\delta\beta_2)\hat{m}]^2 - \frac{1}{2}[\lambda\hat{m}^2+\left(\beta_1^2+\beta_2^2\right)(1+r\sigma^2)].$$

Applying the envelope theorem yields

$$\begin{aligned} \frac{\partial\mathrm{E}(\Pi)}{\partial\beta_1} &= 1+\theta\hat{m} - [\delta\beta_2\theta+(\beta_1-\delta\beta_2)\hat{m}]\hat{m} - \beta_1(1+r\sigma^2) \stackrel{!}{=} 0 \\ \Leftrightarrow\ \hat{\beta}_1 &= \frac{1+\theta\hat{m}-\delta\hat{\beta}_2\hat{m}(\theta-\hat{m})}{1+\hat{m}^2+r\sigma^2} \text{ and} \\ \frac{\partial\mathrm{E}(\Pi)}{\partial\beta_2} &= 1+\delta\theta(\theta-\hat{m}) - \delta[\delta\beta_2\theta+(\beta_1-\delta\beta_2)\hat{m}](\theta-\hat{m}) - \beta_2(1+r\sigma^2) \stackrel{!}{=} 0 \\ \Leftrightarrow\ \hat{\beta}_2 &= \frac{1+\delta(\theta-\hat{\beta}_1\hat{m})(\theta-\hat{m})}{1+\delta^2(\theta-\hat{m})^2+r\sigma^2}. \end{aligned}$$

This completes the proof. ■

Proof of Proposition 1. Evaluating (4) using the incentive rates (5) leads to the second-best investment decision:

$$I^{\mathrm{SB}} = \frac{\lambda\delta\hat{\beta}_2\theta}{\lambda-\left(\hat{\beta}_1-\delta\hat{\beta}_2\right)^2}. \tag{A2}$$

To prove part (a), we calculate the partial derivative of I^{SB} with respect to λ applying the envelope theorem:

$$\frac{\partial I^{\mathrm{SB}}}{\partial\lambda} = -\frac{\delta\hat{\beta}_2\theta\left(\hat{\beta}_1-\delta\hat{\beta}_2\right)^2}{\left[\lambda-\left(\hat{\beta}_1-\delta\hat{\beta}_2\right)^2\right]^2}.$$

This derivative is less than or equal to zero. In the non-degenerate case $\theta > 0$ (otherwise, there is no need to incentivize investments), it is negative. Hence, I^{SB} decreases as λ increases.

To prove part (b), we evaluate the limit of (A2) when λ approaches infinity:

$$\lim_{\lambda\to\infty}\frac{\lambda\delta\hat{\beta}_2\theta}{\lambda-(\hat{\beta}_1-\delta\hat{\beta}_2)^2}=\delta\hat{\beta}_2\theta.$$

Since $I^{FB}=\theta$, we immediately arrive at $\lim_{\lambda\to\infty}I^{SB}<I^{FB}$. Hence, tight constraints induce underinvestment.

To prove part (c), we set $\lambda=1$ and apply the envelope theorem to calculate the partial derivatives of (A2) with respect to $\hat{\beta}_1$ and $\hat{\beta}_2$:

$$\frac{\partial I^{SB}}{\partial\hat{\beta}_1}=\frac{2\delta\hat{\beta}_2\theta(\hat{\beta}_1-\delta\hat{\beta}_2)}{\left[1-(\hat{\beta}_1-\delta\hat{\beta}_2)^2\right]^2}\text{ and }\frac{\partial I^{SB}}{\partial\hat{\beta}_2}=\frac{\delta(1-\hat{\beta}_1^2+\delta^2\hat{\beta}_2^2)\theta}{\left[1-(\hat{\beta}_1-\delta\hat{\beta}_2)^2\right]^2}.$$

Since $\hat{\beta}_1-\delta\hat{\beta}_2\geqq 0$ (to assure $\hat{m}\geqq 0$; see 3), both derivatives are greater than or equal to zero. A supremum of I^{SB} is therefore

$$\bar{I}^{SB}=\lim_{\hat{\beta}_1,\hat{\beta}_2\to 1}\frac{\delta\hat{\beta}_2\theta}{1-(\hat{\beta}_1-\delta\hat{\beta}_2)^2}=\frac{\delta\theta}{1-(1-\delta)^2}=\frac{\theta}{2-\delta}.$$

Since $\delta\leqq 1\Rightarrow 2-\delta\geqq 1$ and $I^{FB}=\theta$, we immediately arrive at $\bar{I}^{SB}\leqq I^{FB}$, which implies $I^{SB}<I^{FB}$. Hence, weak constraints also induce underinvestment. This completes the proof. ■

Proof of Lemma 2. As in the proof of Lemma 1, the principal maximizes $E(\Pi)=E(\pi_1+\pi_2)-E(w_1+w_2)$ subject to the incentive compatibility and participation constraints. The latter again hold in equality, that is, $CE_1(\cdot)=CE_2(\cdot)=0$, and thus require the expected wage to equal the manager's personal costs plus the risk premium in each period. While the respective condition regarding Period 2 is the same as in (A1), the condition for Period 1 is now

$$E(w_1)+\delta E(w_2)=\frac{1}{2}\left[a_1^2+I^2+\lambda m^2+\delta a_2^2+(\beta_1^2+2\beta_1\gamma+\gamma^2+\delta^2\beta_2^2)r\sigma^2+\gamma^2 r\sigma_\tau^2\right]. \tag{A3}$$

Since these conditions implicitly determine $\hat{\alpha}_1$ and $\hat{\alpha}_2$, the principal needs to maximize $E(\Pi)$ with respect to β_1,β_2, and γ only. Using the first-order conditions $a_1=\hat{a}_1, a_2=\hat{a}_2, I=\hat{I}$, and $m=\hat{m}$ to formulate the incentive compatibility constraints, the principal's program is

$$E(\pi_1+\pi_2)-E(w_1+w_2)\to\max_{\beta_1,\beta_2,\gamma}\text{ subject to } a_1=\beta_1,\ a_2=\beta_2,\quad I=\frac{\lambda(\delta\beta_2\theta+\gamma\nu)}{\lambda-(\beta_1-\delta\beta_2)^2},\ m=\frac{(\delta\beta_2\theta+\gamma\nu)(\beta_1-\delta\beta_2)}{\lambda-(\beta_1-\delta\beta_2)^2},\quad E(w_1)+\delta E(w_2)$$
$$=\frac{1}{2}\left[a_1^2+I^2+\lambda m^2+\delta a_2^2+(\beta_1^2+2\beta_1\gamma+\gamma^2+\delta^2\beta_2^2)r\sigma^2+\gamma^2 r\sigma_\tau^2\right],\qquad E(w_2)=\frac{1}{2}\left(a_2^2+\beta_2^2 r\sigma^2\right).$$

While the incentive compatibility constraints again imply $E(\pi_1+\pi_2)=\beta_1+\beta_2+\theta\hat{I}$, the expected sum of wages is now

$$\begin{aligned}E(w_1+w_2)&=\frac{1}{2}\left[\beta_1^2+\beta_2^2+\hat{I}^2+\lambda\hat{m}^2+(\beta_1^2+2\beta_1\gamma+\gamma^2+\beta_2^2)r\sigma^2+\gamma^2 r\sigma_\tau^2\right]\\&=\frac{1}{2}\left[\hat{I}^2+\lambda\hat{m}^2+(\beta_1^2+\beta_2^2)(1+r\sigma^2)+2\beta_1\gamma r\sigma^2+\gamma^2 r(\sigma^2+\sigma_\tau^2)\right].\end{aligned}$$

Together with $\hat{I}=\delta\beta_2\theta+(\beta_1-\delta\beta_2)\hat{m}+\gamma\nu$ according to (8), we arrive at

$$\begin{aligned}E(\Pi)&=\beta_1+\beta_2+\delta\beta_2\theta^2+(\beta_1-\delta\beta_2)\theta\hat{m}+\gamma\theta\nu-\frac{1}{2}[\delta\beta_2\theta+(\beta_1-\delta\beta_2)\hat{m}+\gamma\nu]^2\\&-\frac{1}{2}\left[\lambda\hat{m}^2+(\beta_1^2+\beta_2^2)(1+r\sigma^2)+2\beta_1\gamma r\sigma^2+\gamma^2 r(\sigma^2+\sigma_\tau^2)\right].\end{aligned}$$

Applying the envelope theorem yields

$$\begin{aligned}
\frac{\partial \mathrm{E}(\Pi)}{\partial \beta_1} &= 1+\theta\hat{m}-[\delta\beta_2\theta+(\beta_1-\delta\beta_2)\hat{m}+\gamma\nu]\hat{m}-\beta_1(1+r\sigma^2)-\gamma r\sigma^2 \overset{!}{=} 0\\
\Leftrightarrow \hat{\beta}_1 &= \frac{1+\theta\hat{m}-\delta\hat{\beta}_2\hat{m}(\theta-\hat{m})-\hat{\gamma}(\nu\hat{m}+r\sigma^2)}{1+\hat{m}^2+r\sigma^2},\\
\frac{\partial \mathrm{E}(\Pi)}{\partial \beta_2} &= 1+\delta\theta(\theta-\hat{m})-\delta[\delta\beta_2\theta+(\beta_1-\delta\beta_2)\hat{m}+\gamma\nu](\theta-\hat{m})-\beta_2(1+r\sigma^2)\overset{!}{=} 0\\
\Leftrightarrow \hat{\beta}_2 &= \frac{1+\delta(\theta-\hat{\beta}_1\hat{m}-\hat{\gamma}\nu)(\theta-\hat{m})}{1+\delta^2(\theta-\hat{m})^2+r\sigma^2}, \text{ and}\\
\frac{\partial \mathrm{E}(\Pi)}{\partial \gamma} &= \theta\nu-[\delta\beta_2\theta+(\beta_1-\delta\beta_2)\hat{m}+\gamma\nu]\nu-\beta_1 r\sigma^2-\gamma r(\sigma^2+\sigma_\tau^2)\overset{!}{=} 0\\
\Leftrightarrow \hat{\gamma} &= \frac{\theta\nu-\hat{\beta}_1(\nu\hat{m}+r\sigma^2)-\delta\hat{\beta}_2\nu(\theta-\hat{m})}{\nu^2+r(\sigma^2+\sigma_\tau^2)}.
\end{aligned}$$

This completes the proof. ■

Proof of Proposition 2. To prove part (a), we evaluate the incentive rates (10) assuming $r=0$:

$$\begin{aligned}
\hat{\beta}_1 &= \frac{1+\theta\hat{m}-\delta\hat{\beta}_2\hat{m}(\theta-\hat{m})-\hat{\gamma}\nu\hat{m}}{1+\hat{m}^2},\\
\hat{\beta}_2 &= \frac{1+\delta(\theta-\hat{\beta}_1\hat{m}-\hat{\gamma}\nu)(\theta-\hat{m})}{1+\delta^2(\theta-\hat{m})^2}, \text{ and}\\
\hat{\gamma} &= \frac{\theta-\hat{\beta}_1\hat{m}-\delta\hat{\beta}_2(\theta-\hat{m})}{\nu}.
\end{aligned} \tag{A4}$$

Straightforward algebra reveals that the system of Equations (9) and (A4) has the unique solution

$$\hat{\beta}_1=1, \hat{\beta}_2=1, \hat{\gamma}=\frac{(\lambda+\delta-1)(1-\delta)\theta}{\lambda\nu}, \text{ and } \hat{m}=\frac{(1-\delta)\theta}{\lambda}. \tag{A5}$$

Together with $\hat{I}=\delta\beta_2\theta+(\beta_1-\delta\beta_2)\hat{m}+\gamma\nu$ according to (8), we arrive at

$$I^{SB}=\delta\theta+\frac{(1-\delta)^2\theta}{\lambda}+\frac{(\lambda+\delta-1)(1-\delta)\theta}{\lambda}=\theta.$$

Since $I^{FB}=\theta$, it is obvious that $I^{SB}=I^{FB}$. Hence, risk neutrality leads to efficient investments.

To prove part (b), we evaluate the partial derivative of the manager's second-best investment decision:

$$I^{SB}=\frac{\lambda(\delta\hat{\beta}_2\theta+\hat{\gamma}\nu)}{\lambda-(\hat{\beta}_1-\delta\hat{\beta}_2)^2}, \tag{A6}$$

with respect to r applying the envelope theorem:

$$\begin{aligned}
\frac{\partial I^{SB}}{\partial r} =& \frac{\lambda}{\left[\lambda-(\hat{\beta}_1-\delta\hat{\beta}_2)^2\right]^2}\cdot\left\{\left(\delta\theta\cdot\frac{\partial\hat{\beta}_2}{\partial r}+\nu\cdot\frac{\partial\hat{\gamma}}{\partial r}\right)\cdot\left[\lambda-(\hat{\beta}_1-\delta\hat{\beta}_2)^2\right]\right.\\
&\left.+\left[2(\delta\hat{\beta}_2\theta+\hat{\gamma}\nu)(\hat{\beta}_1-\delta\hat{\beta}_2)\right]\cdot\left(\frac{\partial\hat{\beta}_1}{\partial r}-\delta\cdot\frac{\partial\hat{\beta}_2}{\partial r}\right)\right\}.
\end{aligned} \tag{A7}$$

Since all terms in square brackets are non-negative, the sign of $\partial I^{SB}/\partial r$ depends on the derivatives of the incentive rates with respect to r:

$$\frac{\partial \hat{\beta}_1}{\partial r} = \frac{-\hat{\gamma}\sigma^2 \cdot \left[1+\hat{m}^2+r\sigma^2\right] - \left[1+\theta\hat{m} - \delta\hat{\beta}_2\hat{m}(\theta-\hat{m}) - \hat{\gamma}(\nu\hat{m}+r\sigma^2)\right]\sigma^2}{\left[1+\hat{m}^2+r\sigma^2\right]^2} = -\frac{(\hat{\beta}_1+\hat{\gamma})\sigma^2}{1+\hat{m}^2+r\sigma^2} < 0,$$
$$\frac{\partial \hat{\beta}_2}{\partial r} = -\frac{\left[1+\delta(\theta-\hat{\beta}_1\hat{m}-\hat{\gamma}\nu)(\theta-\hat{m})\right]\sigma^2}{\left[1+\delta^2(\theta-\hat{m})^2+r\sigma^2\right]^2} = -\frac{\hat{\beta}_2\sigma^2}{1+\delta^2(\theta-\hat{m})^2+r\sigma^2} < 0,$$
$$\frac{\partial \hat{\gamma}}{\partial r} = \frac{-\hat{\beta}_1\sigma^2 \cdot \left[\nu^2+r(\sigma^2+\sigma_\tau^2)\right] - \left[\theta\nu - \hat{\beta}_1(\nu\hat{m}+r\sigma^2) - \delta\hat{\beta}_2\nu(\theta-\hat{m})\right](\sigma^2+\sigma_\tau^2)}{\left[\nu^2+r(\sigma^2+\sigma_\tau^2)\right]^2} = -\frac{(\hat{\beta}_1+\hat{\gamma})\sigma^2+\hat{\gamma}\sigma_\tau^2}{\nu^2+r(\sigma^2+\sigma_\tau^2)} < 0.$$

Hence, the first line in (A7) is less than or equal to zero, while the sign of the difference

$$\frac{\partial \hat{\beta}_1}{\partial r} - \delta \cdot \frac{\partial \hat{\beta}_2}{\partial r} = -\frac{(\hat{\beta}_1+\hat{\gamma})\sigma^2}{1+\hat{m}^2+r\sigma^2} + \frac{\delta\hat{\beta}_2\sigma^2}{1+\delta^2(\theta-\hat{m})^2+r\sigma^2} \tag{A8}$$

in the second line requires more attention. Substituting the incentive rates in (A5) into (A8) and straightforward algebra reveal that

$$\frac{\partial \hat{\beta}_1}{\partial r} - \delta \cdot \frac{\partial \hat{\beta}_2}{\partial r} = \frac{\Delta\sigma^2}{(1+\hat{m}^2)[1+\delta^2(\theta-\hat{m})^2]\lambda^3\nu}$$

at $r=0$, where

$$\Delta = [\delta\lambda^2 + \delta(1-\delta)^2\theta^2]\lambda\nu - [\lambda\nu + (\lambda+\delta-1)(1-\delta)\theta] \cdot [\lambda^2 + \delta^2(\lambda+\delta-1)^2\theta^2].$$

Note that (A8) and Δ have equal signs. Furthermore, $\theta \in [0;1]$, $(\lambda+\delta-1)(1-\delta)\theta \geqq 0$, and $\delta^2(\lambda+\delta-1)^2\theta^2 \geqq 0$ ensure that

$$\overline{\Delta} = [\delta\lambda^2 + \delta(1-\delta)^2]\lambda\nu - \lambda^3\nu = (1-\delta)[\delta(1-\delta)-\lambda^2]\lambda\nu$$

is a supremum of Δ. Since $\delta(1-\delta) \leqq 0.25$ and $\lambda \geqq 1$, $\overline{\Delta}$ and therefore (A8) is less than or equal to zero. Hence, risk neutrality ensures efficient investments (see part (a)), while risk aversion negatively impacts investments and thus causes underinvestment compared to the efficient level.

To prove part (c), we calculate the partial derivative of (A6) with respect to λ applying the envelope theorem:

$$\frac{\partial I^{SB}}{\partial \lambda} = -\frac{(\delta\hat{\beta}_2\theta+\hat{\gamma}\nu)(\hat{\beta}_1-\delta\hat{\beta}_2)^2}{\left[\lambda-(\hat{\beta}_1-\delta\hat{\beta}_2)^2\right]^2}.$$

This derivative is less than or equal to zero. In line with the proof of Proposition 1 (a), it is negative in the non-degenerate case $\theta > 0$. Hence, I^{SB} decreases as λ increases. This completes the proof. ∎

Proof of Corollary 1. We calculate the partial derivative of $\hat{\gamma}$ as given in (10) with respect to λ applying the envelope theorem. Because $\hat{\gamma}$ only depends on λ via $\hat{m}$ according to (9), the chain rule yields

$$\frac{\partial \hat{\gamma}}{\partial \lambda} = \frac{\partial \hat{\gamma}}{\partial \hat{m}} \cdot \frac{\partial \hat{m}}{\partial \lambda} = \frac{(\hat{\beta}_1-\delta\hat{\beta}_2)\nu}{\nu^2+r(\sigma^2+\sigma_\tau^2)} \cdot \frac{(\delta\hat{\beta}_2\theta+\hat{\gamma}\nu)(\hat{\beta}_1-\delta\hat{\beta}_2)}{\left[\lambda-(\hat{\beta}_1-\delta\hat{\beta}_2)^2\right]^2}.$$

Since $\hat{\beta}_1 - \delta\hat{\beta}_2 \geqq 0$ (to assure $\hat{m} \geqq 0$; see 8), this derivative is greater than or equal to zero. In the non-limit case $\lambda < \infty$ (otherwise, further tightening of timing constraints is impossible) $\hat{m} > 0$ assures that $\partial\hat{\gamma}/\partial\lambda$ is positive. Hence, tighter timing constraints increase $\hat{\gamma}$. This completes the proof. ∎