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Essays on Accounting Conservatism, Managerial Incentives, and Investment Efficiency

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Chapter 1

Literature Review on Accounting Conservatism

1.1 Introduction

Accounting conservatism is a long-standing principle that requires firms to anticipate possible future losses but not future gains. This policy gives guidance on how to record uncertain events and estimates. Although this definition is not controversial, the literature has incorporated or has modeled conservatism in different ways.

Basu (1997) and Watts (2003) interpret accounting conservatism as the asymmetric degrees of verification to recognize good news as gains and bad news as losses. The asset impairment policy is an example that fits this interpretation. Impairment losses require a lower degree of verification, and thus can be recognized immediately. However, impairment gains require a higher degree of verification, and thus should be deferred to the future when adequate evidence is available to justify the recognition. Guay and Verrecchia (2006) interpret conservatism in the same way and view a legal system as conservative if it penalizes the upward bias in disclosures. Thus, bad news is fully disclosed while all good news is pooled and reported equal to the prior mean.

One prominent feature of accounting is the use of binary classifications (Dye, 2002). Thus, the literature usually views accounting as a system that converts unobservable outcomes into a reduced message space, such as translating complex and myriad economic transactions and events into summary financial statistics (Gigler et al., 2009). Therefore, a model of accounting conservatism defines how to map unobservable outcomes to a reduced message space. Using the asset impairment policy as an example again, an asset's fair value (FV) can be low (losses), medium, or high (gains). Because accounting conservatism requires a lower degree of verification to recognize losses, the reduced message space should be {losses, no losses}. This message space leads to the impairment policy. Firms take asset impairment tests annually but can only recognize losses not gains. Unrealized losses need a lower degree of verification, but firms cannot record unrealized gains until they sell the asset. Chapter 3 follows this stream of literature and extends the analysis to a real options framework by studying how accounting conservatism affects the value of real options and thus indirectly influences investment efficiency.

It is without controversy that bad news is useful for outsiders. A pessimistic report helps outsiders evaluate the lower bound of the asset's value (or future cash flow). This evaluation helps outsiders to take remedial actions, such as renegotiation or selling of a firm's shares. However, good news is also valuable to outsiders. Therefore, delaying the recognition of gains (pooling good news with intermediate news) only fits with multi-period settings because the firms can disclose valuable information on gains in the future. This method might not fit with single-period models because firms cannot incorporate good news later.

Kwon et al. (2001) and Gigler et al. (2009) adopt a different method to fit with single-period models. The main idea is to still convert a larger set of unobservable outcomes into a reduced message space. In a single-period model, the authors cannot use delayed recognition to represent a higher degree of verification, so they link the degree of verification to the posterior belief. Using the example above, the asset's FV can be low, medium, or high; and the reduced message space can be either {losses, no losses} or {no gains, gains}.

A message space is deemed as conservative if it results in a higher posterior belief that the unobservable asset's FV is high when observing a favorable report. Clearly, using this definition, the message space {no gains, gains} is more conservative, which is the opposite of the earlier example. Interestingly, both methods are consistent with Basu's interpretation, but the methods conflict with each other on which system is more conservative.

Accounting practice widely uses binary classifications and thresholds (Dye, 2002; Kaplow, 2011; Gao, 2015). Firms often design an accounting system to determine a threshold and to specify what action should be taken if an accounting signal is above or below that threshold. Although [Goex and Wagenhofer (2009); Demski et al. (2008)] and [Gigler et al. (2009); Kwon et al. (2001)] are inconsistent in defining which system is more conservative, they are consistent in defining a conservative system as a threshold below which news requires a low degree of verification. The only difference lies in the threshold. Goex and Wagenhofer (2009) and Demski et al. (2008) set a relatively lower threshold and pool more right-tail information because firms can disclose this information later. In contrast, Gigler et al. (2009) and Kwon et al. (2001) set a relatively higher threshold and pool more left-tail information. This approach reduces false positive (Type I) errors because these errors are more costly in an agency model when agents have limited liability.

The literature generally views accounting conservatism as a means of combating optimism or the insider's tendency to overstate (Watts, 2003; Ball and Shivakumar, 2005; Francis and Martin, 2010; Bushman et al., 2011). But Moonitz (1951) states that:

> "Historically this [conservative] bias was undoubtedly useful in neutralizing the tendency of a businessman to overstate his profits and his net worth in order to make a better impression with creditors and absentee owners. At the present time, however, with income tax rates at high levels, the incentive is probably in the other direction; so that the traditional rules of conservatism may actually be dangerous. Recently, [labor] unions have made much of the level of corporate earnings in collective bargaining negotiations, adding more incentive for management to choose the smaller rather than

the larger figure."

Moonitz (1951) warns that the existence of high income (or corporate) taxes and powerful labor unions might reduce a businessman's (or a firm's) incentive to overstate. This reluctance does not mean that the existence of high income (or corporate) taxes and powerful labor unions totally eliminates the businessman's (or the firm's) incentive to bias upward but does warn the accounting academia that combating overstatement is not the only reason why conservatism is beneficial.

Devine (1963) defines conservatism in a very different way:

> "Suppose, given accounting measurements A and B, that users *change* their course of action in response to measurement A more frequently than in response to measurement B; then choice B is sometimes said to be conservative. This approach associates conservatism with the tendency of users to be content with existing activities and non-conservatism is thus associated with reluctance to change from traditional patterns. With this usage, conservative accounting tends to preserve the *status quo*."

Devine's definition takes into account the action associated with the disclosure of information. A system is more conservative if users are less likely to make changes. Chapter 2 is consistent with this definition. In Chapter 2, the intermediate accounting report can be low, medium, or high. Both the shareholders and the manager use this intermediate report. Specifically, the shareholders decide whether to fire the manager based on the report, while the retained manager decides whether to keep working in the second period. According to Devine's definition, a system is more conservative if that system commits the shareholders to less firing, and increases the manager's incentives to keep working in the second period. Consistent with this definition, I define medium to high pooling as a conservative system. Clearly, medium to high pooling prompts the shareholder to fire less often as compared to a system with low to medium pooling. Also, medium to high pooling encourages the manager to keep working by not letting her condition the effort on the intermediate accounting report.

Devine's definition of accounting conservatism may have its roots in political philosophy. However, this definition is satisfactory if those who use the accounting reports do not have conflicting goals. For example, both current shareholders and potential investors use the earnings reports. Low earnings encourage current shareholders to sell their stocks, but encourage potential investors to refrain from purchasing; thus, Devine's definition views lower earnings as aggressive from the current shareholders' perspective, but as conservative from the potential investors' perspective. Otherwise, Devine's definition fits the principal-agent setting. Hence, the defense for conservatism becomes that the discouragement of users from making changes is desirable. Chapter 2 suggests a previously unrecognized reason why fostering steadiness in good times can mitigate the moral hazard problem.

1.2 Literature Review

Chapter 2 studies the effect of accounting conservatism on managerial incentives in a limited commitment setting. When the principal cannot credibly commit ex ante to a certain ex-post decision, Arya et al. (1998) show that earnings management helps commit the principal to delaying intervention ex post. Crémer (1995) shows that the principal prefers installing inefficient monitoring technology as a credible threat of firing the agent on observing a low output. The principal prefers this choice because an efficient monitoring technology ruins the credibility of the principal's commitment to not investigating the agent's ability ex post. Also, some papers show that a system with less information is optimal because less information ex post prevents the principal from taking certain actions that she cannot credibly commit to ex ante (Arya et al., 1997, 2000). Chapter 2 is consistent with this stream of literature and shows that conservative accounting fosters a long-term relationship by "committing" the principal to less firing.

Chapter 2 also relates to the literature on the value of information for contracting. Chaigneau et al. (2014) show that the precision of the accounting signal changes the agent's

incentives in that an increase in the signal precision can change the agent's incentive for working and for shirking differently; thus the optimal precision should increase the agent's incentive to work rather than to shirk. Kwon et al. (2001) show that conservative financial reporting facilitates motivating agents in a limited liability setting because it increases the informativeness of the high outcome. Christensen et al. (2002) shows that installing a system that allows the agent to under-report the first-period output dominates a system that precludes any such under-reporting. This result emerges because rationing the supply of information counters the detrimental force from the possibility of renegotiation that weakens the initial contract. Chapter 2 extends this stream of literature and studies why a conservative system, which fosters steadiness (e.g., less firing), is desirable. Chapter 2 shows that conservatism can substitute for a commitment of less firing and thus foster steadiness, which motivates agents to keep working in the second period.

Chapter 3 studies the effect of accounting conservatism on investment efficiency. Numerous studies demonstrate that conservative accounting mitigates overinvestment because asymmetric recognition motivates managers to discontinue poorly performing projects (Ball and Shivakumar, 2005; Francis and Martin, 2010; Caskey and Hughes, 2011; Bushman et al., 2011). Lu and Sapra (2009) investigate the effect of auditor's conservatism on investment efficiency and argue that, given auditor's conservatism, an unfavorable report results in overinvestment. García Lara et al. (2015) find that more conservative firms are less likely to both over- and under-invest. André et al. (2015) find that conservatism mitigates both over- and under- investment in the pre-IFRS period but does not improve investment efficiency in the post-IFRS period, because adoption of the IFRS reduces the level of conservatism. Chapter 3 extends this stream of literature to the real options framework. The real options are abandonment options and staged investments. Lawrence et al. (2014) study the interaction between conditional conservatism and abandonment decisions and provide evidence that asset write-downs result in abandonment, which in turn reduces the persistence of losses. Two close theoretical papers are Arya and Glover (2003) and Smith (2007). Arya and Glover

(2003) show that, although the abandonment option limits the principal's downside risk, this option makes motivating the agent more expensive, because abandoning the project eliminates the information regarding the agent's unobservable effort. Smith (2007) studies how the bias in information affects investment in the real options framework and derives conditions under which conservative bias is optimal. However, the literature does not address how the accounting system affects the value of the abandonment options and thereby influences investment efficiency. Chapter 3 shows that although the impairment-based system makes abandonment decisions ex post inefficient for weak firms and thus reduces the value of abandonment options, it improves the strong firms' investment efficiency ex ante.

1.3 Conclusion

Accounting conservatism is a long-standing concept. One view of conservatism is that it is a means of combating optimism or incentives that managers have to bias (or manipulate) upwards rather than downwards. Although this view of conservatism is without controversy, combating optimism is not the only reason. Gigler et al. (2009) and Kwon et al. (2001) show that a conservative system improves the efficiency of contracts, because the conservative system reduces Type I (false positive) errors that are more costly when agents have limited liability. Another benefit of conservatism is the avoidance of early payments in good times, such as excessive dividend payments (Ahmed et al., 2002). Excessive dividend payouts ruin the bondholder's fixed claims in the future when facing negative shocks. Viewing conservatism as the tendency of the users of information to preserve existing activities (Devine, 1963), Chapter 2 suggests a previously unrecognized reason why fostering steadiness is desirable.

Accounting conservatism requires firms to anticipate possible future losses but not future gains. Basu (1997) and Watts (2003) interpret accounting conservatism as the asymmetric degree of verification to recognize good news as gains and to recognize bad news as losses.

Although this definition is not controversial, the literature has incorporated or has modeled conservatism in different ways. My dissertation models conservatism as the early reporting of bad news: the firm fully discloses news below a threshold, while pools all good news above the threshold. This model is similar in spirit to [Guay and Verrecchia (2006); Goex and Wagenhofer (2009); Bertomeu and Magee (2015); Demski et al. (2008)] and is fundamentally different from [Gigler et al. (2009); Kwon et al. (2001)], who do not consider the timing of reporting. The purpose of my dissertation is to understand the effect of pooling all of the good news above the threshold (and delay recognizing gains) on managerial incentives and investment efficiency.

The remainder of the dissertation proceeds as follows: Chapter 2 examines how accounting conservatism affects the long-term relationship between the manager (agent) and shareholders (principal) and thus influences managerial incentives. Chapter 3 studies the effect of accounting for fixed assets on investment efficiency in a real options framework.

Chapter 2

Timely Loss Recognition and Long-term Incentive[1]

Abstract

In this paper, we model conservatism as delayed reaction to uncertainty—bad news (signal below a threshold) is fully disclosed on a timely basis while uncertain information (signal above the threshold) is delayed. In a two-period agency model with only moral hazard, the principal effectively commits to less firing at the end of the first period by adopting a conservative system. We show that the principal prefers the conservative system even when the principal finds it valuable ex ante to commit to a threat of firing. A credible threat of firing motivates the manager, who intends to reduce the chance of losing future rent, to work hard in the first period. However, the conservative system can substitute for the threat of firing without increasing the first-period incentive cost, if conservatism also blurs the manager's information in the good times. This result emerges because motivating the incumbent manager in the second period is less costly than motivating a new manager, due to the complementary effect between the incumbent's efforts in two periods. Thus, the conservative system allows the shareholders to reduce the incentive cost over two periods. In

[1]This chapter is based on a joint work with Jonathan Glover and Haijin Lin.

an extension in which the manager obtains private information, we show that conservatism can still be optimal when firing is explicitly costly (e.g., a requirement of minimum severance pay). Intuitively, a positive severance pay rewards shirking, thus the conservative system, which commits to less firing, saves both the direct cost (severance pay) and the indirect cost (counter-incentive caused by a positive severance pay). In sum, our findings suggest that conservative accounting could be beneficial as it fosters long-term relationship by committing the principal to less firing, and thus makes motivating the manager less expensive in long run.

Keywords: accounting conservatism, firing/retention decision, long-term relationship

2.1 Introduction

This paper studies the effect of accounting conservatism on a long-term relationship when the principal cannot credibly commit to ex-post firing/retaining an agent. Many papers have shown that, when the principal cannot credibly commit ex ante, a system with less information may be optimal, since less information ex post prevents the principal from taking certain actions that she cannot credibly commit to ex ante (Arya et al., 1997, 2000). If a coarse information system is preferred, is it better to install a system that discloses good news early (an aggressive system) or a system that discloses bad news early (a conservative system)? We show that the principal prefers a conservative system, which commits to less firing and thus fosters long-term relationship. Moreover, when conservatism also limits the information provided to the manager, we show that conservatism makes motivating the manager less expensive, because it keeps the manager in the dark about intermediate early performance.

We model conservatism as an early reporting of bad news: news below a threshold is fully disclosed, while all good news (above the threshold) is pooled. This model is similar in spirit to Guay and Verrecchia (2006) and is fundamentally different from Gigler et al. (2009)

and Kwon et al. (2001), who do not consider the timing of reporting. In our model, only bad news is recognized on a timely basis and thus results in firing; while good (and intermediate) news is delayed. Rationing the supply of early information delays the reaction to uncertain events and thus fosters steadiness, such as less firing. The idea that conservatism fosters steadiness is also consistent with Devine (1963), who views conservatism as the tendency of the users of information to preserve existing activities. One purpose of this paper is to understand why fostering steadiness is beneficial.

Our paper studies a two-period principal-agent model in which neither the shareholders nor the manager knows the manager's ability (fitness or productivity) ex ante. The shareholders demand an accounting report to update the manager's type and make firing/retention decisions at the intermediate stage. Absent strategic considerations, a full information report is always desirable for the shareholders to replace poorly-fit managers. From an ex-ante perspective, however, this may lead to firing the manager too often and thus making motivating the manager more expensive. However, due to lack of credible commitment, although committing to less firing may be optimal ex ante, the shareholders cannot commit to retaining the incumbent manager if the updated belief is lower than a new manager. In this case, a conservative system can function as a credible substitute for a commitment to less firing, because keeping the shareholders from learning whether the intermediate signal is medium or high can prevent the shareholders from firing in both cases. Similarly, an aggressive system can substitute for a credible threat of firing, because low to medium pooling commits the shareholders to firing in both.

We show that a conservative system, which fosters steadiness (e.g., less firing), makes motivating the manager less costly in both periods, when compared with an aggressive system which uses the threat of firing to incentivize the manager. A credible threat of firing the manager (unless the intermediate report is high) imposes an implicit punishment on shirking in the first period, because the manager who shirks has a higher chance of being fired and losing rents in the second period. This, in turn, motivates the manager to work in

the first period to reduce the chance of being fired. Thus, the threat of firing saves the first-period incentive cost. A conservative system which commits to less firing, however, does not increase the first-period incentive cost, if conservatism also blurs the manager's information in the good times (pooling medium and high). When the manager's information is limited by the conservative system, it is incentive compatible for the shareholders to pay only a big bonus on observing a total output of high (the first output) plus high (the second output) at the end of the second period. Thus, the manager with a first output of medium also ends up with no payment, which, in turn, penalizes shirking in the first period. Therefore, the conservative system does not increase the first-period incentive cost. Further, we show that the conservative system can substitute for the threat of firing, because it makes motivating high effort less expensive in the second period. Since the incumbent is paid at the end of the second period, her efforts in two periods are complement (that is, high effort in the first period increases the marginal return of the second effort); thus, it is cheaper to incentivize the incumbent in the second period (under the conservative system) than to incentivize a new manager (under the aggressive system).

Moreover, keeping the manager from perfectly learning the intermediate report prevents the manager from conditioning her effort on the intermediate signal. For example, under the fully revealing system, the manager may want to work if the intermediate report is high, but to shirk if the intermediate report is medium. Thus, the intermediate report of medium increases the second-period incentive cost. The conservative system, however, mitigates this conflict by blinding the manager's information about the intermediate report. Hence, the conservative system is always less expensive than both the fully revealing system and the aggressive system. However, to determine the optimal accounting system should also consider the expected output. Replacement with a better manager always improves expected productivity. Thus, the optimal accounting system balances between the benefit of cheaper contracts and the cost of poorly-fit managers. We provide conditions under which the conservative system maximizes the shareholders' payoff.

In the main model, we assume that the true output is unobservable, and the manager knows no more than what the accounting system reveals. This assumption is reasonable if the firm has high operation uncertainty, since high operation uncertainty prevents the manager from perfectly learning the true output, and thus relying on the intermediate accounting report. In the extension, we discuss an alternative assumption that the firm has low operation uncertainty, thus the manager perfectly observes the first-period output. In this case, regardless of the accounting system, the manager privately learns the first output, thus conservative system cannot threaten to not paying the manager if the first output is medium, unless the shareholders want to motivate low effort (similar as firing) in the second period. Therefore, the conservative system loses the implicit incentive in the first period. Furthermore, the shareholders' information is still limited by the conservative system, in that they cannot distinguish between a total output of medium (in the first period) plus high (in the second period) from a total output of high plus medium. To motivate the second-period effort, the shareholders should compensate both cases; otherwise, the manager with a first output of medium will shirk in the second period. Compensating a second output of medium creates inefficiency and increases the incentive cost in the second period, thus the conservative system is suboptimal. However, if firing is explicitly costly, such as a requirement of minimum severance pay, we show that the conservative system can be optimal. Intuitively, a positive severance pay rewards shirking (the manager is less likely to be fired and take severance pay if working) and thus makes incentivizing the manager more expensive in the first period. Thus, a conservative system which commits to retaining some unproductive manager saves both the direct cost (severance pay) and indirect cost (counter-incentive caused by positive severance pay). This result is consistent with the idea that, since employee turnover is costly, firms may find it optimal to retain unproductive workers (Blanchard and Portugal, 2001).

In terms of modeling, our paper is close to Crémer (1995). His paper shows that the principal prefers installing inefficient monitoring technology as a credible threat of firing

the agent on observing a low output. The principal prefers this choice because an efficient monitoring technology ruins the credibility of the principal's commitment to not investigating the agent's ability ex post. Our paper is consistent and shows that the principal prefers installing a conservative system as a credible commitment to less firing, which fosters the long-term relationship between the manager and shareholders.

Our result is also consistent with Devine's idea that fostering steadiness is desirable in good times. Our main model has moral hazard problem but not adverse selection, and the moral hazard problem is alleviated by the managerial contracts. In other words, the manager has already been motivated to work in the first period, so the conservative system which discourages the manager to make changes (e.g., conditioning her second-period effort on the intermediate report) is beneficial.

Accounting conservatism is a long-standing concept. One view of conservatism is that it is a means of combating optimism or incentives that managers have to bias (or manipulate) upwards rather than downwards. Although this view of conservatism is without controversy, combating optimism is not the only reason. Gigler et al. (2009) and Kwon et al. (2001) show that conservative system improves the efficiency of contracts, because the conservative system reduces Type I (false positive) errors that are more costly when agents have limited liability. Another benefit of conservatism is the avoidance of early payments in good times, such as excessive dividend payment (Ahmed et al., 2002). Excessive dividend payouts ruin the bondholder's fixed claims in the future when facing negative shocks. Viewing conservatism as the tendency of the users of information to preserve existing activities (Devine, 1963), our paper contributes to the literature by suggesting a previously unrecognized reason why fostering steadiness is desirable. We demonstrate that blurring the agent's information in the good times substitutes for the threat of firing, thus implicitly incentivizing the agent to work in the first period. Also, we show that keeping the agent in the dark about the intermediate report makes motivating the agent less expensive in the second period.

The rest of the paper proceeds as follows. Section 2.2 describes the model details. Section

2.3 presents the benchmark results. Section 2.4 analyzes the optimal accounting system that maximizes the shareholder's payoff. Section 2.5 discusses an alternative assumption that the manager privately learns the first output. Section 2.6 concludes the paper. All proofs are in the appendix.

2.2 The Model

Consider the shareholders invest capital I and hire an agent to manage a productive asset for two periods. The manager (the agent) supplies costly effort in each period. The shareholders decide whether to replace the manager at the end of period 1. The stochastic outputs are independent across periods.

To fix idea, the manager can be a good fit (good type) or a poor fit (bad type) for the firm, denoted by $\theta \in \{G,\, B\}$. A good-fit manager better utilizes the asset and produces higher future output than a poorly-fit manager. The manager's type is not directly observable but could be inferred based on some information publicly available at the end of period 1 (introduced shortly). The shareholders and the manager initially share the same prior that with probability $Pr\,(G) = g$ the manager is a good fit and with probability $Pr\,(B) = 1 - g$ the manager is a poor fit.

The output $x_t \in \{x_L,\, x_M,\, x_H\}$ is determined by the manager's type θ, the manager's effort in period t, $a_t \in \{a_H,\, a_L\}$, and a random state of nature. The variable a_t also represents the cost of effort, $0 \leq a_L < a_H$; moreover, we assume $0 \leq x_L < x_M < x_H$. Let $r_j = Pr\,(x_j|G,\, a_H)$ and $p_j = Pr\,(x_j|B,\, a_H)$ denote the probabilities of output x_j conditional on a good-fit manager exerting high effort and a poorly-fit manager exerting high effort, respectively. Let $q_j = Pr\,(x_j|\theta,\, a_L)$ denote the probability of output x_j conditional on a type θ manager exerting low effort. A good-fit manager is more productive than a poorly-fit manager so that $r_H > p_H$ and $r_L < p_L$. In addition, we assume $\dfrac{q_j}{r_j}$ and $\dfrac{q_j}{p_j}$ satisfy Monotone Likelihood Ratio Property (MLRP) (that is, $\dfrac{q_L}{r_L} \geq \dfrac{q_M}{r_M} \geq \dfrac{q_H}{r_H}$ and $\dfrac{q_L}{p_L} \geq \dfrac{q_M}{p_M} \geq \dfrac{q_H}{p_H}$).

At the end of period 1, the shareholders evaluate the incumbent manager and decide whether to fire him. The asset's output in each period is not observable but its total output is observable at the end of period 2, the latter denoted by $X = x_1 + x_2$.[2] In this setting, demand for information arises at the end of period 1 to help the shareholders update their beliefs regarding the manager's type. For ease of exposition, we assume the labor market remains unchanged across periods so that a new manager is a good fit with probability g and a bad fit with probability $(1 - g)$. We also assume that the stochastic outputs when a new manager is hired are identical to those in period 1.

The shareholders initially choose an accounting system which produces a report y at the end of period 1. The accounting report is informative about the first-period realized output. By construction, the first-period output is one-to-one mapping with the updated mean of the total expected output and therefore, the accounting report is informative about the total output. When the total output is expected to be low or high (relative to the prior specified as the initial investment I), the accounting issue at hand is to determine whether unrealized loss or unrealized gain should be recognized. Without loss of generality, assume $E[X|x_1 = x_j] \geq I$ for $x_j \in \{x_M, x_H\}$ and $E[X|x_1 = x_L] < I$. In words, if the book value of the asset is I, then the asset is impaired at the end of period 1 if and only if a low output is realized.

We consider four accounting systems denoted by y^δ, where $\delta \in \{C, A, full, null\}$. A conservative system $y^C = \{y_L^C, y_H^C\}$ produces one of two possible accounting reports at the end of period 1, of which a low report (y_L^C) is produced whenever a low output (x_L) is realized. Otherwise if the output is medium (x_M) or high (x_H), a high report (y_H^C) is produced. An aggressive system $y^A = \{y_L^A, y_H^A\}$ also produces one of two possible reports at the end of period 1. In contrast to a conservative system, an aggressive system produces a high report (y_H^A) at the end of period 1 whenever a high output is realized and a low report whenever a low or medium output is realized. In this setup, only unrealized loss (a.k.a. impairment loss)

[2]We also assume $x_M + x_M \neq x_L + x_H$, so that the shareholders can differentiate.

is recognized under a conservative accounting system while only unrealized gain is recognized under an aggressive accounting system.

Intuitively, one can think of x_1 as future shocks, learning of which could help predict future performance of the asset. If x_1 is low, the total output of the asset at the end of period 2 won't be too high regardless of the output realized in period 2. If x_1 is high, the total output of the asset would be high in the sense that $2x_H$ would likely be observed at the end of period 2. Under a conservative accounting system, the asset is not written up but written down (that is, reporting an impairment loss if and only if x_L is realized). Our formulation of conservatism ensures that bad news are reported on a timely basis while good news are delayed to report, which essentially is consistent with accounting practice such as lower-of-cost-or-market or impairment. Under an aggressive accounting system, the asset is not written down but written up (that is, reporting an unrealized gain if and only if x_H is realized) in the sense that good news are reported on a timely basis while bad news are delayed.

The shareholders may also consider two additional information systems—one providing perfect information and one providing no information. A fully revealing system $y^{full} = \left\{y_L^{full},\, y_M^{full},\, y_H^{full}\right\}$ produces one of three possible reports at the end of period 1, of which a low (y_L^{full}), medium (y_M^{full}) or high report (y_H^{full}) is produced whenever a low, medium or high output is realized. Both impairment loss and unrealized gain would be recognized so that the asset will always be marked to its expected value (measured based on expected output). Perfect information is revealed. A null system $y^{null} = \{\emptyset\}$ does not produce any report since neither impairment loss nor unrealized gain will be recognized and the asset will always be recorded at its initial book value.

The shareholders offer a contract $s\left(y,\, X\right)$ to motivate high efforts in both periods conditioning on the accounting report (y) and the total output (X). If the incumbent manager is fired, he is paid $s\left(y\right)$, which can be thought of as severance pay. If a new manager is hired, the shareholders would offer a contract $s^N\left(X\right)$ conditioning on the total output at the end

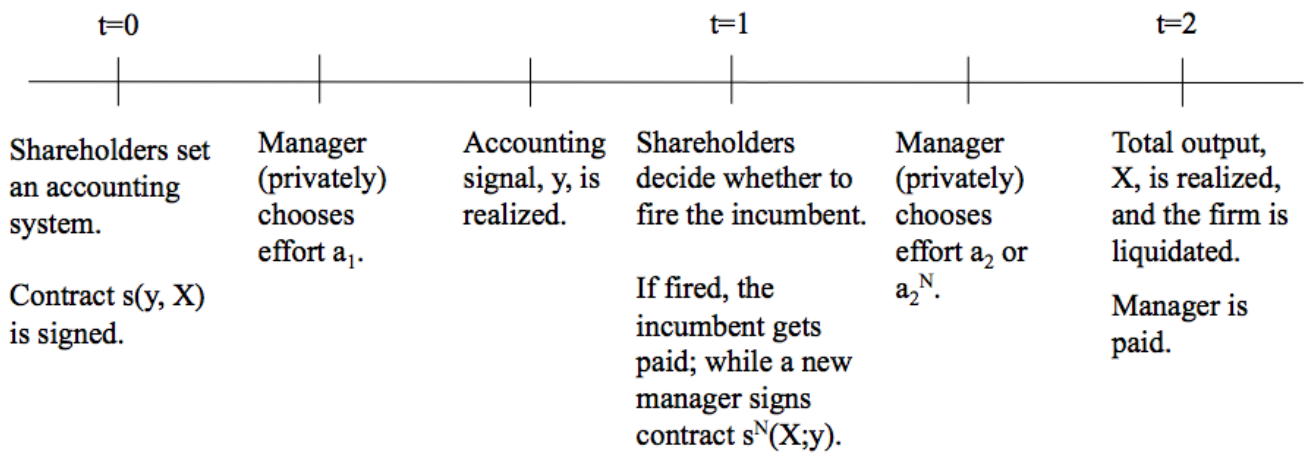

Figure 2.1: Timeline of Events

of period 2. Both the shareholders and the manager are risk neutral. The shareholders consume the total output net of incentive pays; while the manager consumes the total payments net of the costs of his efforts.

The timing of events is as follows. At $t = 0$, the shareholders choose an accounting system δ and determine the managerial compensation contract $s(\cdot)$. After accepting the offer, the manager exerts effort a_1. At $t = 1$, an accounting report y is produced, conditional upon which the shareholders decide whether to fire the manager. If the incumbent manager is retained, she exerts effort a_2. If the incumbent manager is fired, the shareholders hire a new manager and determine a contract $s^N(\cdot)$. After accepting the offer, the new manager exerts effort $a_2^N \in \{a_H, a_L\}$. At $t = 2$, the asset is liquidated and the shareholders consume the total output net of the manager's pay. Fig. 2.1 summarizes the timeline.

Before proceed, we consider a benchmark setting in which output is observable at the end of each period and the shareholders can contract on the manager's efforts. In this case, there is no demand for accounting. Whenever high effort is observed, the shareholders pay the manager a constant wage at the amount equal the sum of the manager's reservation utility and her cost of effort (a_H). Without loss of generality, the manager's reservation utility is normalized to zero. At the end of period 1, the shareholders use x_1 to update their beliefs regarding the manager's type and fire the incumbent manager if and only if she is less likely

to be a good fit than a new (average) manager. In particular, when output x_j is observed, the shareholders update in the following fashion:

$$Pr\left(G|x_j;\ a_H\right) = \frac{g\, r_j}{g\, r_j + (1-g)\ p_j}; \tag{2.1}$$

so that the incumbent manager is more likely a good fit than a new manager as long as $Pr\left(G|x_j;\ a_H\right) \geq g \ \Leftrightarrow\ r_j \geq p_j$. The assumptions $r_H > p_H$ and $r_L < p_L$ suggest that the shareholders always retain (fire) the incumbent manager when a high (low) output is observed. When a medium output is observed, the shareholders retain the incumbent manager as long as $r_M \geq p_M$, that is, a good-fit manager more likely produces a medium output than a poorly-fit manager.

2.3 Benchmark Analysis: Ex Ante Commitment

We first analyze two benchmark cases in which shareholders can commit to certain firing/retention decision ex ante. The first benchmark considers a setting in which the shareholders commit to a long-term contract and not firing the incumbent manager. We show that the intermediate accounting report is not only useless, but also detrimental, in that it makes incentivizing the manager more expensive in the later periods. The second benchmark considers a setting in which the shareholders can credibly commit ex ante to certain firing/retention decision. For example, the shareholders can commit to firing the incumbent even though the updated belief of the incumbent's ability is at least equal to a new manager. We show that the ability to credibly threaten of firing is valuable to the shareholders.

No replacement

The shareholders initially commit not to firing the manager at the end of the first period. From the shareholders' perspective, there is no demand for the intermediate information report and therefore a null system (y^{null}) is preferred. To see this, we formalize the share-

holders' problem in Program PN. Since high effort in each period is always motivated, the expected gross payoff will remain the same irrespective of the underlying incentive problems. The shareholders choose an accounting system y^{δ} and the contract $s\left(y^{\delta},\, x_i + x_j\right)$ to minimize the expected compensation.

For any given accounting system y^{δ}, the shareholders solve for the optimal incentive contract subject to the following constraints. The first constraint (2.2) ensures that the manager is paid at least his reservation utility $\bar{U} = 0$ so that it is individually rational to accept the contract. The second constraint (2.3) ensures high efforts for both periods are incentive compatible for the manager. Lastly, all the payments must be nonnegative so that the shareholders pay the manager. The optimal accounting system maximizes the shareholders' expected payoff.

Program PN

$$\underset{y^{\delta},\, s(\cdot)\geq 0}{Minimize} \left\{ \sum_{i=L,M}^{H} \sum_{j=L,M}^{H} \left[g\, r_i\, r_j \;+ (1-g)\; p_i\, p_j\right] s\left(y^{\delta},\, x_i + x_j\right) \right\}$$

Subject to

$$U\left[s\left(y^{\delta},\, x_i + x_j\right),\, a_H,\, a_H\right] \geq 0; \tag{2.2}$$

$$U\left[s\left(y^{\delta},\, x_i + x_j\right),\, a_H,\, a_H\right] \geq U\left[s\left(y^{\delta},\, x_i + x_j\right),\, a_1,\, a_2\left(y^{\delta}\right)\right],\; for\; a_1,\, a_2 \in \{a_H,\, a_L\}, \tag{2.3}$$

where $U\left[s\left(y^{\delta},\, x_i + x_j\right),\, a_1,\, a_2\left(y^{\delta}\right)\right]$ denotes the manager's expected utility over two periods given accounting system y^{δ}, the contract $s(\cdot)$, efforts a_1 and $a_2(y^{\delta})$ and is written as

$$\begin{aligned} & U\left[s\left(y^{\delta},\, x_i + x_j\right),\, a_1,\, a_2\left(y^{\delta}\right)\right] \\ =& \sum_{\theta=G}^{B} \sum_{i=L,M}^{H} \sum_{j=L,M}^{H} \left\{ Pr\left(\theta\right) Pr\left(x_i|\theta,\, a_1\right) Pr\left(x_j|\theta,\, a_2\right) \left[s\left(y^{\delta},\, x_i + x_j\right) - a_1 - a_2\right] \right\}. \end{aligned}$$

Information report y would expand the manager's second-period effort space, that is, the manager could vary her second-period effort choice with y. As the number of the incentive compatibility constraints (2.3) increase, Program PN becomes more constrained. That is, it becomes more costly to motivate the manager to exert high effort based on all the realizations of information signal y. The optimal way to minimize the incentive cost is not to produce information at all. Proposition 1 summarizes our finding.

Proposition 1. *Suppose the shareholders commit not to firing the incumbent manager. The null system prevails in terms of maximizing the shareholders' expected payoff.*

Proposition 1 implies that the (intermediate) accounting signal y can be detrimental whenever the shareholders commit to a long-term contractual relationship. The intuition is that accounting report enables the manager to condition her second-period effort on the report and in turn, induces a more severe agency problem in the second period. The shareholders optimally choose a null system to eliminate the negative effect of the intermediate report, which minimizes the expected compensation and therefore maximizes their expected net payoff.

A threat of firing incentivizes the manager

It is without controversy that firing benefits the shareholder in replacing poorly-fit managers and thus increasing the expected total output. However, it is unclear whether a credible threat of firing a fit manager is beneficial for the shareholders. To separate the benefit of firing a poorly-fit manager from the benefit of incentivizing the manager, we discuss the case $Pr(G|x_M; a_H) = Pr(G)$. That is, if the (unobservable) first period output x_1 is medium (x_M), the incumbent is believed to be as fit as a new manager; thus, firing cannot bring in

a better manager. Under the fully revealing system, we compare two different strategies. In the first case, the shareholders make the firing/retention decision based on the ex-post updated belief; thus the incumbent is fired only if y_L^{full} is reported. In the second case, the shareholders commit to firing the incumbent when y_L^{full} or y_M^{full} is reported. By construction, the only difference between two strategies is whether the manager is fired when y_M^{full} is reported. Since $Pr(G|y_M^{full}; a_H) = Pr(G)$, the incumbent is the same as a new manager in terms of productivity. Thus, both strategies lead to the same expected output, and the one resulting in lower rent should dominate. The next result shows that, even when firing ex post does not change the manager's ability ($r_M = p_M$), as long as the output x_M indicates a high probability of shirking ($max\left[r_M, p_M\right] < q_M$), a credible threat of firing benefits the shareholders in reducing the incentive cost.

Proposition 2. *Assume that $r_M = p_M < q_M$, and that the fully revealing system is prescribed. The ability to commit ex ante to firing when y_M^{full} is observed is strictly valuable to the shareholders.*

Intuitively, $r_M = p_M$ means that the updated belief of the incumbent's type $Pr\left(G|y_M^{full}; a_H\right)$ equals the prior belief of a new manager $Pr\left(G\right)$, thus firing does not bring in a better manager. Also, $max\left[r_M, p_M\right] < q_M$ means that both the good type and the bad type are less likely to receive y_M^{full} with a high effort than with a low effort. Thus, if working hard in the first period, both types can reduce their chance of receiving a medium report and being fired. Proposition 2 states that a credible threat of firing can incentivize the manager in the first period. Intuitively, firing at y_M^{full} penalizes the manager through not receiving future rents. Thus, the manager is more willing to work in the first period to reduce the chance of receiving y_M^{full} and being fired. This makes incentivizing the manager less expensive in the first period.

2.4 Main Findings

We now consider the setting in which the shareholders cannot directly commit to certain firing/retention decisions. At the end of the first period, demand for information arises naturally to facilitate the shareholders' firing decision. The shareholders use the accounting report y^{δ} to update their beliefs regarding the manager's type and fire the incumbent manager if and only if she is less likely to be a good fit than a new (average) manager. Mathematically, the shareholders fire (retain) the incumbent if $Pr\left(G|y^{\delta}; a_H\right) < (\geq)\, g$.

We consider four accounting systems, including the null system, the fully revealing system, the conservative system, and the aggressive system. Under the null system, there is no intermediate accounting signal, thus $Pr\left(G|y^{null}; a_H\right) = g$, and the shareholders always retain the incumbent. Under the fully revealing system, since $Pr\left(G|y_L^{full}; a_H\right) = \frac{gr_L}{gr_L+(1-g)p_L} < g$, the shareholders fire the incumbent when a low signal (y_L^{full}) is reported. The last inequality holds because $r_L < p_L$. Similarly, the shareholders retain the incumbent when a high signal (y_H^{full}) is reported, and the firing decision with a medium signal (y_M^{full}) depends on the ordering between r_M and p_M. If $r_M \geq p_M$, the shareholders retain the incumbent; otherwise firing the incumbent. Under the conservative system, since $Pr\left(G|y_L^{C}; a_H\right) = \frac{gr_L}{gr_L+(1-g)p_L} < g$ and $Pr\left(G|y_H^{C}; a_H\right) = \frac{g(1-r_L)}{g(1-r_L)+(1-g)(1-p_L)} > g$, the shareholders fire (retain) the incumbent when y_L^C $\left(y_H^C\right)$ is reported. Note that, regardless of the the ordering between r_M and p_M, the shareholders retain the incumbent when a high report $\left(y_H^C\right)$ is reported; thus, the conservative system commits the shareholders to retaining the incumbent manager when y_H^C is reported. Similarly, under the aggressive system, since $Pr\left(G|y_L^{A}; a_H\right) = \frac{g(1-r_H)}{g(1-r_H)+(1-g)(1-p_H)} < g$ and $Pr\left(G|y_H^{A}; a_H\right) = \frac{gr_H}{gr_H+(1-g)p_H} > g$, the shareholders fire (retain) the incumbent when y_L^A $\left(y_H^A\right)$ is reported. The last two inequality hold because $r_H > p_H$. Thus, the aggressive system credibly threatens to firing the incumbent manager when $x_1 = x_M$.

Recall from Proposition 2 that, if $r_M = p_M < q_M$, a credible threat of firing at y_M^{full} reduces the first-period incentive cost. Thus, the aggressive system which commits to more firing makes motivating the manager cheaper in the first period. However, it remains unan-

swered whether the aggressive system is the cheapest in terms of minimizing the total expected incentive pay.

In what follows, we first compare the total expected rent between each accounting system in Section 2.4.1, and then determine the optimal accounting system in terms of maximizing the shareholder's payoff in Section 2.4.2.

2.4.1 Total expected rent

In this subsection, we focus exclusively on the cost side and analyze which system is cheaper to motivate the manager. Proposition 2 implies that the aggressive system implicitly incentivizes the manager in the first period through a credible threat of firing. This implicit incentive comes from the punishment of not receiving future rents if being fired. Thus, the manager has more incentive to work hard to reduce the chance of being fired.

However, the aggressive system is not the only system that can motivate the manager in this manner. We show that the conservative system which keeps the manager from accurately learning the intermediate signal has the same effect. Because the manager cannot distinguish x_M from x_H when observing a high report (y_H^C), the shareholders can use a big bonus (paying the incumbent if and only if the total outputs are $x_H + x_H$) to motivate the manager in the second period. Thus, the manager with a total output of $x_M + x_j$ ends up with no pay. Hence, the manager has more incentive to work hard in the first period to reduce the chance of getting a medium output (x_M) and being not paid at the end. The next result shows that the conservative system can substitute for the threat of firing without increasing the first-period incentive cost.

Proposition 3. *The total expected rent in the conservative system is always smaller than the total expected rent in the aggressive system.*

Proposition 3 states that, compared with the aggressive system, the conservative system is

always cheaper to motivate high effort in both periods. One thing needs subtle consideration. We have demonstrated that a threat of not paying the manager when $x_1 = x_M$ makes incentivizing the manager less expensive in the first period, but it remains unanswered whether a new manager is cheaper to be motivated than the incumbent in the second period. At the first sight, it seems natural that replacing a poorly-fit manager with a better one should save rent, since it is cheaper to motivate high effort (a good-fit manager has a higher likelihood ratio). However, this argument overlooks the fact that a good-fit manager also has a higher probability of getting paid. Furthermore, the incumbent is paid at the end of the second period, so the first effort and the second effort are complement, in that high effort in the first period increases the marginal return of the second effort. Since the incumbent has already been motivated to exert high effort in the first period, she has more incentives to exert high effort in the second period, which makes motivating the incumbent less expensive than a new manager.

Isolated from consideration of productivity, firing is not beneficial. The more detailed the accounting signal y is, the less likely the shareholders can commit to less firing. Proposition 4 shows that the null system which commits the shareholders to the least firing is the cheapest system to motivate high effort in both periods.

Proposition 4. *The null system is always the cheapest system to motivate high effort in both periods.*

Isolated from consideration of productivity, the null system is the cheapest system. However, to determine the optimal accounting system, the shareholders should take both productivity and the manager's rent into consideration. In the next subsection, we compare the revenue side and then determine the optimal accounting system that maximizes the shareholders' payoff. Clearly, the optimal accounting system balances the benefit from a cheaper

contract and the cost of less productivity.

2.4.2 Optimal accounting system

Before comparing the productivity between each accounting system, we first show that the fully revealing system is always weakly dominated; thus, it is enough to consider the other three systems, the null system, the conservative system, and the aggressive system.

Proposition 5. *Fully revealing system is always weakly dominated in terms of maximizing the shareholder's payoff.*

Although the fully revealing system enables the shareholders to implement first-best firing/retention decision, Proposition 5 reports that fully reveling system is always weakly dominated by one of the other three systems. Specifically, if $r_M \geq p_M$, the fully revealing system is dominated by the conservative system; while if $r_M < p_M$, the fully revealing system is equivalent to the aggressive system. Comparison between the fully-revealing system and the conservative system warrants brief mention. When $r_M \geq p_M$, both systems implement the first-best firing/retention decision. However, the conservative system prevents the manager from perfectly learning the first output, so that the manager cannot condition her effort on the intermediate report, which makes incentivizing the manager less expensive in the second period. Thus, the conservative system dominates the fully revealing system when $r_M \geq p_M$.

It is straightforward to compare the total expected productivity between each accounting system. Clearly, the accounting system that adopts the first-best firing/retention decision achieves the highest total expected productivity. The result is summarized in the following lemma.

Lemma 1. *When $r_M \geq (<) p_M$, the conservative (aggressive) system generates the highest expected output.*

Lemma 1 states that adopting the first-best replacement decision generates the highest expected output. When the intermediate signal y indicates that the incumbent is more likely to be a poorly-fit manager, replacing with a new manager is more efficient in terms of productivity; otherwise, retain the incumbent. Therefore, isolated from consideration of the manager's incentive, the shareholders should fire the incumbent whenever the updated belief of the incumbent's type is lower than a new manager. However, this result changes when the shareholders take the manager's incentive into consideration.

We first compare the conservative system and the null system. As discussed in Lemma 1, the conservative system generates higher expected (gross) output than the null system, precisely because the shareholder always retain a poorly-fit incumbent under the null system. However, Proposition 4 states that the null system pays less rent. Therefore, the conservative system is more efficient in terms of productivity; while the null system is more efficient in terms of incentivizing the manager. In what follows, we provide a sufficient condition with which the conservative system dominates the null system in terms of maximizing the shareholders' payoff. With little abuse of notation, we denote the expected output generated by a new manager and the expected incentive pay to the new manager, respectively, by R_{new} and S_{new}.

Proposition 6. *The conservative system dominates the null system as long as both (2.4) and (2.5) hold:*

$$\frac{gr_L}{gr_L + (1-g)\,p_L} \sum_{j=L,M}^{H} r_j x_j + \frac{(1-g)\,p_L}{gr_L + (1-g)\,p_L} \sum_{j=L,M}^{H} p_j x_j < R_{new} - S_{new}; \tag{2.4}$$

$$\frac{2}{gr_H r_H + (1-g)p_H p_H - q_H q_H} \geq \frac{g\,(1-r_L) + (1-g)\,(1-p_L) + q_L}{gr_H\,(r_H - q_H) + (1-g)p_H\,(p_H - q_H)}. \tag{2.5}$$

Intuitively, (2.4) ensures that, given y_L^C is reported, the incumbent's expected productivity is lower than the new manager's expected productivity (net of the new manager's rent); (2.5) guarantees that the rent paid to the incumbent in the null system is higher than that in the conservative system. Combining (2.4) and (2.5), it is clear that firing the incumbent when y_L^C is reported benefits the shareholders; thus, the conservative system dominates the null system. Note that, the result in Proposition 6 is independent of the ordering between r_M and p_M, precisely because neither the conservative system nor the null system reports y_M.

We next compare the conservative system with the aggressive system. Lemma 1 shows that, when $r_M \geq p_M$, the conservative system generates the highest expected output. In addition, Proposition 3 shows that the total expected rent in the conservative system is always smaller than that in the aggressive system. Thus, when $r_M \geq p_M$, the conservative system dominates the aggressive system. In what follows, we focus on the comparison between the conservative system and the aggressive system when $r_M < p_M$.

Proposition 7. *Define p_M^* as the threshold with which the conservative system and the aggressive system are equivalent in maximizing the shareholders' payoff. The conservative system dominates the aggressive system as long as $p_M < p_M^*$; and, in equilibrium, $p_M^* > r_M$.*

Proposition 7 reports that, the conservative system still dominates the aggressive system when p_M is larger than r_M but smaller than the threshold p_M^*. When $p_M > r_M$, the manager is more likely to be a poorly-fit when the true output is x_M. From the productivity

perspective, firing the incumbent increases the expected output. However, from the strategic incentive perspective, committing to retaining the incumbent reduces the incentive cost. When the benefit from a cheaper contract exceeds the cost from less productivity, the conservative system which retains the unproductive manager is preferred. Proposition 7 implies that, in equilibrium, the optimal accounting system retains some unproductive managers. This result provides some new insight why firms may find it optimal to retain unproductive workers, in addition to the common explanation of direct costs associated with hiring and training of new employees.

Combining Proposition 6 and Proposition 7, the following result reports that the conservative system dominates all others when $p_M < p_M^*$ and both (2.4) and (2.5) hold.

Corollary 1. *The conservative system prevails as long as $p_M < p_M^*$ and both (2.4) and (2.5) hold.*

2.4.3 Discussion

When $p_M > p_M^*$, Proposition 7 suggests that the aggressive system dominates the conservative system. However, this claim needs subtle consideration. The baseline model assumes that the true output x_1 takes three possible values, low, medium, or high. This assumption limits our analysis to four accounting systems. If, instead, x_1 is a continuum variable, we could extend our analysis to compare a more conservative system verse a less conservative system (Goex and Wagenhofer, 2009). The shareholders can pick different thresholds to make an accounting system more or less conservative; a more conservative system commits the shareholders to less firing. Note that, however, a less conservative system is fundamentally different from the aggressive system. A less conservative system is still a right-censoring

system with a relatively higher right-censoring threshold than a more conservative system. In contrast, the aggressive system is a left-censoring system in which only good news are disclosed. For the contracting purpose, the shareholders always prefer the right-censoring system to foster steadiness in good times, since it makes incentivizing the agent less expensive in both periods.

2.5 Extension

In the main model, we assume that the outputs in each period are unobservable, and the manager knows no more than what the accounting system reveals. This assumption is reasonable if the firm has high operation uncertainty, since high operation uncertainty prevents the manager from perfectly learn the true output and thus relying on the intermediate accounting report. In what follows, we discuss an alternative assumption that the firm has low operation uncertainty, thus the manager perfectly observes the first-period output.

In this case, the shareholders' information is still limited by the conservative system, so the shareholders retain the incumbent when y_H^C is reported. However, since the accounting system does not limit the manager's information, the manager can condition her second-period effort on the intermediate accounting report; thus the shareholders should compensate $s\left(y_H^C, x_M + x_H\right) > 0$ to incentivize the manager. Otherwise, the manager will shirk after privately observing $x_1 = x_M$. A positive $s\left(y_H^C, x_M + x_H\right)$ prevents the shareholders from penalizing the manager of not receiving future rents, thus the conservative cannot substitute for a credible threat of firing, losing the benefits discussed in Section 2.4.1. Also, because the shareholders cannot distinguish $\left(y_H^C, x_M + x_H\right)$ from $\left(y_H^C, x_H + x_M\right)$, the shareholders should pay $s\left(y_H^C, x_M + x_H\right) = s\left(y_H^C, x_H + x_M\right) > 0$ in equilibrium. This inefficiency increases the incentive cost in the second period. The next result shows that, if $p_M \leq q_M$, the conservative system is always dominated by the fully revealing system.

Proposition 8. *Suppose the manager perfectly observes the first output x_1. If $p_M \leq q_M$, the conservative system is always dominated by the fully revealing system.*

When $r_M \geq p_M$, both systems retain the manager when $x_1 = x_M$; thus both systems adopt the same firing/retention decisions ex post. Since the shareholders' information is limited by the conservative system, the shareholders cannot distinguish $\left(y_H^C, x_M + x_H\right)$ from $\left(y_H^C, x_H + x_M\right)$, and thus increasing the second-period incentive cost. Therefore, if $r_M \geq p_M$, the conservative system is dominated by the fully revealing system.

When $r_M < p_M$, the conservative system retains unproductive managers and thus decreasing the expected productivity. Also, the conservative system increases the second-period incentive cost, due to the binding constraint $s\left(y_H^C, x_M + x_H\right) = s\left(y_H^C, x_H + x_M\right) > 0$. Furthermore, a positive $s\left(y_H^C, x_M + x_H\right)$ makes the conservative system unable to threaten of not paying the manager when the first-period output is medium. In contrast, the fully revealing system implicitly incentivizes the manager by a credible threat of firing at y_M^{full}. Thus, the fully revealing system dominates the conservative system.

However, as shown by the next result, the conservative system can still be optimal if firing is explicitly costly, such as a requirement of minimum severance pay. Specifically, if the cost of firing is higher than the inefficiency from less productivity and expensive contracts, the conservative system dominates.

In terms of modeling, a requirement of minimum severance pay means an additional constraint $s\left(y^\delta\right) \geq k > 0$, where k is the minimum severance pay. Clearly, a positive severance pay rewards shirking and thus makes motivating high effort more costly in the first period; thus the shareholders will not pay more than the minimum severance pay. That is, in equilibrium, $s\left(y^\delta\right) = k$. If k is too small, the conservative system is dominated by the aggressive system and the fully revealing system, since expected productivity weights more than the firing cost. Similarly, if k is too large, the conservative system is dominated by the null system. Proposition 9 provides conditions of k with which the conservative system is

optimal. Denote k^* as the value with which the conservative system equals the fully-revealing system and the aggressive system in terms of maximizing the shareholders' payoff, and k^{**} is the value with which the conservative system equals the null system.

Proposition 9. *Suppose the manager perfectly observes the first output x_1. Also assume that $\frac{r_L}{p_L} < \frac{r_M}{p_M}$. The conservative system is optimal in terms of maximizing the shareholders' payoff, as long as the minimum severance pay k satisfies both (2.6) and (2.7):*

$$k < \left(g - \frac{g r_M}{g r_M + (1-g)\, p_M} \right) \sum_{j=L,M}^{H} r_j x_j + \left((1-g) - \frac{(1-g)\, p_M}{g r_M + (1-g)\, p_M} \right) \sum_{j=L,M}^{H} p_j x_j; \quad (2.6)$$

$$0 \leq k^* < k < k^{**}. \quad (2.7)$$

Condition (2.6) determines the firing decision ex post in the fully revealing system. Note that, the shareholders make the decision ex post by comparing the severance pay with the change in productivity. The right-hand side of (2.6) is the difference in productivity between a new manager and the incumbent when y_M^{full} is realized. When condition (2.6) holds, the difference in productivity is higher than the severance pay, so the shareholders fire the incumbent when y_M^{full} is realized. In this case, the fully revealing system is equivalent to the aggressive system. Also, condition (2.6) guarantees

$$k < \left(g - \frac{g r_L}{g r_L + (1-g)\, p_L} \right) \sum_{j=L,M}^{H} r_j x_j + \left((1-g) - \frac{(1-g)\, p_L}{g r_L + (1-g)\, p_L} \right) \sum_{j=L,M}^{H} p_j x_j,$$

so, under the conservative system, the shareholders fire the incumbent when y_L^C is realized. Also, condition (2.7) ensures that k is neither too large nor too small.

We now present a numerical example to demonstrate that there exists a parameter's space satisfying both conditions (2.6) and (2.7).

Example: $g = 0.5$, $r_L = 0$, $r_M = 0.45$, $p_L = 0.1$, $p_M = 0.5$, $q_L = 0.3$, $q_M = 0.7$, $a_H = 10$, $a_L = 0$, $x_L = 0$, $x_M = 40$, $x_H = 100$, $k = 0.34$.

Solutions:

Null system: $s(x_i + x_j) = 0$, for $i, j = \{L, M\}$; $s(x_L + x_H) = s(x_H + x_L) = 25$; $s(x_M + x_H) = s(x_H + x_M) = 21.2291$; $s(x_H + x_H) = 43.7672$. The shareholder's expected utility is 112.379.

Aggressive system: $s^N\left(x_i + x_j; y_L^A\right) = 0$, for $i, j = \{L, M\}$; $s^N\left(x_L + x_H; y_L^A\right) = s^N\left(x_M + x_H; y_L^A\right) = 21.0526$; $s\left(y_L^A\right) = 0.34$; $s\left(y_H^A, x_H + x_L\right) = s\left(y_H^A, x_H + x_M\right) = 0$; $s\left(y_H^A, x_H + x_H\right) = 64.4822$. The shareholder's expected utility is 113.148.

Conservative system: $s^N\left(x_L + x_L; y_L^C\right) = s^N\left(x_L + x_M; y_L^C\right) = 0$; $s^N\left(x_L + x_H; y_L^C\right) = 21.0526$; $s\left(y_L^C\right) = 0.34$; $s\left(y_H^C, x_M + x_L\right) = s\left(y_H^C, x_M + x_M\right) = s\left(y_H^C, x_H + x_L\right) = 0$; $s\left(y_H^C, x_M + x_H\right) = s\left(y_H^C, x_H + x_M\right) = 21.2291$; $s\left(y_H^C, x_H + x_H\right) = 43.8645$. The shareholder's expected utility is 113.164.

It is straightforward to check that parameter's values satisfy condition (2.6). Thus, under the fully revealing system, the shareholders fire the incumbent when y_M^{full} is realized, and the fully revealing system is equivalent to the aggressive system. Also, it is clear that the conservative system dominates the other three systems in this example. Thus, this example shows that we can find a parameter's space that makes the conservative system optimal.

2.6 Conclusion

This paper studies under what circumstance a conservative system, which right-censors good news, is optimal. We show that the shareholders may prefer conservative accounting, even though a threat of firing under an aggressive system is valuable ex ante. Although a credible threat of firing saves the first-period incentive cost, conservative accounting can substitute for the threat of firing, if the manager's information is also limited by the ac-

counting system (e.g., when the operation uncertainty is high). It is because motivating the incumbent manager in the second period is less costly than motivating a new manager, due to the complementary effect between the incumbent's efforts in two periods. Thus, the conservative system, which commits to less firing, is beneficial to the shareholders. If the manager perfectly learns the first output, we show that conservative system is dominated, because the conservative system limits shareholders' information and thus making incentivizing the manager more expensive in the second period. We also show that if firing is explicitly costly (e.g., minimum severance pay), a conservative system is beneficial by saving both the direct cost (severance pay) and the indirect cost (counter-incentive caused by positive severance pay). These findings suggest a previously unrecognized reason why fostering steadiness (long-term relationship) in good times is beneficial.

A common view why firms retain some unproductive employee is that high employee turnover rate hurts firms because of direct costs of hiring and training new employees. This paper provides an alternative explanation and suggests that fostering a long-term relationship makes it cheaper to incentivize the agent in both periods. Although this paper shows that the shareholders always prefer a right-censoring system, this paper does not address the optimal right-censoring threshold (optimal employee turnover rate) for different firms. Future research can investigate the relationship between firm-specific characteristics and the optimal level of conservatism.

Future research can also extend this study to the debt contracting. Specifically, the project is funded by both the shareholders and lenders and operates for two periods, and lenders can liquidate the project at the end of the first period. This setting captures some tension between liquidating the project and letting the shareholders replace the manager. Future research can examine how accounting conservatism affects this tension.

2.7 Appendix

Proof of Proposition 1

We first show that a conservative system is dominated by a null system. Program PN under a null system can be written as Program PN-null.

Program PN-null

$$\underset{s(\cdot)\geq 0}{Minimize} \left\{ \sum_{i=L,M}^{H} \sum_{j=L,M}^{H} \left[g\, r_i\, r_j \; + (1-g)\; p_i\, p_j \right] s\left(x_i + x_j\right) \right\}$$

Subject to

$$U\left[s\left(y^{null},\, x_i + x_j\right),\, a_H,\, a_H \right] \geq 0; \tag{2.8}$$

$$U\left[s\left(y^{null},\, x_i + x_j\right),\, a_H,\, a_H \right] \geq U\left[s\left(y^{null},\, x_i + x_j\right),\, a_H,\, a_L \right]; \tag{2.9}$$

$$U\left[s\left(y^{null},\, x_i + x_j\right),\, a_H,\, a_H \right] \geq U\left[s\left(y^{null},\, x_i + x_j\right),\, a_L,\, a_H \right]; \tag{2.10}$$

$$U\left[s\left(y^{null},\, x_i + x_j\right),\, a_H,\, a_H \right] \geq U\left[s\left(y^{null},\, x_i + x_j\right),\, a_L,\, a_L \right]. \tag{2.11}$$

The nonnegativity constraints on payments when $X \neq 2x_H$ is realized are binding, i.e., $s\left(x_H + x_M\right) = s\left(x_H + x_L\right) = s\left(2x_M\right) = s\left(x_M + x_L\right) = s\left(2x_L\right) = 0$. Similarly, Program PN under a conservative system can be written as Program PN-C.

Program PN-C

$$\underset{s(\cdot)\geq 0}{Minimize} \sum_{j=L,M}^{H} \left[g\, r_L\, r_j \; + (1-g)\; p_L\, p_j \right] s\left(y_L^C,\, x_L + x_j\right) + \sum_{i=M}^{H} \sum_{j=L,M}^{H} \left[g\, r_i\, r_j \; + (1-g)\; p_i\, p_j \right] s\left(y_H^C,\, x_i + x_j\right)$$

Subject to

$$U\left[s\left(y^C,\, x_i+x_j\right),\, a_H,\, a_H(y_L^C),\, a_H(y_H^C)\right]\geq 0; \tag{2.12}$$

$$U\left[s\left(y^C,\, x_i+x_j\right),\, a_H,\, a_H(y_L^C),\, a_H(y_H^C)\right]\geq U\left[s\left(y^C,\, x_i+x_j\right),\, a_H,\, a_2(y_L^C),\, a_2(y_H^C)\right]; \tag{2.13}$$

$$U\left[s\left(y^C,\, x_i+x_j\right),\, a_H,\, a_H(y_L^C),\, a_H(y_H^C)\right]\geq U\left[s\left(y^C,\, x_i+x_j\right),\, a_L,\, a_2(y_L^C),\, a_2(y_H^C)\right]. \tag{2.14}$$

The binding nonnegativity constraints under y^C include $s\left(y_L^C,\, x_L+x_L\right)=s\left(y_L^C,\, x_L+x_M\right)=s\left(y_H^C,\, x_M+x_j\right)=s\left(y_H^C,\, x_H+x_L\right)=0$.

Program PN-null can be revised by expanding the contract from $s\left(x_i+x_j\right)$ to $s\left(y^C,\, x_i+x_j\right)$ while imposing the following two additional constraints:

$$s\left(y_L^C,\, x_L+x_M\right)=s\left(y_H^C,\, x_M+x_L\right);$$

$$s\left(y_L^C,\, x_L+x_H\right)=s\left(y_H^C,\, x_H+x_L\right).$$

Both constraints are dominated by the binding nonnegativity constraints $s\left(x_H+x_L\right)=s\left(x_M+x_L\right)=0$ and therefore the revised PN-null Program is equivalent to Program PN-null. It remains to prove that the revised PN-null program dominates Program PN-C. To see this, both programs have the same objective functions. Under Program PN-C, the agent is motivated to exert high effort in the second period when a low signal is observed. The following constraint is binding:

$$U\left[s\left(y^C,\, x_i+x_j\right),\, a_H,\, a_H,\, a_H\right]\geq U\left[s\left(y^C,\, x_i+x_j\right),\, a_H,\, a_L,\, a_H\right]. \tag{2.15}$$

But (2.15) can never be satisfied under the revised PN-null program. Program PN-C has more (binding) IC constraints than the revised PN-null and therefore the compensation cost is higher under y^C than under y^{null}. Program PN-null dominates Program PN-C. Analogous arguments apply to show y^{null} dominates y^A and y^{full}, respectively. Analogous arguments

also apply to prove y^C dominates y^{full}.

Proof of Proposition 2

Suppose the fully revealing system is prescribed. When y_L^{full} is observed, the shareholders fire the incumbent because the posterior belief of the manager's ability $Pr\left(G|y_L^{full}, a_H\right) < g$. When y_M^{full} is observed, the shareholders retain the incumbent because $Pr\left(G|y_M^{full}, a_H\right) = g$. We show that committing to firing the manager at y_M^{full} dominates retaining the manager at y_M^{full}, in terms of maximizing the shareholders' payoff. Note that, when $r_M = p_M$, the new manager has the same ability as the incumbent, so the expected total outputs are the same under both strategies. Thus, it is equivalent to show that committing to firing at y_M^{full} reduces the expected incentive pay compared with retention. Specifically, we compare two principal's programs. The first one, named as Program P-full, is the fully revealing program without commitment, so that the shareholders fire the manager only when y_L^{full} is observed. The second one, named as Program P-CF, is to fire the manager when either y_L^{CF} or y_M^{CF} is observed, where the superscript CF stands for committing to firing.

Under the Program P-full, the shareholders minimize the expected compensation cost subject to the following constraints. Constraint (2.16) ensures it is rational for the incumbent to accept the contract. Constraints (2.17) - (2.20) ensure the incumbent exerts high efforts in period 1 and in period 2 when y_M^{full} or y_H^{full} is observed. Constraints (2.21) and (2.22) solve the single-period contract offered to the new manager when signal y_L^{full} is observed.

Program P-full

$$\underset{s(\cdot),s^N(\cdot)\geq 0}{Minimize} \quad [gr_L + (1-g)\,p_L]\left[s\left(y_L^{full}\right) + S_{new}^{full}\right] + \sum_{i=M}^{H}\sum_{j=L,M}^{H}\left[g\,r_i\,r_j\; + (1-g)\;p_i\,p_j\right] s\left(y_i^{full}, X_{i+j}\right)$$

Subject to

$$U^{full}\left[s\left(y_L^{full}\right),\, s\left(y_i^{full},\, X_{i+j}\right),\, a_H,\, a_H\right] \geq 0; \tag{2.16}$$

$$\left[Pr\left(G|y_M^{full},a_H\right)\sum_{j=L,M}^{H}r_j+Pr\left(B|y_M^{full},a_H\right)\sum_{j=L,M}^{H}p_j\right]s\left(y_M^{full},X_{M+j}\right)-a_H\geq\sum_{j=L,M}^{H}q_j s\left(y_M^{full},X_{M+j}\right);\tag{2.17}$$

$$\left[Pr\left(G|y_H^{full},a_H\right)\sum_{j=L,M}^{H}r_j+Pr\left(B|y_H^{full},a_H\right)\sum_{j=L,M}^{H}p_j\right]s\left(y_H^{full},X_{H+j}\right)-a_H\geq\sum_{j=L,M}^{H}q_j s\left(y_H^{full},X_{H+j}\right);\tag{2.18}$$

$$U^{full}\left[s\left(y_L^{full}\right),\,s\left(y_i^{full},\,X_{i+j}\right),\,a_H,\,a_H\right]\geq U^{full}\left[s\left(y_L^{full}\right),\,s\left(y_i^{full},\,X_{i+j}\right),\,a_L,\,a_H\right];\tag{2.19}$$

$$U^{full}\left[s\left(y_L^{full}\right),\,s\left(y_i^{full},\,X_{i+j}\right),\,a_H,\,a_H\right]\geq U^{full}\left[s\left(y_L^{full}\right),\,s\left(y_i^{full},\,X_{i+j}\right),\,a_L,\,a_L\right];\tag{2.20}$$

$$S_{new}^{full}-a_H=\sum_{j=L,M}^{H}\left[gr_j+(1-g)\,p_j\right]s^N\left(X_{L+j};y_L^{full}\right)-a_H\geq 0;\tag{2.21}$$

$$\sum_{j=L,M}^{H}\left[gr_j+(1-g)\,p_j\right]s^N\left(X_{L+j};y_L^{full}\right)-a_H\geq\sum_{j=L,M}^{H}q_j s^N\left(X_{L+j};y_L^{full}\right);\tag{2.22}$$

where $U^{full}\left[s\left(y_L^{full}\right),\,s\left(y_i^{full},\,X_{i+j}\right),\,a_1,\,a_2\right]$ denotes the incumbent manager's expected utility over two periods and is written as

$$\begin{aligned}U^{full}[\cdot]=&\sum_{\theta=G}^{B}Pr\left(\theta\right)\,Pr\left(x_L|\theta,\,a_1\right)\,s\left(y_L^{full}\right)\\&+\sum_{\theta=G}^{B}\sum_{i=M}^{H}\sum_{j=L,\,M}^{H}Pr\left(\theta\right)Pr\left(x_i|\theta,\,a_1\right)Pr\left(x_j|\theta,\,a_2\right)\,\left[s\left(y_i^{full},\,X_{i+j}\right)-a_2\right]-a_1.\end{aligned}$$

The binding nonnegativity constraints include $s\left(y_L^{full}\right)=s^N\left(X_{L+L};y_L^{full}\right)=s^N\left(X_{L+M};y_L^{full}\right)=0$; and $s\left(y_M^{full},\,X_{M+L}\right)=s\left(y_M^{full},\,X_{M+M}\right)=s\left(y_H^{full},\,X_{H+L}\right)=s\left(y_H^{full},\,X_{H+M}\right)=0$. Also, constraint (2.22) is binding, and we solve

$$s^N\left(X_{L+H};y_L^{full}\right)=\frac{a_H}{gr_H+(1-g)\,p_H-q_H}.\tag{2.23}$$

Similarly, constraint (2.17) is binding, and since $r_M = p_M$,we solve

$$s\left(y_M^{full}, X_{M+H}\right) = \frac{a_H}{gr_H + (1-g)\,p_H - q_H}. \tag{2.24}$$

It is readily to check that constraint (2.18) is dominated by (2.19). If constraint (2.19) binds, the payment to the incumbent manager is

$$\begin{aligned} s\left(y_H^{full},\, X_{H+H}\right) \equiv B_1 \;&=\; \frac{[g\,(q_M - r_M)\,r_H + (1-g)\,(q_M - p_M)\,p_H]\,s\left(y_M^R, X_{M+H}\right)}{g\,r_H\;(r_H - q_H) + (1-g)\,p_H\;(p_H - q_H)} \\ &+\; \frac{[g\,(1-r_L) + (1-g)\,(1-p_L) + q_L]\,a_H}{g\,r_H\;(r_H - q_H) + (1-g)\,p_H\;(p_H - q_H)}. \end{aligned} \tag{2.25}$$

If constraint (2.20) binds, the payment is

$$s\left(y_H^{full},\, X_{H+H}\right) \equiv B_2 = \frac{[q_M q_H - g r_M r_H - (1-g)\,p_M p_H]\,s_{M+H}^R + [g\,(2-r_L) + (1-g)\,(2-p_L)]\,a_H}{g\,r_H\,r_H + (1-g)\;p_H\,p_H - q_H\,q_H}. \tag{2.26}$$

Therefore, the optimal payment $s\left(y_H^{full},\, X_{H+H}\right)$ depends on which of the two constraints, (2.25) and (2.26), binds, that is, $s\left(y_H^{full},\, X_{H+H}\right) = max\,\{B_1,\, B_2\}$.

Under the Program P-CF, the shareholders commit to firing the manager when y_L^{CF} or y_M^{CF} is reported; and minimize the expected compensation cost subject to the following constraints. Constraint (2.27) ensures it is rational for the incumbent to accept the contract. Constraints (2.28) - (2.30) ensure the incumbent exerts high efforts in period 1 and in period 2 when y_H^{CF} is observed. Constraints (2.31), (2.32), and (2.33) solve the single-period contract offered to the new manager when signal y_L^{CF} or y_M^{CF} is observed.

Program P-CF

$$\begin{aligned} \underset{s(\cdot),s^N(\cdot)\geq 0}{Minimize} \;\; \sum_{i=L}^{M} \; &[gr_i + (1-g)\,p_i]\left[s\left(y_i^{CF}\right) + S_{new}^{CF}\right] \\ &+ \sum_{j=L,M}^{H} [g\,r_H\,r_j \;+ (1-g)\;p_H\,p_j]\,s\left(y_H^{CF}, X_{H+j}\right) \end{aligned}$$

Subject to

$$U^{CF}\left[s\left(y_L^{CF}\right), s\left(y_M^{CF}\right), s\left(y_H^{CF}, X_{H+j}\right), a_H, a_H\right] \geq 0; \tag{2.27}$$

$$U^{CF}\left[s\left(y_L^{CF}\right), s\left(y_M^{CF}\right), s\left(y_H^{CF}, X_{H+j}\right), a_H, a_H\right] \geq U^{CF}\left[s\left(y_L^{CF}\right), s\left(y_M^{CF}\right), s\left(y_H^{CF}, X_{H+j}\right), a_H, a_L\right]; \tag{2.28}$$

$$U^{CF}\left[s\left(y_L^{CF}\right), s\left(y_M^{CF}\right), s\left(y_H^{CF}, X_{H+j}\right), a_H, a_H\right] \geq U^{CF}\left[s\left(y_L^{CF}\right), s\left(y_M^{CF}\right), s\left(y_H^{CF}, X_{H+j}\right), a_L, a_H\right]; \tag{2.29}$$

$$U^{CF}\left[s\left(y_L^{CF}\right), s\left(y_M^{CF}\right), s\left(y_H^{CF}, X_{H+j}\right), a_H, a_H\right] \geq U^{CF}\left[s\left(y_L^{CF}\right), s\left(y_M^{CF}\right), s\left(y_H^{CF}, X_{H+j}\right), a_L, a_L\right]; \tag{2.30}$$

$$S_{new}^{CF} - a_H = \sum_{j=L,\,M}^{H} \left[g\, r_j + (1-g)\, p_j\right]\, s^N\left(X_{i+j}; y_i^{CF}\right) - a_H \geq 0, \text{ for } i = L, M; \tag{2.31}$$

$$\sum_{j=L,M}^{H} \left[g r_j + (1-g)\, p_j\right] s^N\left(X_{L+j}; y_L^{CF}\right) - a_H \geq \sum_{j=L,M}^{H} q_j s^N\left(X_{L+j}; y_L^{CF}\right); \tag{2.32}$$

$$\sum_{j=L,M}^{H} \left[g r_j + (1-g)\, p_j\right] s^N\left(X_{M+j}; y_M^{CF}\right) - a_H \geq \sum_{j=L,M}^{H} q_j s^N\left(X_{M+j}; y_M^{CF}\right); \tag{2.33}$$

where $U^{CF}\left[s\left(y_L^{CF}\right), s\left(y_M^{CF}\right), s\left(y_H^{CF}, X_{H+j}\right), a_1, a_2\right]$ denotes the incumbent manager's expected utility over two periods and is written as

$$\begin{aligned} U^{CF}[\cdot] = & \sum_{\theta=G}^{B} \sum_{i=L}^{M} Pr(\theta)\; Pr(x_i|\theta, a_1)\; s\left(y_i^{CF}\right) \\ & + \sum_{\theta=G}^{B} \sum_{j=L,\,M}^{H} Pr(\theta)\, Pr(x_H|\theta, a_1)\, Pr(x_j|\theta, a_2)\; \left[s\left(y_H^{CF}, X_{H+j}\right) - a_2\right] - a_1. \end{aligned}$$

The binding nonnegativity constraints include $s\left(y_i^{CF}\right) = s^N\left(X_{i+j}; y_i^{CF}\right) = 0$, for $i, j = \{L, M\}$; and $s\left(y_H^{CF}, X_{H+L}\right) = s\left(y_H^{CF}, X_{H+M}\right) = 0$. Also, constraint (2.32) and (2.33) are binding, and we solve

$$s^N\left(X_{L+H}; y_L^{CF}\right) = s^N\left(X_{M+H}; y_M^{CF}\right) = \frac{a_H}{gr_H + (1-g)\,p_H - q_H}. \tag{2.34}$$

For the incumbent manager, the IC constraints (2.28) and (2.30) are dominated by (2.29). Thus, constraint (2.29) binds and determines the payment $s\left(y_H^{CF}, X_{H+H}\right)$ as

$$s\left(y_H^{CF}, X_{H+H}\right) = \left[\frac{g\,(1+r_H) + (1-g)\,(1+p_H) - q_H}{g\,r_H\;(r_H - q_H) + (1-g)\;p_H\;(p_H - q_H)}\right] a_H. \tag{2.35}$$

Clearly, Program P-CF and Program P-R have the same objective functions, and all payments are the same except for $s\left(y_H^{\delta}, X_{H+H}\right)$. Thus, we proceed to show that $s\left(y_H^{CF}, X_{H+H}\right) < s\left(y_H^{full}, X_{H+H}\right) = max\left\{B_1, B_2\right\}$ (defined in (2.25) and (2.26) under the Program P-full). That is to show that one of the following two results, $s\left(y_H^{CF}, X_{H+H}\right) < B_1$ or $s\left(y_H^{CF}, X_{H+H}\right) < B_2$. It is easier to show $s\left(y_H^{CF}, X_{H+H}\right) < B_1$.

If, constraint (2.19) binds so that $s\left(y_H^{full}, X_{H+H}\right) = B_1$ (defined in (2.25)) under the Program P-full. Also, plug in $s_{M+H}^{full} = \frac{a_H}{gr_H + (1-g)p_H - q_H}$, we compare B_1 in (2.25) with $s\left(y_H^{CF}, X_{H+H}\right)$ in (2.35). Note that, the denominators are the same, so that we proceed to compare the numerator.

$$\begin{aligned}
\Delta &= \left[g\,(q_M - r_M)\,r_H + (1-g)\,(q_M - p_M)\,p_H\right] s\left(y_M^R, X_{M+H}\right) - \left[q_M - gr_M - (1-g)\,p_M\right] a_H \\
&= \frac{\left[g\,(q_M - r_M)\,r_H + (1-g)\,(q_M - p_M)\,p_H\right] a_H}{gr_H + (1-g)\,p_H - q_H} - \left[q_M - gr_M - (1-g)\,p_M\right] a_H \\
&\quad \text{(Recall that } r_M = p_M\text{)} \\
&= \frac{q_H\,(q_M - r_M)}{gr_H + (1-g)\,p_H - q_H} a_H > 0.
\end{aligned}$$

The last inequality holds because $r_M = p_M < q_M$. Therefore, $B_1 > s\left(y_H^{CF}, X_{H+H}\right)$.

If, constraint (2.20) binds so that $s\left(y_H^{full},\, X_{H+H}\right) = B_2$ (as defined in (2.26)) under the Program P-full. Then, by definition, $B_2 > B_1$, thus $B_2 > s\left(y_H^{CF},\, X_{H+H}\right)$.

Therefore, when $r_M = p_M < q_M$, $s\left(y_H^{CF},\, X_{H+H}\right) < s\left(y_H^{full},\, X_{H+H}\right)$, so that the shareholders prefer committing ex ante to firing the incumbent manager when y_M is reported, because it results in higher expected shareholders' payoff.

Proof of Proposition 3

Under either y^C or y^A, the shareholders always optimally fire the incumbent whenever a low signal is observed. The two systems differ when $x_1 = x_M$: the manager is retained under y^C whereas the manager is fired under y^A. We first solve for the optimal contracts under both systems then compare the expected compensation costs.

When y^A is in place, the shareholders minimize the expected compensation cost subject to the following constraints. Constraint (2.36) ensures that it is rational for the incumbent to accept the contract. Constraints (2.37) - (2.39) ensure that the incumbent exerts high efforts in period 1 and in period 2 when y_H^A is observed. Constraints (2.40) and (2.41) solve the single-period contract offered to the new manager when signal y_L^A is observed.

Program P-A

$$\begin{array}{ll} \underset{s(\cdot),\, s^N(\cdot)\geq 0}{Minimize} & \sum_{i=L}^{M}\left[g\, r_i + (1-g)\, p_i\right]\left[s\left(y_L^A\right) + S_{new}^A\right] \\ & + \sum_{j=L,\, M}^{H}\left[g\, r_H\, r_j + (1-g)\, p_H\, p_j\right] s\left(y_H^A,\, X_{H+j}\right) \end{array}$$

Subject to

$$U^A\left[s\left(y_L^A\right),\, s\left(y_H^A,\, X_{H+j}\right),\, a_H,\, a_H\right] \geq 0; \tag{2.36}$$

$$U^A\left[s\left(y_L^A\right),\, s\left(y_H^A,\, X_{H+j}\right),\, a_H,\, a_H\right] \geq U^A\left[s\left(y_L^A\right),\, s\left(y_H^A,\, X_{H+j}\right),\, a_H,\, a_L\right]; \tag{2.37}$$

$$U^A\left[s\left(y_L^A\right),\, s\left(y_H^A,\, X_{H+j}\right),\, a_H,\, a_H\right] \geq U^A\left[s\left(y_L^A\right),\, s\left(y_H^A,\, X_{H+j}\right),\, a_L,\, a_H\right]; \tag{2.38}$$

$$U^A\left[s\left(y_L^A\right),\, s\left(y_H^A,\, X_{H+j}\right),\, a_H,\, a_H\right] \geq U^A\left[s\left(y_L^A\right),\, s\left(y_H^A,\, X_{H+j}\right),\, a_L,\, a_L\right]; \tag{2.39}$$

$$S^A_{new} - a_H = \sum_{i=L}^{M} Pr\left(x_i|y^A_L\right) \sum_{j=L,\,M}^{H} \left[p_j + g\ (r_j - p_j)\right]\ s^N\left(X_{i+j}\right) - a_H \geq 0; \tag{2.40}$$

$$\sum_{i=L}^{M} Pr\left(x_i|y^A_L\right) \sum_{j=L,\,M}^{H} \left[p_j + g\ (r_j - p_j)\right]\ s^N\left(X_{i+j}\right) - a_H \geq \sum_{i=L}^{M} Pr\left(x_i|y^A_L\right) \sum_{j=L,\,M}^{H} q_j\, s^N\left(X_{i+j}\right); \tag{2.41}$$

where $U^A\left[s\left(y^A_L\right),\ s\left(y^A_H,\ X_{H+j}\right),\ a_1,\ a_2\right]$ denotes the incumbent manager's expected utility over two periods and is written as

$$\begin{aligned} U^A[\cdot] = &\sum_{\theta=G}^{B} \sum_{i=L}^{M} Pr\left(\theta\right)\ Pr\left(x_i|\theta,\ a_1\right)\ s\left(y^A_L\right) \\ &+ \sum_{\theta=G}^{B} \sum_{j=L,\,M}^{H} Pr\left(\theta\right) Pr\left(x_H|\theta,\ a_1\right) Pr\left(x_j|\theta,\ a_2\right)\ \left[s\left(y^A_H,\ X_{H+j}\right) - a_2\right] - a_1. \end{aligned}$$

The binding nonnegativity constraints on payments include $s\left(y^A_L\right) = s^N\left(X_{L+L}; y^A_L\right) = s^N\left(X_{L+M}; y^A_L\right) = s^N\left(X_{M+L}; y^A_L\right) = s^N\left(X_{M+M}; y^A_L\right) = 0$; and $s\left(y^A_H,\ X_{H+L}\right) = s\left(y^A_H,\ X_{H+M}\right) = 0$. In the second period when a new manager is hired, the shareholders can perfectly infer whether a high output is realized from X_{L+H} or X_{M+H} and therefore set $s^N\left(X_{L+H};\ y^A_L\right) = s^N\left(X_{M+H};\ y^A_L\right)$. The IC constraint (2.41) is binding and we solve

$$s^N\left(X_{L+H};\ y^A_L\right) = s^N\left(X_{M+H};\ y^A_L\right) = \frac{a_H}{g\ (r_H - p_H) + p_H - q_H}. \tag{2.42}$$

For the incumbent manager, the IC constraints (2.37) and (2.39) are dominated by (2.38). Thus, constraint (2.38) binds and determines the payment $s\left(y^A_H,\ X_{H+H}\right)$ as

$$s\left(y^A_H,\ X_{H+H}\right) = \left[\frac{1 - q_H + p_H + g\ (r_H - p_H)}{g\, r_H\ (r_H - q_H) + (1-g)\ p_H\ (p_H - q_H)}\right] a_H. \tag{2.43}$$

The expected compensation cost under Program P-A can now be written as

$$\begin{aligned} Obj^A \;&= [g\;(1-r_H)+(1-g)\;(1-p_H)]\,[g\,r_H+(1-g)\;p_H]\left[s^N\left(X_{L+H};\,y_L^A\right)\right] \\ &\quad +[g\,r_H\,r_H+(1-g)\;p_H\,p_H]\;s\left(y_H^A,\,X_{H+H}\right). \end{aligned} \tag{2.44}$$

Under y^C, the shareholders minimizes the expected compensation cost subject to the following constraints. Constraint (2.45) ensures that it is rational for the incumbent to accept the contract. Constraints (2.46) - (2.48) ensure that the incumbent exerts high efforts in period 1 and in period 2 when y_H^C is observed. Constraints (2.49) and (2.50) solve the single-period contract offered to the new manager when y_L^C is observed.

Program P-C

$$\begin{aligned} \underset{s(\cdot),\,s^N(\cdot)\geq 0}{Minimize} \quad & [g\,r_L+(1-g)\;p_L]\left[s\left(y_L^C\right)+S_{new}^C\right] \\ & +\textstyle\sum_{i=M}^{H}\sum_{j=L,\,M}^{H}[g\,r_i\,r_j+(1-g)\;p_i\,p_j]\,s\left(y_H^C,\,X_{i+j}\right) \end{aligned}$$

Subject to

$$U^C\left[s\left(y_L^C\right),\,s\left(y_H^C,\,X_{i+j}\right),\,a_H,\,a_H\right]\geq 0; \tag{2.45}$$

$$U^C\left[s\left(y_L^C\right),\,s\left(y_H^C,\,X_{i+j}\right),\,a_H,\,a_H\right]\geq U^C\left[s\left(y_L^C\right),\,s\left(y_H^C,\,X_{i+j}\right),\,a_H,\,a_L\right]; \tag{2.46}$$

$$U^C\left[s\left(y_L^C\right),\,s\left(y_H^C,\,X_{i+j}\right),\,a_H,\,a_H\right]\geq U^C\left[s\left(y_L^C\right),\,s\left(y_H^C,\,X_{i+j}\right),\,a_L,\,a_H\right]; \tag{2.47}$$

$$U^C\left[s\left(y_L^C\right),\,s\left(y_H^C,\,X_{i+j}\right),\,a_H,\,a_H\right]\geq U^C\left[s\left(y_L^C\right),\,s\left(y_H^C,\,X_{i+j}\right),\,a_L,\,a_L\right]; \tag{2.48}$$

$$S_{new}^C-a_H=\sum_{j=L,\,M}^{H}[p_j+g\;(r_j-p_j)]\;s^N\left(X_{L+j}\right)-a_H\geq 0; \tag{2.49}$$

$$\sum_{j=L,\,M}^{H}[p_j+g\;(r_j-p_j)]\;s^N\left(X_{L+j}\right)-a_H\geq\sum_{j=L,\,M}^{H}q_j\,s^N\left(X_{L+j}\right); \tag{2.50}$$

where $U^C\left[s\left(y_L^C\right),\,s\left(y_H^C,\,X_{i+j}\right),\,a_1,\,a_2\right]$ denotes the incumbent manager's expected utility

over two periods and is written as

$$U^C[\cdot] = \sum_{\theta=G}^{B} Pr(\theta)\ Pr(x_L|\theta,\, a_1)\ s\left(y_L^C\right)$$
$$+\sum_{\theta=G}^{B}\sum_{i=M}^{H}\sum_{j=L,\,M}^{H} Pr(\theta)\, Pr(x_i|\theta,\, a_1)\, Pr(x_j|\theta,\, a_2)\ \left[s\left(y_H^C,\, X_{i+j}\right) - a_2\right] - a_1.$$

The binding nonnegativity constraints on payments include $s\left(y_L^C\right) = s^N\left(X_{L+L}; y_L^C\right) = s^N\left(X_{L+M}; y_L^C\right) = 0$; $s\left(y_H^C,\, X_{M+H}\right) = 0$; and $s\left(y_H^C,\, X_{i+L}\right) = s\left(y_H^C,\, X_{i+M}\right) = 0$ $for\ i = M\ or\ H$. In the second period when a new manager is hired, the shareholders make an incentive pay as long as a high output is inferred; as a result, constraint (2.50) binds and determines payment $s^N\left(X_{L+H}; y_L^C\right)$ as:

$$s^N\left(X_{L+H};\, y_L^C\right) = \frac{a_H}{g\ (r_H - p_H) + p_H - q_H}. \tag{2.51}$$

The IC constraint (2.46) is dominated by (2.47). If constraint (2.47) binds, the payment to the incumbent manager is

$$s\left(y_H^C,\, X_{H+H}\right) = \left[\frac{g\ (1-r_L) + (1-g)\ (1-p_L) + q_L}{g\, r_H\ (r_H - q_H) + (1-g)\, p_H\ (p_H - q_H)}\right] a_H \equiv D_1. \tag{2.52}$$

If constraint (2.48) binds, the payment is

$$s\left(y_H^C,\, X_{H+H}\right) = \left[\frac{1 + g\ (1-r_L) + (1-g)\ (1-p_L)}{g\, r_H\, r_H + (1-g)\ p_H\, p_H - q_H\, q_H}\right] a_H \equiv D_2. \tag{2.53}$$

Therefore, the optimal payment $s\left(y_H^C,\, X_{H+H}\right)$ depends on which of the two constraints, (2.47) and (2.48), binds, that is, $s\left(y_H^C,\, X_{H+H}\right) = max\left\{D_1,\, D_2\right\}$. The expected compensation cost under Program P-C can now be written as

$$Obj^C = [g\, r_L + (1-g)\ p_L]\,[g\, r_H + (1-g)\ p_H]\left[s^N\left(X_{L+H};\, y_L^C\right)\right]$$
$$+\,[g\, r_H\, r_H + (1-g)\ p_H\, p_H]\ s\left(y_H^C,\, X_{H+H}\right). \tag{2.54}$$

We proceed to compare the objective function values of Program P-A and P-C. Comparing (2.44) and (2.54), the difference is written as

$$\begin{aligned}\Delta Obj &= Obj^A - Obj^C \\ &= [g\, r_M + (1-g)\; p_M]\, \tfrac{[g\, r_H + (1-g)\, p_H] a_H}{g\,(r_H - p_H) + p_H - q_H} \\ &+ [g\, r_H\, r_H + (1-g)\; p_H\, p_H]\; \left[s\left(y_H^A,\, X_{H+H}\right) - s\left(y_H^C,\, X_{H+H}\right)\right]. \end{aligned} \tag{2.55}$$

The first term in (2.55) is the expected incentive pay the shareholders need to pay to the new agent due to more frequent firing under y^A (note $s^N\left(X_{L+H};\, y_L^A\right) = s^N\left(X_{L+H};\, y_L^C\right)$); while the second term is the difference in expected compensation cost to the incumbent manager between the two systems. It remains to show that the expression in (2.55) is positive. There are two cases depending on which IC constraint binds under Program P-C.

Case 1: Constraint (2.47) binds so that $s\left(y_H^C,\, X_{H+H}\right) = D_1$ (defined in (2.52)) under y^C. In this case, (2.55) is written as

$$\begin{aligned}\Delta Obj &= [g\, r_M + (1-g)\; p_M]\, \tfrac{[g\, r_H + (1-g)\, p_H] a_H}{g\,(r_H - p_H) + p_H - q_H} \\ &+ [g\, r_H\, r_H + (1-g)\; p_H\, p_H]\; \left[\tfrac{q_M - g\, r_M - (1-g)\, p_M}{g\, r_H\,(r_H - q_H) + (1-g)\, p_H\,(p_H - q_H)}\right]\; a_H > 0. \end{aligned} \tag{2.56}$$

Some algebraic manipulations yield that inequality (2.56) holds for $q_M = 0$:

$$\begin{aligned} &Sign\,[\Delta Obj] \\ &= Sign\left\{\frac{g\, r_H + (1-g)\; p_H}{g\;(r_H - p_H) + p_H - q_H} - \frac{g\, r_H\, r_H + (1-g)\; p_H\, p_H}{g\, r_H\;(r_H - q_H) + (1-g)\, p_H\;(p_H - q_H)}\right\} \\ &= Sign\left\{g\;(r_H - q_H)\;(1-g)\;p_H - (1-g)\;(p_H - q_H)\;g\, r_H\right\} \\ &= Sign\left\{q_H\;(r_H - p_H)\right\} > 0. \end{aligned}$$

When $q_M = 0$, the expected pay to the incumbent manager is less under y^A than under y^C— the second term in (2.56) is negative. The inequality (2.56) indicates that the incumbent

manager is paid less due to more frequent firing under an aggressive system than under a conservative system; however such benefit is overweighted by the increase in expected incentive pay offered to the new manager. As a result, a conservative system is preferred. As for $q_M > 0$, the expected pay for the incumbent manager under y^A increases while all else remains unaffected, the aggressive system becomes even less appealing (that is, the inequality in (2.56) holds for all $q_M > 0$).

Case 2: Constraint (2.48) binds so that $s\left(y_H^C,\, X_{H+H}\right) = D_2$ (as defined in (2.53)) under y^C.

Under y^A, if we relax constraints (2.46) and (2.47), the payment $s\left(y_H^A,\, X_{H+H}\right)$ can be determined by constraint (2.48) and written as

$$\tilde{s}\left(y_H^A,\, X_{H+H}\right) = \left[\frac{1 + g r_H + (1-g)\, p_H}{g\, r_H\, r_H + (1-g)\; p_H\, p_H - q_H\, q_H}\right]\; a_H. \tag{2.57}$$

From (2.44), the expected compensation cost with (2.43) is higher than the expected compensation cost with (2.57) as long as

$$s\left(y_H^A,\, X_{H+H}\right) > \tilde{s}\left(y_H^A,\, X_{H+H}\right). \tag{2.58}$$

The constraint (2.38) dominates (2.39) so that the payment $\tilde{s}\left(y_H^A,\, X_{H+H}\right)$ does not satisfy constraint (2.38) while the payment $s\left(y_H^A,\, X_{H+H}\right)$ satisfies constraint (2.39). As a result, (2.44) is higher with payment $s\left(y_H^A,\, X_{H+H}\right)$ than with payment $\tilde{s}\left(y_H^A,\, X_{H+H}\right)$. It now remains to show the difference in expected compensation cost in (2.55) is positive when we substitute $\tilde{s}\left(y_H^A,\, X_{H+H}\right)$ and D_2. (2.55) is written as

$$\begin{aligned}\Delta Obj \;\; &= \left[g\, r_M + (1-g)\; p_M\right] \tfrac{\left[g\, r_H + (1-g)\, p_H\right] a_H}{g\,(r_H - p_H) + p_H - q_H} \\ &\quad - \left[g\, r_H\, r_H + (1-g)\; p_H\, p_H\right] \left[\tfrac{g\, r_M + (1-g)\, p_M}{g\, r_H\, r_H + (1-g)\, p_H\, p_H - q_H\, q_H}\right]\; a_H > 0.\end{aligned} \tag{2.59}$$

The inequality in (2.59) states that the expected compensation cost of Program P-C is

less than that of P-A with payment $\tilde{s}\left(y_H^A,\, X_{H+H}\right)$, the latter is less than the expected compensation cost of P-A with payment $s\left(y_H^A,\, X_{H+H}\right)$.

Proof of Proposition 4

With little abuse of notation, we denote the expected total rent by S^{δ}.

Conservative system: as shown in the proof of Proposition 3, the optimal contract of the new manager under the conservative system is as follows:

$$s^N\left(X_{L+L}; y_L^C\right) = s^N\left(X_{L+M}; y_L^C\right) = 0, \text{ and } s^N\left(X_{L+H}; y_L^C\right) = \frac{a_H}{gr_H + (1-g)p_H - q_H}.$$

Thus, the expected total incentive pay of the new manager is

$$S_{new} = \frac{\left[gr_H + (1-g)p_H\right] a_H}{gr_H + (1-g)p_H - q_H}. \tag{2.60}$$

Also, as shown in (2.52) and (2.53), the optimal contract of the incumbent under the conservative system is as follows:

$$s\left(y_L^C\right) = s\left(y_H^C, X_{M+j}\right) = s\left(y_H^C, X_{H+L}\right) = s\left(y_H^C, X_{H+M}\right) = 0, \text{ for } j = L,\ M,\ H; \text{ and}$$

$$\begin{aligned} & s\left(y_H^C, X_{H+H}\right) \\ =& max\left\{ \frac{\left[g\left(1-r_L\right) + (1-g)\left(1-p_L\right) + q_L\right] a_H}{gr_H\left(r_H - q_H\right) + (1-g)p_H\left(p_H - q_H\right)} \equiv D_1, \frac{\left[1 + g\left(1-r_L\right) + (1-g)\left(1-p_L\right)\right] a_H}{gr_H r_H + (1-g)p_H p_H - q_H q_H} \equiv D_2 \right\}. \end{aligned}$$

Thus, the expected total incentive pay under the conservative system is

$$S^C \;=\; \left[gr_H r_H + (1-g)p_H p_H\right] s\left(y_H^C, X_{H+H}\right) + \left[gr_L + (1-g)\, p_L\right] S_{new}. \tag{2.61}$$

Null system: there is no information revealed at the end of the first period, so that the shareholders always retain the incumbent. Thus the program is the same as Program PN-null in the proof of Proposition 1. The nonnegativity constraints on payments when $X \neq 2x_H$ is realized are binding, Also, it is readily to check that, the IC constraints (2.9) and (2.10) are dominated by the IC constraint (2.11). Thus, the optimal contract under the null system is as follows:

$$s\left(X_{i+j}\right) = s\left(X_{H+L}\right) = s\left(X_{H+M}\right) = 0, \text{ for } i = L,\ M \text{ and } j = L,\ M,\ H; \text{ and}$$

$$s\left(X_{H+H}\right) = \frac{2a_H}{gr_H r_H + (1-g)p_H p_H - q_H q_H}.$$

Thus, the expected total incentive pay under the null system is

$$S^{null} = \left[gr_H r_H + (1-g)p_H p_H\right]\ s\left(X_{H+H}\right). \tag{2.62}$$

Next, we compare S^{null} in (2.62) with S^C in (2.61).

Note that, $s\left(y_H^C, X_{H+H}\right) = max\left\{D_1, D_2\right\}$, where $D_1 \equiv \frac{[g(1-r_L)+(1-g)(1-p_L)+q_L]a_H}{gr_H(r_H-q_H)+(1-g)p_H(p_H-q_H)}$ and $D_2 \equiv \frac{[1+g(1-r_L)+(1-g)(1-p_L)]a_H}{gr_H r_H+(1-g)p_H p_H-q_H q_H}$.

When $D_2 \geq D_1$, $\left(\text{the binding constraint is } (a_H; a_H) \succeq (a_L; a_L),\ s\left(y_H^C, X_{H+H}\right) = D_2\right)$, it is straightforward to derive

$$S^C - S^{null} = \frac{(1-g)\,p_H\left(r_H^2 - p_H q_H\right) + gr_H^2\left(r_H - q_H\right)\left[gr_L + (1-g)\,p_L\right]}{(1-g)\left[gr_H + (1-g)\,p_H - q_H\right]\left(r_H^2 - p_H^2\right)} a_H > 0.$$

The last inequality always holds because $r_H > p_H > q_H$. In addition, $s\left(y_H^C, X_{H+H}\right) = max\left\{D_1, D_2\right\} \geq D_2$; thus, it is obvious that, $S^C > S^{null}$.

Proof of Proposition 5

First, we consider the case in which $r_M \geq p_M$, the shareholders replace the incumbent if and only if y_L^{full} is realized. Clearly, the replacement decision under the full revealing system

is the same as that under the conservative system.

Similar to the proof of Proposition 1, Program under the conservative system (Program P-C) can be revised by expanding the contract from $s\left(y^C, x_i + x_j\right)$ to $s\left(y^{full}, x_i + x_j\right)$ while imposing the following an additional constraint:

$$s\left(y_M^{full}, x_M + x_H\right) = s\left(y_H^{full}, x_H + x_M\right).$$

This constraint is dominated by the binding nonnegativity constraints $s\left(y_H^C, x_M + x_H\right) = s\left(y_H^C, x_H + x_M\right) = 0$ and therefore the revised Program P-C is equivalent to the original Program P-C. Also, it is readily to check that both programs have the same objective functions, but the Program P-FR under the fully revealing system has more (binding) constraints than the revised Program P-C. Therefore the compensation cost is higher under y^{full} than under y^C.

Second, we consider the case in which $r_M < p_M$, the shareholders retain the incumbent if and only if y_H^{full} is realized. In this case, it is readily to check that the fully revealing system and the aggressive systems have the same objective functions and the same binding constraints, thus both systems are equivalent in maximizing the shareholders' payoff.

Hence, the fully revealing system is weakly dominated, and it is enough to consider three systems, the null system δ^{null}, the conservative system δ^C, and the aggressive system δ^A.

Proof of Lemma 1

With little abuse of notation, we denote the expected gross output by R^δ. It is straightforward to derive that

$$R_{new} = g \sum_{j=L,M}^{H} r_j x_j + (1-g) \sum_{j=L,M}^{H} p_j x_j;$$

$$R^{null} = 2\left[g \sum_{i=L,M}^{H} r_i x_i + (1-g) \sum_{i=L,M}^{H} p_i x_i\right];$$

$$R^C = (2 - r_L)\, g \sum_{i=L,M}^{H} r_i x_i + (2 - p_L)\,(1 - g) \sum_{i=L,M}^{H} p_i x_i + [g r_L + (1 - g)\, p_L]\, R_{new};$$

$$R^A = (1 + r_H)\, g \sum_{i=L,M}^{H} r_i x_i + (1 + p_H)\,(1 - g) \sum_{i=L,M}^{H} p_i x_i + [g\,(1 - r_H) + (1 - g)\,(1 - p_H)]\, R_{new}.$$

Case 1: $r_M \geq p_M$

First, we show that the conservative system always generates higher expected (gross) output than the null system. Comparing R^C with R^{null}, it is readily to check that

$$R^C - R^{null} = [g r_L + (1 - g)\, p_L]\, R_{new} - g r_L \sum_{j=L,M}^{H} r_j x_j - (1 - g)\, p_L \sum_{j=L,M}^{H} p_j x_j$$

$$= [g r_L + (1 - g)\, p_L] \left[g \sum_{j=L,M}^{H} r_j x_j + (1 - g) \sum p_j x_j \right] - g r_L \sum r_j x_j - (1 - g)\, p_L \sum_{j=L,M}^{H} p_j x_j$$

$$= g\,(1 - g)\,(p_L - r_L) \left[\sum_{j=L,M}^{H} r_j x_j - \sum_{j=L,M}^{H} p_j x_j \right] > 0.$$

The last inequality holds because $r_L < p_L$. Therefore, $R^C > R^{null}$. Similarly, $R^C \geq R^A$. Therefore, when $r_M \geq p_M$, the conservative system generates the highest expected output.

Case 2: $r_M < p_M$

Similarly, it is straightforward to show that, $R^A \geq max\left\{R^C,\, R^{null}\right\}$. That is, when $r_M < p_M$, the aggressive system generates the highest expected output.

Proof of Proposition 6

It is straightforward to show that, with (2.5) holds, $s^{null}_{H+H} > s^C_{H+H}$. In addition, when (2.4) holds,

$$\frac{g r_L}{g r_L + (1 - g)\, p_L} \sum_{j=L,M}^{H} r_j x_j + \frac{(1 - g)\, p_L}{g r_L + (1 - g)\, p_L} \sum_{j=L,M}^{H} p_j x_j - [g r_H r_H + (1 - g) p_H p_H]\, s^{null}_{H+H}$$

$$< R_{new} - S_{new} - [g r_H r_H + (1 - g) p_H p_H]\, s^C_{H+H}.$$

It is straightforward to derive that the inequality above suggests that the shareholder's payoff in the null system is lower than that in the conservative system.

Proof of Proposition 7

Recall that, when $p_M > r_M$, the aggressive system generates higher expected total output than the conservative system, but also pays higher expected rent. Thus, p_M^* is the threshold where the difference in expected total output equals the difference in expected total incentive pay. Clearly, $p_M^* > r_M$ always hold, since, for all $p_M \leq r_M$, the conservative system dominates the aggressive system.

Proof of Corollary 1

Proposition 7 shows that the conservative system dominates the aggressive system when $p_M \in [0,\ p_M^*]$, and $p_M^* > r_M$. Proposition 6 shows that the conservative system dominates the null system when both (2.4) and (2.5) hold. Note that, (2.4) and (2.5) do not set any restriction on the ordering between r_M and p_M, precisely because neither the conservative system nor the null system report y_M. In this case, (2.4) and (2.5) are not conflicting with $p_M < p_M^*$ and $p_M^* > r_M$. Therefore, the conservative system prevails as long as $p_M < p_M^*$ and both (2.4) and (2.5) hold.

Proof of Proposition 8

Case 1: $r_M \geq p_M$

When $r_M \geq p_M$, the fully revealing system retains the incumbent when y_M^{full} is reported, since $Pr\left(G|y_M^{full}, a_H\right) > g$. Thus, both the conservative system and the fully revealing system adopt the same firing/retention decisions, which results in the same expected output. Therefore, we only compare the expected incentive pay. Note that, the manager privately learns x_1, thus the manager's information is not affected by the accounting system, and both IR and IC constraints are exactly the same in both systems. The only difference is that the shareholders cannot distinguish $\left(y_H^C, x_M + x_H\right)$ and $\left(y_H^C, x_H + x_M\right)$ in the conservative system; thus the conservative system has one more binding constraint $s\left(y_H^C, x_M + x_H\right) =$

$s\left(y_H^C, x_H + x_M\right)$. Therefore, the compensation cost is higher under y^C than under y^{full}, and the fully revealing system dominates the conservative system.

Case 2: $r_M < p_M$

When $r_M < p_M$, the fully revealing system fires the incumbent when y_M^{full} is reported, since $Pr\left(G|y_M^{full}, a_H\right) < g$. We first construct a new program, say Program P-M, then we show the fully revealing system dominates Program P-M and Program P-M dominates conservative system.

Step 1. Construct the new program P-M.

Now we construct a new program, say Program P-M under a system y^M so that (a) system y^M is fully-revealing; (b) the shareholders retain the manager if and only if a high signal y_H^M is observed; (c) the new manager is a good fit with probability g if a low signal y_L^M is observed; (d) the new manager is a good fit with probability $Pr\left(G|y_M^M, a_H\right)$ if a medium signal y_M^M is observed; and (e) high effort is always motivated.

Program P-M

$$\underset{s(\cdot),\, s^N(\cdot)\geq 0}{Minimize} \sum_{i=L}^{M} \left[g\, r_i + (1-g)\; p_i\right]\left[s\left(y_i^M\right) + S_{new}\left(y_i^M\right)\right] + \sum_{j=L,\,M}^{H} \left[g\, r_H\, r_j + (1-g)\; p_H\, p_j\right] s\left(y_H^M,\, X_{H+j}\right)$$

Subject to

$$U^M\left[s\left(y_L^M\right),\, s\left(y_M^M\right),\, s\left(y_H^M,\, X_{H+j}\right),\, a_H,\, a_H\right] \geq 0; \tag{2.63}$$

$$U^M\left[s\left(y_L^M\right),\, s\left(y_M^M\right),\, s\left(y_H^M,\, X_{H+j}\right),\, a_H,\, a_H\right] \geq U^M\left[s\left(y_L^M\right),\, s\left(y_M^M\right),\, s\left(y_H^M,\, X_{H+j}\right),\, a_H,\, a_L\right]; \tag{2.64}$$

$$U^M\left[s\left(y_L^M\right),\, s\left(y_M^M\right),\, s\left(y_H^M,\, X_{H+j}\right),\, a_H,\, a_H\right] \geq U^M\left[s\left(y_L^M\right),\, s\left(y_M^M\right),\, s\left(y_H^M,\, X_{H+j}\right),\, a_L,\, a_H\right]; \tag{2.65}$$

$$U^M\left[s\left(y_L^M\right),\, s\left(y_M^M\right),\, s\left(y_H^M,\, X_{H+j}\right),\, a_H,\, a_H\right] \geq U^M\left[s\left(y_L^M\right),\, s\left(y_M^M\right),\, s\left(y_H^M,\, X_{H+j}\right),\, a_L,\, a_L\right]; \tag{2.66}$$

$$S_{new}\left(y_L^M\right) - a_H = \sum_{j=L,\,M}^{H} \left[g\, r_j + (1-g)\; p_j\right]\; s^N\left(X_{L+j}; y_L^M\right) - a_H \geq 0; \tag{2.67}$$

$$\sum_{j=L,\,M}^{H} \left[g\, r_j + (1-g)\; p_j\right]\; s^N\left(X_{L+j}; y_L^M\right) - a_H \geq \sum_{j=L,\,M}^{H} q_j\, s^N\left(X_{L+j}; y_L^M\right); \tag{2.68}$$

$$S_{new}\left(y_M^M\right) - a_H = \sum_{j=L,\,M}^{H} \left[p_j + \frac{g\, r_M}{g\, r_M + (1-g)\; p_M}\; (r_j - p_j)\right]\; s^N\left(X_{M+j}; y_M^M\right) - a_H \geq 0; \tag{2.69}$$

$$\sum_{j=L,\,M}^{H} \left[p_j + \frac{g\, r_M}{g\, r_M + (1-g)\; p_M}\; (r_j - p_j)\right]\; s^N\left(X_{M+j}; y_M^M\right) - a_H \geq \sum_{j=L,\,M}^{H} q_j\, s^N\left(X_{M+j}; y_M^M\right); \tag{2.70}$$

where $U^M\left[s\left(y_L^M\right),\, s\left(y_M^M\right),\, s\left(y_H^M,\, X_{H+j}\right),\, a_1,\, a_2\right]$, for $a_1,\; a_2 \in \{a_H,\, a_L\}$, denotes the incumbent manager's expected utility over two periods and is written as

$$\begin{aligned} U^M[\cdot] = & \sum_{\theta=G}^{B} \sum_{i=L}^{M} Pr(\theta)\; Pr\left(x_i|\theta,\, a_1\right)\; s\left(y_i^M\right) \\ & + \sum_{\theta=G}^{B} \sum_{j=L,\,M}^{H} Pr(\theta)\, Pr\left(x_H|\theta,\, a_1\right) Pr\left(x_j|\theta,\, a_2\right)\; \left[s\left(y_H^M,\, X_{H+j}\right) - a_2\right] - a_1. \end{aligned}$$

In Program P-M, constraint (2.63) ensures that the contract offered to the incumbent is at least her reservation utility; constraints (2.64) - (2.66) ensure that the incumbent exerts high effort in period 1 and in period 2 when signal y_H^M is observed. Constraints (2.67) and (2.68) characterize the single-period contract offered to the new manager when signal y_L^M is observed; while constraints (2.69) and (2.70) characterize the single-period contract offered to the new manager when signal y_M^M is observed.

The binding nonnegativity constraints on payments include $s\left(y_i^M\right) = s^N\left(X_{i+L}; y_i^M\right) = s^N\left(X_{i+M}; y_i^M\right) = 0$, for $i = L$ or M; and $s\left(y_H^M,\, X_{H+L}\right) = s\left(y_H^M,\, X_{H+M}\right) = 0$. Also, IC constraints (2.64) and (2.66) are dominated, so that the IC constraint (2.65) is binding.

Thus we can easily derive that

$$s\left(y_H^M, X_{H+H}\right) = \frac{g\left(1+r_H-q_H\right)+(1-g)\left(1+p_H-q_H\right)}{gr_H\left(r_H-q_H\right)+(1-g)\,p_H\left(p_H-q_H\right)}a_H. \tag{2.71}$$

Step 2. Prove Program P-M dominates fully revealing system in terms of maximizing the shareholders' payoff. Note that, $r_M < p_M$, the fully revealing system fires the incumbent when y_M^{full} is reported, so that the program under fully-revealing system is the same as Program P-CF in the proof of Proposition 2.

We show that (i) the expected total output is higher under Program P-CF than under Program P-M; (ii) the incumbent is paid the same under both systems; and (iii) the new manager is paid less under Program P-CF than under Program P-M.

It is readily to check (i), because $r_M < p_M \Rightarrow Pr\left(G|y_M^{full}, a_H\right) < g$, Program P-M hires a new manager with lower than average ability, so that the expected total output is higher under the Program P-CF than under the Program P-M.

To see (ii), the binding nonnegativity constraints on payments to the incumbent in Program P-M include $s\left(y_L^M\right) = s\left(y_M^M\right) = 0$; and $s\left(y_H^M,\, X_{H+L}\right) = s\left(y_H^M,\, X_{H+M}\right) = 0$. The payment $s\left(y_H^M,\, X_{H+H}\right)$ is determined based on the constraints (2.63) - (2.66) which are identical to constraints (2.28) - (2.30) in Program P-CF. Therefore, $s\left(y_H^M,\, X_{H+H}\right) = s\left(y_H^{CF},\, X_{H+H}\right)$. In Program P-M, the binding nonnegativity constraints on payments to the new manager include $s^N\left(X_{L+L}; y_L^M\right) = s^N\left(X_{L+M}; y_L^M\right) = s^N\left(X_{M+L}; y_M^M\right) = s^N\left(X_{M+M}; y_M^M\right) = 0$. Payment $s^N\left(X_{L+H}; y_L^M\right)$ is determined by the binding constraint constraint (2.68) which is identical to (2.32) in Program P-CF, so that $s^N\left(X_{L+H}; y_L^M\right) = \frac{a_H}{gr_H+(1-g)p_H-q_H}$. Consequently, the incentive cost is identical under both systems if the incumbent manager is retained (when y_H is observed) or if a new manager is hired (when y_L is observed).

Recall that we show constraint (2.33) under Program P-CF is binding, and MLRP ensures

that $s^N\left(y_M^{CF},\, X_{M+H}\right) = \frac{a_H}{gr_H+(1-g)p_H-q_H}$. Thus, the rent of the new manager is

$$S_{new}^{CF} = \frac{[g\, r_H + (1-g)\ p_H]\, a_H}{gr_H + (1-g)\, p_H - q_H}.$$

The binding IC constraint (2.70) combined with $s^N\left(X_{M+j}; y_M^M\right) = 0$, for $j = L,\, M$, determines the payment

$$s^N\left(X_{M+H};\, y_M^M\right) = \frac{(g\, r_M + (1-g)\ p_M)\, a_H}{gr_M\,(r_H - q_H) + (1-g)\,(p_H - q_H)}. \tag{2.72}$$

The incentive cost for the new manager when y_M^M is observed is less under Program P-CF than under Program P-M because the following inequalities must hold:

$$\begin{aligned}
&[g\, r_M + (1-g)\ p_M]\, S_{new}^{CF} - [g\, r_M r_H + (1-g)\ p_M p_H]\, s^N\left(X_{M+H};\, y_M^M\right) \\
=&\frac{[gr_M + (1-g)\, p_M]\,[gr_H + (1-g)\, p_H]\, a_H}{gr_H + (1-g)\, p_H - q_H} - \frac{[gr_M r_H + (1-g)\, p_M p_H]\,[gr_M + (1-g)\, p_M]\, a_H}{gr_M\,(r_H - q_H) + (1-g)\,(p_H - q_H)} \\
=&\,[gr_M + (1-g)\, p_M]\, a_H \frac{(1-g)\, gq_H(p_H - r_H)(p_M - r_M)}{(gr_H + (1-g)\, p_H - q_H)\,(gr_M\,(r_H - q_H) + (1-g)\,(p_H - q_H))} < 0.
\end{aligned}$$

The last inequality holds because $r_H > p_H$ and $r_M < p_M$. Therefore, the fully revealing system strictly dominates the Program P-M in terms of maximizing the shareholders' payoff. Intuitively, both systems have the symmetric firing decision, but Program P-M hires a worse manager after y_M^M is observed. Next, we show that Program P-M dominates the conservative system.

Step 3. Construct the new program P-E, and show that Program P-M dominates Program P-E.

We construct a new program, say Program P-E under a system y^E so that (a) system y^E is conservative; (b) the shareholders can perfectly observe the output in each period at the end of Period 2, meaning the shareholder can distinguish $(x_M + x_H)$ from $(x_H + x_M)$; (c) the shareholder retain the manager if observing y_H^E and fire the manager if observing y_L^E; and (d) high effort is always motivated.

It is clear that Program P-E dominates the conservative system, since the shareholders can distinguish $(x_M + x_H)$ from $(x_H + x_M)$ in Program P-E, while the shareholders should pay $s\left(y_H^C, x_M + x_H\right) = s\left(y_H^C, x_H + x_M\right) > 0$ in the conservative system. Thus, as long as the Program P-M dominates Program P-E, we can show that Program P-M dominates the conservative system.

Program P-E

$$\underset{s(\cdot),\, s^N(\cdot) \geq 0}{\overset{Minimize}{}} \quad [g\, r_L + (1-g)\, p_L]\left[s\left(y_L^E\right) + S_{new}^E\right] + \\ + \sum_{i=M}^{H} \sum_{j=L,\,M}^{H} \left[g\, r_i\, r_j + (1-g)\, p_i\, p_j\right] s\left(y_H^E,\, X_{i+j}\right) \quad (2.73)$$

$$subject \quad to$$

$$U^E\left[s\left(y_L^E\right), s\left(y_H^E,\, X_{M+j}\right),\, s\left(y_H^E,\, X_{H+j}\right),\, a_H,\, a_H\right] \geq 0; \quad (2.74)$$

$$\sum_{j=L,M}^{H} \left[Pr\left(G|x_M, a_H\right) r_j + Pr\left(B|x_M, a_H\right) p_j\right] s\left(y_H^E, X_{M+j}\right) - a_H \geq \sum_{j=L,M}^{H} q_j s\left(y_H^E, X_{M+j}\right); \quad (2.75)$$

$$\sum_{j=L,M}^{H} \left[Pr\left(G|x_H, a_H\right) r_j + Pr\left(B|x_H, a_H\right) p_j\right] s\left(y_H^E, X_{H+j}\right) - a_H \geq \sum_{j=L,M}^{H} q_j s\left(y_H^E, X_{H+j}\right); \quad (2.76)$$

$$U^E\left[s\left(y_L^E\right), s\left(y_H^E,\, X_{M+j}\right),\, s\left(y_H^E,\, X_{H+j}\right),\, a_H,\, a_H\right] \geq U^E\left[s\left(y_L^E\right), s\left(y_H^E,\, X_{M+j}\right),\, s\left(y_H^E,\, X_{H+j}\right),\, a_H,\, a_L\right]; \quad (2.77)$$

$$U^E\left[s\left(y_L^E\right), s\left(y_H^E,\, X_{M+j}\right),\, s\left(y_H^E,\, X_{H+j}\right),\, a_H,\, a_H\right] \geq U^E\left[s\left(y_L^E\right), s\left(y_H^E,\, X_{M+j}\right),\, s\left(y_H^E,\, X_{H+j}\right),\, a_L,\, a_H\right]; \quad (2.78)$$

$$U^E\left[s\left(y_L^E\right), s\left(y_H^E,\, X_{M+j}\right),\, s\left(y_H^E,\, X_{H+j}\right),\, a_H,\, a_H\right] \geq U^E\left[s\left(y_L^E\right), s\left(y_H^E,\, X_{M+j}\right),\, s\left(y_H^E,\, X_{H+j}\right),\, a_L,\, a_L\right]; \quad (2.79)$$

$$S_{new}^E - a_H = \sum_{j=L,\,M}^{H} \left[p_j + g\,\left(r_j - p_j\right)\right] s^N\left(X_{L+j}; y_L^E\right) - a_H \geq 0; \quad (2.80)$$

$$\sum_{j=L,\,M}^{H}\left[p_j+g\,\left(r_j-p_j\right)\right]\,s^N\left(X_{L+j};y_L^E\right)-a_H\geq\sum_{j=L,\,M}^{H}q_j\,s^N\left(X_{L+j};y_L^E\right);\tag{2.81}$$

where $U^E\left[s\left(y_L^E\right),\ s\left(y_H^E,\,X_{M+j}\right),\,s\left(y_H^E,\,X_{H+j}\right),\,a_1,\,a_2\right]$ denotes the incumbent manager's expected utility over two periods and is written as

$$\begin{aligned}U^E\left[\cdot\right]&=\sum_{\theta=G}^{B}Pr\left(\theta\right)\,Pr\left(x_L|\theta,\,a_1\right)\,s\left(y_L^E\right)\\&+\sum_{\theta=G}^{B}\sum_{i=M}^{H}\sum_{j=L,\,M}^{H}Pr\left(\theta\right)Pr\left(x_i|\theta,\,a_1\right)Pr\left(x_j|\theta,\,a_2\right)\,\left[s\left(y_H^E,\,X_{i+j}\right)-a_2\right]-a_1.\end{aligned}$$

Constraint (2.74) ensures that it is rational for the incumbent to accept the contract. Constraints (2.75) - (2.79) ensure that the incumbent exerts high efforts in period 1 and in period 2 if retained.[3] Constraints (2.80) and (2.81) solve the single-period contract offered to the new manager when signal y_L^E is observed.

The binding nonnegativity constraints on payments include $s\left(y_L^E\right)=s^N\left(X_{L+L};y_L^E\right)=s^N\left(X_{L+M};y_L^E\right)=0$; and $s\left(y_H^E,\,X_{i+L}\right)=s\left(y_H^E,\,X_{i+M}\right)=0$, for $i=M$ or H.

Also, constraint (2.75) in Program P-E binds, and we solve

$$s\left(y_H^E,\,X_{M+H}\right)=\frac{a_H\left(gr_M+\left(1-g\right)p_M\right)}{gr_M\left(r_H-q_H\right)+\left(1-g\right)p_M\left(p_H-q_H\right)}.\tag{2.82}$$

Similar to the proof of Proposition 4, it is readily to check that the IC constraints (2.76) and (2.77) are always dominated by constraint (2.78). The optimal solution $s\left(y_H^E,\,X_{H+H}\right)$ depends on which of the two constraints, Constraint (2.78) and (2.79), binding. Thus, $s\left(y_H^E,\,X_{M+H}\right)=max\left\{E_1,E_2\right\}$, where E_1 is the solution when Constraint (2.78) binding, and E_2 is the solution when Constraint (2.79) binding.

Clearly, Program P-M and Program P-E have the same objective functions, and all payments are the same except for $s\left(y_H^\delta,\,X_{H+H}\right)$. Thus, we proceed to show that $s\left(y_H^M,\,X_{H+H}\right)<$

[3]The manager perfectly observes x_1, and thus updates her ability using x_1. Hence, we use $Pr\left(G|x_1,a_H\right)$ in the second-period IC constraints (2.75) and (2.76).

$s\left(y_H^E,\, X_{H+H}\right) = max\left\{E_1,\, E_2\right\}$. That is to show that one of the following two results, $s\left(y_H^M,\, X_{H+H}\right) < E_1$ or $s\left(y_H^M,\, X_{H+H}\right) < E_2$. It is easier to show $s\left(y_H^M,\, X_{H+H}\right) < E_1$.

Note that, E_1 is the solution that makes constraint (2.78) binding. We proceed to show that, with the solution $s\left(y_H^M, X_{H+H}\right)$, IC constraint (2.78) is violated, meaning E_1 should be larger than $s\left(y_H^M, X_{H+H}\right)$ to satisfy the IC constraint (2.78).

Plug the optimal solution $s\left(y_H^E,\, X_{M+H}\right)$ (solved in (2.82) under Program P-E) and $s\left(y_H^M, X_{H+H}\right)$ (solved in (2.71) under Program P-M) into the IC constraint (2.78), it is readily to show that the constraint is violated when $r_M < p_M \leq q_M$. To see this, after plugging in, we move all parameters to the left-hand side (LHS), and we can derive that LHS is

$$
\begin{aligned}
&\left[g\left(r_M - q_M\right) r_H + (1-g)\left(p_M - q_M\right) p_H\right] s\left(y_H^E, X_{M+H}\right) \\
&+ \left[g\left(r_H - q_H\right) r_H + (1-g)\left(p_H - q_H\right) p_H\right] s\left(y_H^M, X_{H+H}\right) \\
&- \left[g\left(1 + r_M + r_H\right) + (1-g)\left(1 + p_M + p_H\right) - \left(q_M + q_H\right)\right] a_H \\
=&\frac{(1-g)^2 p_M q_H \left(p_M - q_M\right) + g^2 q_H r_M \left(r_M - q_M\right)}{g r_M \left(r_H - q_H\right) + (1-g) p_M \left(p_H - q_H\right)} a_H \\
+&\frac{g(1-g)\left(-p_M\left(r_H - p_H + q_H\right) q_M + r_M\left(2 p_M q_H + \left(r_H - p_H - q_H\right) q_M\right)\right)}{g r_M \left(r_H - q_H\right) + (1-g) p_M \left(p_H - q_H\right)} a_H \\
=&\frac{(1-g)^2 p_M q_H \left(p_M - q_M\right) + g^2 q_H r_M \left(r_M - q_M\right)}{g r_M \left(r_H - q_H\right) + (1-g) p_M \left(p_H - q_H\right)} a_H \\
+&\frac{g(1-g)\left(\left(r_M - p_M\right)\left(r_H - p_H + q_H\right) q_M + 2 r_M q_H \left(p_M - q_M\right)\right)}{g r_M \left(r_H - q_H\right) + (1-g) p_M \left(p_H - q_H\right)} a_H < 0.
\end{aligned}
$$

The last inequality holds when $r_M < p_M \leq q_M$. That is, when the IC constraint (2.78) is binding, the solution E_1 should be larger than $s\left(y_H^M, X_{H+H}\right)$. Moreover, if the IC constraint (2.79) is binding, the solution E_2 should be larger than E_1, and thus should be larger than $s\left(y_H^M, X_{H+H}\right)$. Therefore, the Program P-M dominates the Program P-E.

Also, recall from Step 2 and 3, fully revealing system dominates Program P-M, and Program P-E dominates the conservative system; thus when $r_M < p_M \leq q_M$, the fully revealing system dominates the conservative system.

Proof of Proposition 9

The shareholders make the decision ex post by comparing the severance pay with the change in productivity. The right-hand side of (2.6) is the difference in productivity between a new manager and the incumbent when y_M^{full} is realized. When condition (2.6) holds, the difference in productivity is higher than the severance pay, so the shareholders fire the incumbent when y_M^{full} is realized. In this case, the fully revealing system is equivalent to the aggressive system, so it is enough to compare the other three systems, the conservative system, the aggressive system, and the null system.

Also, when $\frac{r_L}{p_L} < \frac{r_M}{p_M}$, condition (2.6) implies

$$k < \left(g - \frac{gr_L}{gr_L + (1-g)\,p_L}\right) \sum_{j=L,M}^{H} r_j x_j + \left((1-g) - \frac{(1-g)\,p_L}{gr_L + (1-g)\,p_L}\right) \sum_{j=L,M}^{H} p_j x_j,$$

so, under the conservative system, the shareholders will fire the incumbent when y_L^C is realized. The last inequality follows directly from the fact that the right-hand side of the inequality above is larger than the right-hand side of condition (2.6).

By definition, k^* is the value with which the conservative system equals the aggressive system. Any increase in k favors the conservative system, when compared with the aggressive system, because it increases the firing cost (the minimum severance pay) and the conservative system has less firing; thus, the conservative system dominates the aggressive system when $k > k^*$. Similarly, any decrease in k favors the conservative system, when compared with the null system, because it decreases the firing cost and the conservative system has more firing; thus, the conservative system dominates the null system when $k < k^{**}$.

Chapter 3

Effect of Accounting for Fixed Assets on Investment Efficiency in the Real Options Framework[1]

Abstract

This paper studies the benefits of accounting for fixed assets in a setting with privately informed managers who care about investment profitability and their company's short-term share price. In a perfect world, a manager's investment in fixed assets should increase with the assets' profitability. However, managers of less profitable firms face temptations to overinvest to pool with strong firms. This creates pressure on strong firms to overinvest to the point where weak firms cease to find it worthwhile to mimic strong firms. I show that, when firms have abandonment options, the willingness of a weak firm's manager to mimic depends on the expected future resale value of the fixed assets. An impairment policy (prohibiting write-ups) reduces the value of abandonment options, which are particularly

[1]This chapter is based on my job market paper. I thank my dissertation committee members Jonathan Glover (co-chair), Jing Li (co-chair), and Jack Stecher for their valuable advice and comments. I am also grateful to Carlos Corona, Pierre Liang, Austin Sudbury, and workshop participants at Carnegie Mellon University. This paper has also benefited from discussions with my fellow students Ryan Kim and Ronghuo Zhenng. All remaining errors are my own.

important to weak firms. The reduced value of the abandonment options decreases the amount of overinvestment required by strong firms to separate from weak firms. In an extension of the baseline model, I show that allowing firms to choose depreciation schedules improves investment efficiency; strong firms choose faster depreciation in equilibrium. These findings rationalize the current accounting standards for fixed assets and contribute to related policy debates on accounting measurement.

Keywords: accounting for fixed assets, investment efficiency, abandonment options, staged-investments

3.1 Introduction

Long-term investments in fixed assets are important decisions. Short-term managerial objectives and private information about investment profitability can lead to overinvestment in long-term projects (Bebchuk and Stole, 1993).[2] Numerous studies have addressed the relationship between financial reporting quality and investment efficiency,[3] but relatively little is known about the role that accounting policies play in investment efficiency. This paper studies the relationship between accounting for fixed assets and investment efficiency. My focus is on the impact of accounting on the value of an abandonment option for a firm's fixed assets, which affects the cost of strong firms separating from weak firms via overinvestment. Without understanding this issue, the governing bodies such as the Financial Accounting Standards Board (FASB) and the International Accounting Standards Board (IASB) may risk setting up accounting policies that diminish investment efficiency.

A full fair value (FV) policy, which allows both write-ups and write-downs, provides more information about a fixed asset's resale value. Absent strategic considerations, this would be

[2]This paper focuses on the overinvestment issue that arises from adverse selection. Stein (2003) provides a useful summary of capital budgeting under asymmetric information and agency problems, including both overinvestment and underinvestment problems.

[3]Prior research shows that financial reporting quality is positively related to investment efficiency (Biddle et al., 2009; Chen et al., 2011). Dechow et al. (2010) provides an extensive literature review on financial reporting quality.

the end of the story. An impairment policy that right-censors information on resale values can affect a manager's incentives and thus strategic behavior. The fundamental tension here reflects a general trade-off between more information and strategic incentives. I focus exclusively on this trade-off and abstract from questions over whether FV reporting is reliable or easily manipulable for assets that do not have active market prices (Allen and Carletti, 2008; Plantin et al., 2008; Ball, 2006). Aboody et al. (1999) argues that reliability of fixed assets' revaluation appears to be of little practical importance.

Several papers have found that firms are reluctant to adopt FV accounting for fixed assets when given a free choice between fair value and historical cost accounting (Christensen and Nikolaev, 2013; Jung et al., 2013). This paper suggests a previously unrecognized reason why firms might make this choice. By electing an impairment-based regime, firms can limit their temptation to overinvest in fixed assets. This is true both for unprofitable firms, for which the inaccurate estimate of exit value makes it too costly to try to pool with profitable ones, and for highly profitable firms, which can separate from unprofitable firms at lower cost under an impairment-based regime than they can under a full FV regime.

Similar to Bebchuk and Stole (1993), I assume that firms differ in the project's productivity and that firms care about how the stock market perceives them. Because investment is a signal shown to the stock market, weak firms face temptations to mislead the stock market through investment. After making investment, managers estimate the resale value (exit price) based on the information that the accounting system provides about the asset's FV before making the abandonment decision. The accounting system influences the estimated exit price and, thus, alters the manager's abandonment decision.[4] Different abandonment decisions change the manager's payoff from an investment. Therefore the accounting system indirectly affects the manager's investment incentives. The central aim of this paper is to identify the optimal accounting system that induces the most efficient investment.

I show that an asset impairment policy is beneficial, because it leads to the least over-

[4]If the estimated exit price exceeds the continuation value, the manager exercises the abandonment option; otherwise, the manager continues running the project.

investment ex ante. An asset impairment policy is, in fact, a right-censoring system that withholds good news above a certain threshold. The censored data limit the manager's information for estimating the exit price, which leads to inefficient abandonment decisions of assets-in-place and thus reduces the value of the abandonment options. Although inefficient ex post, the reduced value of the abandonment options increases weak firms' mimicry costs ex ante, thus mitigating the ex-ante signaling cost of overinvestment by strong firms.

Furthermore, the right-censoring threshold is determined by the asset's book value (BV), which is endogenously chosen. Thus the manager has some discretion to alter the reported FV by adopting different depreciation schedules. Specifically, if a manager chooses faster depreciation, it results in lower BV and thus more severe censoring.[5] I show that more severely censored data increase weak firms' mimicry costs ex ante. Therefore, strong firms choose faster depreciation in equilibrium to make it cheaper to separate from weak firms.

In the first extension, I relax the assumption that the manager knows no more than the accounting system reveals about the asset's FV. Instead, I assume that the manager perfectly observes the FV. As I will explain shortly, it is not important that the manager learns about the FV from the accounting system. What is important is that shareholders learn about the FV from the accounting system and that the manager cares about the market's perception of the FV. Under an impairment-based regime, the stock market imperfectly learns the asset's FV through financial statements and, thereby, misprices the firm's abandonment value. Specifically, shareholders overprice (underprice) the exit value when the asset's FV is low (high).[6] Because the manager cares about the share price, shareholders' overpricing can induce the manager to abandon the project even when the asset's exit value is lower than its continuation value. From an ex-ante perspective, the manager's gain from shareholders'

[5]Beaver and Ryan (2005) demonstrate the same idea that faster depreciation prevents future write-downs of fixed assets. They also show that write-downs reset the asset's cost base and thus affect subsequent depreciation. However, Beaver and Ryan (2005) focus on analyzing the effect of the interaction between faster depreciation and write-downs on earnings and returns, whereas this paper studies the effect of that interaction on information structure and investment efficiency.

[6]This mispricing is not caused by shareholders' irrational expectation but rather by less precise information.

overpricing is exactly offset by the loss from underpricing. From an ex-post perspective, however, the manager inefficiently abandons the project that is worthwhile to continue. This ex-post inefficiency is costly ex ante and limits weak firms' temptations to pool with strong firms and, thus, reduces the amount of overinvestment required by strong firms to separate from weak firms.

In the second extension, I extend the baseline model to a three-period model in which the manager has sequential investments. The manager makes the first investment decision when the manager shares the same information with shareholders and makes the second investment when the manager has private information about the project's profitability. I show that the size of the first investment has a positive spillover effect on the signaling cost in the second period. A larger initial investment strengthens the weak firm's temptation to imitate the strong firm's investment in the second period; thus, underinvestment in the first period saves the signaling cost in the second period. However, the overinvestment problem is less severe if the system prohibits write-ups; therefore, the manager has less incentive to underinvest in the first period. Thus, an impairment policy leads to the least underinvestment.

Several theoretical studies have addressed the rationale for an impairment policy (Goex and Wagenhofer, 2009; Caskey and Hughes, 2011; Demski et al., 2008). Goex and Wagenhofer (2009)[7] and Caskey and Hughes (2011) focus on debt financing and renegotiation, respectively, whereas Demski et al. (2008) study the underinvestment problem brought by disclosure costs. Also, numerous studies demonstrate that conservative accounting mitigates overinvestment because asymmetric recognition motivates managers to discontinue poorly performing projects (Ball and Shivakumar, 2005; Francis and Martin, 2010; Caskey and Hughes, 2011; Bushman et al., 2011). This paper contributes to the existing literature in the following ways. First, a large body of literature has addressed the relationship between

[7]My paper is similar to Goex and Wagenhofer (2009) in that an absence of impairment makes financial statements less informative. In Goex and Wagenhofer (2009), a less informative financial statement increases the firm's chance of getting financed ex ante, whereas in this paper, a less informative financial statement makes the abandonment decision of assets-in-place less efficient for weak firms, which reduces the cost of strong firms separating from weak firms.

financial reporting quality (or accounting conservatism) and investment efficiency, but relatively little is known about the role that accounting policies play in investment efficiency. This paper investigates the interaction between accounting for fixed assets and real options and demonstrates how information structure affects the value of real options and, thereby, influences investment efficiency.[8] Second, this paper contributes to related policy debates over US Generally Accepted Accounting Principles (GAAP) and International Financial Reporting Standards (IFRS) by investigating the effect of different treatments of impairment[9] on investment efficiency, and tries to make recommendations for convergence. Finally, this paper provides an alternative explanation of why asset impairment mitigates overinvestment and also examines whether asset impairment distorts investment on positive net present value (NPV) projects.

The rest of the paper proceeds as follows. Section 3.2 reviews previous literature. Section 3.3 describes the model details. Section 3.4 presents two benchmark results. Section 3.5.1 analyzes how an asset impairment policy interacts with abandonment options and thus affects investment efficiency. Section 3.5.2 studies the optimal depreciation schedule chosen by the firm in equilibrium. Section 3.5.3 rationalizes the recoverability test required by US GAAP. Section 3.6 checks the robustness of my main results in the presence of an alternative assumption. Section 3.7 extends the baseline model and discusses how the accounting system affects the initial investment in the context of sequential investments. Section 3.8 concludes the paper.

3.2 Literature Review

The extant literature in accounting has extensively examined the role of conservatism in

[8]My finding is consistent with empirical evidence from Mazboudi (2012). He found that restricting upward revaluation reduces overinvestment, because delaying good news constraints opportunistic behavior by managers. In contrast, my paper focuses on the impact of accounting on the value of the abandonment option, which affects the cost of strong firms separating from weak firms via overinvestment.

[9]IFRS allows firms to choose between the cost model and the revaluation model. The cost model is similar to US GAAP, whereas the revaluation model allows for reversal of previously recognized impairment loss up to the BV of a fixed asset adjusted for depreciation, which is specifically prohibited by US GAAP.

both the capital market and the debt market. A common view is that conservative policy reduces the frequency of reporting good news and, thus, makes good news more informative (Basu, 1997; Kwon et al., 2001; Gigler et al., 2009). For example, Kwon et al. (2001) show that conservative financial reporting facilitates motivating agents in a limited-liability setting because it increases the informativeness of higher outcome. In contrast, this paper models conservatism as producing additional information in bad states. This is consistent with such accounting practice as lower-of-cost-or-market or impairment and is the view adopted in the literature on asset impairment (Beaver and Ryan, 2005; Demski et al., 2008; Goex and Wagenhofer, 2009; Lawrence et al., 2013). Also, many papers examine the role of conservatism in investment. Watts (2003) suggests that conservatism allows debt holders to receive early signals to liquidate the project and, thus, reduces ex-ante overinvestment. Lu and Sapra (2009) investigate the effect of auditor's conservatism on investment efficiency and argue that, given auditor conservatism, an unfavorable report results in overinvestment. García Lara et al. (2015) find that more conservative firms are less likely to both over- and under-invest. André et al. (2015) find that conservatism mitigated both over- and under-investment in the pre-IFRS period but does not improve investment efficiency in the post-IFRS period, because adoption of IFRS reduces the level of conservatism. My paper extends this stream of literature to the real options framework. The real options I consider are abandonment options and staged investments. Lawrence et al. (2014) study the interaction between conditional conservatism and abandonment decisions and provide evidence that asset write-downs result in abandonment, which in turn reduces the persistence of losses. Two close theoretical papers are Arya and Glover (2003) and Smith (2007). Arya and Glover (2003) show that, although limiting the principal's downside risk, the abandonment option makes it more expensive to motivate the agent, because abandoning the project eliminates the information regarding the agent's unobservable effort. Smith (2007) studies how the bias in information affects investment in the real options framework and derives conditions under which conservative bias is optimal. However, prior literature does not

address how the accounting system affects the value of abandonment options and, thereby, influences investment efficiency. I show that, although the impairment-based system makes abandonment decisions ex post inefficient for weak firms and thus reduces the value of abandonment options, it improves strong firms' investment efficiency ex ante.

This paper is also related to the literature on asset impairment policy. Demski et al. (2008) and Demski et al. (2009) examine the optimal design of asset revaluation policies. Demski et al. (2008) show that a conservative impairment policy naturally arises when the disclosure cost is nontrivial and that the nontrivial disclosure cost prohibits some firms from voluntary disclosing and thereby leads to underinvestment. Demski et al. (2009) show that the optimal policy balances between the benefits from accurate pricing and the costs of disclosure. Goex and Wagenhofer (2009) study the optimal accounting policy of financially constrained firms that pledge assets to raise debt capital. They show that the optimal accounting regime is conditionally conservative, because after a firm commits to a harsher reporting regime, the absence of impairment indicates to the lender that the asset is sufficiently valuable to meet the firm's financing position. Caskey and Hughes (2011) show that a conservative FV measure tends to perform best in reducing the probability of renegotiation and shareholders' incentives to engage in costly asset substitution. Bertomeu and Magee (2015) examine the demand for disclosure rules by informed managers interested in increasing the market price of their firms. They find that, in equilibrium, disclosure rules are asymmetric with greater levels of disclosure over adverse events (e.g., values below the median value). My paper is different from prior literature in the following three aspects. First, there is no direct disclosure cost related with asset revaluation in my model, whereas the nontrivial disclosure cost is the driving force of Demski et al. (2008), Demski et al. (2009), and Bertomeu and Magee (2015). Second, although both Demski et al. (2009) and my paper focus on the fundamental tradeoff between more information and managers' strategic incentives, their paper focus on the lemons problem in the assets' resale market, whereas my paper studies the problem caused by managerial short-termism. Third, I study investment

efficiency in a staged-investments setting and derive an interesting result that the conservative accounting system can also mitigate underinvestment if neither the manager nor the shareholders know the project's type.

This paper is also related to the literature on investment efficiency. Biddle et al. (2009) find that higher reporting quality is associated with both lower over- and under- investment. Liang and Wen (2007) investigate how the accounting measurement bias affects the efficiency of the firm's investment decisions. Kanodia et al. (2005) show that, absent agency and risk-sharing considerations, some degree of accounting imprecision could enhance value. My finding also indicates that conservative bias in accounting information (i.e., prohibiting write-ups) improves the firm's investment efficiency. This paper further suggests that prohibiting write-ups not only reduces overinvestment in a late stage but also mitigates underinvestment in an initial stage. In terms of modeling, this paper extends Bebchuk and Stole (1993) by adding in accounting for fixed assets, including asset impairment and depreciation. I show that the current accounting standards for fixed assets help mitigate overinvestment suggested by Bebchuk and Stole (1993). This paper points out that anticipating future abandonment options changes managers' investment strategies ex ante.

3.3 Elements of the Model

This section introduces a simple model extending Bebchuk and Stole (1993). I use this setting to study the firm's investment decision under adverse selection.

At $t = 0$, an accounting system is set, which specifies how to impair the fixed asset at the end of $t = 1$. At the beginning of $t = 1$, a risk-neutral firm (manager) has an opportunity to invest in a project and privately observes the project's profitability (or rate of return) $\tilde{\theta}$, good (θ_G) or bad (θ_B).[10] The prior distribution of $\tilde{\theta}$ is common knowledge, $\tilde{\theta} = \theta_G$ with probability $pr(\theta_G) \equiv \pi^G$. Then, the manager publicly chooses an investment level, denoted by $I \in R^+$. The investment is recorded as a fixed asset on the firm's balance sheet, and

[10] θ can also be interpreted as the manager's type, with θ_B meaning low ability.

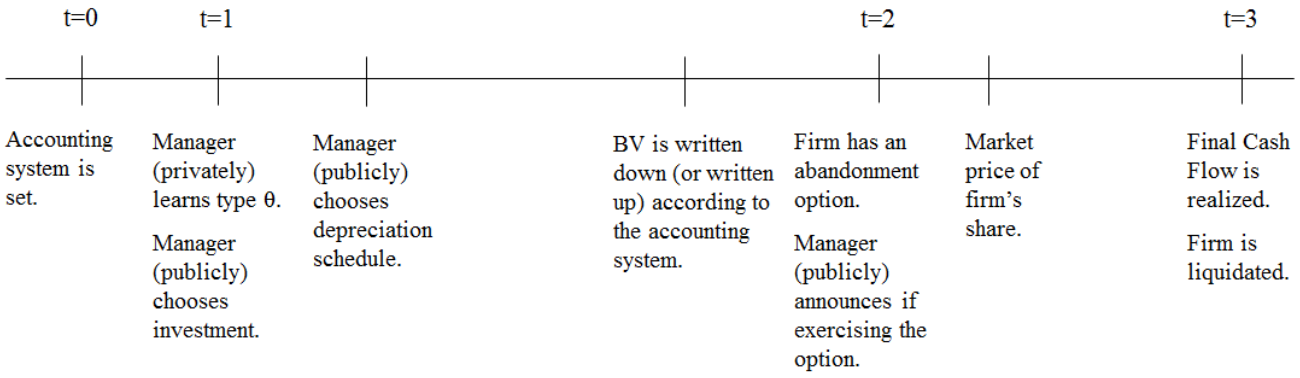

Figure 3.1: Timeline of events.

the manager chooses a depreciation schedule, denoted by d. At the end of $t = 1$, the asset impairment test is taken, and BV is adjusted to reflect the asset's FV in accordance with the requirement of the accounting regime. At the beginning of $t = 2$, the manager has an option to abandon the project. If the manager decides to exercise the option, abandonment is publicly announced. At $t = 3$, terminal cash flow (CF) net of the investment cost $C(I)$, denoted by x, is realized, and the firm is liquidated.

$$x = \begin{cases} \theta I - C(I), & \text{if the manager continues the project at t=2} \\ vI - C(I), & \text{if the manager abandons the project at t=2.} \end{cases}$$

Assume that the cost function is quadratic, $C(I) = \frac{1}{2}I^2$. [11] Fig. 3.1 summarizes the sequence of events, and details are explained in the following.

Accounting for fixed assets:

Book value and depreciation: Initial BV of the long-lived asset (the total investment capitalized on the balance sheet) is I. At the end of $t = 1$, the asset is depreciated at the predetermined schedule d. To separate the effect of the accounting regime on investment efficiency from the effect of depreciation, I first analyze the case with fixed depreciation in Section 3.5.1; I then discuss the case with discretionary depreciation in Section 3.5.2, where

[11] $C(I)$ is associated with the terminal CF, including both the investment cost I and the cost of running the project. Assume that the cost of running the project is convex in I.

the depreciation method is detailed.

Fair value: At the end of $t = 1$, the FV of (per unit) assets-in-place is $\tilde{v} = \{v_H,\ v_M,\ v_L\}$, where $v_L < v_M < v_H$.[12] FV is the estimated asset's exit price under the current market condition. Assume that v_M equals BV after fixed depreciation. Thus, the asset's value is appreciated if the true FV is high (v_H), or depreciated if it is low (v_L), or remains the same if it is medium (v_M). Let $pr(v_j) \equiv q_j$ be the probability that the true FV is v_j, where $j = L, M, H$, and $\sum_{j=L}^{H} q_j = 1$. "Fair Value Measurement (Topic 820)" states that "fair value is a market-based measurement, not an entity-specific measurement; fair value is the estimated exit price that would be received to sell the asset at the measurement date." Thus, I assume that $\tilde{v}$ is *not* informative of $\tilde{\theta}$.[13] Furthermore, assume that neither the manager nor shareholders observe the true FV $\tilde{v}$ at the end of $t = 1$, but use financial statement information to estimate FV.[14] Managers do not have to rely on the financial statement information exclusively, but the additional cost associated with acquiring more information may lead managers to make abandonment decisions based on financial statement information, especially for fixed assets. I relax this assumption in Section 3.6 and discuss the case in which managers perfectly learn the asset's FV.

Accounting regimes: At $t = 0$, the accounting system is set, which specifies how to report FV at the end of $t = 1$. Denote the reported FV[15] by z. An accounting regime can be null, fully revealing, conservative or aggressive, denoted by $\delta \in \{\delta^{null},\ \delta^{FR},\ \delta^{C},\ \delta^{A}\}$, respectively.

A null regime does not provide any information regarding FV, $z^{null} = \{\phi\}$, so the asset is always reported at its BV (adjusted for depreciation) in the null regime.

[12] $\tilde{v}$ is per unit asset's FV, and the total FV is $\tilde{v}I$. For the rest of the paper, unless directly stated otherwise, I refer to the per unit asset's FV when I say FV $\tilde{v}$.

[13] This assumption captures the idea that value-in-use $\tilde{\theta}$ is an entity-specific characteristic, not an asset-specific characteristic; both the good firm and the bad firm have the same fixed asset. Therefore the asset's FV is the same for both firms, and FV $\tilde{v}$ is *not* informative about the entity-specific characteristics $\tilde{\theta}$.

[14] An unmodeled accountant does the asset impairment test in accordance with the requirements of the accounting system and adjusts the asset's BV on financial statements. Both the manager and shareholders learn the asset's FV from financial statements.

[15] The reported FV is the adjusted BV on the balance sheet *after* the impairment test. When I say BV at the end of $t = 1$, I refer to BV adjusted for depreciation *before* the impairment test.

A fully revealing regime (hereinafter FR regime) provides accounting signals that fully reveal FV, $z^{FR} \in \{v_H, v_M, v_L\}$, so the FR regime can write down the asset's value to v_L if the true FV is low, or write up the asset's value to v_H if the true FV is high.

A conservative regime perfectly reveals FV that is below BV, $z^C \in \{\{v_H, v_M\} \equiv v_U, v_L\}$; thus, the asset's value can be written down but not written up. Therefore, when an asset is reported at its BV (adjusted for depreciation) in the conservative regime, neither the shareholders nor the manager knows whether the asset's value is appreciated (v_H) or remains the same (v_M).

An aggressive regime perfectly reveals FV that is above BV, $z^A \in \{v_H, \{v_M, v_L\} \equiv v_D\}$. The aggressive regime can write up the asset's value but cannot write it down.

Abandonment option: At $t = 2$, the manager has an option to abandon the project and resell the asset. Denote the manager's choice of abandonment by $S = \{\text{abandon, continue}\}$. Assume that the abandonment choice S is publicly observable at $t = 2$. Note that, before the manager makes the abandonment decision, the manager's estimate of the exit price is $E[\tilde{v}|z^\delta]$.

Market price: At the end of $t = 2$, the firm's share is priced in a competitive risk-neutral capital market. The market price P equals the expected value of terminal cash flow x based on all publicly available information, denoted by Ω. Ω includes the accounting regime δ, the investment I, the reported asset's value $\tilde{z}$, and the abandonment decision S.

$$P = E[x|\Omega] = \begin{cases} E[\theta|I]I - C(I), & \text{if } S = \text{continue} \\ E[v|z^\delta]I - C(I), & \text{if } S = \text{abandon.} \end{cases}$$

Manager's preferences: The manager's utility function is a weighted average of the period 2 market price P and the terminal CF (net of the investment costs), $\alpha P + (1-\alpha)x$.[16] The weight α is exogenously determined, representing the manager's short-term incentives.[17]

[16] All results still hold if assuming that the manager also cares about the period 1 market price.

[17] Here I implicitly assume that α is sufficiently large that overinvestment exists. Were α very small, the bad-type firm would not imitate the good type's investment decision; in that case, there is no signaling

The manager chooses investment I and depreciation schedule d so as to maximize expected payoff:

$$\max_{I,\ d} E\left[\alpha P + (1-\alpha)x\right].$$

Assumptions: To make my analysis meaningful, I assume that the following conditions hold.

Condition 1.

$$\text{(C1)} \qquad \theta_G > v_H > v_M > \theta_B > v_L \geq 0.$$

(C1) specifies the socially optimal abandonment decision. Specifically, the good-type firm's manager always continues the project, because the good type's continuation value, θ_G, exceeds the highest possible resale value, v_H. In contrast, the bad-type firm's manager wants to abandon the project when the true FV is either $v = v_H$ or $v = v_M$, since the continuation value θ_B is less than the resale value.

Let $\Theta \equiv \alpha\theta_G + (1-\alpha)\theta_B$.[18]

Condition 2.

$$\text{(C2)} \qquad v_H > \Theta > v_M.$$

(C2) assumes that FV is relevant for bad firms when making the abandonment decision.[19]

Let $\bar{v} \equiv \sum_{j=L}^{H} q_j v_j$ be the unconditional mean of FV $\tilde{v}$.

problem.

[18] In the separating equilibrium, shareholders price the firm according to the conjectured type based on the observable investment decision. On the off-the-equilibrium path, when a bad firm mimics a good firm's investment, shareholders price the firm as θ_G. The manager cares both the share price and the terminal CF, so the manager's payoff (per unit of investment) is $\alpha\theta_G + (1-\alpha)\theta_B$.

[19] I ignore two less interesting cases $\Theta > v_H$ or $\Theta < v_M$ in which FV is irrelevant for bad firms when making the abandonment decision, and the fully revealing regime leads to the same abandonment decision as the conservative regime; in that case, two systems are equivalent.

Condition 3.

$$\text{(C3)} \qquad \Theta > \bar{v} > \theta_B.$$

Intuitively, the second inequality in (C3) specifies that the bad-type firm's productivity is less than the average exit value.[20] In the separating equilibrium, when the bad-type firm mimics the good-type firm's investment (off-the-equilibrium path), the first inequality assumes that the bad-type firm's payoff of continuation exceeds the average exit value.

Different from Bebchuk and Stole (1993), a special feature of this paper is that the manager has two choices: the investment I and the abandonment decision S. The equilibrium should be sequentially rational in that each decision should be optimal upon anticipating future decisions are *subgame perfect equilibria*. For example, the manager chooses I so as to maximize payoff, knowing that she will choose the equilibrium abandonment strategy in the future.

3.4 Benchmark Analysis

In what follows, I consider two benchmark cases. In Section 3.4.1, assume that the manager only cares about terminal CF ($\alpha = 0$) and that the accounting system fully reveals the true FV $z = \{v_H,\ v_M,\ v_L\}$; thus, the investment represents the socially optimal investment. The first-best investments described in Lemma 2 serve as the benchmark throughout the whole paper and are used to determine investment efficiency later. An overinvestment (underinvestment) arises if the optimal investment exceeds (is smaller than) the first-best investment. In Section 3.4.2, I consider the setting in which the manager has short-term concerns ($\alpha \neq 0$), but does not have the abandonment option. The result resembles the

[20] FV $\tilde{v}$ represents the asset's exchange value that is affected by the productivity of a potential buyer. Using the same asset, a potential buyer, on average, generates more CF than the bad-type firm does.

classic finding of Bebchuk and Stole (1993).

3.4.1 First-Best Investments

Lemma 2 describes the socially optimal investments. Note that the socially optimal abandonment decision is specified by Condition (C1).

Lemma 2. ***(First-Best Investment)***

(i) Assume that the manager does not have the abandonment option. The socially optimal investment policy $I^{FB}(\theta)$ *maximizes* $\tilde{\theta}I - C(I)$*. In equilibrium, we have* $I^{FB}(\theta) = \theta$*.*

(ii) Assume (C1) holds. Also assume that the manager has the abandonment option. The socially optimal investment policy $I^{FB}(\theta)$ *maximizes* $max[\tilde{\theta}, \tilde{v}]I - C(I)$*. In equilibrium, we have* $I^{FB}(\theta_G) = \theta_G$ *and* $I^{FB}(\theta_B) = q_L\theta_B + \sum_{j=M}^{H} q_j v_j$*.*

Proof. Proof is in the appendix.

□

Clearly the socially optimal investment policy requires the good-type firm to invest more than the bad-type firm does, $I^{FB}(\theta_G) > I^{FB}(\theta_B)$. In other words, in addition to the signaling effect (discussed in Section 3.5), the investment itself also has a real effect. Because of the real effect, the contents of this paper differ from money-burning signaling models.

In addition, the abandonment option does not change the good type's optimal investment but rather increases the bad type's optimal investment. Therefore, adding the abandonment option does not change the good type's utility but strictly increases the bad type's utility. This result changes when the manager has short-term concerns ($\alpha \neq 0$); the good type's utility decreases.

3.4.2 No Abandonment Option

I now consider the setting in which the manager has short-term concerns ($\alpha \neq 0$) but no abandonment option. The firm's type θ is privately known to the manager; thus, shareholders should conjecture the firm's type based on the manager's investment decision that is publicly observable, when evaluating the market price of the firm's shares. In this case, a systematic short-term mispricing arises, and this mispricing induces a suboptimal investment decision. The well-known result from Bebchuk and Stole (1993) shows that the good-type firm should over-invest to signal its type, so as to prevent the bad-type firm from imitating its investment decision.

Note that v is *not* informative about θ, so the reported FV z does not have value when there is no abandonment option. The shareholders can rationally infer the firm's type θ from the manager's investment decision in a separating equilibrium. In the (least cost) separating equilibrium, there are no incentives for the bad-type firm to imitate the good type's investment strategy, so the bad-type firm chooses the same investment as the first-best investment shown in Lemma 2.

To economize on notation, I use superscripts to indicate the accounting regime[21] and subscripts to represent the firm's true type (and the perceived type). Let I_i^δ be the investment decision chosen by the type θ_i under the accounting regime δ, and U_{ik}^δ be the utility of the type θ_i under the accounting regime δ when choosing the investment strategy of type-θ_k, where $i, k \in \{G, B\}$. In other words, the first subscript states the true type, whereas the second subscript represents the perceived type based on the investment decision. For example, U_{BG}^N means the bad type's utility in the no-abandonment-option regime when the bad type imitates the good type's investment decision.

The corresponding optimization problem for the good-type firm's manager in a separating equilibrium in the no-abandonment-option regime reads as follows:

[21] The superscript N stands for the no-abandonment-option system.

$$\max_{I_G^N \geq 0} E[U_{GG}^N] \tag{3.1}$$

$$st. \qquad E[U_{BG}^N] \leq \max_{I_B^N \geq 0} E[U_{BB}^N], \tag{3.2}$$

where $U_{ik}^N = \alpha P(I_k^N) + (1-\alpha)[\theta_i I_k^N - \frac{1}{2} I_k^{N^2}]$ and $i, k = \{G, B\}$.

The good-type manager chooses I_G so as to maximize her utility with a nonmimicry constraint (3.2) ensuring that the bad-type manager is worse off by misleading the shareholders into believing she is of the good type. My first result resembles the classic finding of Bebchuk and Stole (1993).

Proposition 10. *Assume (C1) holds. Also assume that the manager privately observes $\tilde{\theta}$ and does not have the abandonment option. With publicly observable investment I_i, there exists a separating equilibrium. In this equilibrium, the nonmimicry constraint (3.2) is binding; a good-type firm over-invests, $I_G^N > I_G^{FB} = \theta_G$, whereas a bad-type firm chooses $I_B^N = I_B^{FB} = \theta_B$.*

Proof. The proof is omitted.

□

Proposition 10 provides a description of the (least cost) separating equilibrium when the manager does not have the abandonment option. Note that, as suggested by Cho and Kreps (1987), some intuitive equilibria can be eliminated if restricting some unreasonable off-the-equilibrium beliefs, and a continuum of pooling equilibria do not survive the equilibrium refinement under the Intuitive Criterion. Therefore, I focus on the (least cost) separating equilibrium for the rest of the paper.

3.5 Main Analysis

I now consider the setting in which the manager has both short-term concerns ($\alpha \neq 0$) and abandonment options. In this case, accounting information has value, because both the manager and shareholders make nontrivial use of the reported FV (e.g., estimate the resale price). Note that, in the conservatism regime (the aggressive regime), only FV that is below (above) BV can be disclosed, and BV can be altered by adopting different depreciation schedules. To separate the effect of the accounting regime and the effect of depreciation on the reported FV, I first analyze the case with fixed depreciation in Section 3.5.1; I then discuss the case in which the manager is allowed to choose the depreciation schedule in Section 3.5.2.

3.5.1 Fixed Depreciation

With fixed depreciation, BV is out of the manager's control; thus the reported FV z is merely affected by the accounting regime.

When the reported FV z does not equal the initial BV (adjusted for fixed depreciation), both the shareholders and the manager know that it is the true FV, so the expected exit value $E[v] = z$. In contrast, when the reported FV z equals the initial BV (adjusted for fixed depreciation), they may or may not infer the true value v, depending on the accounting system. In particular, the true value v equals the observed value z in the fully revealing regime, and it is at least (at most) equal to the observed value z in the conservative (aggressive) regime. In other words, upon observing the same reported value (no impairment), the estimated asset's exit value $E[v]$ differs across different accounting systems. Mathematically,

$$E[v|\text{No Impairment}, \delta^C] \geq E[v|\text{No Impairment}, \delta^{FR}] \geq E[v|\text{No Impairment}, \delta^A].$$

The first (second) inequality holds strictly when the conservative regime (the aggressive regime) pools at least two possible FVs together. In this case, the conservative regime (the

aggressive regime) impedes the manager to accurately estimate the asset's resale price and, thus, leads to inefficient abandonment decisions. In addition, the abandonment decision affects the bad-type manager's payoff after imitating the good type's investment decision and thereby alters the manger's ex-ante investment decision. Therefore, identifying the optimal accounting system that induces the most efficient investment is the central issue of this paper.

I consider four accounting systems, including the null regime, the fully revealing regime, the conservative regime, and the aggressive regime. Interestingly, regardless of the accounting system, the corresponding optimization problem for the good-type firm's manager in a separating equilibrium shares the same functional form, as follows:

$$\max_{I_G^\delta \geq 0} E[U_{GG}^\delta] \tag{3.3}$$

$$st. \qquad E[U_{BG}^\delta] \leq \max_{I_B^\delta \geq 0} E[U_{BB}^\delta]. \tag{3.4}$$

As guaranteed by Condition (C1), the good-type firm's manager always continues the project regardless of the accounting system. Thus, the good type's utility function is the same in all accounting systems, so that my focus is on how the accounting system affects the nonmimicry constraint (3.4). In general, if an accounting system relaxes the nonmimicry constraint (3.4) by decreasing the left-hand side (or increasing the right-hand side), it improves investment efficiency in that the good type's investment I_G moves toward the socially optimal investment.

Note that the good-type firm's manager never abandons the project, so the abandonment option only changes the bad type's incentives. Clearly, the abandonment option is in the money when the exit value exceeds the continuation value, so the manager's payoff is bounded above the exit value. In addition, the manager's estimate of the exit value is shaped by the accounting system; thus, different accounting systems alter the bad-type manager's abandonment decision, which affects the nonmimicry constraint (3.4).

As discussed before, the equilibrium should be subgame perfect equilibrium in that the bad-type manager chooses the abandonment choice S so as to maximize her payoff. Because the abandonment choice S is binary, the manager decides by comparing payoffs between continuation and abandonment. When the bad-type manager does not imitate the good type's investment strategy, the abandonment decision is determined by Condition (C1). When the bad-type manager imitates the good type's investment strategy, the abandonment strategy in the FR regime is determined by Condition (C2), whereas the abandonment strategy in the conservative regime is determined by the following condition (C4).

Condition 4.

$$\text{(C4)} \qquad \Theta \geq \frac{\sum_{j=M}^{H} q_j v_j}{\sum_{j=M}^{H} q_j}.$$

If Condition (C4) holds, the manager continues when observing no impairment $z = \{v_M, v_H\}$. If Condition (C4) does not hold, the manager abandons the project when observing no impairment.

3.5.1.1 Optimal Investment in the Null Regime

As a reference point, I first discuss the optimal investment in the null regime. The null regime does not disclose FV. Thus, the estimated exit value $E[v] = \bar{v}$. In this case, Condition (C3) ensures that the bad-type manager abandons the project when the shareholders can rationally infer that the firm is of bad type, but continues when the bad-type manager imitates the good type's investment strategy.

The corresponding optimization problem for a good-type firm's manager in a separating equilibrium reads as follows:

$$\max_{I_G^{null} \geq 0} E[U_{GG}^{null}] \tag{3.5}$$

$$st. \qquad E[U_{BG}^{null}] \leq \max_{I_B^{null} \geq 0} E[U_{BB}^{null}]. \tag{3.6}$$

where $E[U_{GG}^{null}] = \theta_G I_G^{null} - \frac{1}{2} I_G^{null^2}$, $E[U_{BG}^{null}] = \Theta I_G^{null} - \frac{1}{2} I_G^{null^2}$, and $E[U_{BB}^{null}] = \bar{v} I_B^{null} - \frac{1}{2} I_B^{null^2}$.

Denote the solution to this program by I_G^{null}. The good-type firm's manager chooses I_G so as to distinguish herself from the bad-type firm's manager, by ensuring that the nonmimicry constraint (3.6) holds. The next result reports that, in equilibrium, the good-type firm's manager over-invests to signal her type, whereas the bad-type firm's manager under-invests, $I_B^{null} = \bar{v}$.

Lemma 3. *Assume that the null system is prescribed. Assume (C1), (C2), and (C3) hold. Also assume that the manager privately observes $\tilde{\theta}$ and has an abandonment option. With publicly observable investment I_i, there exists a separating equilibrium. In this equilibrium, the nonmimicry constraint (3.6) is binding; a good-type firm over-invests, $I_G^{null} > \theta_G$, whereas a bad-type firm under-invests, $I_B^{null} = \bar{v} < I_B^{FB}$.*

Proof. Proof is in the appendix.

□

Lemma 3 states that the good type over-invests whereas the bad type under-invests. The underinvestment arises because the null regime does not disclose any information about the asset's FV. This leads to the inefficient abandonment in equilibrium when the continuation value θ_B actually exceeds the exit value v_L. Note that the null regime resembles historical cost accounting. This result is consistent with the argument that historical cost accounting cannot provide timely information for the manager to take corrective actions.

Comparing the optimal investments in the no-abandonment-option regime with the optimal investments in the null regime, Proposition 11 shows that the null regime dominates

the no-abandonment-option regime.

Proposition 11. *Assume (C1), (C2), and (C3) hold. Also assume that the manager privately observes $\tilde{\theta}$ and that investment is publicly observable. The abandonment option helps mitigate overinvestment of the good-type firm and thus improves investment efficiency.*

Proof. Proof is in the appendix.

□

Proposition 11 states that the abandonment option mitigates the overinvestment of the good type. The intuition behind the result is as follows: as guaranteed by Condition (C3), the unconditional expectation of the exit value $\bar{v}$ exceeds the bad type's continuation value θ_B; thus, the bad type achieves a higher utility when abandoning the project than when continuing. In other words, the abandonment option increases the bad type's equilibrium utility. This increase in utility weakens the bad type's incentives to imitate the good type's investment strategy and thus makes it less costly to separate the good type from the bad type. Mathematically, the abandonment option relaxes the nonmimicry constraint (3.4) and, thus, leads to more efficient investments.

3.5.1.2 Optimal Investment in the Fully Revealing Regime

I now consider the FR regime in which accounting signals fully reveal FVs. In the FR regime, the firm can write down the asset's value to v_L if the true FV is low (v_L), or write up the asset's value to v_H if the true FV is high (v_H). Condition (C1) implies that the bad-type manager abandons the project when either v_H or v_M is reported if she truthfully reveals her type, whereas Condition (C2) ensures that the bad-type manager abandons the project when v_H is reported if she imitates the good type's investment strategy. The corresponding

optimization problem for a good-type firm's manager in a separating equilibrium reads as follows:

$$\max_{I_G^{FR} \geq 0} E[U_{GG}^{FR}] \tag{3.7}$$

$$st. \qquad E[U_{BG}^{FR}] \leq \max_{I_B^{FR} \geq 0} E[U_{BB}^{FR}], \tag{3.8}$$

where $E[U_{GG}^{FR}] = \theta_G I_G^{FR} - \frac{1}{2} I_G^{FR^2}$, $E[U_{BG}^{FR}] = [\sum_{j=L}^{M} q_j \Theta + q_H v_H] I_G^{FR} - \frac{1}{2} I_G^{FR^2}$, and $E[U_{BB}^{FR}] = (q_L \theta_B + \sum_{j=M}^{H} q_j v_j) I_B^{FR} - \frac{1}{2} I_B^{FR^2}$.

Denote the solution to this program by I_G^{FR}. Similar to Lemma 3, the good-type manager chooses I_G so as to distinguish herself from the bad-type manager by ensuring the nonmimicry constraint (3.8) holds, and the bad-type manager resells the project when v_H or v_M is reported. In equilibrium, the bad-type manager invests in the socially optimal level $I_B^{FR} = q_L \theta_B + \sum_{j=M}^{H} q_j v_j$, and the good-type manager over-invests to signal her type. The result is summarized in the following lemma.

Lemma 4. *Assume that the fully revealing system is prescribed. Assume (C1) and (C2) hold. Also assume that the manager privately observes $\tilde{\theta}$ and has an abandonment option. With publicly observable investment I_i, there exists a separating equilibrium. In this equilibrium, the nonmimicry constraint (3.8) is binding; a good-type firm over-invests, $I_G^{FR} > \theta_G$, whereas a bad-type firm invests in the socially optimal level, $I_B^{FR} = q_L \theta_B + \sum_{j=M}^{H} q_j v_j$.*

Proof. The proof is omitted.

□

The proof is similar to the proof of Lemma 3. However, two additional elements warrant brief mention. First, the FR regime is the only accounting system that always leads to efficient abandonment decisions ex post, precisely because FR regime fully reveals the asset's FV, which enables the manager to accurately estimate the project's exit value and make

efficient abandonment decisions. Second, the abandonment option is in the money when the exit price exceeds the continuation value. Because the estimated exit price in the FR regime is more volatile compared with that in other systems, the abandonment option is more valuable. Interestingly, however, as shown in Section 3.5.1.4, the efficient ex-post abandonment decision and more valuable abandonment option lead to inefficient investment ex ante.

3.5.1.3 Optimal Investment in the Aggressive Regime

I now consider a hypothetical regime – an aggressive regime in which FV that exceeds the initial BV (adjusted for fixed depreciation) is perfectly revealed. In particular, the firm can write up the asset's value to v_H if the true FV is high (v_H), but the asset's value cannot be written down if the true FV is low (v_L). Therefore, if no impairment is reported in the aggressive regime, neither the shareholders nor the manager knows whether the asset's value is depreciated (v_L) or remains the same (v_M). Mathematically,

$$E[v|\delta^A, \text{No Impairment}] = \frac{\sum_{j=L}^{M} q_j v_j}{\sum_{j=L}^{M} q_j}.$$

Clearly, $v_L < E[v|\delta^A,\text{No Impairment}] < v_M$. Because of Condition (C2) $v_H > \Theta > v_M$, if the bad-type firm imitates the good type's investment strategy, the bad type abandons the project when v_H is reported but continues when $v_D = \{v_L, v_M\}$ is reported. In this case, when the bad-type manager imitates the good type's investment decision, the equilibrium abandonment strategy in the aggressive regime is the same as that in the FR regime. In contrast, if the bad-type manager truthfully reveals her type, she abandons the project when v_H is reported, but the abandonment strategy is not unambiguous when v_D is reported. However, in general, the second-best utility can never exceed the first-best utility, and the bad-type manager invests in the socially optimal level in the FR regime. Thus, the next

result shows that the FR regime always induces more efficient investment than the aggressive regime does.

Proposition 12. *Assume (C1) and (C2) hold. Also assume that the manager privately observes $\tilde{\theta}$ and has an abandonment option. The fully revealing regime is always preferable to the aggressive regime.*

Proof. Proof is in the appendix.

□

Proposition 12 states that the investment in the aggressive regime is less efficient than that in the FR regime. As shown in the proof, the aggressive regime leads to more overinvestment of the good firm ex ante, precisely because it tightens the nonmimicry constraint (3.4) by decreasing the right-hand side. The intuition behind this result is as follows: in the aggressive system, neither the shareholders nor the manager knows whether the asset's value is v_L or v_M when observing no impairment; thus, it makes the manager's abandonment decision inefficient. In particular, the manager inefficiently abandons (continues) the project when the estimated exit value $\frac{\sum_{j=L}^{M} q_j v_j}{\sum_{j=L}^{M} q_j}$ exceeds (is smaller than) the continuation value θ_B. The inefficient abandonment decision reduces the bad-type firm's equilibrium utility, which, in turn, provides the bad type with more incentives to imitate the good type's investment strategy. Therefore, it is more costly to separate the good type from the bad type, and the good-type manager should over-invest more to signal her type in the aggressive regime.

3.5.1.4 Optimal Investment in the Conservative Regime

I now consider the conservative regime in which FV that is below the initial BV (adjusted for fixed depreciation) is perfectly revealed. The conservatism regime resembles the current

accounting practice such as lower-of-cost-or-market and long-lived asset impairment; thus, this subsection rationalizes the asset impairment policy.

In the conservative regime, the firm writes down the asset's value to v_L if the true FV is low (v_L), but cannot write up the asset's value if the true FV is high (v_H). Therefore, if there is no impairment, neither the shareholders nor the manager knows whether the asset's value is appreciated (v_H) or remains the same (v_M). Mathematically, the estimated exit value is

$$E[v|\delta^C, \text{No Impairment}] = \frac{\sum_{j=M}^{H} q_j v_j}{\sum_{j=M}^{H} q_j},$$

and

$$v_M < E[v|\delta^C, \text{No Impairment}] < v_H.$$

When the bad type imitates the good type's investment, the bad type's abandonment decision is determined by Condition (C4). If (C4) holds, $\Theta > \frac{\sum_{j=M}^{H} q_j v_j}{\sum_{j=M}^{H} q_j}$, the bad type never abandons the project. In contrast, if Condition (C4) does not hold, $\frac{\sum_{j=M}^{H} q_j v_j}{\sum_{j=M}^{H} q_j} > \Theta$, the bad type abandons the project when $v_U = \{v_M, v_H\}$ is reported. In addition, if the bad-type manager truthfully reveals her type, she continues the project when v_L is reported but abandons the project when v_U is reported, since $\frac{\sum_{j=M}^{H} q_j v_j}{\sum_{j=M}^{H} q_j} > \theta_B$ is ensured by Condition (C1).

The corresponding optimization problem for a good-type firm's manager in a separating equilibrium reads as follows:

$$\max_{I_G^C \geq 0} E[U_{GG}^C] \tag{3.9}$$

$$st. \qquad E[U_{BG}^C] \leq \max_{I_B^C \geq 0} E[U_{BB}^C], \tag{3.10}$$

where

$$E[U_{GG}^C] = \theta_G I_G^C - \frac{1}{2} I_G^{C^2};$$

$$E[U_{BG}^C] = \begin{cases} \Theta I_G^C - \frac{1}{2} I_G^{C^2}, & \text{if (C4) holds} \\ (q_L \Theta + \sum_{j=M}^H q_j v_j) I_G^C - \frac{1}{2} I_G^{C^2}, & \text{if (C4) does not hold;} \end{cases}$$

$$E[U_{BB}^C] = (q_L \theta_B + \sum_{j=M}^H q_j v_j) I_B^C - \frac{1}{2} I_B^{C^2}.$$

Denote the solution to this program by I_G^C. The good-type manager chooses I_G so as to distinguish herself from the bad-type manager by ensuring the nonmimicry constraint (3.10) holds. Condition (C2) implies that the bad type abandons the project when v_U is reported if she does not imitate the good type's investment strategy; thus, the bad-type manager invests in the socially optimal level $I_B^C = q_L \theta_B + \sum_{j=M}^H q_j v_j$, and the good-type manager over-invests to signal her type. The result is summarized in the following lemma.

Lemma 5. *Assume that the conservative system is prescribed. Assume (C1) and (C2) hold. Also assume that the manager privately observes $\tilde{\theta}$ and has an abandonment option. With publicly observable investment I_i, there exists a separating equilibrium. In this equilibrium, the nonmimicry constraint (3.10) is binding; a good-type firm over-invests, $I_G^C > \theta_G$, whereas a bad-type firm invests in the socially optimal level, $I_B^C = q_L \theta_B + \sum_{j=M}^H q_j v_j$.*

Proof. The proof is omitted.

□

The proof is similar to the proof of Lemma 3.

So far I have described the optimal investment level in each regime. In particular, the bad-type firm under-invests in both the null regime and the aggressive regime, and invests in the socially optimal level in both the FR regime and the conservative regime, whereas the good-type firm over-invests to signal her type in all regimes. However, it remains unanswered that which regime induces the least overinvestment. Recall from Proposition 11 and Proposition 12, respectively, that the null regime dominates the no-abandonment-option regime and

the FR regime dominates the aggressive regime. Therefore, it is enough to compare the conservative regime, the null regime, and the FR regime.

At first sight, it appears intuitive that the FR regime should result in the most efficient investment since it provides the manager with more information to make the ex-post abandonment decision. This reasoning is also consistent with the argument from proponents of FV accounting. However, as shown in the next result, this argument is misleading because it overlooks the change in the manager's incentives. Because the FR regime makes the ex-post abandonment decision of assets-in-place more efficient, it increases the bad type's mimicry utility. This increase makes it more costly to separate the bad type from the good type and, thus, leads to more overinvestment of the good-type firm ex ante. Therefore, the FR regime is dominated by the conservative regime, and the latter one induces the most efficient investment.

Proposition 13. ***(Conservative Regime Mitigates Overinvestment)*** *Assume (C1), (C2), (C3), and (C4) hold. Also assume that the manager privately observes $\tilde{\theta}$ and has an abandonment option. With publicly observable investment, the conservative regime induces the least overinvestment of the good-type firm and thus improves investment efficiency.*

Proof. Proof is in the appendix.

□

Proposition 13 states that the conservative regime dominates all other regimes discussed in this paper. As shown in the proof, the conservative regime disciplines the firm's investment decision precisely because it relaxes the nonmimicry constraint (3.4).

However, the intuition behind this result deserves more subtle consideration. Although the reason why the conservative regime dominates is from disciplining the off-the-equilibrium path, the mechanism is quite different. On one hand, the conservative regime beats the

FR regime, because the conservative regime weakens the manager's short-term incentives and disciplines the off-the-equilibrium investment. In particular, the manager's inaccurate estimate of the exit value in the conservative regime prevents her from making efficient abandonment decisions. Therefore, the conservative regime decreases the bad-type firm's mimicry utility, which serves as a penalty for the value-destroying actions (e.g., off-the-equilibrium investment). On the other hand, the conservative regime beats the null regime, because the conservative regime improves the bad type's investment efficiency in equilibrium. In this case, the conservative regime increases the bad type's equilibrium utility, which, in turn, reduces the bad type's incentives to imitate the good type's investment strategy. In both cases, the conservative regime makes it less costly to separate the good type from the bad type and, thus, improves the ex-ante investment efficiency.

3.5.2 Discretionary Depreciation

In the baseline model, the accounting regime is set ex ante, and the manager does not have any discretion to choose the asset impairment policy after learning the project's type. This setting is consistent with US GAAP, which requires historical cost accounting with impairment for fixed assets. However, US GAAP allows the firm to choose the depreciation schedule, which indirectly affects the asset impairment. Specifically, a faster depreciation results in lower BV in earlier periods, which decreases the firm's chance of recognizing impairment losses in the future. Therefore, committing to a faster depreciation schedule shrinks the set of FVs that can be credibly disclosed in the future.[22]

In what follows, I extend the baseline model by allowing the manager to choose the depreciation schedule after making the investment decision. Assume that the manager decides

[22]Unlike US GAAP, IFRS provides a free choice between fair value accounting and historical cost accounting, but requires ex ante commitment to one of the two accounting policies (Christensen and Nikolaev, 2013). Therefore, the manager has some discretion to choose the accounting regime, but the analysis is fundamentally similar to allowing the manager to choose the depreciation schedule.

the depreciation schedule before the impairment test.[23] Without loss of generality, assume that there are two depreciation schedules, fast depreciation ($BV = d^F I$) and slow depreciation ($BV = d^S I$). Also assume $d^F < v_M < d^S$. Intuitively, the fast depreciation results in relatively lower BV in earlier periods.

Assume that the initial investment is fully absorbed in liquidation with zero residual value; thus different depreciation schedules do not alter the terminal cash flow. However, adopting different depreciation schedules may change the reported FV of assets.[24] For example, when the accounting system prohibits write-ups (e.g., the conservative regime), the firm can merely disclose FV that is below BV. With the fast depreciation d^F, the asset's value is written down when the true FV is v_L, and there is no impairment when the true FV is v_M or v_H. With the slow depreciation d^S, the asset's value is written down when the true FV is v_M or v_L, and there is no impairment when the true FV is v_H. Therefore, committing ex ante to the slow depreciation enlarges the set of FVs that can be disclosed in the future.

Furthermore, with the fast depreciation, the manager and the shareholders cannot know whether the asset's value is appreciated (v_H) or remains the same (v_M), whereas with the slow depreciation, the manager and the shareholders know that $v = v_H$ when observing no impairment. In this case, the fast (slow) depreciation resembles the conservative (fully revealing) system in the baseline model. Therefore, similar to Proposition 13, the fast depreciation leads to more efficient investment decisions, and the good-type firm chooses the fast depreciation schedule in equilibrium. This result is summarized in the following proposition.

Proposition 14. ***(Good Type Chooses Fast Depreciation)*** *Assume (C1) and (C2) hold. Also assume that the manager privately observes $\tilde{\theta}$ and has an abandonment option,*

[23]This assumption makes the analysis compatible with the fixed asset impairment policy of IFRS, since IFRS requires the firm to commit to one accounting policy before she knows the effect of the FV estimate on financial statements.

[24]Under the FR regime, FV is reported without any restrictions; thus, the manager's choice of depreciation does not change the support of the reported FV.

investment is publicly observable, and the accounting system prohibits write-ups. In equilibrium, the good-type firm chooses the fast depreciation schedule. This mitigates overinvestment of the good-type firm and thus improves investment efficiency.

Proof. The proof is omitted.

□

Proposition 14 states that, if the manager has discretion in choosing the depreciation schedule, the good-type firm commits to the fast depreciation schedule that shrinks the set of FVs that can be disclosed in the future. The intuition behind this result is fundamentally similar to the discussion in Proposition 13. The fast depreciation schedule pools $\{v_H, v_M\}$ together, resulting in less efficient abandonment decisions ex post. However, this inefficiency reduces the bad-type firm's mimicry utility and, thus, serves as a penalty for the value-destroying actions (e.g., off-the-equilibrium investment). Therefore, the fast depreciation schedule reduces the signaling cost of the good-type firm and, thus, disciplines the ex-ante investment.

However, one additional element of Proposition 14 warrants brief mention. In equilibrium, the bad-type firm is indifferent between fast and slow depreciation schedules; thus, a fast depreciation schedule alone cannot serve as a credible signal for the manager to signal her type. Instead, as a second signal, the depreciation schedule helps reduce the signaling cost of the first signal – the ex-ante investment. This result is different from Lin (2006), in which a fast depreciation schedule alone serves as a commitment device for the agent to signal her type.

3.5.3 Discussion

I implicitly assume that the firm always discloses the reported FV z. This assumption

makes my setting slightly different from the current impairment policy of long-lived assets (ASC 360). US GAAP requires a two-step method to recognize and measure the impairment of a long-lived asset to be held and used.

Step 1. The firm performs a recoverability test by comparing the sum of the estimated undiscounted future cash flows attributable to the asset in question to its carrying amount. Note that firms cannot record impairment losses for a held and used asset unless the asset first fails this recoverability test.

Step 2. If the undiscounted cash flows used in the test for recoverability are less than the long-lived asset's carrying amount, determine the FV of the long-lived asset and recognize an impairment loss if the carrying amount of the long-lived asset exceeds its FV.

I have modeled the second step without comparing the undiscounted future cash flows θ to the carrying amount BV. With Step 1, the firm cannot record an impairment loss when the undiscounted future cash flows θ exceed the carrying amount BV, so that the good-type firm can neither write down the asset's value to v_L nor write up the asset's value to v_H, since θ_G exceeds BV. In other words, the shareholders can rationally infer that the firm is of the bad type if the firm writes down the asset's value.[25] Therefore, the recoverability test restricts the bad type's ability to imitate the good type. Recall from Lemma 5 that when the true FV is low (v_L), the bad-type firm is perceived as the good type as long as the bad type imitates the good type's investment and continues the project. However, with the recoverability test, the shareholders can rationally infer that the firm is of bad type when observing the asset's write-downs. In this case, the bad type's mimicry utility drops, which, in turn, helps reduce the good type's signaling cost. Thus, US GAAP's requirement of the recoverability test (Step 1) improves investment efficiency.

[25]The shareholders can also rationally infer that the firm is of the bad type if the firm writes up the asset's value. However, this case is irrelevant in the equilibrium analysis, since the bad-type firm abandons the project according to Condition (C2). Shareholders evaluate the share price based on the expected resale price rather than the conjectured continuation value.

3.6 Extension I: Managers Perfectly Learn v

In the baseline model, I assume that managers know no more than the accounting system reveals about the asset's FV. In what follows, I relax this assumption and, instead, assume that managers perfectly learn the asset's FV. As I will explain shortly, it is not important that the accounting system limits the manager's information about the FV. What is important is that shareholders learn about the FV from the accounting system and that the manager cares about the market's perception of the FV.

The model setup is similar to the baseline model in Section 3.5.1, except for the following two changes. First, at the end of $t = 1$, the manager privately observes the asset's FV and discloses the FV in accordance with the requirement of the accounting system. Second, assume that the abandonment choice S is publicly announced at $t = 2$, but the exit price v is not publicly observable until $t = 3$.[26] In this case, shareholders rely on the financial statement information to estimate the terminal CF $x^A = vI - C(I)$ after the manager announces the abandonment plan, but before the transaction price is disclosed.

The conservative system limits shareholders' information about the asset's FV when compared with the fully revealing system; therefore, shareholders misprice the firm[27] before the transaction price is disclosed. Specifically, shareholders overprice (underprice) the exit value at $\frac{\sum_{j=M}^{H} q_j v_j}{\sum_{j=M}^{H} q_j}$ when the asset's true FV is v_M (v_H). When the continuation value is sufficiently small, $v_M < \Theta < \alpha \frac{\sum_{j=M}^{H} q_j v_j}{\sum_{j=M}^{H} q_j} + (1-\alpha) v_M$, shareholders' overpricing can induce the manager to abandon the project even when the asset's exit value v_M is lower than the

[26] It usually takes a couple months to complete the transaction. For example, Google hired Barclays to help sell the acquired Motorola's Home Business division, and the transaction price was not disclosed until four months later.

[27] Mispricing arises unless the manager can credibly signal her private information about the exit value v through the abandonment decision. For example, when the following condition holds

$$\Theta > \alpha v_H + (1-\alpha) v_M, \tag{3.11}$$

the manager with v_H can be separated from the manager with v_M. The manager with v_H abandons the project because of Condition (C2) $\Theta < v_H$. In contrast, the manager with v_M is worse off to abandon the project, even if she can mislead shareholders into believing that the true value v is high (v_H). This case is less interesting, since shareholders learn the true value from the manager's abandonment decision and the two accounting systems are equivalent.

continuation value Θ. From the ex-ante perspective, the manager's gain from shareholders' overpricing is exactly offset by the loss from underpricing. From the ex-post perspective, however, the manager inefficiently abandons a project that is worthwhile to continue. When the continuation value is sufficiently large, $\alpha\frac{\sum_{j=M}^{H} q_j v_j}{\sum_{j=M}^{H} q_j} + (1-\alpha)v_H < \Theta < \alpha v_H + (1-\alpha)v_M$, shareholders' underpricing can induce the manager to inefficiently continue the project even when the asset's exit value v_H exceeds the continuation value Θ. In both cases, the ex-post inefficient abandonment decision is costly ex ante and reduces bad firms' incentives to mimic good firms, thus making it cheaper to separate good firms from bad firms. This result is summarized in the next proposition.

Proposition 15. *Assume (C1), (C2), (C3), and (C4) hold. Also assume that the manager privately observes $\tilde{\theta}$ and $\tilde{v}$ and has an abandonment option. With publicly observable investment, the conservative regime induces the least overinvestment of the good-type firm and thus improves investment efficiency.*

Proof. Proof is in the appendix.

□

3.7 Extension II: Staged Investments

In the Main Analysis, I have demonstrated that, when managers are better informed than shareholders, the conservative regime helps managers reduce overinvestment. However, it leaves one question unanswered: what if the manager shares the same information with shareholders?

In what follows, I extend the baseline model to a three-period model in which the manager has sequential investments. The manager makes the first investment decision when she

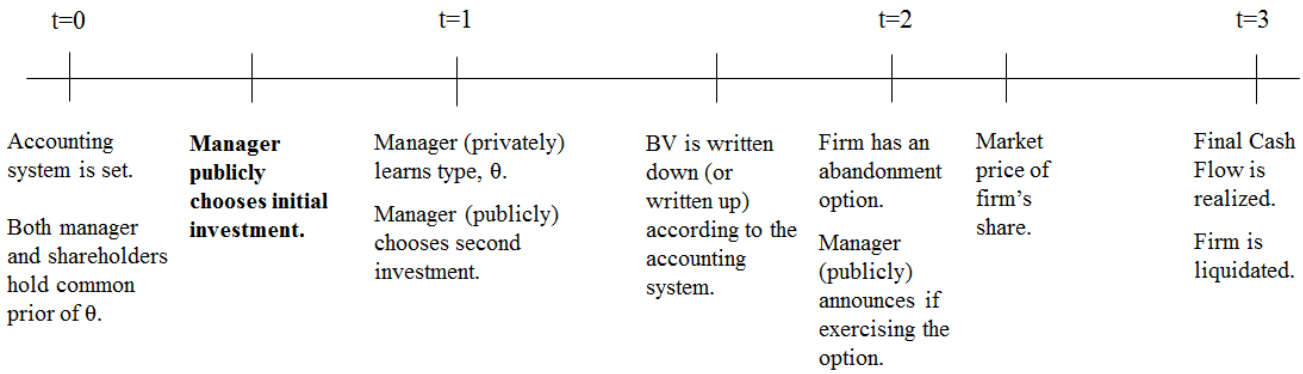

Figure 3.2: Timeline of events (staged investments).

shares the same information with shareholders and then makes the second investment when she has private information about the project's profitability. Specifically, at $t = 0$, the firm is faced with an investment opportunity. Neither the manager nor the shareholders know the project's profitability θ. The prior distribution of $\tilde{\theta}$ is that $\tilde{\theta} = \theta_G$ with probability $\Pr(G) \equiv \pi^G$. The manager publicly chooses an initial investment, denoted by $I_0 \in R^+$. Note that, at $t = 0$, neither the manager nor the shareholders know the exact profitability θ, but they hold the same prior belief; therefore, no information asymmetry exists ex ante. From $t = 1$ on, the timeline is similar to the baseline model in Section 3.5.1. The project generates terminal cash flows (net of the investment cost) at $t = 3$, denoted by

$$x = \begin{cases} \theta(I_0 + I) - C(I_0, I), & \text{if the manager continues the project at } t = 2 \\ v(I_0 + I) - C(I_0, I), & \text{if the manager abandons the project at } t = 2. \end{cases}$$

Assume that the cost function is $C(I_0, I) = \frac{1}{2}(I_0^2 + I^2)$. Also assume that the manager's utility function is a weighted average of the period 2 market price P and the terminal CF (net of the investment costs), $\alpha P + (1 - \alpha)x$.[28] The sequence of the events is summarized in Figure 3.2.

At first sight, it appears intuitive that the initial investment I_0 should equal the first-

[28] All results still hold if assuming that the manager also cares about the period 0 market price after the initial investment. The period 0 market price would be $E[\theta] I_0 - C(I_0)$.

best investment I_0^{FB} that reflects the unconditional expectation of productivity $E[\theta]$, because symmetric information between the manager and the shareholders should not lead to any investment distortion. However, this argument is misleading because it overlooks the spillover effect of the initial investment I_0 on the second investment I_i. In what follows, I demonstrate how the spillover effect results in inefficient investment decisions at the initial stage and whether this inefficiency is influenced by the accounting system.

With little abuse of notation, let U_0^δ be the total utility of both periods under the accounting regime δ. For example, $E[U_0^C]$ is the expected total utility in the conservative regime. Let U_{ii}^δ be the total utility of the type θ_i under the accounting regime δ when choosing the investment strategy of θ_k given the initial investment I_0^δ has already been chosen, $i, k \in \{G, B\}$.

The corresponding optimization problem in a separating equilibrium reads as follows:

$$\max_{I_0^\delta, I_i^\delta \geq 0} \; E[U_0^\delta] \tag{3.12}$$

$$st. \qquad U_{BG}^\delta \leq U_{BB}^\delta. \tag{3.13}$$

Two additional elements of the optimization problem warrant brief mention. First, the equilibrium should be sequentially rational in that each decision should be optimal upon anticipating that future decisions are subgame perfect equilibria.[29] Second, the equilibrium abandonment strategies are different across different regimes. Thus the utility functions, including U_0^δ, U_{BG}^δ, and U_{BB}^δ, are different.

Following the standard game theory method, I solve this problem backward. First, I solve for the optimal investment I_i^δ at $t = 1$. Note that this step is similar to the analysis in Section 3.4.2. In the least cost separating equilibrium, the shareholders can rationally infer θ based on observed I_i. In this case, the good-type manager chooses I_G^δ so as to satisfy the nonmimicry constraint (3.13). Second, I solve for the optimal investment I_0^δ at $t = 0$.

[29]The manager chooses the initial investment I_0 so as to maximize her payoff, knowing that she will choose the equilibrium investment I_i and the equilibrium abandonment strategy S in the future.

When the manager chooses I_0, she does not have any information advantage; therefore, I_0 does not convey any information. However, the next result shows that the size of the initial investment I_0 affects the signaling cost in the second period.

Proposition 16. *Assume (C1), (C2), and (C3) hold. Also assume that $\tilde{\theta}$ is unknown to both the manager and shareholders. With publicly observable investment I_0, a firm chooses to under-invest in the first period, $I_0^\delta < I_0^{FB} = E[\theta]$.*

Proof. Proof is in the appendix.

□

Proposition 16 states that the size of the initial investment I_0 has a positive spillover effect on the signaling cost in the later period; thus, it is optimal to under-invest in the first period, to save the signaling cost in the later period. Intuitively, the bad-type manager's payoff of imitating the good type's investment is $\max[\Theta, v](I_0^\delta + I_G^\delta)$, whereas the bad-type manager's payoff of not mimicking is $\max[\theta_B, v](I_0^\delta + I_B^\delta)$. Because $\Theta > \theta_B$, ceteris paribus, increasing I_0 provides the bad-type firm's manager with more incentives to imitate the good type's investment strategy. Therefore, the size of the initial investment I_0 has a positive spillover effect on the second investment in the late stage; thus it is optimal to under-invest in the first period regardless of the accounting systems.

Note that underinvestment in the first period would not offset the overinvestment in the second period. In the extreme case, if $I_0 = 0$ (the most underinvestment), the second investment problem is exactly the same as the baseline model in Section 3.5.1. Therefore, any amount of increase in I_0 increases the bad manager's mimicry utility in the later stage.

However, it remains unanswered which regime is the most efficient (e.g., inducing the least underinvestment). As shown by the next result, the conservative regime induces the most efficient initial investment (the least underinvestment).

Proposition 17. ***(Conservative Regime Mitigates Underinvestment)*** *Assume (C1), (C2), (C3), and (C4) hold. Also assume that $\tilde{\theta}$ is unknown to both the manager and shareholders. With publicly observable investment I_0, the conservative regime helps mitigate underinvestment and thus improves investment efficiency.*

Proof. The proof is omitted.

□

The intuition behind this result is as follow: recall from the proof of Proposition 16 that the underinvestment level balances between the loss from underinvestment in I_0 and the gain from reducing signaling costs of I_G. The equilibrium investment is reached when the marginal loss equals the marginal gain. Note that the marginal loss from underinvestment in I_0 is exactly the same in all regimes, but the marginal gains from reducing signaling costs of I_G are different. This follows directly from the fact that the overinvestment problem is less severe in the conservative regime. In other words, for the same amount of underinvestment in I_0, the conservative regime gains the least from saving signaling costs. Thus, it is less beneficial for the manager to under-invest in the first period in the conservative regime, which results in the least underinvestment. So, $\max[I_0^N, I_0^{null}, I_0^{FR}, I_0^A] < I_0^C < I_0^{FB} = E[\theta]$.

3.8 Conclusion

My results seem to contradict the conventional wisdom that credibly disclosing more information, by definition, makes financial statements more informative and potentially benefits shareholders. I study a plausible market setting where (1) managers have concern about how their decisions are priced in the capital market; (2) managers have real options – abandonment options (and staged investments); and (3) in the staged-investments setting, managers are not better informed than the market at the initial stage but have superior in-

formation at the late stage. I show that an asset impairment policy (prohibiting write-ups) makes the abandonment decision ex post inefficient, but improves investment efficiency ex ante and thus increases social welfare. In addition, this paper suggests that allowing the firm to choose the depreciation schedule improves investment efficiency, and, in equilibrium, the good-type firm chooses faster depreciation to avoid costly signaling through real investments. Also, I rationalize the two-step impairment test imposed by FASB and show that the recoverability test (Step 1) required by US GAAP disciplines the firm's investment decision. Last, I show that, in addition to reducing overinvestment in a late stage, an asset impairment policy also mitigates underinvestment in an initial stage. These findings provide a new rationale for current accounting standards for fixed assets and also contribute to related policy debates on accounting measurement.

Future research can consider the case in which the asset's FV is informative about the project's type. It does not seem to alter my primary qualitative conclusions in the separating equilibrium, because the shareholders can conjecture the project's type from the publicly observable investment. Thus, the asset's FV is redundant in estimating the project's type. However, if the asset's FV provides some noisy information about the project's type, the pooling equilibrium may not be eliminated by Intuitive Criteria. In general, the more accurate the FV is about the project's type, the more likely it is that the pooling equilibrium will survive the Intuitive Criteria.

Future research may also consider the case in which shareholders could force a liquidation of the project. In the staged-investments setting, if such opportunities exist, the asset impairment policy may induce suboptimal liquidation after the initial investment, which would reduce a manager's incentives to invest at the initial stage. This may be socially undesirable.

Appendix

Proof of Lemma 2

(i) Without abandonment option, clearly, $I_G^{FB} = \theta_G$ and $I_B^{FB} = \theta_B$.

(ii) With abandonment option and Condition (C1), the bad-type firm abandons the project when either $v = v_H$ or $v = v_M$ is realized. Therefore,

$$E[U_B^{FB}] = (q_L\theta_B + \textstyle\sum_{j=M}^{H} q_j v_j) I_B^{FB} - \frac{1}{2} I_B^{FB^2}.$$

Take the first-order derivative of $E[U_B^{FB}]$ w.r.t. I_B^{FB}; I can derive that

$$\frac{\partial E[U_B^{FB}]}{\partial I_B^{FB}} = q_L\theta_B + \textstyle\sum_{j=M}^{H} q_j v_j - I_B^{FB} = 0.$$

Therefore, $I_B^{FB} = q_L\theta_B + \sum_{j=M}^{H} q_j v_j$. Similarly, when Condition (C1) holds, the good-type firm never abandons the project, so $I_G^{FB} = \theta_G$.

Proof of Lemma 3

Condition (C3) ensures that the bad-type firm's manager abandons the project when she truthfully reveals her type; that is, $E[U_{BB}^{null}] = \bar{v} I_B^{null} - \frac{1}{2} I_B^{null^2}$. Thus, I can derive that

$$I_B^{null} = \bar{v} < I_B^{FB} = q_L\theta_B + \textstyle\sum_{j=M}^{H} q_j v_j.$$

The inequality follows directly from Condition (C1) that $\theta_B > v_L$.

Similar to Proposition 10, suppose $I_G^{FB} = \theta_G$ does not satisfy the nonmimicry constraint (3.6); then $I_G^{null} > I_G^{FB}$, and I_G^{null} is the level of investment at which the nonmimicry constraint (3.6) becomes binding.

Proof of Proposition 11

As mentioned before, the corresponding optimization problem for the good-type firm's manager in a separating equilibrium shares the same functional form, as follows:

$$\max_{I_G^\delta \geq 0} E[U_{GG}^\delta]$$

$$st. \qquad E[U_{BG}^\delta] \leq \max_{I_B^\delta \geq 0} E[U_{BB}^\delta].$$

My focus is on how the accounting system affects the nonmimicry constraint.

Note that the left-hand sides of nonmimicry constraints are the same in both regimes, because the bad type continues the project when she imitates the good type's investment strategy. In this case, it is enough to compare the right-hand sides of the nonmimicry constraints:

$$E[U_{BB}^N] = \theta_B I_B^N - \frac{1}{2} I_B^{N^2};$$

$$E[U_{BB}^{null}] = \max\{\theta_B,\ E[v|z^{null}]\} I_B^{null} - \frac{1}{2} I_B^{null^2}.$$

Clearly, $\max\{\theta_B,\ E[v|z^{null}]\} \geq \theta_B$. Therefore, $U_{BB}^{null} > U_{BB}^N$, which relaxes the nonmimicry constraints (by increasing the right-hand side). Thus, the null regime has a more relaxed nonmimicry constraint, which guarantees a better solution. That is, the null regime mitigates overinvestment.

Proof of Proposition 12

Similar to the proof of Proposition 11, my focus is still on how the accounting system affects the nonmimicry constraint. Because $v_L < E[v|\delta^A,\ \text{No Impairment}] < v_M < \Theta < v_H$, if the bad type imitates the good type's investment strategy, the bad type abandons the project when $v = v_H$ but continues when $v = v_D$ is reported. In this case, the equilibrium abandonment strategy in the aggressive regime is the same as that in the FR regime, so $E[U_{BG}^{FR}]$ and $E[U_{BG}^A]$ share the same functional form. Therefore, the left-hand sides of both

nonmimicry constraints are the same, and it is enough to compare the right-hand sides of the nonmimicry constraints.

In the aggressive regime, $E[v|\delta^A,\ \text{No Impairment}] = \frac{\sum_{j=L}^{M} q_j v_j}{\sum_{j=L}^{M} q_j}$, and

$$E[U_{BB}^{FR}] = E_v[\max\{\theta_B,\ v\}]I_B^{FR} - \frac{1}{2}I_B^{FR^2};$$

$$E[U_{BB}^{A}] = E_v[\max\{\theta_B,\ E[v|z^A]\}]I_B^{A} - \frac{1}{2}I_B^{A^2}.$$

Because max{} is a convex function, it is straightforward to derive that

$$E_v[\max\{\theta_B,\ E[v|z^A]\}] < E_v[\max\{\theta_B,\ v\}]$$

The last inequality comes from Jensen's inequality. Therefore, $E[U_{BB}^{FR}] > E[U_{BB}^{A}]$, and the FR regime relaxes the nonmimicry constraint by increasing the right-hand side; thus, it improves the firm's investment decision.

Proof of Proposition 13

Because Proposition 11 shows that the null regime dominates the no-abandonment-option regime, and Proposition 12 shows that the FR regime dominates the aggressive regime, it is equivalent to show that the conservative regime dominates both the FR regime and the null regime. Similar to preceding proofs, my focus is on how the accounting system affects the nonmimicry constraint.

(1) Compare the conservative regime and the FR regime: as guaranteed by Condition (C1), when the bad-type firm's manager truthfully reveals her type, she chooses the same abandonment decision in both the conservative regime and the FR regime, so $E[U_{BB}^{C}] = E[U_{BB}^{FR}]$. In contrast, the equilibrium abandonment strategies may be different when the bad-type firm imitates the good type's investment decision (by choosing I_G).

Note that,

$$E[U_{BG}^{FR}] = E_v[\max\{\Theta,\ v\}]I_G^{FR} - \frac{1}{2}I_G^{FR^2};$$

$$E[U_{BG}^{C}] = E_v[\max\{\Theta,\ E[v|z^C]\}]I_G^{C} - \frac{1}{2}I_G^{C^2}.$$

Because $\max\{\Theta, \ldots\}$ is a convex function, it is straightforward to derive that

$$E_v[\max\{\Theta,\ E[v|z^C]\}] < E_v[\max\{\Theta,\ v\}].$$

The last inequality comes from Jensen's inequality. Therefore, $E[U_{BG}^{FR}] > E[U_{BG}^{C}]$, and the conservative regime relaxes the nonmimicry constraint by decreasing the left-hand side; thus, it improves the firm's investment decision. That is, the conservative regime is always preferable to the FR regime.

(2) Compare the conservative regime and the null regime: similar to the preceding comparison between the conservative regime and the FR regime above, it is straightforward to derive that the bad-type firm's manager has a higher equilibrium payoff in the conservative regime, $E[U_{BB}^{C}] > E[U_{BB}^{null}]$. When Condition (C4) holds, it is clear that the bad-type firm's manager chooses the same abandonment decision in both systems when she imitates the good type's investment, so $E[U_{BG}^{C}] = E[U_{BG}^{null}]$. In this case, the conservative regime is preferable to the null regime. However, when Condition (C4) does not hold, the bad-type firm's manager achieves a higher payoff in the conservative regime when she imitates the good type's investment, so $E[U_{BG}^{C}] > E[U_{BG}^{null}]$. Then the ordering between the conservative regime and the null regime is undetermined. The conservative regime is preferable if $E[U_{BB}^{C}] - E[U_{BG}^{C}] > E[U_{BB}^{null}] - E[U_{BG}^{null}]$.

Proof of Proposition 15

Similar to preceding proofs, my focus is on how the accounting system affects the nonmimicry constraint, and I show that the conservative system results in the most relaxed nonmimicry constraint. I take the comparison between the conservative regime and the FR regime as an example.

Comparisons between the conservative regime and other systems are fundamentally similar.

As guaranteed by Condition (C1), when the bad-type firm's manager truthfully reveals her type, she chooses the same abandonment decision (abandon when v_M or v_H; continue when v_L) in both the conservative regime and the FR regime, so $U_{BB}^{C} = U_{BB}^{FR}$. In contrast, the equilibrium abandonment strategies may be different when the bad-type firm imitates the good type's investment decision (by choosing I_G).

In the FR regime, there is no mispricing for the abandonment value. Therefore, the bad-type manager's payoff after abandonment is $vI - C(I)$, and the bad-type manager's expected payoff of mimicry is as follow:

$$U_{BG}^{FR} = E_v[\max\{\Theta,\ v\}]I_G^{FR} - \frac{1}{2}I_G^{FR^2}.$$

In contrast, mispricing for the abandonment value arises in the conservative regime unless (3.11) holds. Therefore, the bad-type manager's payoff after abandonment is $\{\alpha E[v|z^C]+(1-\alpha)v\}I-C(I)$, and the bad-type manager's expected payoff of mimicry is as follow:

$$U_{BG}^{C} = E_v[\max\{\Theta,\ \alpha E[v|z^C] + (1-\alpha)v\}]I_G^{C} - \frac{1}{2}I_G^{C^2}.$$

Because $\max\{\Theta, \ldots\}$ is a convex function, it is straightforward to derive that

$$E_v[\max\{\Theta,\ \alpha E[v|z^C] + (1-\alpha)v\}] < E_v[\alpha\max\{\Theta,\ E[v|z^C]\} + (1-\alpha)\max\{\Theta, v\}]$$

$$= \alpha\max\{\Theta,\ E[v|z^C]\} + (1-\alpha)E_v[\max\{\Theta, v\}]$$

$$< E_v[\max\{\Theta,\ v\}].$$

The first inequality follows the property of the convex function, whereas the second inequality comes from Jensen's inequality. Therefore, $U_{BG}^{FR} > U_{BG}^{C}$, and the conservative regime relaxes the nonmimicry constraint by decreasing the left-hand side. Therefore, the conservative system reduces overinvestment when compared with the FR regime. Both regimes lead to the same investment if and only if the manager can use the abandonment decision to signal her private information about v, such as (3.11) in the footnote holds.

Proof of Proposition 16

The proof is similar in all regimes; thus, I take the no-abandonment-option regime as an example, and show that $I_0^N < I_0^{FB} = E[\theta]$.

The corresponding optimization problem in a separating equilibrium reads as follows:

$$\max_{I_0^N, I_i^N \geq 0} E[U_0^N]$$

$$st. \quad U_{BG}^N \leq U_{BB}^N,$$

where

$$U_0^N = \alpha P(I_0^N, I_i^N) + (1-\alpha)x;$$

$$U_{BG}^N = \alpha P(I_0^N, I_G^N) + (1-\alpha)[\theta_B(I_0^N + I_G^N) - \frac{1}{2}(I_0^{N^2} + I_G^{N^2})];$$

$$U_{BB}^N = \alpha P(I_0^N, I_B^N) + (1-\alpha)[\theta_B(I_0^N + I_B^N) - \frac{1}{2}(I_0^{N^2} + I_B^{N^2})].$$

The proof is decomposed into three steps.

Step 1: I solve for the optimal second investment I_G^N, I_B^N. The method is nearly the same as the proof of Proposition 10. In the least cost separating equilibrium, there are no incentives for the bad-type firm to mimic the good type's strategy; therefore, the bad-type firm will choose $I_B^N = I_B^{FB} = \theta_B$. When α is big enough, $I_G^N = \theta_G$ does not satisfy the nonmimicry constraint (3.13); then $I_G^N > I_G^{FB}$. Given the cost of signaling, it is never optimal for θ_G-type to invest more than necessary to deter mimicking by θ_B-type. Therefore, I_G^N is the level of investment at which the nonmimicry constraint (3.13) becomes binding.

Step 2: Instead of explicitly solving I_0^N, I show that an increase in the initial investment I_0 increases the signaling cost in the later stage. This spillover effect arises because I_0 affects the nonmimicry constraint (3.13). Rewrite the nonmimicry constraint (3.13) as follows:

$$\alpha(\theta_G - \theta_B)I_0^N + \Theta\ I_G^N - \frac{1}{2}I_G^{N^2} \leq \theta_B I_B^N - \frac{1}{2}I_B^{N^2}.$$

Because $\theta_G > \theta_B$ by assumption, clearly an increase in I_0^N tightens the nonmimicry constraint by increasing the left-hand side. Therefore, an increase in I_0 makes signaling in the second period more costly.

Step 3: I show that underinvestment in the initial stage ($I_0^N < I_0^{FB}$) is optimal. In particular, I show that a marginal decrease (ϵ) in I_0 from the socially optimal investment I_0^{FB} leads to more gain from reducing overinvestment of I_G than the inefficiency from underinvestment of I_0.

Assume that $I_0 = I_0^{FB} - \epsilon$. The marginal loss from underinvestment of I_0 is as follow:

$$U(I_0^{FB}) - U(I_0) = \{E[\theta]I_0^{FB} - \frac{1}{2}(I_0^{FB})^2\} - \{E[\theta]I_0 - \frac{1}{2}(I_0)^2\}$$

$$= E[\theta]\epsilon - \frac{1}{2}(2E[\theta] - \epsilon)\epsilon = \frac{1}{2}\epsilon^2. \tag{3.14}$$

Note that the manager does not know her type when she chooses the initial investment, but knows that she is of the good type with probability π^G. Thus the marginal gain from reducing the signaling cost is

$$\pi^G[U(I_G^N) - U(I_G^{'})] = \pi^G\{\theta_G I_G^N - \frac{1}{2}(I_G^N)^2\} - \pi^G\{\theta_G I_G^{'} - \frac{1}{2}(I_G^{'})^2\}$$

$$= \pi^G\theta_G\{I_G^N - I_G^{'}\} - \frac{1}{2}\pi^G\{(I_G^N + I_G^{'})(I_G^N - I_G^{'})\}, \tag{3.15}$$

where $I_G^{'}$ is the good type's optimal investment at $t = 1$ in the no-abandonment-option regime given that the manager invests I_0^{FB} at $t = 0$. Thus, $I_G^{'}$ implicitly solves

$$\alpha(\theta_G - \theta_B)I_0^{FB} + \Theta\ I_G^{'} - \frac{1}{2}(I_G^{'})^2 = \theta_B I_B^N - \frac{1}{2}I_B^{N^2}, \tag{3.16}$$

and I_G^N implicitly solves

$$\alpha(\theta_G - \theta_B)I_0 + \Theta\ I_G^N - \frac{1}{2}(I_G^N)^2 = \theta_B I_B^N - \frac{1}{2}I_B^{N^2}. \tag{3.17}$$

Solving, respectively, for the quadratic equation (3.16) and (3.17), I can derive

$$I'_G = \Theta + \sqrt{\Theta^2 - 2[\theta_B I_B^N - \frac{1}{2} I_B^{N^2} - \alpha(\theta_G - \theta_B) I_0^{FB}]};$$

$$I_G^N = \Theta + \sqrt{\Theta^2 - 2[\theta_B I_B^N - \frac{1}{2} I_B^{N^2} - \alpha(\theta_G - \theta_B) I_0]}.$$

It is clear that

$$I_G^N - I'_G = \sqrt{\Phi - 2\alpha(\theta_G - \theta_B)\epsilon} - \sqrt{\Phi},$$

where $\Phi \equiv \Theta^2 - 2[\theta_B I_B^N - \frac{1}{2} I_B^{N^2} - \alpha(\theta_G - \theta_B) I_0^{FB}]$. Applying Taylor Expansion and Mean Value Theorem, I can derive

$$I_G^N - I'_G = -\frac{1}{2\sqrt{\Phi}} 2\alpha(\theta_G - \theta_B)\epsilon - \frac{1}{8\chi^{\frac{3}{2}}}[2\alpha(\theta_G - \theta_B)\epsilon]^2, \tag{3.18}$$

where $\chi \in (\Phi - 2\alpha(\theta_G - \theta_B)\epsilon, \Phi)$. Taking (3.18) into (3.15), I can then derive

$$\pi^G[U(I_G^N) - U(I'_G)] = \pi^G(\frac{1}{2}(I_G^N + I'_G) - \theta_G)(\frac{1}{2\sqrt{\Phi}} 2\alpha(\theta_G - \theta_B)\epsilon + \frac{1}{8\chi^{\frac{3}{2}}}[2\alpha(\theta_G - \theta_B)\epsilon]^2).$$

Because $I_0^{FB} > I_0$, *Step 2* indicates that $I'_G > I_G^N$. Moreover, Proposition 10 shows that the good type should over-invest $I_G^N > I_G^{FB} = \theta_G$. Therefore, $\pi^G(\frac{1}{2}(I_G^N + I'_G) - \theta_G) > 0$, and thus $\pi^G[U(I_G^N) - U(I'_G)] > 0$.

Furthermore, if θ_G is sufficiently larger than θ_B or the following condition holds

$$\pi^G(\frac{1}{2}(I_G^N + I'_G) - \theta_G)\alpha^2(\theta_G - \theta_B)^2 > \chi^{\frac{3}{2}},$$

then $\pi^G[U(I_G^N) - U(I'_G)] > U(I_0^{FB}) - U(I_0)$, so the marginal gain from reducing signaling costs of I_G^N is higher than the marginal loss from underinvestment in I_0. Note that the equilibrium investment I_0^N is reached when the marginal loss equals the marginal gain. This suggests that $I_0^N < I_0^{FB}$.

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