Earnings Management, Incentive Contracts and Private Information Acquisition

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ABSTRACT: This paper analyzes the optimal design of compensation contracts in the presence of earnings management incentives, and its interplay with investors' information acquisition decisions. We consider a setting in which compensation contract is based on both accounting earnings and stock price when an agent engages in predictable, pernicious earnings management and stock price is endogenously determined in a Noisy Rational Expectations Equilibrium (NREE) that reflects both the public information from reported earnings and a costly, noisy signal privately acquired by investors. We show that an increase in the precision of the firm's financial reporting system could reduce the informativeness of stock price and exacerbate the agency problem by inducing lower productive effort and higher earnings management, implying that the firm may not choose a more precise financial reporting system.

Key Words: *Compensation contract; Earnings management; Private information acquisition*

JEL Classification: D82; M41

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1. Introduction

Earnings and stock price are widely-used performance measures in managerial incentive contracts.[1] Agency theory suggests tying managers' pay to the performance of their firms for efficiency reasons. Recent empirical studies and corporate scandals (e.g., Enron and WorldCom), however, reveal a "dark side" of using earnings- and price-based compensations: they can induce earnings management (Healy, 1985; Guidry et al., 1999; Ke, 2001; Cheng and Warfield, 2005; Bergstresser and Philippon, 2006). As stock price aggregates information from investors and thus serves as a market monitoring mechanism (Holmstrom and Tirole, 1993), a manager's incentive to manipulate earnings should also be influenced by how informative the stock price is. Meanwhile, an investor's incentive to acquire costly private information is affected by the precision of reported earnings because a more precise public report decreases the profits from informed trading by reducing the information asymmetry between informed and uninformed investors. Thus, it is important to analyze the optimal design of managerial contracts in the presence of earnings management incentives, and its interplay with investors' information acquisition decisions.

Our model features the public firm as a principal-agent contract between the board, representing the interests of long-term shareholders (the principal), and the risk-averse, work-averse manager (the agent); the firm's stock is traded in a market with informed traders, liquidity traders and a market maker. The firm's output (its terminal cash flow) is a noisy measure of the agent's productive effort. Compensation contracts are based on reported earnings and stock price, both of which are noisy measures of the firm's output. Reported earnings are, however, subject to manipulation by the agent. Thus, productive effort and unproductive manipulation are substitutes in terms of increasing the firm's reported earnings and are costly to the agent. In contrast, stock price is endogenously determined in a Noisy

[1] Murphy (1999) states that most executive pay packages contain four basic components: a base salary, an annual bonus tied to accounting performance, stock options, and long-term incentive plans (including restricted stock plans and multi-year accounting-based performance plans). Despite the use of price-based performance plans has gained popularity since 1980s (Chapter 3 in Ronen and Yaari, 2008), compensation plans based on accounting-based performance goals are still used by a large portion of firms. According to Mishra et al. (2000), about 35% of firms surveyed by the Conference Board in 1995 and 1996 use long-term accounting-based performance plans.

Rational Expectations Equilibrium (NREE) that reflects both the public information from reported earnings and a costly, noisy signal of the firm's output privately acquired by investors. We refer to the incremental information conveyed by the stock price that is beyond what is known from the reported earnings as the "filtered" price. Different from the reported earnings, the filtered price can be used as another performance measure to induce productive effort without stimulating costly earnings manipulation. In order to induce a given level of productive effort, the principal chooses the relative incentive rates for the two noisy performance measures to trade off the cost of inducing earnings manipulation and the risk premium paid to the agent. The more informative the filtered price, the higher the relative compensation weight placed on it, thereby suppressing the agent's incentive to manipulate earnings and increasing productive effort. Taking the precision of the earnings report as exogenous, we derive the optimal linear contract, the equilibrium number of informed investors and investigate some of their properties.

We show that an increase in the precision of reported earnings, which is expected to alleviate the agency problem as suggested by the conventional wisdom, may actually lead to the opposite, undesirable outcomes of higher earnings management and lower productive effort (see part (i) of Proposition 2). The key is that a more informative earnings report drives out sophisticated investors, because the better the public information, the lower the profit of the informed investors from acquiring a costly private signal. Under certain conditions, this negative impact on the equilibrium number of informed investors leads to decreased informativeness of the filtered price (see part (ii) of Proposition 1). More compensation weight is then shifted from filtered price to reported earnings, resulting in more manipulative effort substituting for productive effort. We further show that there exist conditions under which the agency problem becomes so acute that the principal may choose to install the least precise financial reporting system (see Proposition 3).

Our paper contributes to two strands of literature: compensation contracts and earnings management. The literature on compensation contracts shows that the optimal contract is determined by the relative efficiency of performance measures in order to induce effort and reduce risk, and should place greater reliance on measures of performance that are more precise for the agent's unobservable productive effort (Lambert and Larcker, 1987; Banker and Datar, 1989; Feltham and Xie, 1994). Prior studies in this literature allow the precision of one of the performance measures, i.e., the stock price, be endogenously determined in a NREE (Bushman and Indjejkian, 1993a & 1993b; Kim and Suh, 1993; Baiman and Verrechia, 1995) and the agent's actions be two-dimensional so that an effort allocation decision made by the agent must also be induced (Feltham and Wu, 2000). This literature, however, often ignores earnings management. In contrast to prior studies, we show that earnings-based compensation does not necessarily get higher weight when the earnings report become more precise because more reliance on earnings-based compensation may only cause more distortive earnings management.

Our paper also contributes to the literature on earnings management. One strand of this research mostly focuses on identifying the conditions that give rise to earnings management in equilibrium (Dye, 1988; Evans and Sridhar, 1996; Bagnoli and Watts, 2000; Demski et al., 2004; Ronen et al., 2006; Elitzur, 2010).[2] Another strand of the earnings management literature focuses on how the manager's incentive to manipulate earnings influences investor's perceptions of the firm's value in capital markets (Narayanan, 1985; Stein, 1989; Fischer and Verrecchia, 2000; Fischer and Stocken, 2004).[3] However, this literature usually ignores how the equilibrium compensation contract is derived and its impact on earnings management behavior. On the contrary, the setting of our model allows us to investigate the effect of investors' private information acquisition activities on earnings management through the optimal compensation contract. We show that investors' information acquisition activities influence the informativeness of the stock price and its relative compensation weight, thereby

[2] This literature initially studied a one-period, single firm's principal-agent setting with rational players. Bagnoli and Watts (2000) extend this literature by considering a setting with multiple firms and show that all firms inflate earnings in equilibrium as they see themselves compete in a "beauty contest". In a repeated setting, Demski et al. (2004) identify conditions under which the principal optimally permits, or even assists, the agent to manipulate the accounting signal so as to reduce the agent's opportunity cost of continued manipulation, thereby increasing the long-term productive effort from the agent. Ronen et al. (2006) argue that earnings management is an outcome of governance failure whereby the opportunistic directors and manager tacitly collude on earnings management to increase their own wealth. Elitzur (2010) shows how earnings management emerges in equilibrium when managers have bounded rationality.

[3] This strand of research initially developed models that have signaling-jamming equilibria whereby earnings management has neither a cash flow nor wealth distribution effect as the manager's incentive to manipulate earnings is common knowledge and therefore the earnings management is well anticipated and fully discounted. Fischer and Verrecchia (2000) relax this common knowledge assumption. Fischer and Stocken (2004) consider the external monitoring role of speculators' information on earnings management behavior.

affecting the earnings manipulation behaviour of the agent. In this way, our paper also complements some recent studies on the relationship between compensation contract and earnings management (Goldman and Slezak, 2006; Crocker and Slemrod, 2007).[4] By modelling reported earnings and stock price as two performance measures, where the former is subject to manipulation and the later contains incremental information that is privately acquired by investors and uncontaminated by earnings management, we are able to investigate the effect of information environment on agent's choices of earnings manipulation and productive effort.

The remainder of the paper is organized as follows. Section 2 describes the model. Section 3 characterizes the stock market equilibrium and the optimal information acquisition activities. Section 4 characterizes the optimal compensation contract. In Section 5, we perform some comparative-static analyses and discuss their empirical/policy implications. The final section concludes. All proofs are relegated to the Appendix.

2. The Model

Our one-period model consists of a publicly traded firm with a principal, an agent, informed traders, liquidity traders and a market maker. The agent alone is risk-averse; all other players are risk-neutral.[5] The timeline is presented in Figure 1. At the first stage, the board, acting in the interests of long-term shareholders (the principal), designs a compensation contract to hire an agent (the manager) to run the firm.[6] At the second stage, the agent exerts unobservable effort that stochastically affects the firm's end-of-period gross cash flow and at the same time covertly creates opportunities for future misreporting of information concerning the cash flow. At the third stage, the agent publicly issues an earnings report that reflects the firm's end-of-period gross cash flow. At the fourth stage, investors submit their demand for the firm's stock to the market maker after observing the earnings

[4] While Goldman and Slezak (2006) ignore the use of earnings report as a performance measure in their model, Crocker and Slemrod (2007) assume that the earnings report is the only performance measure. In contrast, we show that both earnings and filtered price receive positive weights on the optimal compensation contract. See Lemma 3 for details.

[5] The assumption of risk neutrality for all players other than the agent allows us to focus the analysis exclusively on managerial incentive issues.

[6] Long-term shareholders are value-oriented investors who will normally hold the firm's shares until the firm is liquidated, although they might also be subject to a random liquidity shock before the firm is liquidated.

report. There are two types of investors: (i) an endogenously determined number of informed traders who, not only observe the earnings report, but also privately acquire costly and noisy information about the firm's end-of-period gross cash flow; and (ii) an exogenously given number of liquidity-motivated traders (who may include shareholders, as well as other traders) who trade for reasons that are not related to any information about the firm. At the fifth stage, the market maker sets the stock price conditional on the earnings report and the total net demand submitted to him. The compensation contract is then settled. At the last stage, the firm's cash flow, net of the compensation to the agent, is paid to the principal.

[Insert Figure 1 about here]

2.1 Production Technology and Compensation Contract

The firm's stochastic production process is represented by $\tilde{v} = e + \tilde{\varepsilon}$, where $\tilde{v}$ is the firm's gross cash flow (gross of any compensation paid to the agent), e is the unobservable effort taken by the agent at stage 2, and $\tilde{\varepsilon}$ is a normally distributed noise term with mean 0 and precision h.[7] The distribution of the production noise term (i.e., the cash-flow-related risk) is independent of the agent's effort.

At stage 1, the principal chooses a compensation contract to efficiently motivate the agent to exert effort. We assume that the only information on which the agent's contract can be based is the earnings report and the stock price.[8] Furthermore, for tractability, we assume that the compensation contract is linear in the two observables: $\tilde{w} = \omega + \alpha\tilde{r} + \beta\tilde{P}$, where $\tilde{r}$ is earnings report publicly issued by the agent, $\tilde{P}$ is stock price for the firm's end-of-period gross cash flow, and ω, α and β are the linear compensation coefficients chosen by the principal.[9] When designing the contract, the principal knows that the agent is able to

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[7] Throughout the paper, random variables have a tilde (~) while their realizations do not.

[8] In particular, we assume that the firm's end-of-period gross cash flow is not contractible. If contracts could be written on the realized cash flow of the firm, then no earnings management would occur. In reality, the firm's gross cash flow is usually realized well after the end of the contract and therefore not contractible before the agent needs to be rewarded.

[9] Following Baiman and Verrecchia (1995, 1996), we let $\tilde{P}$ represent the stock price for the firm's end-of-period gross cash flow rather than the cash flow net of compensation for notational convenience. This assumption does not qualitatively affect the results. In particular, since we have a linear framework, the stock price for the gross cash flow and that for the net cash flow are two

manipulate the earnings report to be issued at stage 3. Although earnings management could be perfectly anticipated by the principal and the market, it could not be contracted upon. The principal also anticipates that the stock price to be determined at stage 5 impounds valuable information about the firm's end-of-period gross cash flow and, hence, the agent's effort.[10]

2.2 Accounting Information, Agent's Effort and Reporting Strategy

At stage 2, after the contract is signed, the agent exerts unobservable costly effort and covertly creates opportunities (at a cost described shortly) to introduce an amount of reporting bias, η, into the future earnings report that reflects the firm's end-of-period gross cash flow.[11] We assume that the agent has multiplicatively separable, negative exponential utility, $U_m(e,\eta) = -\exp\{-\rho[\tilde{w} - V(e,\eta)]\}$, with a separable and quadratic (monetary) cost function of effort and earnings management, $V(e,\eta) = \frac{1}{2}(e^2 + b\eta^2)$, where $\rho > 0$ is the agent's coefficient of constant absolute risk aversion, and $b \in (0,\infty)$ represents the intensity of the marginal cost of earnings management.[12] Without loss of generality the agent's reservation utility is normalized to minus one.

At stage 2, given a compensation contract $\tilde{w}$, the agent's objective is to choose e and η to maximize his expected utility:

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informationally equivalent constructs. To convert one from the other one only needs public information. However, this assumption implies that the compensation is paid by the long-term shareholders and thus simplifies the analysis considerably as it makes trading independent of incentive contracting, and thereby allowing us to analyze trading and incentive contracting separately. Jensen and Murphy (1990, p. 228) suggest that, as a measure of managerial performance, stock price before compensation is more appropriate than stock price after compensation.

[10] Thus, we model private information acquisition as a market monitoring mechanism as in Holmstrom and Tirole (1993).

[11] Two remarks are in order here. First, if the agent is allowed to trade the firm's stock, then he might have an incentive to misreport down, whereas in our model without insider trading he only has an incentive to misreport up, i.e., $\eta > 0$. Second, we assume that η is not observable to anyone except the agent (although other players will be able to anticipate the level of η in equilibrium since the agent's reporting incentives are common knowledge). Otherwise the agent would be able to effectively commit to truthful reporting simply by setting $\eta = 0$. As is well-known in the signal-jamming literature, the agent bears the cost of manipulating the earnings report without being able to distort market participants' beliefs about the firm's gross cash flow (e.g., Narayanan 1985 and Stein 1989). Nevertheless, the agent still has incentives to bias the earnings report upward because otherwise he would be perceived by the market as exerting less effort and, accordingly, would receive lower compensation.

[12] The costs to the agent from engaging in earnings management include the agent's personal time cost for manipulation as well as his reputation, psychic and litigation costs when the manipulation is discovered. The assumptions of a linear production and a quadratic cost functions ensure interior and closed-from solutions for the optimal effort and earnings management.

$$\underset{e,\eta}{Max}\, E\left[U_m(e,\eta)\right]. \tag{1}$$

Then, at stage 3, the agent publicly issues an earnings report, $\tilde{r} = \tilde{v} + \eta + \tilde{\tau}$, where $\tilde{\tau}$ represents noise in the financial reporting system that is not affected by the agent's actions and is assumed to be normally distributed with mean 0 and precision m.[13] It is noteworthy that the agent regards productive effort and unproductive earnings management as substitutes because they both improve his reported performance and hence the compensation. As such, earnings management undermines incentives to exert effort, and thus exacerbates the agency problem.

2.3 Private Information Acquisition and Stock Trading

After observing the earnings report, r, investors submit their demand for the firm's stock to the market maker. There are two types of investors: informed traders and liquidity traders. We assume that there exists an endogenously determined number of $N > 1$ informed traders who, not only observe the earnings report, but also acquire private information about the firm's end-of-period gross cash flow at a cost of C before the market opens for the firm's shares.[14] For simplicity, we further assume that each informed trader privately receives a common imperfect signal of the form: $\theta = \tilde{v} + \tilde{\kappa}$, where $\tilde{\kappa}$ is a normally distributed noise term with mean 0 and precision s.[15] Conditional on the observed private information, θ, and the observed earnings report, r, each informed trader privately submits a market demand of d_i, $i = 1, ..., N$, to maximize his expected trading profit:

$$\underset{d_i}{Max}\, E\left[(\tilde{v} - \tilde{P})d_i \mid \tilde{\theta} = \theta, \tilde{r} = r\right], \tag{2}$$

where $(\tilde{v} - \tilde{P})d_i$ is the informed trader *i*'s random trading profit. The aggregate demand of liquidity traders, $\tilde{l}$, is exogenously given and assumed to be normally distributed with mean

[13] We use the terminologies "precision of the firm's financial reporting system", "precision of earnings report" and "precision of public information" interchangeably in this paper.

[14] We implicitly assume that the private information is inaccessible to the principal so as to focus on the informational benefit of price-based compensation.

[15] That is, we model the investors' private signal as a noisy measure of the firm's cash flow, and therefore a noisy measure of the agent's contribution to the firm's cash flow. The basic intuition underlying the form of investors' private signal is the idea that information markets exist to provide investors with financial analysis and other advisory services from which the investors might obtain information about the firm's cash flow.

0 and precision t. The total market demand is then given by $\tilde{q}=\sum_{i=1}^{N} d_i+\tilde{l}$.[16] The stock trading mechanism is that of Kyle (1985) in which the stock price is semi-strong informationally efficient. That is, conditional on all the information available to him, namely, the total market demand q and the agent's earnings announcement r, the market maker sets market price P equal to the expected gross cash flow of the firm:

$$P=E(\tilde{v}\mid \tilde{q}=q,\tilde{r}=r)\,. \tag{3}$$

Equation (3) implies that the market maker is competitive and earns zero expected profits.

All random noises are independent of each other with a finite precision. The model structure of the game is common knowledge. Table 1 summarizes the notation used in the model.

[Insert Table 1 about here]

Given the sequential nature of the game, we solve for the equilibrium of the model by backward induction. In the next section we characterize the stock market equilibrium when the market participants have the same common conjectures of the unobservable productive effort, e^c, and the unobservable reporting bias, η^c, taking the number of informed traders and the compensation contract as given.[17] Then, we analyze how the equilibrium number of informed traders is determined. The optimal compensation contract is then derived in Section 4.

3. Informed Trading, Stock Price Formation and Endogenous Private Information Acquisition

The stock market equilibrium consists of trading strategies d_i, $i=1,\ldots,N$, and a pricing

[16] We implicitly assume that the agent/manager is not allowed to trade. For studies on managerial trading, see, for example, Baiman and Verrecchia (1995, 1996).

[17] Two remarks are noteworthy here. First, that the number of informed traders is common knowledge at the time of trading because everyone can solve for the optimization problem of an investor who has to choose whether to become informed or not, and thus determine how many investors have become informed traders. Second, productive effort e and reporting bias η are assumed to be unobservable to the market maker (and informed traders), so that the market maker sets market price based on the conjectured productive effort e^c and conjectured reporting bias η^c. In equilibrium the conjectures of the market participants always equal to the agent's actual choices.

function P such that (i) the trading strategy of each informed trader maximizes his expected trading profit in response to all other informed traders' strategies, and (ii) P satisfies equation (3) in response to the trading strategies of all informed traders. The following lemma characterizes the stock market equilibrium.

Lemma 1: Given a pair of common conjectures of productive effort and reporting bias, (e^c, η^c), and taking the number of informed traders, N, and the incentive contract, (ω, α, β), as given, there exists a unique linear rational expectations equilibrium whereby the strategies of each of the N informed traders and the market maker are given as follows:

$$d_i = d_0 + d_\theta \theta + d_r r, \quad \text{for all } i = 1,\ldots, N, \tag{4}$$

$$P = P_0 + P_q q + P_r r, \tag{5}$$

where

$$d_0 = -\Omega(he^c - m\eta^c)\sqrt{\frac{1}{Nt}}, \qquad d_\theta = \Omega(h+m)\sqrt{\frac{1}{Nt}}, \qquad d_r = -\Omega m\sqrt{\frac{1}{Nt}},$$

$$P_0 = \frac{he^c - m\eta^c}{h+m}, \quad P_q = \frac{\Omega\sqrt{Nt}}{N+1}, \quad P_r = \frac{m}{h+m}, \quad \text{and}$$

$$\Omega \equiv \sqrt{\frac{s}{(h+m)(h+m+s)}}. \tag{6}$$

Lemma 1 shows that, except for the intercept terms (i.e., d_0 and P_0), none of the coefficients in the market participants' strategies (i.e., d_θ, d_r, P_q and P_r) is affected by the reporting bias. This result reflects the fact that the reporting bias is perfectly anticipated in equilibrium. However, such a predictable earnings manipulation is pernicious as it destroys firm value (since P_0 is decreasing in η^c).

To obtain more insights into the informed traders' demand, we can rewrite equation (4) as:[18]

$$d_i = \frac{E(\tilde{v} \mid \tilde{\theta} = \theta, \tilde{r} = r) - E(\tilde{v} \mid \tilde{r} = r)}{P_q(N+1)}, \quad \text{for all } i = 1,\ldots, N. \tag{7}$$

[18] See the Appendix for a derivation of equation (7).

Equation (7) reveals that the private signal confers an information advantage on the informed traders relative to all other uninformed traders who only observe the earnings report. Thus, we can use $\Omega \equiv SD\left[E(\tilde{v} \mid \tilde{\theta} = \theta, \tilde{r} = r) - E(\tilde{v} \mid \tilde{r} = r)\right]$ in equation (6) as an ex-ante measure of the information asymmetry between informed and uninformed traders (see, e.g., Bushman and Indjejikian 1995), where $SD(\cdot)$ is the standard derivation operator. Equation (6) reveals that the information advantage of the informed traders decreases when the firm's gross cash flow or the earnings report becomes more precise, and increases when the private information becomes more precise.

Anticipating that the linear rational expectations equilibrium is characterized in Lemma 1, each of the informed trader's ex-ante expected trading profit is given by:[19]

$$\Pi_i \equiv \frac{E[E(\tilde{v} \mid \tilde{\theta} = \theta, \tilde{r} = r) - E(\tilde{v} \mid \tilde{r} = r)]^2}{P_q (N+1)^2} = \frac{P_q}{Nt}, \quad \text{for all } i = 1,\dots, N. \tag{8}$$

In a competitive equilibrium, the equilibrium number of informed traders, N^*, is determined such that the ex-ante expected trading profit of each informed trader, Π_i, is equal to the cost of information acquisition, C:

$$\frac{P_q}{N^* t} = C, \tag{9}$$

where for analytical convenience we ignore the integer constraint on N^*. Moreover, since all informed traders make zero ex-ante expected profits in equilibrium, investors are indifferent between becoming informed and staying uninformed.

It is easy to see from equation (9) that the equilibrium number of informed traders, N^*, decreases in both the precision of liquidity trades, t, and the cost of information acquisition, C. The intuition behind these comparative-static results is straightforward. First, when the liquidity trades become more precise, it is easier for the market maker to infer private information from the total demand. This makes the informed traders harder to conceal their private information and thus makes the acquisition of private information become less attractive. Hence, fewer investors become informed. Second, more costly information makes the acquisition of private information less attractive, and therefore leads to fewer investors

[19] See the Appendix for a derivation of equation (8).

becoming informed.

Below we analyze how the precision of private information, s, and the precision of earnings report, m, affect the equilibrium number of informed traders, N^*.

Lemma 2: The equilibrium number of informed traders, N^*, increases in the precision of private information, s, and decreases in the precision of earnings report, m.

The intuition behind Lemma 2 is as follows. As discussed, the informed traders' information advantage increases when the precision of private information increases or the precision of earnings report decreases. As a result, the private information becomes more valuable and therefore the equilibrium number of informed traders increases. Lemma 2 implies that the informed traders regard the public report and the private signal as substitutes.

4. Optimal Effort, Earnings Management and Linear Compensation Contract

We now go back to stages 1 and 2 to determine the optimal linear compensation contract and the choices of optimal effort and earnings management. At stage 1, the board chooses an incentive contract (ω, α, β) that maximizes the long-term shareholders' expected terminal wealth:

$$\max_{\omega,\alpha,\beta} E(\tilde{v} - \omega - \alpha\tilde{r} - \beta\tilde{P}),$$

subject to the agent's incentive compatibility constraint:

$$\{e^*, \eta^*\} \in \arg\max_{e,\eta} E[U_m(e,\eta)],$$

and the agent's participation constraint:

$$E[U_m(e,\eta)] \geq -1,$$

When price and earnings serve as two performance measures, the informational value of price for contracting (as well as investment) purposes arises from its incremental information beyond what is known from the earnings report. To filter out earnings information from the stock price, we carry out the same normalization process as in Kim and Suh (1993). Using equations (4) and (5), we can rewrite the agent's compensation as:

$$\tilde{w} = \omega + \alpha \tilde{r} + \beta\{P_0 + P_q[N^*(d_0 + d_\theta \tilde{\theta} + d_r \tilde{r}) + \tilde{l}\,] + P_r \tilde{r}\} \equiv \hat{\omega} + \hat{\alpha}\tilde{r} + \hat{\beta}\tilde{z}, \quad (10)$$

where,

$$\hat{\omega} \equiv \omega + P_0(\beta - \hat{\beta}), \quad \hat{\alpha} \equiv \alpha + P_r(\beta - \hat{\beta}), \quad \hat{\beta} \equiv \beta P_q N^* d_\theta \text{ , and}$$

$$\tilde{z} \equiv \tilde{\theta} + \frac{\tilde{l}}{N^* d_\theta} = \tilde{\theta} + \sqrt{\frac{t(h+m+s)}{N^* s(h+m)}}\tilde{l} \text{ .}$$

Equation (10) shows how a linear function of $\tilde{r}$ and $\tilde{P}$ can be converted to a linear function of $\tilde{r}$ and $\tilde{z}$, and vice versa. In other words, the information set $\{\tilde{r}, \tilde{P}\}$ is equivalent to $\{\tilde{r}, \tilde{z}\}$. Here, signal $\tilde{z}$ represents the incremental information in the stock price,[20] i.e.,

$$\tilde{z} = \frac{\tilde{P} - (1 - P_q N^* d_\theta)(P_0 + P_r \tilde{r})}{P_q N^* d_\theta}.$$

Accordingly, $\hat{\alpha}$ represents the total compensation weight on earnings report, both directly and indirectly through price.[21] For expositional convenience, we will refer to $\tilde{z}$ as the "filtered" price and solve for an optimal linear compensation contract that is based on $\{\tilde{r}, \tilde{z}\}$.[22]

We now define the informativeness of the filtered price in our model, which measures the increase in the posterior precision of $\tilde{v}$ due to observing $\tilde{z}$ in addition to $\tilde{r}$ and is given by:[23]

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[20] Although z is not directly observable, it is invertible from P. To convert z from P, one only needs public information about r and the equilibrium values of P_0, P_q, P_r, d_θ, and N.

[21] According to Baiman and Verrecchia (1995), using the adjusted compensation weights $\hat{\alpha}$ and $\hat{\beta}$ rather than their corresponding "unadjusted" weights allows researchers to overcome the empirical problem of controlling the reporting precision in the regression equations of compensation weights. Moreover, by using the adjusted compensation weights, compensation could be decomposed into two orthogonal information sources, reported earnings and filtered price (total net demand in their model) that are statistically independent to each other. Such an advantage is absent in our model owing to different information structures. In particular, we assume that the private signal is noisy information of the firm's cash flow while Baiman and Verrecchia (1995) assume that it is a perfect signal of the agent's effort.

[22] Once it is done, transforming the optimal linear contract written in terms of $\{\tilde{r}, \tilde{z}\}$ to that of $\{\tilde{r}, \tilde{P}\}$ is straightforward.

[23] The informativeness of the filtered price is invariant to the exogenous agent-specific parameter b that affects the incentive of earnings management. It is because in our model of "signal-jamming", earnings management does not have any systemic impact on the efficiency of stock market price formation as the rational investors are able to back out the degree of earnings management and hence a correct assessment would be reflected in the stock price.

$$I \equiv Var^{-1}(\tilde{v} \mid \tilde{r}=r, \tilde{z}=z) - Var^{-1}(\tilde{v} \mid \tilde{r}=r) = \frac{N^*}{(N^*+1)/s + 1/(h+m)}. \tag{11}$$

Taking N^* as exogenous, it is easy to see that I is increasing in N^*, s and m. The intuition behind the first two direct effects on the informativeness of the filtered price is straightforward. More informed traders in the market or more precise private signal each trader receives leads to a more informative filtered price. The last direct effect is more subtle. At first blush, the precision of reported earnings seems to have no direct impact on the informativeness of the filtered price because by definition the filtered price "filters" out information from the earnings report. However, one should not ignore the link between the precision of earnings report and the amount of the private information transferred to the market through trading. *Ceteris paribus*, the more aggressive the informed traders trade on their information advantage, the more informative the filtered price. To see how the precision of reported earnings affects the informed traders' decision to trade, observe that $[P_q(N+1)]^{-1} = (\Omega\sqrt{Nt})^{-1}$ in equation (7) is a measure of an informed trader's trading intensity on his information advantage. This trading intensity measure is increasing in the market depth, P_q^{-1}, which is in turn increasing in m (since Ω is decreasing in m). The idea is that when the precision of earnings report increases, the information asymmetry between informed and uninformed traders decreases. Lower information asymmetry in turn implies higher market liquidity and thus allows the informed traders to trade more on their information advantage. To conclude, the informed traders trade more aggressively when the precision of earnings report increases. As a consequence, more of the informed traders' private information will be impounded into the stock price. This serves to increase the informativeness of the filtered price.

The equilibrium number of informed traders, N^*, is actually endogenously determined and, thus, any exogenous change that affects N^* also indirectly affects I. From Lemma 2, N^* is increasing in s but decreasing in m. Therefore, there is also a positive (negative) indirect effect on the informativeness of the filtered price via the increased (decreased) equilibrium number of informed traders when the precision of private signal (earnings report) increases. Below we examine the sensitivity of the informativeness of the filtered price to changes in the precision of private information, s, and the precision of earnings report, m, by combining both the direct and indirect effects.

Proposition 1:

(i) The informativeness of the filtered price, I, increases in the precision of private information, s.

(ii) For any given value of the precision of earnings report, m, there exists a unique critical value $\bar{s}(m)$ such that the informativeness of the filtered price, I, increases in the precision of earnings report, m, if, and only if, the precision of private information, s, is greater than $\bar{s}(m)$.

The intuition for part (i) of Proposition 1 is straightforward. Given that both its direct and indirect effects on the informativeness of the filtered price are positive, an increase in the precision of private information increases the informativeness of the filtered price because the latter becomes more reflective of the informed traders' more precise private information.

Part (ii) is less intuitive because increasing the precision of earnings report increases the trading intensity of each informed trader but decreases the equilibrium number of informed traders. While the first effect increases the informativeness of the filtered price, the second effect decreases it. When the precision of private information is sufficiently high (low), i.e., $s > (<)\, \bar{s}(m)$, the first effect dominates (is dominated by) the second one and hence the net effect of increasing the precision of earnings report on the informativeness of the filtered price is positive (negative). This result is interesting because it shows that the sensitivity of the informativeness of the filtered price to changes in the precision of earnings report depends crucially on the precision of private information which is impounded into the filtered price.

An interesting implication of part (ii) of Proposition 1 is that increasing the precision of one performance measure (i.e., the earnings report in this case) may dampen the usefulness of the other performance measure (i.e., the filtered price).[24] The key is that the informed traders

[24] Unlike our paper, Lemma 4 of Bushman and Indjejikian (1993b) shows that an increase in the precision of earnings report unambiguously decreases the informativeness of the filtered price in a setting different from ours. It is noteworthy that this difference is not owing to the presence of earnings

regard the public earnings report and the private signal as substitutes so that a more precise earnings report will induce fewer investors to become informed and hence may lead to lower informativeness of the filtered price. We will show later that, because of this potential negative impact on the informativeness of the filtered price, an increase in the precision of earnings report may exacerbate rather than alleviate the agency problem, thereby resulting in a lower productive effort.

The following lemma characterizes the optimal compensation contract in terms of the adjusted compensation weights.

Lemma 3: There is a unique optimal solution to the principal-agent problem characterized by:

$$\hat{\alpha}^* = \frac{\frac{1}{I}}{\left(1+\frac{\rho}{h}\right)\left(\frac{1}{m}+\frac{1}{\rho b}\right)+\left(1+\frac{\rho}{h}+\frac{\rho}{m}+\frac{1}{b}\right)\frac{1}{I}} > 0, \tag{12}$$

$$\hat{\beta}^* = \frac{\frac{1}{m}+\frac{1}{\rho b}}{\left(1+\frac{\rho}{h}\right)\left(\frac{1}{m}+\frac{1}{\rho b}\right)+\left(1+\frac{\rho}{h}+\frac{\rho}{m}+\frac{1}{b}\right)\frac{1}{I}} > 0, \tag{13}$$

$$e^* = \hat{\alpha}^* + \hat{\beta}^* \in (0,1)\,, \tag{14}$$

$$\eta^* = \frac{\hat{\alpha}^*}{b} > 0. \tag{15}$$

Lemma 3 establishes four characteristics of the optimal compensation. First, consistent with Holmstrom's (1979) informativeness principle, the optimal choices of $\hat{\alpha}^*$ and $\hat{\beta}^*$ are all positive reflecting that the principal, whose objective is to provide incentives at the lowest possible cost, uses both earnings report and filtered price to filter some non-cash-flow-related

management in our model. Rather, this difference occurs because the earnings report and the filtered price are not orthogonal in our model as in Bushman and Indjejikian (1993b) due to different assumptions on the price formation process. In particular, Bushman and Indjejikian (1993b) derive the equilibrium price in a noisy rational expectations competitive economy wherein the informed traders perceive their trades have no impact on the price. In contrast, in our model the informed traders trade strategically. Therefore, not only their information acquisition decision, but also their trading intensity on their private information, will depend on the precision of earnings report.

noise from both (i.e., $1/m$, $1/s$ and $1/t$). However, filtered price, apart from reducing the non-cash-flow-related noise from earnings report, also allows the principal to differentiate the agent's actions in order to provide distinct incentives/disincentives for e and η.[25]

The dual roles for price as an additional contracting variable to alleviate agency problem in our setting wherein the managed earnings report is pernicious, albeit truth-revealing, can also be better understood by considering a hypothetical benchmark case under which the regulatory system can determine the maximum legally permitted upward bias $\bar{\eta} \in (0, \infty)$ such that earnings management is costless to the agent (i.e., $b = 0$) when $\eta \le \bar{\eta}$ or prohibitively costly (i.e., $b \to \infty$) otherwise.[26] In such a benchmark case, the agent will optimally choose $\eta^+ = \bar{\eta}$ in equilibrium but the truth-revealing earnings management is neutral as it does not have any cash flow implication (as $b = 0$ when $\eta \le \bar{\eta}$). Since there is no need to de-motivate η, the only role for price in this case is to help filter the non-cash-flow-related noise from reported earnings. The role of price as a mechanism to de-motivate η emerges when the cost of earnings management is positive and finite, which is arguably an empirically more descriptive assumption. This role is driven by the principal's desire to thwart the agent's incentives for costly earnings management that the principal must ultimately pay for to meet the agent's participation constraint. The following corollary compares the equilibrium under the benchmark case with that characterized in Lemma 3.

Corollary 1: $e^* < e^+$, $\hat{\alpha}^* < \hat{\alpha}^+$ and $\hat{\beta}^* > \hat{\beta}^+$, where $e^+, \hat{\alpha}^+, \hat{\beta}^+$ are the optimal effort and compensation weights on accounting earnings and filtered price, respectively, when $\eta^+ = \bar{\eta}$.

In the presence of costly earnings management, compensation weight is shifted away from accounting earnings to filtered price (i.e., $\hat{\alpha}^* < \hat{\alpha}^+$ and $\hat{\beta}^* > \hat{\beta}^+$) so as to alleviate earnings management. However, as long as a positive compensation weight is put on accounting earnings, costly earnings management will not be entirely eliminated. The optimal

[25] It is easy to see that $\hat{\beta}^* > 0$ even if $1/m \to 0$, implying that the additional role of filtered price puts a positive weight on filtered price.

[26] We thank an anonymous referee for suggesting this benchmark case to us.

effort that can be induced from the agent is thus lower (i.e., $e^* < e^+$), reflecting that the moral hazard problem becomes more severe in the presence of costly earnings management.

Second, since both performance measures reflect the impact of the agent's effort in a symmetric fashion, their incentive effects on effort are identical. In particular, Lemma 3 shows that the induced level of effort, e^*, is positive, but less than the first-best level of $e = 1$. As such, the incongruity of the agent's overall performance measure, $\hat{\alpha}^*\tilde{r} + \hat{\beta}^*\tilde{z}$, to the firm's outcome, $\tilde{v}$, is measured by $(1-e^*)^2 = [1-(\hat{\alpha}^* + \hat{\beta}^*)]^2$. The principal designs the contract to make the agent's overall performance measure as congruent as possible with the firm's outcome.

Third, the incentive powers for e and η are different since incentives/disincentives for η can only be provided through earnings report.[27] This result supports the view that using accounting earnings as a measure of managerial performance creates incentives to manipulate the accounting system (see, e.g., Chapter 8 of Ronen and Yaari, 2008).[28]

Finally, the optimal adjusted compensation weights, $\hat{\alpha}^*$ and $\hat{\beta}^*$, are functions of agent-, firm- and market-specific characteristics as well as precisions of the two performance measures. Lambert and Larcker (1987) show that in order to carry out cross-sectional analyses of the attributes of compensation contracts with two performance measures, it is preferable to focus on the relative weight placed on performance measures in order to reduce

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[27] Notice that this result is driven by our assumption that the investors' private information is a noisy signal of the firm's cash flow only, not affected by earnings management. If the private information is also affected by the agent's manipulation of reported earnings, then both reported earnings and filtered price will induce the agent to exert effort and to engage in earnings management. Our result here differs significantly from that of Goldman and Slezak (2006) in which they implicitly assume that the optimal compensation weight on reported earnings is zero.

[28] Results of recent empirical studies, however, suggest that price-based compensation also induces earnings management (e.g., Cheng and Warfield, 2005 and Bergstresser and Philippon, 2006). It should be emphasized that existing empirical studies estimate weights on performance measures based on raw prices. To link our results to empirical studies, one can convert the contract based on the filtered price to one based on the raw price. In particular, using $\hat{\alpha}^* = \alpha^* + P_r(\beta^* - \hat{\beta}^*)$ and $\hat{\beta}^* = \beta^* P_q N^* d_\theta$, we can rewrite equation (15) as:

$$\eta^* = \frac{1}{b}\left\{\alpha^* + P_r\left[\frac{(N^*+1)(h+m)+s}{(N^*+1)(h+m+s)}\right]\beta^*\right\}.$$

It is then evident from the above equation that the weight on price-based compensation, β^*, also positively affects earnings management.

the confounding factors of agent-specific characteristics. Using equations (12) and (13), the relative adjusted compensation weight of earnings report to filtered price can be stated as:

$$\frac{\hat{\alpha}^*}{\hat{\beta}^*} = \left(1 + \frac{m}{\rho b}\right)^{-1} \frac{m}{I}. \tag{16}$$

Equation (16) implies that the relative adjusted compensation weight, $\hat{\alpha}^* / \hat{\beta}^*$, is proportional to the relative precisions of these two performance measures. The expression $(1 + m / \rho b)^{-1}$ in equation (16) captures the role of filtered price in differentiating e and η. This expression is a function of exogenous firm- and agent-specific parameters, m, ρ and b, reflecting the fact that these parameters have asymmetric impacts on different incentive variables and therefore do not disappear in the computation of the relative adjusted compensation weight in the presence of earnings management. By contrast, in the absence of earnings management (i.e., when $b \to \infty$ such that $\eta^* \to 0$), equation (16) reduces to

$$\lim_{b \to \infty} \frac{\hat{\alpha}^*}{\hat{\beta}^*} = \frac{m}{I}. \tag{17}$$

That is, the relative adjusted compensation weight is a ratio of precisions of these two performance measures. It is evident from comparing equations (16) and (17) that the presence of earnings management leads to a lower relative adjusted compensation weight. The results of moral hazard models without earnings management (Banker and Datar, 1989; Feltham and Xie, 1994) show that optimal compensation contracts place greater reliance on measures of performance that are more precise for the agent's unobservable productive effort. This result is generally true in the setting wherein the precisions of performance measures are exogenous. When private information acquisition and hence the informativeness of the filtered price are endogenous, the informativeness of the filtered price may increase or decrease as a response to changes in the precision of earnings report (see part (ii) of Proposition 1). Therefore, the impact of an increase in the precision of earnings report on the relative adjusted compensation weight is potentially ambiguous. Specifically, differentiating equation (17) with respect to m yields

$$\lim_{b\to\infty}\frac{d\left(\hat{\alpha}^*/\hat{\beta}^*\right)}{dm}=\frac{1}{I}\left(1-\frac{m}{I}\frac{dI}{dm}\right),$$

implying that the relative adjusted compensation weight increases in the precision of earnings report if, and only if, the elasticity of the informativeness of the filtered price with respect to the precision of earnings report, $\frac{m}{I}\frac{dI}{dm}$, is less than 1. Moreover, since $\lim_{b\to\infty} e^* = \lim_{b\to\infty}(\hat{\alpha}^* + \hat{\beta}^*) = \frac{1}{1+\rho/h+\rho/(I+m)}$ and therefore $\text{sign}\left[\lim_{b\to\infty}\frac{de^*}{dm}\right]=\text{sign}\left[\frac{d(I+m)}{dm}\right]$

$=\text{sign}\left[\frac{dI}{dm}+1\right]$, the agent's effort increases in the precision of earnings report if, and only if, the sensitivity of the informativeness of the filtered price with respect to the precision of earnings report, $\frac{dI}{dm}$, is greater than -1. In the Appendix, we show that $\frac{m}{I}\frac{dI}{dm}<1$ and $\frac{dI}{dm}>-1$, and hence $\lim_{b\to\infty}\frac{d\left(\hat{\alpha}^*/\hat{\beta}^*\right)}{dm}>0$ and $\lim_{b\to\infty}\frac{de^*}{dm}>0$ in the setting wherein the informativeness of the filtered price is endogenous. Nevertheless, it is unsure that whether these unambiguous comparative-static results remain true in our model wherein earnings management is present and the informativeness of the filtered price is endogenous. We address this issue in the next section.

5. Information Environment and Compensation Contract

The preceding section has demonstrated that when earnings management is present and the informativeness of the filtered price is endogenous, the incentives for earnings management and private information acquisition crucially influence the optimal compensation, making the effects of increasing the precision of earnings report on the relative adjusted compensation weight and productive effort potential ambiguous. Below we first analyze how the relative adjusted compensation weight, earnings management and productive effort change as a response to changes in some parameters that affect these incentives.

Lemma 4:

(i) An increase in the precision of private information, s, decreases the relative adjusted compensation weight, $\hat{\alpha}^* / \hat{\beta}^*$, decreases the earnings management, η^*, and increases the productive effort, e^*.

(ii) An increase in the cost of earnings management, b, decreases the earnings management, η^*, increases the relative adjusted compensation weight, $\hat{\alpha}^* / \hat{\beta}^*$, and increases the productive effort, e^*.

The intuition underlying part (i) of Lemma 4 is as follows. An increase in the precision of private information increases the informativeness of the filtered price (see part (i) of Proposition 1). When the informativeness of the filtered price goes up, the principal responds by shifting the compensation weight from the earnings report to the filtered price. The decreased relative adjusted compensation weight will then result in a decrease in the induced earnings management. Hence, productive effort becomes less costly to induce and then the optimal level of effort goes up accordingly. These results demonstrate the importance of the market monitoring role of informed traders' private information acquisition activities in the design of the optimal managerial incentive contract and its induced impacts on the agent's choices of effort and earnings management.

With regard to part (ii), an increase in the cost of earnings management reduces the agent's incentive to manipulate earnings. As a consequence, the principal responds by shifting the relative adjusted compensation weight from the filtered price to the earnings report. This effect reflects the fact that the additional role of the filtered price in alleviating the earnings management problem becomes less important when the cost of earnings management increases. Moreover, the optimal effort increases because it becomes less costly for the principal to induce productive effort when the agent's incentive to manipulate earnings decreases. When strong legal environment means better corporate governance, more stringent disclosure requirements and more penalties for noncompliance and/or misreporting (i.e., thus leads to a higher b), our results are consistent with the findings of Carter et al. (2009) and Kalelkar and Nwaeze (2011) that the enforcement of Sarbanes-Oxley leads to higher earnings quality and firms placing more weight on accounting earnings in bonus contract.

We now present the main results in this paper. The next proposition presents the effects of increasing public information precision on the adjusted compensation weight, earnings management and productive effort when the agent's incentive to manipulate earnings is significant.

Proposition 2: For any given value of the precision of earnings report, m, there exist unique critical values $\bar{s}(m)$, $\underline{b}(m \mid s < \bar{s}(m))$, and $\bar{b}(m \mid s > \bar{s}(m))$ such that:

(i) when $s < \bar{s}(m)$ and $b < \underline{b}(m \mid s < \bar{s}(m))$, an increase in the precision of public information, m, increases the relative adjusted compensation weight, $\hat{\alpha}^* / \hat{\beta}^*$, increases the earnings management, η^*, and decreases the productive effort, e^*;

(ii) when $s > \bar{s}(m)$ and $b < \bar{b}(m \mid s > \bar{s}(m))$, an increase in the precision of public information, m, decreases the relative adjusted compensation weight, $\hat{\alpha}^* / \hat{\beta}^*$, decreases the earnings management, η^*, and increases the productive effort, e^*.

In the previous section, we showed that both the relative adjusted compensation weight and productive efforts increase in the precision of earnings report when the informativeness of the filtered price is endogenous and earnings management is absent. In contrast, Proposition 2 shows that when the agent's incentive to manipulate earnings is significant, the effects of increasing the precision of earnings report on the relative adjusted compensation weight and productive effort (as well as earnings management) are no longer monotonous but crucially depend on the level of private information precision. In particular, part (i) of Proposition 2 shows that increasing the precision of public information increases both the relative adjusted compensation weight and earnings management but decreases the productive effort when both the private information precision and manipulation cost are low enough. The intuition is as follows. When private information precision is sufficiently low ($s < \bar{s}(m)$), increasing the precision of earnings report reduces incentives for information gathering and thus leads to a less informative filtered price (see part (ii) of Proposition 1). In this case, the principal would shift more compensation weight from the filtered price to the earnings report so as to reduce the non-cash-flow-related noise of the performance measures. However, the principal also has the incentive to shift compensation weights in the opposite way to tamper the incentive for earnings manipulation when the cost of earnings management is sufficiently low ($b < \underline{b}(m \mid s < \overline{s}(m))$). Coupling these two effects in equilibrium, we find that the incentive effect of reducing the noise of performance measures dominates that of reducing earnings management. Therefore, an increase in the precision of earnings report leads to a higher relative pay-for-performance sensitivity of accounting earnings to stock price which causes a higher level of earnings management. Consequently, the effect of decreased informativeness of the filtered price combined with the increased earnings management results in a lower level of productive effort.

An interesting implication drawn from part (i) of Proposition 2 is that an increase in the precision of earnings report may exacerbate rather than alleviate the agency problem by increasing unproductive earnings manipulation and decreasing productive effort. Parameters s and b can be interpreted as measures of the development of financial markets and legal environment of an economy because a more developed financial market and legal environment is characterized by more active information intermediaries (and thus more informative stock prices) and better corporate governance that curbs earnings management. Under this interpretation, part (i) of Proposition 2 predicts that the adoption of IFRS in a financially less developed country with weak local GAAP (hence, arguably, the precision of earnings report should increase after IFRS adoption) may actually be counter-productive in the sense that it leads to a lower level of productive effort and a higher level of earnings manipulation. Despite an increasing trend of worldwide acceptance of IFRS (Carmona and Trombetta, 2008; Chua and Taylor, 2008), empirical evidence showing the effect of IFRS adoption on the quality of financial reporting is somewhat mixed. Consistent with our prediction, Tendeloo and Vanstraelen (2005) find that in Germany, IFRS-adopters did not engage in less earnings management compared to companies reporting under German GAAP. Similarly, Jeanjean and Stolowy (2008) report that the pervasiveness of earnings management in three IFRS first-time adopter countries, i.e., Australia, France, and the UK, did not decline after the mandatory introduction of IFRS (the pervasiveness of earning management actually increased in France).

Ball et al. (2003) argue that adopting high quality standards is a necessary, but not a sufficient, condition for high quality information. Rather, when adopting more precise accounting reporting standards, an efficient capital market is required to minimize biases in accounting information and thereby reducing the agency problem. We echo their argument. We show in part (ii) of Proposition 2 that in an economy with weak legal environment ($b < \overline{b}(m \mid s > \overline{s}(m))$), it is possible to induce both a higher level of productive effort and a lower level of earnings management through incentive contracts when the precision of private information is sufficiently high ($s > \overline{s}(m)$). This is because increasing the precision of public information also increases the informativeness of stock price in this case (see part (ii) of Proposition 1). With two improved performance measures, the principal does not necessarily increase the relative pay-for-performance sensitivity of accounting earnings to stock price so as to reduce the noise of performance measures. Indeed, since the incentive of the agent to engage in earnings management is significant in this case ($b < \overline{b}(m \mid s > \overline{s}(m))$), the principal shifts the compensation weight away from accounting earnings to the more informative stock price so as to tamper earnings management. Consequently, an increase in the precision of earnings report leads to a lower relative pay-for-performance sensitivity of accounting earnings to stock price and a lower level of earnings management. Moreover, the increased informativeness of the filtered price together with the decreased level of earnings management leads to a higher level of productive effort. Our results suggest that the advancement of financial market and the development of legal environment could be substitutes. When an economy does not have strong law enforcement to alleviate earnings management, an advanced capital market with more active information intermediaries could play the role of reducing the agency problem through a decreased level of earnings management and an increased level of productive effort when the precision of public information is enhanced.

All in all, Proposition 2 suggests that national institutional factors such as the financial development and legal environment of an economy should be taken into account when evaluating the effectiveness of new accounting policies. We believe that our results could help explain the empirical findings about the pervasiveness of earnings management after adopting high quality accounting standards (such as IFRS) across different countries with distinctive institutional and legal features (Tendeloo and Vanstraelen, 2005; Jeanjean and Stolowy, 2008).

It is noteworthy that although our model incorporates the market monitoring role of private information acquisition activities on earnings manipulation behavior, it does not rule out the possibility that the degree of private information acquisition activities (as manifested by the number of informed traders) and earnings management are actually positively correlated in equilibrium.[29] Corollary 2, which follows from Lemma 2 and part (ii) of Proposition 2, shows that such a positive correlation exists under certain conditions.

Corollary 2: When $s > \bar{s}(m)$ and $b < \bar{b}(m \mid s > \bar{s}(m))$, there is a positive relation between the equilibrium number of informed traders, N^*, and earnings management, η^*, if the variation is caused by the precision of public information, m.

Earnings management has increased steadily from the late eighties until the passage of the Sarbanes-Oxley Act in 2002 that increased senior management's responsibility for the financial reports (Daniel et al. 2008). The characteristics and business models of publicly traded companies have also changed dramatically as manifested by a sharp increase of IPOs of high technology companies in the 1990s, while the standards for external corporate reporting have not kept pace with the change. This has led to claims that traditional financial statements have lost relevance as helpful instruments in decision-making (Collins et al., 1997; Brown et al., 1999; Francis and Schipper, 1999). Meanwhile, advances in information and communication technology have improved the timeliness and accuracy of investors' private information as well as expanded the universe of investors with access to information (D'Avolio et al., 2001). All these phenomena are compatible with the model's implication as shown in Corollary 2 that when private information precision is sufficiently high and the agent's incentive to manipulate earnings is significant, there is a positive relation between the equilibrium number of informed traders and earnings management if the variation is caused by the precision of public information.

[29] We are indebted to an anonymous referee for pointing out this possibility and informing the related phenomena to us.

Our analysis thus far has characterized the equilibrium when the precision of the firm's financial reporting system, m, is exogenous and shown how the equilibrium variables change in response to changes in such precision. We now step back and consider the principal's choice of precision of the reporting system. Specifically, we assume that the principal can commit to a precision level of the reporting system before offering a contract to the agent (e.g., by publicly announcing a set of accounting policies and procedures that the firm will follow). We further assume that, while there is a minimum level of precision of the reporting system that the firm should keep (e.g., through complying with the minimum requirements of some accounting standards), i.e., $m \in [\underline{m}, \infty)$, where $\underline{m} > 0$, there is no cost associated with different choices.

Anticipating that the optimal incentive contract is characterized in Lemma 2, the ex-ante expected terminal wealth of the long-term shareholders is given by:

$$E(\tilde{v} - \hat{\omega} - \hat{\alpha}^* \tilde{r} - \hat{\beta}^* \tilde{z}) = e^* - \frac{1}{2} e^{*2} - \frac{b}{2} \eta^{*2} - \frac{\rho}{2} Var(\hat{\omega} + \hat{\alpha}^* \tilde{r} + \hat{\beta}^* \tilde{z}). \tag{18}$$

The principal's objective is to choose m to maximize (18). We denote the principal's optimal choice as m^*. The next proposition demonstrates that the principal may choose the lowest level of precision of the reporting system even if there is no cost associated with different choices.

Proposition 3: When $s < \bar{s}(\underline{m})$ and $b < \underline{b}(\underline{m} \mid s < \bar{s}(\underline{m}))$, the principal chooses an optimal reporting system with precision equal to $m^* = \underline{m}$.

When the principal chooses the precision of the reporting system, she does so anticipating the outcome of the contracting game with the agent. From the result of part (i) of Proposition 2, we know that that when the private information precision and the cost of earnings management are sufficiently low (i.e., $s < \bar{s}(\underline{m})$ and $b < \underline{b}(\underline{m} \mid s < \bar{s}(\underline{m}))$, an increase in the precision of the reporting system, m, increases the earnings management, η^*, and decreases the productive effort, e^*. These two effects together destroy firm value. Hence, Proposition 3 demonstrates that, under certain conditions, the firm is even better off installing the least precise reporting system.

6. Conclusion

In this paper, we characterize the optimal levels of earnings- and price-based compensations in agency contracts when the agent can engage in earnings management and investors can acquire and trade profitably on private information about the firm's cash flow. Taking the precision of earnings report as exogenous, we derive comparative-static results showing how the optimal contract, its induced earnings distortion and productive effort change in response to an increase in such precision. Our results suggest that in an economy with less developed financial market and weak legal environment, an increase in the precision of earnings report may not only induce fewer informed investors and thus lower informativeness of the stock price, but also exacerbate the agency problem by leading to a higher level of earnings manipulation and a lower level of productive effort. Anticipating this negative impact on firm value when choosing the precision of earnings report, the principal may adopt a less precise financial reporting system to reduce the agency cost.

There are two caveats that deserve special attention when interpreting the results of the paper. First, we assume that earnings management does not affect the noise in the financial reporting system. It is possible that earnings management not only affects the level of earnings report, but might also make the earnings report a noisier reflection of the firm's cash flow. As such, it is reasonable to expect that the "double" effects of earnings management on the mean and variance of earnings report will further weaken the role of earnings as a performance measure. Second, our one-period model ignores the reversal effect of earnings management and therefore does not capture the full accounting effect of earnings management. In a more realistic multi-period setting, if earnings are managed up now, they will reverse later. The issue is then about the timing of revenue/expense recognition when management observes a private signal on the demand for reported earnings in the future, while investors may learn about this signal at a different date. The role for stock prices as a market monitoring mechanism for productive effort as well as earnings management will then depend on how effectively stock prices "foresee" the reversal effect of earnings management. Equilibria comparison can be made by varying the timing of when investors learn about the management's private signal. An extension along this dimension would contribute to the debate on when the market knows about earnings management (Chapter 4 of Ronen and Yarri, 2008).[30] We leave this challenge for future research.

[30] We thank an anonymous referee again for suggesting this extension to us.

Appendix: Proof

Proof of Lemma 1: The proof of Lemma 1 is standard yet tedious (see, e.g., Bushman and Indjejikian, 1995). Thus, it is omitted for brevity but is available upon request from the authors. ***Q.E.D.***

Derivation of Equation (7): First, we can rewrite (2) as:

$$\underset{d_i}{Max}\, E\left(\left\{\tilde{v}-\left[P_0+P_r\tilde{r}+P_q(d_i+\sum_{j\neq i}d_j+\tilde{l})\right]\right\}d_i \mid \tilde{\theta}=\theta,\tilde{r}=r\right),$$

where $\sum_{j\neq i}d_j$ is the sum of market order of all the other informed traders. Solving the first-order condition yields

$$d_i=\frac{E(\tilde{v}\mid\tilde{\theta}=\theta,\tilde{r}=r)-(P_0+P_r r+P_q\sum_{j\neq i}d_j)}{2P_q}.$$

Solving for the symmetric Nash equilibrium in which $d_1=d_2=d_3=...=d_N$ yields

$$d_i=\frac{E(\tilde{v}\mid\tilde{\theta}=\theta,\tilde{r}=r)-P_0-P_r r}{P_q(N+1)}. \qquad \text{(A.1）}$$

Second, since $\tilde{v}$ and $\tilde{r}$ are multivariate normally distributed, given a pair of common conjectures of management effort and reporting bias, (e^c, η^c), we have

$$E(\tilde{v}\mid\tilde{r}=r)=e^c+\frac{m}{h+m}(r-e^c-\eta^c)=\frac{he^c-m\eta^c+mr}{h+m}=P_0+P_r r.$$

Substituting the above equation into (A.1) yields equation (7).

Derivation of Equation (8): Using Lemma 1 and equation (7), the expected trading profits of each informed trader conditional on earnings report r and private information θ is given by:

$$E\left[(\tilde{v}-\tilde{P})d_i\mid\tilde{\theta}=\theta,\tilde{r}=r\right]=\frac{\left[E(\tilde{v}\mid\tilde{\theta}=\theta,\tilde{r}=r)-E(\tilde{v}\mid\tilde{r}=r)\right]^2}{P_q(N+1)^2}. \qquad \text{(A.2)}$$

Thus, the ex-ante expected trading profit of each informed trader is given by:

$$\Pi_i \equiv \frac{E\left[E(\tilde{v} \mid \tilde{\theta}=\theta, \tilde{r}=r) - E(\tilde{v} \mid \tilde{r}=r)\right]^2}{P_q(N+1)^2} = \frac{\Omega^2}{P_q(N+1)^2}.$$

Simple algebra transformation yields equation (8). ***Q.E.D.***

Proof of Lemma 2:

Substituting P_q given in Lemma 1 into equation (9) and rearranging terms yields

$$N^*(N^*+1)^2 = \frac{s}{C^2 t(h+m)(h+m+s)}.$$

It is then evident from the above equation that $\frac{dN^*}{ds} > 0$ and $\frac{dN^*}{dm} < 0$. ***Q.E.D.***

Proof of Proposition 1:

(i) Using equation (11), we have $\frac{1}{I} = \frac{1}{s} + \frac{1}{N^* s} + \frac{1}{N^*(h+m)}$. Since $\frac{dN^*}{ds} > 0$, it is straightforward to yield that $\frac{dI}{ds} > 0$.

(ii) It is easy to show that

$$\frac{dI}{dm} = \frac{\partial I}{\partial m} + \frac{\partial I}{\partial N^*}\frac{dN^*}{dm} = \frac{2N^* s\left[N^* s - (N^*+1)(h+m)\right]}{(3N^*+1)[(N^*+1)(h+m)+s]^2}. \tag{A.3}$$

Thus, $\frac{dI}{dm} > 0$ if, and only if, $\frac{N^*}{N^*+1}s > h+m$. Let $F(s) = \frac{N^*}{N^*+1}s - (h+m)$. It is easy to see that $F(s)$ is monotonically increasing in s with $F(0) < 0$ and $F(\infty) > 0$. Thus, by the Intermediate Value Theorem, for any given value of m, there exists a unique $\overline{s}(m) > 0$ at which $F(\overline{s}(m)) = 0$ and $F(s) > 0$ if, and only if, $s > \overline{s}(m)$. Hence, $\frac{dI}{dm} > 0$ if, and only if, $s > \overline{s}(m)$. ***Q.E.D.***

Proof of Lemma 3: The agent's ex-ante expected utility based on a given incentive contract, $(\hat{\omega}, \hat{\alpha}, \hat{\beta})$, is:

$$EU_m(e) = E\left\{-\exp\left[-\rho\left(\hat{\omega} + \hat{\alpha}\tilde{r} + \hat{\beta}\tilde{z} - \frac{1}{2}e^2 - \frac{b}{2}\eta^2\right)\right]\right\}.$$

Taking the first order condition with respect to e and η yields

$$e^* = \hat{\alpha}^* + \hat{\beta}^*, \quad \eta^* = \frac{\hat{\alpha}^*}{b}.$$

To solve for the optimal $\hat{\alpha}$ and $\hat{\beta}$, we go back to stage 1 where the principal sets compensation subject to the agent's participation and incentive compatibility constraints.

$$\underset{\hat{\alpha},\hat{\beta}}{Max}\, E(\tilde{v}-\hat{\omega}-\hat{\alpha}\tilde{r}-\hat{\beta}\tilde{z})$$

$$\text{s.t.}\quad E\left\{-\exp\left[-\rho\left(\hat{\omega}+\hat{\alpha}\tilde{r}+\hat{\beta}\tilde{z}-\frac{1}{2}e^{*2}-\frac{b}{2}\eta^{*2}\right)\right]\right\}\geq -1, \qquad \text{(Participation Constraint)}$$

$$e^{*}=\hat{\alpha}^{*}+\hat{\beta}^{*},\quad \eta^{*}=\frac{\hat{\alpha}^{*}}{b}. \qquad \text{(Incentive Compatibility Constraints)}$$

Substituting the above constraints into the objective function, taking the first order conditions with respect to $\hat{\alpha}$ and $\hat{\beta}$, and making some algebra transformations yield equations (12) and (13). Moreover, it can be easily shown that the principal's objective function is strictly concave in $\hat{\alpha}$, $\hat{\beta}$, e and η, and therefore the optimal solution is unique. ***Q.E.D.***

Proof of Corollary 1: When $\eta \leq \overline{\eta}$, the agent's ex-ante expected utility based on a given incentive contract, $(\hat{\omega},\hat{\alpha},\hat{\beta})$, is:

$$EU_m(e)=E\left\{-\exp\left[-\rho\left(\hat{\omega}+\hat{\alpha}\tilde{r}+\hat{\beta}\tilde{z}-\frac{1}{2}e^{2}\right)\right]\right\}.$$

It is obvious that the agent's optimal choice of earnings management is $\eta^{+}=\overline{\eta}$. Taking the first order condition with respect to e yields:

$$e^{+}=\hat{\alpha}^{+}+\hat{\beta}^{+}.$$

To solve for the optimal $\hat{\alpha}$ and $\hat{\beta}$, we go back to stage 1 where the principal sets compensation subject to the agent's participation and incentive compatibility constraints. By doing so, we get

$$\hat{\alpha}^{+}=\frac{\frac{1}{I}}{\left(1+\frac{\rho}{h}\right)\frac{1}{m}+\left(1+\frac{\rho}{h}+\frac{\rho}{m}\right)\frac{1}{I}} \quad \text{and} \quad \hat{\beta}^{+}=\frac{\frac{1}{m}}{\left(1+\frac{\rho}{h}\right)\frac{1}{m}+\left(1+\frac{\rho}{h}+\frac{\rho}{m}\right)\frac{1}{I}}.$$

Comparison of $\hat{\alpha}^{+}$, $\hat{\beta}^{+}$ and e^{+} with $\hat{\alpha}^{*}$, $\hat{\beta}^{*}$ and e^{*} yields $\hat{\alpha}^{*}<\hat{\alpha}^{+}$, $\hat{\beta}^{*}>\hat{\beta}^{+}$ and $e^{*}<e^{+}$. ***Q.E.D.***

Proof of (i) $\frac{dI}{dm} > -1$ and (ii) $\frac{m}{I}\frac{dI}{dm} < 1$:

(i) From the proof of part (ii) of Proposition 1, $\frac{dI}{dm} > 0$ if, and only if, $s > \bar{s}(m)$. Thus, it suffices to show that $\frac{dI}{dm} > -1$ if $s < \bar{s}(m)$. Using equation (A.3) and the fact that $N^* s - (N^* + 1)(h + m) < 0$ if $s < \bar{s}(m)$, we have

$$-\frac{dI}{dm} = \frac{2N^* s\left[(N^* + 1)(h + m) - N^* s\right]}{(3N^* + 1)[(N^* + 1)(h + m) + s]^2} < \frac{(N^* + 1)(h + m) - N^* s}{(N^* + 1)(h + m) + s} < 1,$$

where the first inequality follows from $N^* > 1$, implying that $\frac{dI}{dm} > -1$.

(ii) Similarly, it suffices to show that $\frac{m}{I}\frac{dI}{dm} < 1$ if $s > \bar{s}(m)$. Using equations (11) and (A.3), we have

$$\frac{m}{I}\frac{dI}{dm} = \frac{2m\left[N^* s - (N^* + 1)(h + m)\right]}{(3N^* + 1)(h + m)[(N^* + 1)(h + m) + s]} < \frac{N^* s - (N^* + 1)(h + m)}{N^*[(N^* + 1)(h + m) + s]} < 1. \quad \textbf{\textit{Q.E.D.}}$$

Proof of Lemma 4:

(i) First, totally differentiating equation (16) with respect to s yields

$$\frac{d\left(\hat{\alpha}^*/\hat{\beta}^*\right)}{ds} = -\left(1 + \frac{m}{\rho b}\right)^{-1} \frac{m}{I^2}\frac{dI}{ds} < 0, \quad \text{since} \quad \frac{dI}{ds} > 0.$$

Next, rearranging terms in equation (12) yields

$$\hat{\alpha}^* = \frac{1}{\left(1 + \frac{\rho}{h}\right)\frac{\hat{\beta}^*}{\hat{\alpha}^*} + \left(1 + \frac{\rho}{h} + \frac{\rho}{m} + \frac{1}{b}\right)}. \tag{A.4}$$

Since $\eta^* = \frac{\hat{\alpha}^*}{b}$, it is straightforward to see that

$$\text{sign}\left[\frac{d\eta^*}{ds}\right] = \text{sign}\left[\frac{d\hat{\alpha}^*}{ds}\right] = \text{sign}\left[\frac{d\left(\hat{\alpha}^*/\hat{\beta}^*\right)}{ds}\right] < 0.$$

Finally, using equations (12) and (13), we can express e^* as:

$$e^* = \hat{\alpha}^* + \hat{\beta}^* = \frac{1}{1 + \frac{\rho}{h} + \frac{\rho}{I + 1/(1/m + 1/\rho b)}}. \tag{A.5}$$

It is then easy to see that $\frac{de^*}{ds} > 0$ since $\frac{dI}{ds} > 0$.

(ii) Similarly, totally differentiating equation (16) with respect to b yields

$$\frac{d\left(\hat{\alpha}^*/\hat{\beta}^*\right)}{db}=\left[\frac{m\rho}{(m+\rho b)^2}\right]\frac{m}{I}=\left[\frac{m}{b(m+\rho b)}\right]\frac{\hat{\alpha}^*}{\hat{\beta}^*}>0.$$

Moreover, totally differentiating equation (15) with respect to b yields

$$\frac{d\eta^*}{db}=\frac{\frac{d\hat{\alpha}^*}{db}b-\hat{\alpha}^*}{b^2}=-\frac{\left(1+\frac{\rho}{h}\right)\left(\frac{\rho b}{m+\rho b}\right)\frac{\hat{\beta}^*}{\hat{\alpha}^*}+\left(1+\frac{\rho}{h}+\frac{\rho}{m}\right)}{b^2\left[\left(1+\frac{\rho}{h}\right)\frac{\hat{\beta}^*}{\hat{\alpha}^*}+\left(1+\frac{\rho}{h}+\frac{\rho}{m}+\frac{1}{b}\right)\right]^2}<0.$$

Finally, from expression (A.5), it is straightforward to see that $\frac{de^*}{db}>0$. ***Q.E.D.***

Proof of Proposition 2:

(i) First, since $\eta^*=\frac{\hat{\alpha}^*}{b}$, it is easy to see from expression (A.4) that

$$\operatorname{sign}\left[\frac{d\eta^*}{dm}\right]=-\operatorname{sign}\left[\frac{1}{m}\left(1+\frac{\rho}{h}\right)\left(\left(1+\frac{m}{\rho b}\right)\frac{dI}{dm}-\frac{I}{m}\right)-\frac{\rho}{m^2}\right]. \quad \text{(A.6)}$$

Let $G(b)=\frac{1}{m}\left(1+\frac{\rho}{h}\right)\left(\left(1+\frac{m}{\rho b}\right)\frac{dI}{dm}-\frac{I}{m}\right)-\frac{\rho}{m^2}$. It is easy to see that $G(b)<0$ when $\frac{dI}{dm}<0$. From part (ii) of Proposition 1, $\frac{dI}{dm}<0$ if, and only if, $s<\overline{s}(m)$. As such, $\frac{d\eta^*}{dm}>0$ if $s<\overline{s}(m)$.

Next, totally differentiating equation (16) with respect to m yields

$$\frac{d\left(\hat{\alpha}^*/\hat{\beta}^*\right)}{dm}=\frac{1}{I}\left(\frac{\rho b}{m+\rho b}\right)\left[\frac{\rho b}{m+\rho b}-\frac{m}{I}\frac{dI}{dm}\right].$$

Thus,

$$\operatorname{sign}\left[\frac{d\left(\hat{\alpha}^*/\hat{\beta}^*\right)}{dm}\right]=\operatorname{sign}\left[\frac{\rho b}{m+\rho b}-\frac{m}{I}\frac{dI}{dm}\right].$$

Since $\frac{dI}{dm}<0$ if $s<\overline{s}(m)$, it then follows that $\frac{d\left(\hat{\alpha}^*/\hat{\beta}^*\right)}{dm}>0$ if $s<\overline{s}(m)$.

Finally, from expression (A.5), it is straightforward to see that

$$\operatorname{sign}\left[\frac{de^*}{dm}\right]=\operatorname{sign}\left[\frac{d\left[I+1/(1/m+1/\rho b)\right]}{dm}\right],$$

where

$$\frac{d\left[I+1/(1/m+1/\rho b)\right]}{dm}=\left(1+\frac{m}{\rho b}\right)^{-2}+\frac{dI}{dm}.$$

Therefore,

$$\text{sign}\left[\frac{de^*}{dm}\right]=\text{sign}\left[\left(1+\frac{m}{\rho b}\right)^{-2}+\frac{dI}{dm}\right].$$

Let $H(b)=\left(1+\frac{m}{\rho b}\right)^{-2}+\frac{dI}{dm}$. It is easy to see that $H(b)$ is monotonically increasing in b with $H(0)=\frac{dI}{dm}$ and $H(\infty)=1+\frac{dI}{dm}$. From our previous proof, $\frac{dI}{dm}>-1$ and hence $H(\infty)>0$. Also, from part (ii) of Proposition 1, $\frac{dI}{dm}<0$ and hence $H(0)<0$ if, and only if, $s<\overline{s}(m)$. As such, by the Intermediate Value Theorem, for any given value of m, there exists a unique $\underline{b}(m\,|\,s<\overline{s}(m))>0$ at which $H(\underline{b}(m\,|\,s<\overline{s}(m)))=0$ and $H(b)>0$ if, and only if, $b>\underline{b}(m\,|\,s<\overline{s}(m))$. Hence, if $s<\overline{s}(m)$, $\frac{de^*}{dm}<0$ if, and only if, $b<\underline{b}(m\,|\,s<\overline{s}(m))$.

(ii) The proof of part (ii) is parallel to that of part (i). First, when $s>\overline{s}(m)$ and hence $\frac{dI}{dm}>0$, $G(b)$ is monotonically decreasing in b with $G(0)>0$ and $G(\infty)=\frac{1}{m}\left(1+\frac{\rho}{h}\right)\left(\frac{dI}{dm}-\frac{I}{m}\right)-\frac{\rho}{m^2}$. From our previous proof, $\frac{m}{I}\frac{dI}{dm}<1$ and hence $G(\infty)<0$. As such, by the Intermediate Value Theorem, for any given value of m, there exists a unique $\overline{b}(m\,|\,s>\overline{s}(m))>0$ at which $G(\overline{b}(m\,|\,s>\overline{s}(m)))=0$ and $G(b)>0$ if, and only if, $b<\overline{b}(m\,|\,s>\overline{s}(m))$. Hence, if $s>\overline{s}(m)$, $\frac{d\eta^*}{dm}<0$ if, and only if, $b<\overline{b}(m\,|\,s>\overline{s}(m))$.

Next, observe from expression (A.6) that $\frac{d\eta^*}{dm}<0$ implies $\frac{d\left(\hat{\beta}^*/\hat{\alpha}^*\right)}{dm}>0$ or, equivalently, $\frac{d\left(\hat{\alpha}^*/\hat{\beta}^*\right)}{dm}<0$. Hence, we can conclude that $\frac{d\left(\hat{\alpha}^*/\hat{\beta}^*\right)}{dm}<0$ if $s>\overline{s}(m)$ and $b<\overline{b}(m\,|\,s>\overline{s}(m))$.

Finally, if $s > \bar{s}(m)$ and hence $\frac{dI}{dm} > 0$, we have $H(0) > 0$. As such, $H(0) > 0$ for all b and hence $\frac{de^*}{dm} > 0$ if $s > \bar{s}(m)$. ***Q.E.D.***

Proof of Proposition 3: Differentiating (18) with respect to m and applying the Envelope Theorem, we obtain

$$\frac{dE(\tilde{v}-\hat{\omega}-\hat{\alpha}^*\tilde{r}-\hat{\beta}^*\tilde{z})}{dm} = \frac{\partial E(\tilde{v}-\hat{\omega}-\hat{\alpha}^*\tilde{r}-\hat{\beta}^*\tilde{z})}{\partial m} = \frac{\rho}{2} \times \frac{1}{B^2} \times \frac{1}{I^2} \times \left(\frac{m+\rho b}{m\rho b}\right)^2 \left[\left(1+\frac{m}{\rho b}\right)^{-2} + \frac{dI}{dm}\right],$$

where

$$B = \left(1+\frac{\rho}{h}\right)\left(\frac{1}{m}+\frac{1}{\rho b}\right) + \left(1+\frac{\rho}{h}+\frac{\rho}{m}+\frac{1}{b}\right)\frac{1}{I} > 0.$$

Therefore,

$$\text{sign}\left[\frac{dE(\tilde{v}-\hat{\omega}-\hat{\alpha}^*\tilde{r}-\hat{\beta}^*\tilde{z})}{dm}\right] = \text{sign}\left[\left(1+\frac{m}{\rho b}\right)^{-2} + \frac{dI}{dm}\right] = \text{sign}\left[\frac{de^*}{dm}\right].$$

From the proof of part (i) of Proposition 2, we have $\frac{de^*}{dm} < 0$ and hence $\frac{dE(\tilde{v}-\hat{\omega}-\hat{\alpha}^*\tilde{r}-\hat{\beta}^*\tilde{z})}{dm} < 0$ if $s < \bar{s}(m)$ and $b < \underline{b}(m \mid s < \bar{s}(m))$ for any given m. Thus, if we can show that $\frac{d\bar{s}(m)}{dm} > 0$ and $\frac{d\underline{b}(m \mid s < \bar{s}(m))}{dm} > 0$ for all $m \in [\underline{m}, \infty)$ such that $\bar{s}(\underline{m})$ and $\underline{b}(\underline{m} \mid s < \bar{s}(m))$ are the respective lowest bounds, then we are done.

Recall from the proof of Proposition 1 that $F(\bar{s}(m)) = \frac{N^*}{N^*+1}\bar{s}(m) - (h+m) = 0.$ Applying the Implicit Function Theorem yields $\frac{d\bar{s}(m)}{dm} > 0$. Similar yet tedious calculations can show that $\frac{d\underline{b}(m \mid s < \bar{s}(m))}{dm} > 0$. Hence, we can conclude that if $s < \bar{s}(\underline{m})$ and $b < \underline{b}(\underline{m} \mid s < \bar{s}(\underline{m}))$, then $\frac{dE(\tilde{v}-\hat{\omega}-\hat{\alpha}^*\tilde{r}-\hat{\beta}^*\tilde{z})}{dm} < 0$ for all $m \in [\underline{m}, \infty)$, implying that the optimal level of precision of the reporting system is $\underline{m}$. ***Q.E.D.***

Figure 1: Timeline

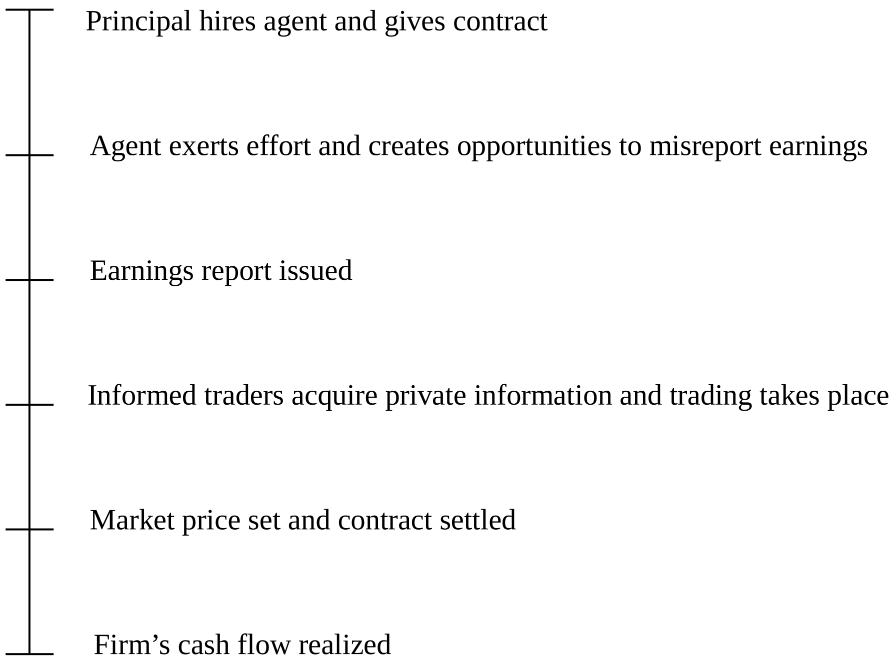

Table 1: Notation

e	= the agent's effort
$\tilde{v}$	= the firm's final gross cash flow, $\tilde{v} = e + \tilde{\varepsilon}$
$\tilde{\varepsilon}$	= the noise associated with the firm's final cash flow, $\tilde{\varepsilon} \sim \mathrm{N}(0,\ 1/h)$
$\tilde{r}$	= the earnings report, $\tilde{r} = \tilde{v} + \eta + \tilde{\tau}$
η	= the reporting bias chosen by the agent
$\tilde{\tau}$	= the noise associated with the earnings report, $\tilde{\tau} \sim \mathrm{N}(0,\ 1/m)$
$V(e,\eta)$	= the agent's (monetary) cost of taking effort e and making reporting bias η, $V(e,\eta) = \frac{1}{2}(e^2 + b\eta^2)$
b	= the agent's marginal cost of earnings management
ρ	= the agent's risk aversion coefficient
$\tilde{\theta}$	= the private signal about the firm's final cash flow, $\tilde{\theta} = \tilde{v} + \tilde{\kappa}$
$\tilde{\kappa}$	= the noise associated with the private signal, $\tilde{\kappa} \sim \mathrm{N}(0,\ 1/s)$
C	= the cost of private information
d_i	= informed trader i's market demand for the firm's stock, $d_i = d_0 + d_\theta \theta + d_r r$, for all i = 1,…, N, where d_0, d_θ and d_r are endogenously determined coefficients
N	= the endogenously determined number of informed traders
$\tilde{l}$	= the liquidity traders' total demand for the firm's stock, $\tilde{l} \sim \mathrm{N}(0,\ 1/t)$
$\tilde{q}$	= total market demand for the firm's stock, $\tilde{q} = \sum_{i=1}^{N} d_i + \tilde{l}$
e^c	= the market participants' common conjecture of the agent's effort
η^c	= the market participants' common conjecture of the agent's reporting bias
$\tilde{P}$	= the stock price of the firm set by the market maker, $P = E(\tilde{v} \mid \tilde{q} = q, \tilde{r} = r) = P_0 + P_q q + p_r r$, where P_0, P_q and P_r are endogenously determined coefficients
Ω	= the information asymmetry between the informed and uninformed traders, $\Omega \equiv SD\left[E(\tilde{v} \mid \tilde{\theta} = \theta, \tilde{r} = r) - E(\tilde{v} \mid \tilde{r} = r)\right] = \sqrt{\frac{s}{(h+m)(h+m+s)}}$
$\tilde{z}$	= the "filtered" price which reflects the incremental information in the stock price, $\tilde{z} \equiv \tilde{\theta} + \frac{\tilde{l}}{N^* d_\theta}$

I	= the informativeness of the filtered price, $I \equiv Var^{-1}(\tilde{v} \mid \tilde{r}=r, \tilde{z}=z) - Var^{-1}(\tilde{v} \mid \tilde{r}=r) = \frac{N^* s(h+m)}{(N^*+1)(h+m)+s}$
$\hat{\alpha}^*$	= the optimal adjusted compensation weight on the earnings report when contract is in the form of $\tilde{w} = \hat{\omega} + \hat{\alpha}\tilde{r} + \hat{\beta}\tilde{z}$
$\hat{\beta}^*$	= the optimal adjusted compensation weight on the filtered price when contract is in the form of $\tilde{w} = \hat{\omega} + \hat{\alpha}\tilde{r} + \hat{\beta}\tilde{z}$
α^*	= the optimal compensation weight on the earnings report when contract is in the form of $\tilde{w} = \omega + \alpha\tilde{r} + \beta\tilde{P}$
β^*	= the optimal compensation weight on the stock price when contract is in the form of $\tilde{w} = \omega + \alpha\tilde{r} + \beta\tilde{P}$

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