Earnings Management, Incentive Contracts,

Private Information Acquisition and Production Efficiency

Derek K. Chan and Jennifer Jie Gao

School of Business
The University of Hong Kong
Hong Kong

ABSTRACT: This paper analyzes the use of both reported earnings and price as compensation measures of performance when the firm manager can engage in earnings management and investors can acquire and trade profitably on private information about the firm's cash flow. We show that the use of price-based compensation, when the only other performance measure is a manipulated earnings report, allows the principal to differentiate between effort and earnings management incentives, in addition to reduce non-cash-flow-related risk from reported earnings. Furthermore, we demonstrate that informed traders' private information acquisition activities play an important market monitoring role by reducing the level of earnings management and improving manager's production efficiency through their impact on the tradeoff between earnings and price-based compensations in the optimal incentive contracts.

Key Words: *Executive compensation; Earnings management; Private information acquisition; Production efficiency*

JEL Classification: D82; M41

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1. Introduction

The use of both earnings- and price-based compensations in executive contracts and the phenomenon of earnings management have been extensively studied in the accounting and finance literature. However, how they are related to each other, and how the private information acquisition activities in the stock market affect their relation, are still imperfectly understood.

The agency theory has suggested tying the managers' pay to the performance of their firms. However, recent empirical studies and corporate scandals (e.g., Enron and WorldCom) have demonstrated a "dark side" of using earnings- and price-based compensations: they can induce earnings management behavior of the managers (see, e.g., Healy 1985, Guidry et al. 1999, Ke 2001, Cheng and Warfield 2005, Bergstresser and Philippon 2006). Previous contracting studies either ignore earnings management (see, e.g., Kim and Suh 1993, Bushman and Indjejikian 1993, Baiman and Verrecchia 1995) or overlook the market monitoring role of the private information production in the price formation process (see, e.g., Goldman and Slezak 2006 and Crocker and Slemrod 2007). To fill this gap, we present a simple, yet comprehensive, model to investigate the use of reported earnings and stock price as two performance measures to compensate its manager when he can engage in earnings management and investors can acquire and trade profitably on private information about the firm's cash flow. While allowing for earnings management implies that accounting earnings is a distorted measure of real economic earnings, the presence of private information acquisition activities implies that the stock price can be leveraged by the principal in designing the optimal incentive contracts. Specifically, we characterize a stock market in which stock price rationally incorporates both public information from accounting earnings, and private information from informed traders' strategic trading activities. In this model, earnings-based compensation is a double-edged sword in that it induces the manager to exert effort and to engage in earnings management. On the other hand, the use of stock price as a performance measure, when the only other performance measure is a manipulated earnings report, allows the principal to differentiate between effort and earnings management incentives, in addition to reduce non-cash-flow-related risk from reported earnings (i.e., the noise in the financial reporting system). Moreover, informed traders' private information acquisition activities not only influence the information content of the stock price, but also interact with the manager's effort and earnings management decisions through their effect on the optimal compensation contract.

Our model generates the following main results. First, by comparing the two settings with vis-à-vis without earnings management, we find that the possibility of earnings management shifts the relative compensation weight away from reported earnings and toward stock price and has the induced effect of lower production efficiency, reflecting a more severe moral hazard problem in the presence of earnings management. Second, the factors that affect private information acquisition activities, such as private information precision, the cost of private information and the precision of liquidity trades interact with the extent of earnings management and production efficiency through their effect on the optimal incentive contract. Specifically, we find that factors that induce more active private information acquisition by informed traders also induce a lower level of earnings management and a higher level of manager's effort. Thus, our model demonstrates the connection between stock market efficiency and economic efficiency. Third, in contrast to the conventional wisdom that an increase in the precision of a performance measure should increase the relative contracting importance of that measure in the optimal incentive contract, we show that earnings-based compensation does not necessarily receive a higher relative weight when earnings report becomes more precise. Finally, we show that our formal linkage among earnings management, optimal contracting and private information acquisition enables us to broaden our perspective and draw some novel empirical implications, such as the relation between risk and incentives and the cross-sectional relations among executive compensations, private information production, and price-earnings association, as well policy implications, such as the choice of financial reporting system and the Sarbanes-Oxley Act (SOX) that aims to improve the reliability of public companies' financial statements.

As mentioned, this study is related to Baiman and Verrecchia (1995), Goldman and Slezak (2006) and Crocker and Slemrod (2007). In Baiman and Verrecchia (1995), like our model, they analyze the use of both accounting earnings and price as a basis for compensating a manager. However, they assume earnings management is absent such that the earnings report provides an unbiased estimate of the firm's gross cash flow. Moreover, they assume that the only informed trader in their model (who might be the manager) observes the realized cash flow before he trades, whereas we assume that multiple informed traders' private information is imperfect, and that the number of informed traders is endogenously determined. Our setting allows us to study the effects of private information acquisition activities on, *inter alia*, the compensation weights, the extent of earnings management, and production efficiency.

Both Goldman and Slezak (2006) and Crocker and Slemrod (2007) develop a model that is different from ours to analyze the optimal compensation contract in the presence of earnings management. While Goldman and Slezak (2006) ignore the use of reported earnings as a performance measure in their model, Crocker and Slemrod (2007) assume that reported earnings is the only performance measure. Furthermore, private information acquisition activity is not studied in either model, so the market monitoring role of private information acquisition activities is not investigated.

Our study is also related to a wide range of other analytical studies in compensation and earnings management literature. For example, Bushman and Indjejikian (1993) and Kim and Suh (1993) examine how earnings and price are used in the optimal incentive contracts in the absence of earnings management when price is not an efficient estimator of cash flow. Fischer and Verrecchia (1998) model the earnings management incentive of a manager without considering either the optimal contract or the market monitoring role of informed traders.

The remainder of the paper is organized as follows. Section 2 describes the model. Section 3 characterizes the stock market equilibrium. Section 4 analyzes the optimal information acquisition activities. Section 5 first analyzes the optimal compensation contract in the absence of earnings management and then performs a parallel analysis for the setting where earnings management is present. Comparisons between these two settings will be made and comparative-static analysis will also be provided in the same section. Section 6 provides some empirical and policy implications. The final section concludes. Proofs are in the appendix.

2. The model

Our one-period model consists of a publicly traded firm with a principal, a manager, informed traders, liquidity traders and a market maker. The manager is risk-averse while all other players are risk-neutral.[1] The timeline for the model is shown in Figure 1. At the first stage, the principal, acting in the interests of long-term shareholders, designs a compensation contract for the

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

manager to motivate him to exert effort to run the firm.[2] At the second stage, the manager 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 manager publicly issues an earnings report that reflects the firm's end-of-period gross cash flow. At the fourth stage, investors submit their demand of the firm's stock to the market maker after observing the earnings report. There are two types of investors: 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 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 manager, is paid to shareholders. In our setting, although earnings management could be perfectly anticipated by the principal and the market, it could not be contracted upon.

[Insert Figure 1 about here]

Production Technology and Managerial Compensation

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 manager), e is the unobservable effort taken by the manager at stage 2, and $\tilde{\varepsilon}$ is the noise term that is normally distributed with mean 0 and precision h.[3] The distribution of the production noise term (i.e., the cash-flow-related risk) is independent of the manager's effort. At stage 1, the principal chooses a compensation contract to efficiently motivate the manager to exert effort. By doing so, the principal takes into account that the manager is able to manipulate the earnings report to be issued at stage 3 and the stock price to be determined at stage 5 impounds valuable information about the firm's end-of-period gross cash

[2] 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.

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

flow and, hence, the manager's effort.[4] We assume that the only information on which the manager's contract can be based is the earnings report and the stock price.[5] Further, for tractability, we assume that the managerial compensation is linear in the two observables: $\tilde{w} = a + \alpha\tilde{r} + \beta\tilde{P}$, where $\tilde{r}$ is earnings report publicly issued by the manager, $\tilde{P}$ is stock price for the firm's end-of-period gross cash flow, and *a*, α and β are the linear compensation coefficients chosen by the principal.[6] The managerial compensation contract is common knowledge.

Accounting Information and Manager's Effort and Reporting Strategy

At stage 2, after the contract is signed, the manager exerts unobservable costly effort and covertly creates opportunities (at a cost described shortly) for allowing him to introduce an amount of reporting bias, η, into the future earnings report that reflects the firm's end-of-period gross cash flow.[7] Then, at stage 3, the manager 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 manager's actions and is assumed to be normally distributed with mean 0 and precision m. The manager's preferences are represented by a constant absolute risk aversion (CARA) utility function defined

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[4] Thus, private information acquisition in this model plays a market monitoring role as in Holmstrom and Tirole (1993).

[5] 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 managerial contract and therefore not contractible before the managers need to be rewarded.

[6] 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 informationally equivalent constructs. To convert one from the other one only needs public information. However, this assumption simplifies the analysis considerably as it makes trading independent of incentive contracting, and thus 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.

[7] Two remarks are in order here. First, if the manager is allowed to trade the firm's stock, then he might have an incentive to misreport down, whereas in our model without managerial 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 manager (although other players will be able to anticipate the level of η in equilibrium since the manager's reporting incentives are common knowledge). Otherwise the manager would be able to effectively commit to truthful reporting simply by setting $\eta = 0$. As is well-known in the signal-jamming literature, the manager 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 manager still has incentives to bias the earnings report upward because otherwise the manager would be perceived by the market as exerting less effort and, accordingly, would receive lower compensation.

over his compensation, $\tilde{w}$, minus the (monetary) costs of effort, $V(e)$, and earnings management, $M(\eta)$:

$$U_m(e,\eta) = -\exp\{-\rho[\tilde{w} - V(e) - M(\eta)]\},$$

where ρ is the manager's coefficient of constant absolute risk aversion. Thus, at stage 2, given a compensation contract $\tilde{w}$, the manager's objective is to choose e and η to maximize his expected utility:

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

To obtain closed-form solutions, we further assume that $V(e) = e^2/2$ and $M(\eta) = b\eta^2/2$, where $b > 0$ is the marginal cost of earnings management. The cost function of earnings management takes the quadratic form to capture the feature that both the total and marginal costs of earnings management increase in the level of reporting bias η.[8]

Private Information Acquisition and Stock Trading

After observing the earnings report, r, investors submit their demand of the firm's stock to the market maker. There are two types of investors: informed traders and liquidity traders. It is assumed 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.[9] For simplicity, it is assumed that each informed trader privately receives a common imperfect information of the form: $\theta = \tilde{v} + \tilde{\kappa}$, where the noise term, $\tilde{\kappa}$, is assumed to be normally distributed with mean 0 and precision s.[10] Conditional on the observed private information, θ, and the observed earnings report, r, each informed trader privately submits a market demand of d_i, $i = 1, \ldots, N$, to maximize his expected trading profit:

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[8] The cost function of earnings management might reflect, for instance, the manager's litigation, reputation and psychic cost of manipulating the firm's earnings report.

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

[10] 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.

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

where $(\tilde{v}-\tilde{P})d_i$ is the informed trader *i*'s random trading profit. In contrast, the aggregate demand of liquidity traders, $\tilde{l}$, is exogenously given and assumed to be normally distributed with mean 0 and precision t. The total market demand is then given by $\tilde{q}=\sum_{i=1}^{N} d_i + \tilde{l}$.[11] 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 manager'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 and have 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 number of informed traders is fixed, the market participants have the same common conjectures of the unobservable managerial effort, e^c, and the unobservable reporting bias, η^c, and the managerial compensation contract is known.[12] Then, we analyze how the equilibrium number of informed traders is determined in Section 4. Finally, the optimal managerial compensation contract is

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

[12] 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, management 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 management effort e^c and conjectured reporting bias η^c. Technically, the manager is playing a Nash game against the informed traders and the market maker relative to his choices of effort and reporting bias. In equilibrium the conjectures of the market participants always equal to the manager's actual choices.

derived in Section 5.

3. Informed Trading and Stock Price Formation

The stock market equilibrium consists of trading strategies d_i, $i = 1, \ldots, N$, and a pricing function P such that (i) the trading strategy of each informed trader maximizes his expected trading profit taking all other informed traders' strategies and price as given, and (ii) P satisfies equation (3) taking the trading strategies of all informed traders as given. The following proposition characterizes the stock market equilibrium.

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

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

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

where

$$d_0 = -\sqrt{\frac{s}{Nt(h+m)(h+m+s)}}(he^c - m\eta^c), \tag{6}$$

$$d_\theta = \sqrt{\frac{s(h+m)}{Nt(h+m+s)}}, \tag{7}$$

$$d_r = -m\sqrt{\frac{s}{Nt(h+m)(h+m+s)}}, \tag{8}$$

$$P_0 = \frac{he^c - m\eta^c}{h+m}, \tag{9}$$

$$P_q = \frac{1}{N+1}\sqrt{\frac{Nst}{(h+m)(h+m+s)}}, \tag{10}$$

and

$$P_r = \frac{m}{h+m}. \tag{11}$$

Recall that the market maker sets price P equal to the expected gross cash flow of the firm and η^c is the market participants' belief about the reporting bias. In equilibrium, the market participants' belief must be self-fulfilling and therefore the reporting bias is perfectly anticipated. Thus, Proposition 1 shows that the expected gross cash flow of the firm is decreasing in the expected extent of reporting bias and that the degree of the market participants' adjustment for the expected reporting bias is increasing in the market response to marginal changes in the reported earnings or, simply, the price-earnings association, P_r. Moreover, since the reporting bias is perfectly anticipated, it should not affect the information content in the earnings report. Hence, Proposition 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.

To obtain more insights into the informed traders' demand, we can rewrite equation (4) as:[13]

$$d_i = \frac{E(\tilde{v} \mid \tilde{\theta} = \theta, \tilde{r} = r) - E(\tilde{v} \mid \tilde{r} = r)}{P_q(N+1)}, \quad \text{for all } i = 1, \ldots, N. \tag{12}$$

Inspection of equation (12) 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 $SD\left[E(\tilde{v} \mid \tilde{\theta} = \theta, \tilde{r} = r) - E(\tilde{v} \mid \tilde{r} = r)\right]$ 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:

$$\Omega \equiv SD\left[E(\tilde{v} \mid \tilde{\theta} = \theta, \tilde{r} = r) - E(\tilde{v} \mid \tilde{r} = r)\right] = \sqrt{\frac{s}{(h+m)(h+m+s)}}. \tag{13}$$

Notice from equations (11) and (13) that both the price-earnings association, P_r, and the information asymmetry between informed and uninformed traders, Ω, are functions solely of exogenous parameters, i.e., they are invariant to the number of informed traders nor the manager's

[13] See the appendix for a derivation of equation (12).

contract. The comparative-static results on P_r and Ω are tabulated in Panel A of Table 2.[14] These results are intuitive. First, the price-earnings association decreases in the precision of the firm's gross cash flow because less noise in the prior beliefs about the cash flow implies that new information contained in the earnings report should receive less weight in the posterior expectation. This serves to decrease the price-earnings association. In contrast, as the precision of the earnings report increases, it leads to higher informativeness of the earnings report and thus higher price-earnings association.[15] Second, since the earnings report is the only information source of the uninformed traders whereas the informed traders also possess private information, the information advantage of the informed traders decreases when the firm's gross cash flow or the earnings report becomes more precise. In contrast, the information advantage of the informed traders increases when the private information becomes more precise.

[Insert Table 2 about here]

Using equation (13), we can rewrite equation (10) as:

$$P_q = \frac{\sqrt{Nt}}{N+1}\Omega. \tag{14}$$

As P_q inversely gauges the market liquidity of the stock (Kyle 1985), it is then evident from equation (14) that, *ceteris paribus*, the market liquidity of the stock declines (i.e., P_q increases) as the private information becomes more valuable (i.e., Ω increases). In contrast, partially differentiating P_q in equation (14) with respect to N yields

$$\frac{\partial P_q}{\partial N} = -\frac{(N-1)\sqrt{t}}{(N+1)^2\sqrt{N}}\Omega < 0,$$

i.e., the market liquidity of the stock increases (i.e., P_q decreases) as more investors become informed (i.e., N increases). The intuition is that informed traders become more aggressive in

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[14] The proof of the comparative-static results tabulated in Table 2 is straightforward but tedious, and therefore, is omitted for brevity. It is, however, available upon request from the authors.

[15] This result is consistent with the previous analytical and empirical studies that the stock price reaction to earnings announcement increases in the precision of public information (see, e.g., Baginski et al 1993, Holthausen and Verrecchia 1988, and Kim and Verrecchia 1991).

stock trading as their number increases. To see this, let us rewrite equation (4) as:

$$d_i = d_\theta(\theta - P_0 - P_r r) = d_\theta[\theta - E(\tilde{v} \mid \tilde{r} = r)], \quad \text{for all } i = 1,\ldots, N,$$

where we have used the facts that $d_0 = -d_\theta P_0$ and $d_r = -d_\theta P_r$. The aggregate order flow from the informed traders is then given by:

$$\sum_{i=1}^{N} d_i = Nd_i = Nd_\theta[\theta - E(\tilde{v} \mid \tilde{r} = r)] = \sqrt{\frac{Ns(h+m)}{t(h+m+s)}}[\theta - E(\tilde{v} \mid \tilde{r} = r)].$$

Thus, *ceteris paribus*, the aggregate order flow from the informed traders increases as their number increases. Greater competition in stock trading then implies greater revelation of private information in stock price which implies a more liquid market.

Notice also that while Ω is a function solely of exogenous parameters, N is an endogenous variable. In the next section, we derive the equilibrium level of N .

4. Endogenous Private Information Acquisition

Anticipating that the linear rational expectations equilibrium is characterized in Proposition 1, each of the informed trader's ex-ante expected trading profit is given by:[16]

$$\Pi_i \equiv \frac{E[E(\tilde{v} \mid \tilde{\theta} = \theta, \tilde{r} = r) - E(\tilde{v} \mid \tilde{r} = r)]^2}{P_q(N+1)^2} = \frac{P_q}{Nt}, \quad \text{for all } i = 1,\ldots, N. \tag{15}$$

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:

$$\frac{P_q}{N^* t} = C, \tag{16}$$

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. The comparative-static results on N^* and P_q are tabulated in Panel B of Table 2 and are very intuitive. First, as discussed, the information advantage of the informed traders decreases when the precision of the firm's gross cash flow

[16] See the appendix for a derivation of equation (15).

increases, the precision of the earnings report increases or the precision of the private information decreases. As a result, the private information becomes less valuable and therefore the equilibrium number of informed traders decreases. The informed traders become less aggressive in stock trading as their number shrinks and less competition in stock trading implies less revelation of private information in stock price which, in turn, implies a less liquid market for the stock. This negative effect on the market liquidity, however, is more than offset by the positive effect on the market liquidity due to the decrease in the information asymmetry between informed and uninformed traders, resulting in a net increase in the market liquidity (i.e., lower P_q). Second, 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, which, for the same reason mentioned above, leads to a less liquid market for the stock. Moreover, from equation (14), an increase in the precision of the liquidity trades also directly decreases the market liquidity. Finally, more costly information makes the acquisition of private information less attractive, thereby leads to less investors becoming informed. As a consequence, the stock becomes less liquid.

5. Optimal Managerial 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. Succinctly, in stage 1 the principal chooses an incentive contract (a, α, β) that maximizes the long-term shareholders' expected terminal wealth:

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

subject to the manager acting in his own interest:

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

and the manager's participation constraint:

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

where without loss of generality the manager's reservation utility is normalized to minus one.

As the informational value of price for contracting (as well as investment) purposes arises from its incremental information over and above what is known from other sources of information, we follow Kim and Suh (1993) by carrying out a normalization that filters out earnings information from the stock price in order to enhance analytical tractability. Using equations (4) and (5), we can rewrite the manager's compensation as:

$$\tilde{w} = a + \alpha\tilde{r} + \beta\{P_0 + P_q[N^*(d_0 + d_\theta\tilde{\theta} + d_r\tilde{r}) + \tilde{l}\,] + P_r\tilde{r}\} \equiv \hat{a} + \hat{\alpha}\tilde{r} + \hat{\beta}\tilde{z}, \tag{17}$$

where,

$$\hat{a} \equiv a + \beta(P_0 + P_q N^* d_0) = a + \beta P_0(1 - P_q N^* d_\theta) = a + P_0(\beta - \hat{\beta}), \tag{18}$$

$$\hat{\alpha} \equiv \alpha + \beta(P_r + P_q N^* d_r) = \alpha + \beta P_r(1 - P_q N^* d_\theta) = \alpha + P_r(\beta - \hat{\beta}), \tag{19}$$

$$\hat{\beta} \equiv \beta P_q N^* d_\theta\,, \tag{20}$$

and

$$\tilde{z} \equiv \tilde{\theta} + \frac{\tilde{l}}{N^* d_\theta} = \tilde{\theta} + \sqrt{\frac{t(h+m+s)}{N^* s(h+m)}}\,\tilde{l}\ . \tag{21}$$

Equation (17) 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 pure additional knowledge due to observing the stock price beyond what is available from the earnings report,[17] i.e.,

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

For expositional convenience, we will refer $\tilde{z}$ to as the "filtered" price and use it for an initial calculation of the optimal linear compensation contract. 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. As the information of earnings report is also impounded into the stock price, 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

[17] 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.

regression equations of compensation weights (see Baiman and Verrecchia 1995).[18] Accordingly, $\hat{\alpha}$ represents the total compensation weight on reported earnings, both directly and indirectly through price. Using equation (A.6) in the appendix, we have

$$\hat{\beta} = \left(\frac{N^*}{N^*+1} \right) \left(\frac{s}{h+m+s} \right) \beta < \beta, \tag{22}$$

and therefore $\hat{\alpha} > \alpha$ as expected. Since $\hat{\alpha} > \alpha$ and $\hat{\beta} < \beta$, then $\hat{\alpha} / \hat{\beta} > \alpha / \beta$, i.e., the relative adjusted weight of reported earnings to filtered price is greater than the relative weight of reported earnings to "raw" price. Moreover, using equations (19) and (22), it is easy to see that

$$\hat{\alpha} + \hat{\beta} = \alpha + \beta \left[P_r + (1-P_r) \left(\frac{N^*}{N^*+1} \right) \left(\frac{s}{h+m+s} \right) \right] < \alpha + \beta,$$

i.e., the combined weight is greater when the weights on the performance measures are based on the filtered price than when the weights are based on the raw price.[19]

The Case of No Earnings Management

To understand the role of earnings management in the optimal contract, we first examine a benchmark setting where the manager commits to not manipulate the earnings report, i.e., $\tilde{r} = e + \tilde{\varepsilon} + \tilde{\tau}$. The following proposition characterizes the optimal solution to the manager's contract in the absence of earnings management in terms of the adjusted weights.

Proposition 2: When the management commits to not manipulate the earnings report, there is a unique optimal solution to the principal-agent problem characterizing by:

$$\hat{\alpha}^+ = \frac{\dfrac{(N^*+1)(h+m)+s}{N^* s(h+m)}}{\left(1+\dfrac{\rho}{h}\right)\dfrac{1}{m} + \left(1+\dfrac{\rho}{h}+\dfrac{\rho}{m}\right)\left[\dfrac{(N^*+1)(h+m)+s}{N^* s(h+m)}\right]} > 0, \tag{23}$$

[18] In Baiman and Verrecchia (1995), there is another advantage of using the adjusted compensation weights: they decompose managerial compensation 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 manager's effort.

[19] Kim and Suh (1993) have the same findings as ours regarding the comparisons of the weights on the performance measures based on the filtered price and the weights based on the raw price. However, unlike our model, price in their model is not an efficient estimator of cash flow.

$$\hat{\beta}^{+} = \frac{\frac{1}{m}}{\left(1+\frac{\rho}{h}\right)\frac{1}{m} + \left(1+\frac{\rho}{h}+\frac{\rho}{m}\right)\left[\frac{(N^{*}+1)(h+m)+s}{N^{*}s(h+m)}\right]} > 0, \tag{24}$$

$$e^{+} = \hat{\alpha}^{+} + \hat{\beta}^{+} \in (0,1), \tag{25}$$

where N^{*} is defined in equation (16).

Proposition 2 establishes three characteristics of the optimal contract. First, 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 reported earnings and filtered price to filter some non-cash-flow-related noise from both (i.e., $1/m$, $1/s$ and $1/t$).[20] Second, since both performance measures reflect the impact of managerial effort in a symmetric fashion, their incentive effects on effort are identical. In particular, Proposition 2 shows that the induced level of effort , e^{+}, is positive, but less than the first-best level of $e = 1$. Third, the optimal adjusted compensation weights, $\hat{\alpha}^{+}$ and $\hat{\beta}^{+}$, are functions of manager, firm and market characteristics and "sensitivity" and precision of the two performance measures.[21] Lambert and Larcker (1987) show that in order to carry out cross-sectional analyses of the attributes of managerial compensation contracts with two performance measures, it is preferable to focus on the relative weight placed on performance measures in order to reduce the confounding factors of manager-specific characteristics. Using equations (23) and (24), the relative adjusted weight of reported earnings to filtered price can be stated as

$$\frac{\hat{\alpha}^{+}}{\hat{\beta}^{+}} = \frac{m[(N^{*}+1)(h+m)+s]}{N^{*}s(h+m)} = P_{r}\left[\frac{(N^{*}+1)(h+m)+s}{N^{*}s}\right], \tag{26}$$

where the second equality follows from using equation (11).

[20] It is noteworthy that if reported earnings reveals cash flow perfectly, filtered price becomes superfluous (i.e., $1/m \to 0$ implies $\hat{\beta}^{+} \to 0$). Therefore, in the absence of earnings management, the only role for filtered price as an additional contracting variable is to help filter the non-cash-flow-related noise from reported earnings. This will be in sharp contrast to the setting in which earnings management is present.

[21] Sensitivity measures the change in the expected value of a performance measure with changes in the level of managerial action(s), adjusted for the correlation between the performance measures.

The Case of Earnings Management

Now, we return to our original setting where the manager cannot commit to not manipulate the earnings report. Before characterizing the optimal compensation contract in this setting, it is useful to consider how price can reduce the agency problem when the only other performance measure is a biased earnings report. The principal is interested in providing distinct incentives/disincentives for e and η in a way that reflects the cost and benefits of each action. When the earnings report is unbiased about the firm's cash flow, both earnings and price are symmetric in the way they reflect information about the firm's mean cash flow. In contrast, when the earnings report is biased, earnings and price are no longer symmetric with respect to their information content about cash flow. The basic intuition underlying the forms of earnings report $\tilde{r} = e + \eta + \tilde{\varepsilon} + \tilde{\tau}$ and private signal $\theta = e + \tilde{\varepsilon} + \tilde{\kappa}$ is that, by using price, the principal will be able to differentiate between e and η incentives/disincentives and, in addition, reduce non-cash-flow-related risk, $\tilde{\tau}$, from reported earnings. Intuitively, for a given realization of reported earnings, a low realization of price is indicative of high η. In effect, from the perspective of de-motivating η only, price behaves as a "pure" filter since it is uninformative about η but can reduce risk.

The following proposition characterizes the optimal solution to the manager's contract in the presence of earnings management in terms of the adjusted weights.[22]

Proposition 3: In the presence of earnings management, there is a unique optimal solution to the principal-agent problem characterizing by:

$$\hat{\alpha}^* = \frac{\dfrac{(N^*+1)(h+m)+s}{N^* s(h+m)}}{\left(1+\dfrac{\rho}{h}\right)\left(\dfrac{1}{m}+\dfrac{1}{\rho b}\right)+\left(1+\dfrac{\rho}{h}+\dfrac{\rho}{m}+\dfrac{1}{b}\right)\left[\dfrac{(N^*+1)(h+m)+s}{N^* s(h+m)}\right]} > 0, \tag{27}$$

$$\hat{\beta}^* = \frac{\dfrac{1}{m}+\dfrac{1}{\rho b}}{\left(1+\dfrac{\rho}{h}\right)\left(\dfrac{1}{m}+\dfrac{1}{\rho b}\right)+\left(1+\dfrac{\rho}{h}+\dfrac{\rho}{m}+\dfrac{1}{b}\right)\left[\dfrac{(N^*+1)(h+m)+s}{N^* s(h+m)}\right]} > 0, \tag{28}$$

[22] The proof of Proposition 3 is analogous to that of Proposition 2 and, therefore, is omitted for brevity.

$$e^* = \hat{\alpha}^* + \hat{\beta}^* \in (0,1)\,, \tag{29}$$

$$\eta^* = \frac{\hat{\alpha}^*}{b} > 0. \tag{30}$$

where N^* is defined in equation (16).

Proposition 3 shows that when the manager is compensated based on reported earnings and filtered price, the incentive powers for e and η are different since incentives/disincentives for η can only be provided through reported earnings. In particular, using reported earnings as a performance measure is a double-edged sword in that it induces the manager to not only exert effort but also to manipulate the reported earnings.[23] This result support the view that using accounting earnings as a measure of managerial performance creates incentives to manipulate the accounting system and thus works against the alignment of shareholder and management interests (e.g., Healy 1985 and Guidry et al. 1999).

Results of recent empirical studies, however, suggest that price-based compensation induces earnings management (see, e.g., Cheng and Warfield 2005 and Bergstresser and Philippon 2006 which document a positive relation between price-based compensation and earnings management). It is noteworthy that existing empirical studies estimate weights on performance measures based on raw prices. In order to link our results to empirical studies, we convert the contract based on the filtered price to one based on the raw price. In particular, using equations (19) and (20), we can write equation (30) 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 and its impact depends on, *inter alia*, the price-earnings association, P_r, which measures how important is the valuation role of earnings.

[23] 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 manager's manipulation of reported earnings, then both reported earnings and filtered price will induce the manager 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.

Proposition 3 also reflects the multiple roles that a price measure can play in alleviating the moral hazard problem when earnings management is present. Filtered price, in addition to reducing the non-cash-flow-related noise from reported earnings, also allows the principal to differentiate the manager's actions in order to provide distinct incentives/disincentives for e and η.[24] The clearest demonstration of how the additional role of filtered price works can be seen in the expression for the relative adjusted weight of reported earnings to filtered price. Using equations (27) and (28), the relative adjusted weight of reported earnings to filtered price can be stated as:

$$\frac{\hat{\alpha}^*}{\hat{\beta}^*} = \frac{m\rho b[(N^*+1)(h+m)+s]}{N^* s(h+m)(m+\rho b)} = \left(\frac{\rho b}{m+\rho b}\right) P_r \left[\frac{(N^*+1)(h+m)+s}{N^* s}\right]. \tag{31}$$

A comparison of expressions (26) and (31) highlights the additional role of filtered price other than filtering non-cash-flow-related noise from reported earnings. The term in the first bracket in (31) captures the role of filtered price in differentiating e and η. This term is a function of firm- and manager-specific variables, m, ρ and b, reflecting the fact that these variables have asymmetric impacts on different incentive variables and therefore no longer cancel in the computation of the relative adjusted weight.

The next proposition shows the effects of earnings management on the optimal incentive contract.

Proposition 4: $\hat{\alpha}^*/\hat{\beta}^* < \hat{\alpha}^+/\hat{\beta}^+$, $\hat{\alpha}^* < \hat{\alpha}^+$, $\hat{\beta}^* > \hat{\beta}^+$ and $e^* < e^+$

The intuition of Proposition 4 is as follows. In the presence of earnings management, the principal designs the manager's compensation contract not only for incentive purposes, but also to alleviate manager's earnings management. Since disincentives for earnings management, η, can only be provided through reported earnings and, from equation (30), earnings management increases in the optimal adjusted weight on reported earnings, $\hat{\alpha}^*$, then in the optimal contract $\hat{\alpha}^*$ should be lower compared with the case of no earnings management. At the same time, the

[24] Note 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.

optimal adjusted weight on filtered price, $\hat{\beta}^*$, increases compared with the case of no earnings management because of its additional role in alleviating the moral hazard problem mentioned before. Then, obviously, the relative adjusted weight of reported earnings to filtered price when earnings management is present is smaller than the case of no earnings management. Finally, the proposition shows that the optimal level of manager's effort decreases under the situation of earnings management, reflecting that the moral hazard problem becomes more severe. It is noteworthy to emphasize that none of the coefficient differences between the regime with earnings management and that without earnings management is attributable to earnings report *per se* being a less informative statistic about the firm's cash flow in the former case. Instead, the results described in Proposition 4 are driven by the principal's desire to thwart the manager's incentives for costly earnings management, which the principal must ultimately pay for given the manager's reservation utility constraint.

Comparative Statics

We now conclude the analysis of the case of earnings management by discussing how the relative adjusted weight of reported earnings to filtered price, the extent of earnings management, and the management effort change as a response to changes in the exogenous parameters in the model. This discussion is based on a set of comparative-static results that is tabulated in Panel C of Table 2.

Before discussing these comparative-static results, it is noteworthy that the optimal choices of $\hat{\alpha}^*$, $\hat{\beta}^*$, e^*, and η^* all depend on the equilibrium number of informed traders, N^*. Hence, any exogenous change that affects the equilibrium number of informed traders also indirectly affects the optimal adjusted compensation weights and the manager's choices of effort and reporting bias. This indirect effect on the optimal contract arises because of the monitoring role of the informed traders' private information (see Holmstrom and Tirole 1993).

Columns (i) and (ii) of Panel C in Table 2 report the comparative-static results regarding how the optimal choices of $\hat{\alpha}^*$, $\hat{\beta}^*$, η^*, and e^* change with changes in the firm-specific characteristics in our model. These comparative-static results are ambiguous in general.[25] The reason for this is that changes in the cash flow precision, h, and the reporting precision, m, have both direct and indirect effects that counteract to each other. First, intuitively, increasing cash flow precision, h, should increase the "sensitivity times precision" of a performance measure (say filtered price) affected by that precision. While this intuition holds true when price is exogenously specified (i.e., P_r and P_q are exogenous), it does not necessary hold when price is endogenously determined in equilibrium because both P_r and P_q are functions of h. We show that the relative adjusted weight of reported earnings to filtered price increases with the cash flow precision if, and only if, the posterior precision of the firm's cash flow conditional on the earnings report is sufficiently high, i.e., $Var^{-1}(\tilde{v} \mid \tilde{r} = r) = h + m > N^* s \big/ (N^* + 1)$, and *vice versa*. On the other hand, while both the adjusted weight on reported earnings and the induced reporting bias increase in the cash flow precision when the posterior precision of the firm's cash flow conditional on the earnings report is sufficiently high, both the adjusted weight on filtered price and the induced optimal effort increase in the cash flow precision when the posterior precision of the firm's cash flow conditional on the earnings report is sufficiently low, i.e., $Var^{-1}(\tilde{v} \mid \tilde{r} = r) = h + m < N^* s \big/ (N^* + 1)$.

Second, increasing reporting precision has the direct effect of making reported earnings more informative and therefore increases the compensation weight on reported earnings. Also, when private information acquisition is endogenous, increasing reporting precision has an indirect effect of decreasing the equilibrium number of informed traders, which, in turn, implies an increase in the noise of the filtered price and thus an increase in $\hat{\alpha}^*$ relative to $\hat{\beta}^*$. However, increasing reporting precision also has another indirect effect of increasing the manager's incentive to distort reported earnings, which, in turn, implies that relatively more weight should be shifted away from

[25] In contrast, Baiman and Verrecchia (1995) find unambiguous comparative static results with respect to changes in the cash flow precision and the reporting precision for their adjusted relative compensation weight. This difference occurs not only because of the absence of earnings management in their model, but also of their assumption that the private information is the realized cash flow. We would have obtained the same comparative static result with respect to changes in the reporting precision for our adjusted relative compensation weight in the absence of earnings management. Furthermore, if we assume that the private information is the realized cash flow, we would also have obtained the same comparative static result with respect to changes in the cash flow precision for our adjusted relative compensation weight.

reported earnings and toward filtered price. We show that when the posterior precision of the firm's cash flow conditional on the earnings report is sufficiently high, i.e., $h+m>N^*s/(N^*+1)$, the relative adjusted weight of reported earnings to filtered price, the adjusted weight on reported earnings, the extent of earnings management all increase, but the adjusted weight on filtered price decreases, as a response to an increase in the reporting precision.[26] However, managerial effort increases in reporting precision when the posterior precision of firm's cash flow conditional on the earnings report is sufficiently low, i.e., $h+m<N^*s/(N^*+1)$. This ambiguous effect of increasing reporting precision on the optimal level of earnings-based compensation is in contrast to the results of previous studies (e.g., Baiman and Verrechia 1995, Banker and Datar 1989, Bushman and Indjejikian 1993, and Kim and Suh 1993), which demonstrate that increasing the precision of a performance measure increases the relative contracting importance of that performance measure. We show that this does not necessarily hold for the case of public information (i.e., reported earnings) when earnings management incentive is also taken into consideration. It is because an increase in the precision of reported earnings will also lead to an increase in the level of earnings management. Thus, under certain conditions, earnings-based compensation does not necessarily receive a higher relative weight so as to dampen the manager's earnings management incentives.

Columns (iii) to (v) of Panel C in Table 2 report the comparative-static results regarding how the optimal choices of $\hat{\alpha}^*$, $\hat{\beta}^*$, η^*, and e^* change in response to changes in the market-specific characteristics that affects private information acquisition activities. The intuition underlying these comparative-static results is as follows. First, observe that, *ceteris paribus*, an increase in the equilibrium number of informed traders, N^*, decreases the noise of the filtered price, since $\partial Var(\tilde{z})/\partial N^* = -(h+m+s)/[N^*s(h+m)]<0$. Then, it follows immediately that an increase in the precision of the liquidity trades, t, or the cost of private information acquisition, C, increases the noise of the filtered price indirectly via its negative impact on the

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[26] Since the optimal N^* is uniquely determined by equation (16), the sufficient condition $h+m>N^*s/(N^*+1)$ can be replaced by a sufficient condition in terms of the exogenous parameters in our model.

equilibrium number of informed traders. In contrast, an increase in the precision of private information, s, decreases the noise of the filtered price via its direct (since $\partial Var(\tilde{z}) \big/ \partial s^* = -(N^* + 1)/(N^* s^2) < 0$) as well as indirect effects. Second, as the noise of the filtered price goes up when the precision of the liquidity trades increases, the cost of private information acquisition increases, or the precision of private information decreases, the principal responds by increasing the earnings-based compensation and decreasing the price-based compensation, which, in turn, implies an increase in $\hat{\alpha}^*$ relative to $\hat{\beta}^*$ as well as an increase in the induced reporting bias, η^*. Third, in all these cases where the relative adjusted weight of reported earnings to filtered price increases as a response to an increase in the noise of the filtered price, the double-edged sword property of the earnings-based compensation implies that managerial effort becomes more costly to induce due to the increase in the manager's incentives to engage in earnings manipulation, and hence the optimal level of managerial effort goes down.[27] In sum, these comparative-static results show that when more investors engage in acquiring private information (i.e., when N increases in response to an increase in s, a decreases in t or a decrease in C), the filtered price will better reflect the firm's cash flow and hence, the manager's effort. As a consequence, the relative weight on adjusted reported earnings to filtered price decreases, which in turn leads to a lower level of earnings management and a higher level of managerial effort. These results demonstrate the importance of the market monitoring role of informed traders' private information acquisition activities in the design of the optimal incentive contract.

Finally, columns (vi) and (vii) of Panel C in Table 2 report the comparative-static results regarding the optimal choices of $\hat{\alpha}^*$, $\hat{\beta}^*$, η^*, and e^* change with changes in the manager-specific characteristics in our model. The intuition for part (vi) is straightforward. Consistent with conventional wisdom, an increase in the cost of earnings management, b, reduces the manager's incentive to engage in such activity. As a consequence, the principal

[27] Baiman and Verrecchia (1995) get a comparative static result with respect to changes in the precision of the liquidity trades for their adjusted relative compensation weight that is opposite to ours. It is noteworthy that this difference is not owing to the presence of earnings management in our model. Rather, this difference occurs since the manager is allowed to strategically trade on private information in their model, while private information acquisition is endogenous in ours.

responds by increasing the earnings-based compensation and decreasing the price-based compensation, where the latter reflects that the additional role of the filtered price in alleviating the earnings management problem becomes less important when the cost of such activity increases. As $\hat{\alpha}^*$ increases and $\hat{\beta}^*$ decreases, both $\hat{\alpha}^* / \hat{\beta}^*$ and the induced reporting bias increase. Moreover, the induced optimal effort increases because it becomes less costly to induce managerial effort when the manager's incentives to engage in earnings manipulation decreases.

Part (vii) is less intuitive. On one hand, an increase in the manager's risk aversion, ρ, makes compensation based on either reported earnings or filtered price more costly for the firm to induce effort and thus leads to a decrease in their use in the optimal compensation contract. On the other hand, as risk aversion increases, in addition to the fact that effort becomes more expensive to induce, manipulation also becomes more expensive to the manager because of the risk associated with the manager's personal cost of earning management. While the first effort-related effect decreases the use of both earnings- and price-based compensations, the second manipulation-related effect increases the use of earnings-based compensation. As a result, the principal responds by decreasing the weight on filtered price (since filtered price is free from the manipulation-related effect), but could also choose to decrease earnings-based compensation, and thus induce a lower reporting bias, when the cost of earnings management is sufficiently high (i.e., $b > hm / \rho^2$). Nevertheless, we are able to show that, as the manager becomes more risk-averse, relatively more weight is shifted away from filtered price and toward reported earnings through a relative less decrease or even an increase in $\hat{\alpha}^*$, which in turn implies an increase in $\hat{\alpha}^*$ relative to $\hat{\beta}^*$.[28] Moreover, as manipulation becomes more expensive to the manager with an increase in the manager's risk aversion, the induced optimal effort increases.

[28] Again, this comparative static result with respect to changes in the manager's risk aversion for their adjusted relative compensation weight is opposite to the corresponding one reported in Baiman and Verrecchia (1995). It is noteworthy that their result differs from ours mainly because the manager is allowed to strategically trade on private information in their model, rather than the absence of earnings management.

6. Empirical and Policy Implications

In this section, we argue that our simple, yet comprehensive, agency model that links managerial compensation contracts with private information acquisition in the presence of earnings management enables us to broaden our perspective and draw some interesting empirical as well as policy implications about the relations between exogenous as well as endogenous variations in information environment and properties in managerial compensation contracts.

Empirical Implications for the Relation between Risk and Incentives

Our first empirical implication is related to the negative relation between risk and incentives that is predicted from a standard agency model (e.g., Holmstrom 1979). Standard agency theory suggests that uncertainty of the environment (like the volatile of the firm's cash flow, i.e., $1/h$, in our model) adds observation error to manager's performance measures and therefore dampens manager's incentives to take actions that maximize shareholders' value. Despite the compelling logic of the risk-incentive tradeoff, empirical evidence supporting this model prediction is rather mixed.[29] Recently, Prendergast (2002) emphasizes that, apart from directly dampening incentives, uncertainty may affect incentive provision through responsibility allocation. He argues that firms are more likely to base compensation on observed output when input monitoring becomes more difficult in a more uncertain setting. Thus, based on his argument, the relationship between risk and incentives should be positive instead. Our model proposes another novel perspective to address this empirical ambiguity by showing that uncertainty may affect incentive provision through the information acquisition activities of the investors which can be leveraged by the principal in designing the optimal incentive contract. In particular, in Table 2 we show that the relation between risk (i.e., $1/h$) and the price-based compensation (i.e., $\hat{\beta}^*$) may not necessarily be negative. The basic idea is that a greater uncertainty about the cash flow leads to more investors becoming informed, and then the principal may be able to glean more information from the stock price to induce a higher level managerial effort. All in all, our model points out that the cross-sectional differences in the risk-incentive tradeoff may be originated from the

[29] For example, while Aggarwal and Samwick (1999) document a significant negative relationship, Core and Guay (1999) report a significant relationship between risk and incentives.

cross-sectional differences in the private information production.

Empirical Implications for the Cross-Sectional Relations among Executive Compensations, Private Information Production, and Price-Earnings Association

The fact that both private information acquisition and the market price are endogenous determined in our model also allows us to make an additional connection to the extant empirical research in executive compensations. In particular, equation (31) states that the relative adjusted compensation weight is related to the equilibrium number of informed traders as well as the price-earnings association. Table 2 shows that there is a negative relation between the relative adjusted compensation weight and the equilibrium number of informed traders (which can be proxied by the degree of analyst coverage) if the variation is caused by the precision of the private information, the precision of the liquidity trades, or the cost of private information. Furthermore, if the posterior precision of the firm's cash flow conditional on the earnings report is sufficiently high, i.e., $h+m > N^{*}s/(N^{*}+1)$, the relative adjusted compensation weight is also negatively related to the equilibrium number of informed traders if the variation is caused by the reporting precision or the cash flow precision, while the relative adjusted compensation weight is positively (negatively) related to the price-earnings association (which can be proxied by the earnings response coefficient) if the variation is caused by the reporting precision (the cash flow precision). These findings point to the general fact that, in empirical analysis, tests should be carefully designed to disentangle the effects of different underlying factors.

Implications for Financial Reporting System Choice

Our analysis has thus far assumed that the principal has no control over the precision of the financial reporting system. We now argue that the principal would not necessarily prefer a more precise financial reporting system even though there is no cost associated with doing so. As discussed, although increasing the reporting precision, m, could make the earnings report better reflect the firm's cash flow (and, hence, managerial effort), it could also induce a higher level of earnings management and less investors becoming informed (and, therefore, decreasing the effectiveness of the stock price as a market monitoring mechanism). These two latter effects together imply that managerial effort may actually become more costly to induce when reporting precision increases. In particular, Table 2 shows that an increase in the reporting precision increases managerial effort if the posterior precision of firm's cash flow conditional on the earnings report is keeping at a relatively low level, i.e., $Var^{-1}(\tilde{v} \mid \tilde{r} = r) = h + m < N^{*}s \big/ (N^{*} + 1)$.

Implications for Sarbanes-Oxley Act

Our model also sheds some light on the economic consequences of the Sarbanes-Oxley Act (SOX), which, *inter alia,* places a stronger emphasis on a company's internal controls, requires auditors to evaluate and report on internal controls, and requires managers to certify their financial statements. These requirements are likely to make earnings management less effective and raise the manager's personal cost of earnings management (i.e., increases b), and thereby reducing the extent of earnings management. The results of our analysis show that earnings management does decreases when the cost of earnings management increases. More importantly, we also show that the induced managerial effort increases when the manager's incentives to engage in earnings management decreases. Thus, while the main stated objective of the SOX is to restore investors' confidence on public companies' financial statements by enhancing their reliability, we demonstrate in our model in which earnings management is perfectly anticipated (and therefore not affecting the information content of the earnings report) that the SOX also has an indirect effect of increasing managerial effort (and, hence, leading to better firm performance).

7. Conclusion

In this paper we analyze the optimal levels of earnings- and price-based compensations in managerial contracts when the manager can engage in earnings management and investors can acquire and trade profitably on private information about the firm's cash flow. We show that earnings-based compensation is a double-edged sword in that it induces the manager to exert effort and to engage in earnings management. The use of stock price as a performance measure, when the only other performance measure is a manipulated earnings report, allows the principal to differentiate between effort and earnings management incentives, as well as to reduce non-cash-flow-related risk from reported earnings. We show that the presence of earnings management shifts the optimal relative compensation weight away from reported earnings and toward stock price, and makes it more costly to induce managerial effort. We also show that the efficiency of (filtered) price as a performance measure depends on investors' private information acquisition activities. We find that, more aggressive informed trading activities (which arise when more investors become informed) caused by a higher private information precision, a lower cost of private information, or a lower precision of liquidity trades, lead to a lower level of earnings management and a higher level of managerial effort through their effect on the optimal compensation contract. Thus, our model demonstrates the connection between stock market efficiency and economic efficiency. Finally, while increasing the precision of private information always increases the relative compensation weight on filtered price, we find that earnings-based compensation does not necessarily receive a higher relative weight when the earnings report becomes more precise.

To the best of our knowledge, this paper is the first study to analyze the optimal compensation contract based on both accounting earnings and stock price by taking both earnings management and private information acquisition as endogenously determined. While some of the issues in our paper have been partially and separately analyzed in previous studies using various forms of "sub-model" of ours, our formal linkage among earnings management, optimal contracting and private information acquisition enables us to broaden our perspective and, therefore, draw some novel empirical as well as policy implications.

Appendix: Proof

Proof of Proposition 1. At stage 4, each informed trader, taking the strategies of all other informed traders, (4), and the pricing function, (5), as given, submits a market order d_i to the market maker to maximize his expected payoff based on the observed earnings announcement r and the private information θ:

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

$$= \underset{d_i}{Max}\, E\left(\left\{\tilde{v}-\left[P_0+P_r\tilde{r}+P_q(d_i+\sum_{j\neq i}d_j+\tilde{l})\right]\right\}d_i \mid \tilde{\theta}=\theta, \tilde{r}=r\right), \tag{A.1}$$

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

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

The second-order condition requires that $P_q>0$. Solving for the symmetric Nash equilibrium in which $d_1=d_2=d_3=...=d_N$ yields

$$d_i = \frac{E(\tilde{v}\mid\tilde{\theta}=\theta,\tilde{r}=r)-P_0-P_r r}{P_q(N+1)}. \tag{A.3}$$

Since $\tilde{v}$, $\tilde{\theta}$, 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

$$E(\tilde{v}\mid\tilde{\theta}=\theta,\tilde{r}=r)=e^c+\begin{pmatrix}\frac{1}{h} & \frac{1}{h}\end{pmatrix}\begin{pmatrix}\frac{1}{h}+\frac{1}{s} & \frac{1}{h}\\ \frac{1}{h} & \frac{1}{h}+\frac{1}{m}\end{pmatrix}^{-1}\begin{pmatrix}\theta-e^c & r-e^c-\eta^c\end{pmatrix}$$

$$=\frac{he^c-m\eta^c+s\theta+mr}{h+m+s}. \tag{A.4}$$

Let $d_i=d_0+d_\theta\theta+d_r r$ for all $i=1,...,N$. Then, equations (A.3) and (A.4) imply that

$$d_0 = \frac{\frac{he^c - m\eta^c}{h+m+s} - P_0}{P_q(N+1)}, \tag{A.5}$$

$$d_\theta = \frac{\frac{s}{h+m+s}}{P_q(N+1)}, \tag{A.6}$$

and

$$d_r = \frac{\frac{m}{h+m+s} - P_r}{P_q(N+1)}. \tag{A.7}$$

We now consider the market maker's pricing rule. At stage 5, taking the strategies of all informed traders, (4), as given, the market maker sets market price P equal to the expected gross cash flow of the firm $\tilde{v}$ conditional on the observed market demand q and the observed earnings announcement r, i.e., equation (3). Since $\tilde{v}$, $\tilde{\theta}$, 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

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

$$= e^c + \frac{Nstd_\theta\{q - N[d_0 + (d_\theta + d_r)e^c + d_r\eta^c]\} + [ms + N^2td_\theta(md_\theta - sd_r)](r - e^c - \eta^c)}{N^2t(h+m+s)d_\theta^2 + s(h+m)}.$$

Let $P = P_0 + P_q q + P_r r$, then the above equation implies that

$$P_q = \frac{Nstd_\theta}{N^2t(h+m+s)d_\theta^2 + s(h+m)}, \tag{A.8}$$

$$P_r = \frac{ms + N^2td_\theta(md_\theta - sd_r)}{N^2t(h+m+s)d_\theta^2 + s(h+m)}, \tag{A.9}$$

and

$$P_0 = e^c - P_qN[d_0 + (d_\theta + d_r)e^c + d_r\eta^c] - P_r(e^c + \eta^c). \tag{A.10}$$

Substituting equation (A.6) into (A.8) yields equation (10). From equation (A.9), we have

$$P_r = \frac{m(s+N^2td_\theta^2)}{N^2t(h+m+s)d_\theta^2 + s(h+m)} - Nd_rP_q. \qquad \text{(A.11)}$$

Substituting equations (A.6), (A.7) and (10) into equation (A.11) yields equation (11). Substituting equations (A.6), (A.7), (10) and (11) into equation (A.10) yields equation (9). Finally, substituting equations (9), (10) and (11) into equations (A.5), (A.6), (A.7) yields equations (6), (7) and (8). ***Q.E.D.***

Derivation of Equation (12): 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

$$E(\tilde{v} \mid \tilde{r} = r) = e^c + \frac{m}{h+m}(r - e^c - \eta^c) = \frac{he^c - m\eta^c + mr}{h+m} = P_0 + P_r r. \qquad \text{(A.12)}$$

Substituting equation (A.12) into equation (A.3) yields equation (12). ***Q.E.D.***

Derivation of Equation (15): Using equations (A.3) and (A.12), the expected trading profits of each informed trader conditional on earnings report r and private information θ is given by:

$$E\left[(\tilde{v} - \tilde{P})d_i \mid \tilde{\theta} = \theta, \tilde{r} = r\right] = \left[E(\tilde{v} \mid \tilde{\theta} = \theta, \tilde{r} = r) - (P_0 + P_r r + P_q N d_i)\right] d_i$$

$$= \frac{\left[E(\tilde{v} \mid \tilde{\theta} = \theta, \tilde{r} = r) - E(\tilde{v} \mid \tilde{r} = r)\right]^2}{P_q (N+1)^2}. \qquad \text{(A.13)}$$

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

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

Substituting equation (14) into the above equation yields equation (15). ***Q.E.D.***

Proof of Proposition 2: We first solve for the optimal managerial effort for a given managerial compensation contract. When the management commits to not manipulate the earnings report, the manager's ex-ante expected utility based on a given incentive contract, $(\hat{a}, \hat{\alpha}, \hat{\beta})$, is:

$$EU_m(e) = E\left\{-\exp\left[-\rho\left(\tilde{w} - \frac{1}{2}e^2\right)\right]\right\}$$

$$= -\exp\left(-\rho\left\{\hat{a}+\hat{\alpha}e+\hat{\beta}e-\frac{1}{2}\hat{e}^2-\frac{\rho}{2}\left[\frac{(\hat{\alpha}+\hat{\beta})^2}{h}+\frac{\hat{\alpha}^2}{m}+\left[\frac{(N^*+1)(h+m)+s}{N^*s(h+m)}\right]\hat{\beta}^2\right]\right\}\right).$$

Taking the first order condition with respect to e yields

$$e^+ = \hat{\alpha}+\hat{\beta}\,. \tag{A.14}$$

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

Program 1:

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

s.t. $E\left\{-\exp\left[-\rho\left(\tilde{w}-\frac{1}{2}e^{+2}\right)\right]\right\}\geq -1,$

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

After substituting the constraints into the objective function, taking the first order conditions with respect to $\hat{\alpha}$ and $\hat{\beta}$, and making some algebra transformations , yields equations (23) and (24). Substituting equations (23) and (24) back into equation (A.14) yields equation (25). Moreover, it can be easily shown that the principal's objective function is strictly concave in $\hat{\alpha}^+$, $\hat{\beta}^+$, and e^+, and therefore the optimal solution is unique. ***Q.E.D.***

Proof of Proposition 4: First, comparing equations (26) and (31), we have

$$\frac{\hat{\alpha}^*}{\hat{\beta}^*} = \frac{\rho b}{m+\rho b}\frac{\hat{\alpha}^+}{\hat{\beta}^+} < \frac{\hat{\alpha}^+}{\hat{\beta}^+}.$$

It is also obvious that $\hat{\alpha}^* < \hat{\alpha}^+$ since $\rho b > 0$. Next, dividing both the numerator and denominator of the right hand side of equation (24) by $\frac{1}{m}$ and dividing both the numerator and denominator of the right hand side of equation (28) by $\frac{1}{m}+\frac{1}{\rho b}$, it is obvious to see that $\hat{\beta}^* > \hat{\beta}^+$. Next, using equations (23) and (24) we have

$$e^{+} = \hat{\alpha}^{+} + \hat{\beta}^{+} = \frac{1}{1 + \frac{\rho}{h} + \frac{\frac{\rho}{m}\left[\frac{(N^{*}+1)(h+m)+s}{N^{*}s(h+m)}\right]}{\frac{1}{m} + \frac{(N^{*}+1)(h+m)+s}{N^{*}s(h+m)}}}.$$

Similarly, using equations (27) and (28) we have

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

Thus, it is obvious that $e^{*} < e^{+}$. ***Q.E.D.***

Figure 1: Timeline

- Shareholders hire manager and give contract
- Manager exerts effort and creates opportunities to misreport earnings
- Earnings report issued
- Informed traders acquire private information and trading takes place
- Market price set and contract settled
- Firm’s cash flow realized

Table 1: Notation

e	= the manager's effort
$V(e)$	= the manager's (monetary) disutility for taking effort e, $V(e) = e^2/2$
$\tilde{v}$	= the firm's final cash flow, $\tilde{v} = e + \tilde{\varepsilon}$
$\tilde{\varepsilon}$	= the noise associated with the firm's final cash flow, $\tilde{\varepsilon} \sim \mathbb{N}(0, 1/h)$
$\tilde{r}$	= the earnings report, $\tilde{r} = \tilde{v} + \eta + \tilde{\tau}$
η	= the reporting bias chosen by the manager
$\tilde{\tau}$	= the noise associated with the earnings report. $\tilde{\tau} \sim \mathbb{N}(0, 1/m)$
$M(\eta)$	= the manager's (monetary) cost of making reporting bias η, $M(\eta) = b\eta^2/2$
b	= the marginal cost of reporting bias
ρ	= manager'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, $\tilde{\kappa} \sim \mathbb{N}(0, 1/s)$
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, $\tilde{l} \sim \mathbb{N}(0, 1/t)$
$\tilde{q}$	= 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 manager's effort
η^c	= the market participants' common conjecture of the manager'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
P_q	= the market liquidity parameter
P_r	= the price-earnings association parameter

Ω	= the information asymmetry between informed and uninformed traders, $\Omega \equiv SD\left[E(\tilde{v} \mid \tilde{\theta}=\theta, \tilde{r}=r) - E(\tilde{v} \mid \tilde{r}=r)\right] = \sqrt{\frac{s}{(m+h)(m+h+s)}}.$
$\tilde{z}$	= the "filtered" price which reflects the pure additional information due to observing the stock price beyond what is available from the earnings report, $\tilde{z} \equiv \tilde{\theta} + \frac{\tilde{l}}{Nd_{\theta}}$
$\hat{\alpha}^{*}$	= the adjusted compensation weight on the earnings report when contract is in the form of $\tilde{w} = \hat{a} + \hat{\alpha}\tilde{r} + \hat{\beta}\tilde{z}$ in the presence of earnings management
$\hat{\beta}^{*}$	= the adjusted compensation weight on the filtered price when contract is in the form of $\tilde{w} = \hat{a} + \hat{\alpha}\tilde{r} + \hat{\beta}\tilde{z}$ in the presence of earnings management
$\hat{\alpha}^{+}$	= the adjusted compensation weight on the earnings report when contract is in the form of $\tilde{w} = \hat{a} + \hat{\alpha}\tilde{r} + \hat{\beta}\tilde{z}$ when the manager commits to not manipulate the earnings report
$\hat{\beta}^{+}$	= the adjusted compensation weight on the filtered price when contract is in the form of $\tilde{w} = \hat{a} + \hat{\alpha}\tilde{r} + \hat{\beta}\tilde{z}$ when the manager commits to not manipulate the earnings report
α^{*}	= the compensation weight on the earnings report when contract is in the form of $\tilde{w} = a + \alpha\tilde{r} + \beta\tilde{P}$ in the presence of earnings management
β^{*}	= the compensation weight on the stock price when contract is in the form of $\tilde{w} = a + \alpha\tilde{r} + \beta\tilde{P}$ in the presence of earnings management
α^{+}	= the compensation weight on the earnings report when contract is in the form of $\tilde{w} = a + \alpha\tilde{r} + \beta\tilde{P}$ when the manager commits to not manipulate the earnings report
β^{+}	= the compensation weight on the stock price when contract is in the form of $\tilde{w} = a + \alpha\tilde{r} + \beta\tilde{P}$ when the manager commits to not manipulate the earnings report

Table 2: Comparative statics

Exogenous / Endogenous	(i) dh	(ii) dm	(iii) ds	(iv) dt	(v) dC	(vi) db	(vii) $d\rho$
Panel A							
dP_r	$-$	$+$	NA	NA	NA	NA	NA
$d\Omega$	$-$	$-$	$+$	NA	NA	NA	NA
Panel B							
dN^*	$-$	$-$	$+$	$-$	$-$	NA	NA
dP_q	$-$	$-$	$+$	$+$	$+$	NA	NA
Panel C							
$d\left(\hat{\alpha}^*/\hat{\beta}^*\right)$	$+^1$	$+^2$	$-$	$+$	$+$	$+$	$+$
$d\hat{\alpha}^*$	$+^2$	$+^2$	$-$	$+$	$+$	$+$	$-^4$
$d\hat{\beta}^*$	$+^3$	$-^2$	$+$	$-$	$-$	$-$	$-$
$d\eta^*$	$+^2$	$+^2$	$-$	$+$	$+$	$-$	$-^4$
de^*	$+^3$	$+^3$	$+$	$-$	$-$	$+$	$-$

NA	= not applicable
$+$	= an increase in the exogenous variable results in an increase in the endogenous variable
$-$	= an increase in the exogenous variable results in a decrease in the endogenous variable
dP_r	= the change in the price-earnings association given a change in an exogenous parameter
$d\Omega$	= the change in the information asymmetry between informed and uninformed traders given a change in an exogenous parameter
dN^*	= the change in the equilibrium number of informed traders given a change in an exogenous parameter
dP_q	= the change in the inverse of the market liquidity given a change in an exogenous parameter
$d\left(\hat{\alpha}^*/\hat{\beta}^*\right)$	= the change in the relative adjusted compensation weight on the earnings report versus the filtered price in the presence of earnings management given a change in an exogenous parameter

$d\hat{\alpha}^*$	= the change in the adjusted compensation weight on the earnings report in the presence of earnings management given a change in an exogenous parameter
$d\hat{\beta}^*$	= the change in the adjusted compensation weight on the filtered price in the presence of earnings management given a change in an exogenous parameter
$d\eta^*$	= the change in the reporting bias given a change in an exogenous parameter
de^*	= the change in the managerial effort in the presence of earnings management given a change in an exogenous parameter
$d\left(\hat{\alpha}^+/\hat{\beta}^+\right)$	= the change in the relative adjusted compensation weight on the earnings report versus the filtered price in the absence of earnings management given a change in an exogenous parameter
$d\hat{\alpha}^+$	= the change in the adjusted compensation weight on the earnings report in the absence of earnings management given a change in an exogenous parameter
$d\hat{\beta}^+$	= the change in the adjusted compensation weight on the filtered price in the absence of earnings management given a change in an exogenous parameter
de^+	= the change in the managerial effort in the absence of earnings management given a change in an exogenous parameter
dh	= the change in the precision of the firm's cash flow
dm	= the change in the precision of the earnings report
ds	= the change in the precision of the private information
dt	= the change in the precision of the liquidity trades
dC	= the change in the cost of private information
db	= the change in the cost of earnings management
$d\rho$	= the change in the manager's risk aversion

Remarks:	
1	if and only if $h+m>\left(\frac{N^*}{N^*+1}\right)s$
2	if $h+m>\left(\frac{N^*}{N^*+1}\right)s$
3	if $h+m<\left(\frac{N^*}{N^*+1}\right)s$
4	if $b>\frac{hm}{\rho^2}$

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