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Higher-Order Beliefs, Market-Based Incentives, and Information Quality

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ABSTRACT We investigate how interdependence among investors' beliefs affects the reliance on market prices as a performance measure and how this in turn affects the firm's preference for financial reporting quality. When investors want to align their values more with other investors' beliefs, optimal contracts become more reliant on the accounting report and less on the market price, emphasizing the stewardship role of accounting in a herding market. If the baseline accounting quality required by a reporting standard is high enough, the firm prefers to increase its accounting quality for the sake of contracting efficiency. However, if the baseline quality is low, the firm further lowers accounting quality for the same reason. The benchmark level that determines whether the firm prefers to increase accounting quality increases with the interdependence of investors' beliefs, implying that it is difficult to align the information and stewardship roles of accounting in a herding market.

Keywords: Higher-order beliefs; Stock-based compensation; Reporting quality; Dual role of accounting

1. Introduction

Investors in financial markets often develop higher-order beliefs by 'anticipating what average opinion expects the average opinion to be' (Keynes, 1936). In the presence of these beliefs, investors' valuation of an asset depends on not only the asset's value itself but also on other investors' estimates of its value in the market.[1] Morris and Shin (2002) demonstrate that higher-order beliefs affect the formation of investor expectations and market prices; Angeletos and Pavan (2004, 2007) show a market's aggregate investment in a risky asset is crucially determined by the presence of higher-order beliefs. Since market-based performance measures, such as firms' market prices, are frequently included in executive compensation contracts, higher-order beliefs likely also influence managerial compensation and incentives.[2] We study whether higher-order beliefs among market participants affect a firm's design of its compensation contracts and its choice of reporting quality in an agency setting.

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[1] Well-known examples of market events induced by higher-order beliefs include the Dutch tulip mania in the 1630s and the Dotcom bubble in the 1990s. Investors buy overvalued assets as they believe other investors believe these assets are of high value.

[2] Indeed, studies like those by Bushman and Indjejikian (1993), Kim and Suh (1993), and Feltham and Xie (1994) suggest market price as a potentially useful performance measure, because it aggregates otherwise noncontractible information, such as investors' equilibrium beliefs about management's actions.

We model a publicly traded firm that is run by a risk-averse manager and governed by a risk-neutral board of directors. The board aims to maximize net firm value, which is determined by the manager's productive effort. Since the manager's effort is unobservable and unverifiable, the board offers the manager a linear contract, which includes both an accounting-based and a market-based performance measure. The former measure is the financial report generated by the firm's accounting system and disclosed to the public, and the latter is the market price formed by a unit mass of investors in the financial market.

Following Angeletos and Pavan (2004, 2007), the investors in our model price the firm based on two sources of information: the firm's public accounting report and their own private information, both of which are noisy signals of the firm value. They form their expectations about the firm value by assigning different weights to the firm's report and their private information. Since the private signals from all investors are integrated into a perfect average signal, the accounting report becomes the noisy component in aggregate investor belief, the variance of which strictly increases with the degree of interdependence among investors. Intuitively, in a herding market, where the investors wish to align their valuations with each other, they assign higher weight to the accounting report since it is not only informative about the firm value but also used by other investors in forming their beliefs. The aggregate investor belief hence has a larger variance in a herding market. In a dispersing market, where the investors wish to differ from one another in assessing the firm value, they assign less weight to the accounting report, and thus aggregate investor belief has a smaller variance.

The firm's market price is the aggregate investor belief with an additional noise term, which captures random market factors, such as sentiment and liquidity trading. Since the variance of the aggregate belief increases with the degree of interdependence among investors, the market price is noisier in a herding market and less noisy in a dispersing market. Further, since optimal compensation contracts assign more weight to precise performance measures than to noisy ones, the boards' reliance on the market price as a performance measure decreases with the degree of investor interdependence.

We then examine the board's preference to the reporting quality of the firm's accounting system. In our setting, higher reporting quality does not always result in a more precise market-based performance measure. It leads the investors to assign more weight to the accounting report, which is the noisier component of the market price (since the aggregate investor private information is perfect). Thus market price as a performance measure may become less useful, and the total contracting efficiency may even decrease. We show that the board's payoff is indeed U-shaped in the firm's reporting quality. That is, for the sake of contracting efficiency, there exists a threshold level of reporting quality above which the board prefers to improve the firm's reporting but below which it prefers to reduce the reporting quality. Our results thus warn against a baseline reporting quality that is too low, since the firm will have incentive to further reduce the reporting quality for the sake of contract efficiency, exacerbating an already weak accounting system. Only when the baseline reporting quality is high enough, will the firm want to keep improving its accounting system, as a more precise accounting report strictly improves contracting efficiency and lowers agency cost. This issue is especially severe in a herding market, since the threshold value of reporting quality increases in the degree of investor interdependence.[3]

The results of our analysis can be empirically tested. Specifically, we can make three predictions about the effects of higher-order beliefs among investors. First, executive compensation

[3] In reality, although firms' accounting systems follow the requirements of accounting regulations, such as the International Financial Reporting Standards (IFRS) or US Generally Accepted Accounting Principles (US GAAP), firms also have some flexibility in influencing their own reporting.

contracts rely less on market-based performance measures as the degree of investor interdependence increases. That is, market-based measures are less used in herding markets. Second, all else equal, managerial effort and firm value are both lower when investor interdependence is high. Third, firms' discretionary change in reporting quality relates negatively to the degree of investor interdependence but positively to the stringency of the reporting standard in place.

Our study makes three contributions to the literature. First, to the best of our knowledge, this paper is the first to study optimal contracting in a market environment with higher-order beliefs. Market-based performance measures are widely used in executive compensation. However, these measures are typically assumed to be formed based on first-order beliefs. Our study shows, in a stylized setting, that a financial market with higher-order beliefs would lead to different contracts and incentives. Further, the agency problem could be alleviated or exacerbated, depending on the nature of the higher-order beliefs. The board of directors, when designing compensation contracts and adopting market-based performance measures, should be aware of the prevalent investor sentiment.

Second, we study a setting where multiple sources of information could affect the performance measure used by a firm. Prior studies have examined optimal contracting with multiple actions, multiple performance measures, and multiple agents (e.g., Banker & Datar, 1989; Dikolli et al., 2013; Feltham & Hofmann, 2012; Feltham & Xie, 1994). While our model involves only one action, one market-based performance measure, and one agent, two sources of information contribute to the formation of the market-based measure. In our setting, the public accounting report is relevant twice for the contract: both directly as a performance measure and indirectly through the price. The different weights on these information sources affect the optimal compensation contract as well as the manager's incentive.

Third, we discuss the complexities surrounding the reporting quality of a firm's accounting system. While the primary purpose of reporting is to communicate with the financial market, reporting quality also affects a firm's managerial incentives and corporate governance. This is consistent with the notion that accounting serves both information and stewardship roles, as stated in the Conceptual Framework for Financial Reporting issued by the International Accounting Standards Board (IASB) in 2018. On the one hand, accounting reports provide information for the financial market in determining the value of the firm; on the other, accounting information helps the board of directors in designing compensation contracts and managerial incentives. Our model examines the interaction between the information and stewardship roles and thus provides support for the important duality of accounting information acknowledged by standard setters.

Our study extends two streams of research. The first is work on higher-order beliefs and beauty contests, first formalized by Morris and Shin (2002) by examining how agents align their actions with those of other market participants. The coordination objective leads agents to pull weight away from private information and shift it to public information when forming expectations. Subsequent studies introduce trading and price formation (Allen et al., 2006), examine agents' decisions regarding investments that are complements (Angeletos & Pavan, 2004) as well as those that are substitutes (Angeletos & Pavan, 2007). The results of these studies hinge on how much weight the agents put on the public versus private information. We combine the elements of these studies to model market price formation in a stylized manner and extend the model by examining how the market price is used as a performance measure in compensation contracts.

The second stream of literature our work closely relates to studies the use of market-based performance measures in managerial contracts.[4] Holmström (1979) demonstrates that including

[4]Empirically, it is well established that managerial pay is based on both accounting and market measures of firm performance (e.g., Antle & Smith, 1986; Jensen & Murphy, 1990). For example, Lambert and Larcker (1987) and Sloan (1993) examine the determinants of the relative weights placed on accounting- and market-based performance measures in

additional performance measures in executive compensation contracts is beneficial if the measures are informative about managerial effort. Banker and Datar (1989) point out that, in compensation contracts with multiple performance measures, the relative weight assigned to each measure depends on its precision. Liang and Nan (2014) find that firm owners may discard informative signals whose precision can be improved by the manager to prevent the manager from diverting attention away from his or her effort. Wagenhofer (2003) identifies conditions under which accruals outperform cash flows as performance measures. However, these studies take market price as given, while we explicitly model how the market price is formed with the influence of both the accounting information and higher-order beliefs.

The implications of higher-order beliefs in an accounting context have not been fully explored. Most of the studies extend the higher-order beliefs model to examine the importance of reporting and disclosure. For example, Gao (2008) shows disclosure could bring firms' market prices closer to their true values, since public disclosure's capacity to provide information for the investors to value the firm dominates its capacity to coordinate investor behavior. Chen et al. (2014) show that information asymmetry among short-horizon investors provides a channel through which public information influences price informativeness. Chen et al. (2017) argue that a uniform reporting regime can create more social welfare than a discretionary regime in the presence of strong strategic complementarities. Arya and Mittendorf (2016) show an investment beauty contest promotes a firm's disclosure of its investment decision to other firms. None of these papers examines the effect of higher-order beliefs on market-based performance measures and contracting efficiency.

2. Model

We consider a firm whose stocks are publicly traded in the financial market. The firm is run by a risk-averse manager and governed by a risk-neutral board of directors. In addition, there are a unit mass of investors who trade the firm's stocks. The investors are risk-neutral, and their average expectations about the firm value determine the firm's market price.

2.1. Compensation Contract

The firm value θ depends on the manager's effort e and a random variable s, i.e., $\theta = e + s$.[5] The manager's effort e is neither observable nor verifiable. The random variable s represents factors that affect the firm value but are independent of the manager's effort choice. It is uniformly distributed over the real line $\mathbb{R}$,[6] and is only realized at the end of the game. To elicit effort from the manager, the board designs a linear compensation contract

$$w = a + b_P P + b_y y, \tag{1}$$

where a is the fixed salary, $b_P P$ and $b_y y$ are the variable portions of pay with b_P and b_y being the bonus coefficients. Since the firm's value θ is unknown at the time when compensation has to be settled, the board uses two observable performance measures in the manager's contract. The first measure of firm performance is market price P, which is market-based and determined

compensation contracts. Schöndube-Pirchegger and Schöndube (2010) show that market prices may be more suitable for contracting with the supervisory board than accounting reports.

[5] More realistically, the firm value can be expressed as $\theta = Ke + s$, where K is a multiple of the manager's effort e. For simplicity, we assume $K = 1$ in our model.

[6] As is common in higher-order belief models, s has an improper prior but a proper posterior. Specifically, the performance measures P and y in our setting are both featured with the posterior distributions of s and are normally distributed.

by the financial market. The second measure y is accounting-based, generated by the firm's accounting system and disclosed to the public. The report y conveys information about the firm value, perturbed by noise η, i.e., $y = \theta + \eta$. The noise term η is normally distributed with zero mean and variance $\frac{1}{h_y}$. The precision of the report, h_y, captures the firm's reporting quality.[7] In our model, the accounting report y is used by the investors for the valuation of the firm, as well as by the board of directors in designing managerial compensation contracts. Our setting thus reflects both the information role and the stewardship role of accounting information explicitly acknowledged by standard setters, such as in the *Conceptual Framework for Financial Reporting* issued by IASB.

To differentiate the board's problem from the manager's problem, we use the subscript B to denote the board and the subscript M to denote the manager. The board of directors wishes to maximize its net payoff

$$U_B = \theta - w, \tag{2}$$

which is the firm value net of the manager's compensation.

The manager's preference is to maximize her compensation net of her cost of effort, which is represented by the typical negative exponential utility function

$$U_M (w, e) = -\exp\left[-\rho \left(w - c\left(e\right)\right)\right], \tag{3}$$

where ρ is her degree of risk aversion, and $c(e) = \frac{1}{2}e^2$ is her cost of effort. The certainty equivalent of the manager's utility function can be expressed through the familiar mean-variance expression

$$CE_M = E\left(w\right) - c\left(e\right) - \frac{\rho}{2} Var\left(w\right). \tag{4}$$

2.2. *Financial Market and Information Structure*

The key feature of the financial market in our model is the presence of higher-order beliefs. This is consistent with many markets in the real world, especially those with herding behavior induced by investor beliefs that are strategic complements. Herding markets often result in asset price bubbles,[8] such as the recent tech bubbles or housing bubbles. By contrast, a dispersing market entails investors shying away from investments that they believe other investors value, perhaps due to fear of bubbles. A dispersing market could result in depressed market prices.

We model the financial market as a continuum of risk-neutral investors, who are uniformly distributed over the unit interval $[0, 1]$ and indexed with i. Investor i's valuation of the firm is

$$v_i = E_i\left(A\right) \tag{5}$$

and the average market valuation from all investors is

$$V = \int_0^1 v_i \, \mathrm{d}i. \tag{6}$$

[7] In reality, management may decide to bias its reports to the financial market and influence the firm's price into its desired direction. In our model, we refrain from including the manager's option to bias her report and view y as a noisy yet unbiased measure of the firm value.

[8] For example, Balakrishnan et al. (2020) and Cremers et al. (2021) examine settings where higher-order beliefs among traders can be coordinated by analyst recommendations, resulting in the formation of asset bubbles. Their findings thus provide empirical evidence and the channel through which price bubbles are linked to higher-order beliefs.

To introduce higher-order belief, the investors' payoff is expressed as[9]

$$A = \alpha V + (1 - \alpha)\,\theta, \tag{7}$$

which is a weighted average of the market valuation V and the firm value θ. The payoff function A implies that investors care about both the firm's true value and the market's assessment of the firm. This is the key feature of higher-order beliefs, which implies that the investors' preference depends on the preferences of other investors in the market. Therefore, the investors have incentives to both coordinate their valuations with other investors and to match it with the firm value. The parameter $\alpha \in (-1, 1)$ denotes the degree of interdependence among the investors' beliefs. When $\alpha > 0$, the investors' beliefs are strategic complements. They seek to align their valuations, which results in a herding market. When $\alpha < 0$, the investors' beliefs are strategic substitutes. They seek to differ in their decisions and thus form a dispersing market. If $\alpha = 0$, there are only first-order beliefs in the market, and the investors have no coordination motive and are solely concerned with matching the valuation with the firm value.

The firm's market price is

$$P = V + \lambda, \tag{8}$$

where λ is a noise term that reflects other random factors in the financial market such as liquidity traders. The noise term λ is normally distributed with $E(\lambda) = 0$ and $Var(\lambda) = \frac{1}{h_\lambda}$. In a nutshell, the market price P is a noisy version of the aggregate investor valuation V, which in itself is a noisy version of the firm's fundamental value θ. Ex-ante, the market price P is unbiased in expectation but its volatility depends on α, the degree of interdependence among investor beliefs.

In assessing the firm's value θ, investor i resorts to two sources of information. The first source of information is the firm's accounting report y, which is disclosed to the public. The second source of information is a noisy private signal about the firm value, $z_i = \theta + \varepsilon_i$, which investor i is endowed with. The error term ε_i is normally distributed with zero mean and variance $\frac{1}{h_z}$. Although each investor's private signal is noisy, in aggregation the whole market's average private signal is perfect as ε_i drops out through integration. All error terms are independent and identically distributed across the investors. While the realization of z_i is only privately observed by investor i, the structure and precision of the information is public knowledge.

2.3. *Timeline*

The timeline in Figure 1 presents the sequence of events. At time 0, the firm's reporting system is set up with a precision level at which the firm measures and discloses financial information. At time 1, the board designs a linear compensation contract and offers it to the manager. At time 2, the manager enters the contract and exerts a productive effort. At time 3, the firm releases its accounting report to the public, and the investors each obtain their private information about the firm. At time 4, the investors assess the firm's value based on their beliefs, the liquidity investors' impact on the market price is realized, and the market price P is formed. The manager is also compensated based on her contract. Finally at time 5, the firm value is revealed and all uncertainties are resolved.

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[9]One could argue that the investor's payoff should be stated as $A = \alpha(V - w) + (1 - \alpha)(\theta - w)$, since θ is the gross firm value before the payment to the manager. However, since V is used as a performance measure in the contract, we follow the convention of the agency literature and use the gross outcome instead of the outcome net of w. See Hofmann et al. (2022) for a more detailed discussion and analyses on this issue.

$t = 0$	$t = 1$	$t = 2$	$t = 3$	$t = 4$	$t = 5$
Firm sets reporting system	Board designs linear compensation contract	Manager signs contract and exerts effort e	Accounting report y is released and each investor obtains z_i	Firm's market price P is formed and manager is compensated	Firm value θ is revealed and all uncertainties are resolved

Figure 1. Timeline of events

3. Optimal Contract

In this section, we use backward induction to solve for the equilibrium market price and the optimal compensation contract offered to the manager. We also analyze the effects of the firm's reporting quality on the form and efficiency of the compensation contract.

3.1. Belief Formation

As defined in Equation (8), the market price P is the investors' average valuation of the firm, V, plus a noise term λ. We follow Angeletos and Pavan (2004) to derive V and present the details in the appendix of the paper. Investor i's belief of the firm value is[10]

$$v_i = \left(\frac{(1-\alpha)\,\delta}{1-\alpha\delta}\right) z_i + \left(1 - \frac{(1-\alpha)\,\delta}{1-\alpha\delta}\right) y, \tag{9}$$

with

$$\delta = \frac{h_z}{h_z + h_y}. \tag{10}$$

As explained in Angeletos and Pavan (2004), the posterior belief of investor i is normal with mean $E_i(\theta|z_i, y) = (\frac{(1-\alpha)\delta}{1-\alpha\delta})z_i + (1 - \frac{(1-\alpha)\delta}{1-\alpha\delta})y$ and variance $Var_i(\theta|z_i, y) = (\frac{(1-\alpha)\delta}{1-\alpha\delta})^2 \frac{1}{h_z} + (1 - \frac{(1-\alpha)\delta}{1-\alpha\delta})^2 \frac{1}{h_y}$. Integrating over all investors' beliefs, we can now obtain the market's average valuation of the firm

$$V = \left(\frac{(1-\alpha)\,\delta}{1-\alpha\delta}\right) \theta + \left(1 - \frac{(1-\alpha)\,\delta}{1-\alpha\delta}\right) y. \tag{11}$$

Examining V, we can see that the investors' private information has aggregated into the firm's true fundamental θ, as the error terms of the investors' private signals are integrated out. The term that still contains any noise is the firm's accounting report y. Thus, the variance of V is $Var(V) = (1 - \frac{(1-\alpha)\delta}{1-\alpha\delta})^2 \frac{1}{h_y}$.

It is easy to see that when $\alpha = 0$, v_i simplifies to a precision-weighted average of investor i's private signal z_i and the accounting report y, i.e., $\delta z_i + (1-\delta)y$. The market's average valuation V in the first-order belief market is thus $\delta\theta + (1-\delta)y$. In the case of a herding market with $\alpha > 0$, the equilibrium investor belief V assigns a heavier weight to the accounting report y. In the case of a dispersing market with $\alpha < 0$, V assigns a heavier weight to θ, the aggregation of private signals. The reason for V to tilt toward y when $\alpha > 0$ is because y is used twice by the investors in forming their beliefs: It is used to infer information about the firm value θ, and it is also known to be the information source used by other investors when they form beliefs. The

[10] As the effort e is the manager's decision variable and is a constant in equilibrium, the investors are essentially forming an expectation of the random variable s. Thus, equation (9) is equivalent to $v_i = e^* + \frac{(1-\alpha)\delta}{1-\alpha\delta}(s + \varepsilon_i) + (1 - \frac{(1-\alpha)\delta}{1-\alpha\delta})(s + \eta)$.

accounting report y therefore helps the investors coordinate if they want to align their valuations in a herding market. On the contrary, when $\alpha < 0$, if the investors want to disperse from each other in valuations, they put less weight on y and rely more on their private information instead.

3.2. Compensation Contract

As discussed before, the firm's market price $P = V + \lambda$ reflects the average investor valuation for the firm and some other random factors such as noise traders. That is,

$$P = \left(\frac{(1-\alpha)\,\delta}{1-\alpha\delta}\right)\theta + \left(1 - \frac{(1-\alpha)\,\delta}{1-\alpha\delta}\right)y + \lambda. \tag{12}$$

The manager's pay is thus $w = a + b_P P + b_y y$. Note that the accounting report y is relevant for performance measurement twice: directly and also indirectly through the effect it has on the price, which is the second performance measure in the manager's contract.

The board wishes to maximize its expected net payoff by solving the following problem:

$$\max_{e,a,b} U_B = E\left(\theta - a - b_P P - b_y y\right)$$

$$\text{s.t.} \quad a + b_P e + b_y e - c\,(e) - \frac{\rho}{2}\left(b_P \sigma_P^2 + b_y \sigma_y^2 + 2 b_P b_y Cov\,(P, y)\right) \geq 0 \tag{IR}$$

$$e \in \arg\max\left\{a + b_P e + b_y e - c\,(e) - \frac{\rho}{2}\left(b_P \sigma_P^2 + b_y \sigma_y^2 + 2 b_P b_y Cov\,(P, y)\right)\right\}, \tag{IC}$$

where σ_P^2 is the variance of the market price, σ_y^2 is the variance of the accounting report, and $Cov(P, y)$ is the covariance of the two performance measures. The manager's individual rationality constraint (IR) ensures that the contract meets the manager's reservation utility, which is set to 0. The incentive compatibility constraint (IC) implies that the effort level induced by the contract is chosen by the manager to maximize her own utility.

The optimal contract is presented in Proposition 3.1 below.

Proposition 3.1 *The optimal contract is characterized by weights on performance measures*

$$b_P = \frac{\sigma_y^2 - Cov\,(P, y)}{\sigma_P^2 + \sigma_y^2 + \rho\sigma_P^2\sigma_y^2 - 2Cov\,(P, y) - \rho Cov\,(P, y)^2}$$

and

$$b_y = \frac{\sigma_P^2 - Cov\,(P, y)}{\sigma_P^2 + \sigma_y^2 + \rho\sigma_P^2\sigma_y^2 - 2Cov\,(P, y) - \rho Cov\,(P, y)^2}.$$

The manager's equilibrium effort is

$$e = b_P + b_y,$$

and the board's expected utility is

$$E\,(U_B) = \frac{1}{2}\frac{\sigma_P^2 + \sigma_y^2 - 2Cov\,(P, y)}{\sigma_P^2 + \sigma_y^2 + \rho\sigma_P^2\sigma_y^2 - 2Cov\,(P, y) - \rho Cov\,(P, y)^2}.$$

Proof: See Appendix.

Proposition 3.1 reflects some familiar results from the contracting literature. The second-best contract includes the two variable compensation components, which render the manager's pay contingent on her exerted effort. In this setting, a compensation contract with the two performance measures P and y is always superior to a contract with a single measure. Holmström (1979) shows that adding another performance measure is beneficial as long as the new measure contains additional information about the manager's effort. Intuitively, in our setting, adding market price as a performance measure is useful as it contains aggregated private information from the investors about the firm value. Further, both performance measures are noisy and the risk-sharing between the manager and the board is costly for the board.

The relative variances of the performance measures determine their optimal weights. Therefore, the more volatile the market price, the lower is the weight b_P assigned to it by the firm's board of directors. Similarly, the more precise the accounting report is in measuring managerial effort (i.e., the lower σ_y^2), the higher is the weight b_y assigned to it in the compensation contract.

More importantly, however, Proposition 3.1 shows that the optimal contract is affected by the variance of the price P, which strictly increases in the degree of interdependence among investor beliefs.

3.3. Effects of Different Beliefs

In this section, we examine the effects of different types of beliefs on the compensation contract. For better intuition, when we discuss the specific type of market by the investor beliefs, we use the superscript F to denote the market with only first-order beliefs, i.e., $\alpha = 0$; and the superscript H for the market with higher-order beliefs, i.e., $\alpha \neq 0$. Further, if the market with higher-order beliefs is a herding market, i.e., $\alpha > 0$, we use the superscript Hh; if the market with higher-order beliefs is a dispersing market, we use the superscript Hd.

Since the volatility of the performance measures plays an important role in managers' compensation contracts, we first examine the variance and covariance structure of the two performance measures P and y. The variance of P is

$$\sigma_P^2 = \left(1 - \frac{(1-\alpha)\,\delta}{1-\alpha\delta}\right)^2 \frac{1}{h_y} + \frac{1}{h_\lambda}, \tag{13}$$

and the covariance of P and y is

$$Cov\,(P, y) = \left(1 - \frac{(1-\alpha)\,\delta}{1-\alpha\delta}\right) \frac{1}{h_y}. \tag{14}$$

In the special case with $\alpha = 0$, only first-order beliefs exist, and the variance of the market price simplifies to $\sigma_P^2 = (1-\delta)^2 \frac{1}{h_y} + \frac{1}{h_\lambda}$ and the covariance becomes $Cov(P, y) = (1-\delta)\frac{1}{h_y}$. It is immediately clear that the type of beliefs present in the market has an impact on the performance measure's variance. Differentiating σ_P^2 with respect to α shows that σ_P^2 is an increasing function of α. Corollary 3.2 presents the difference in the variances of prices across different types of markets.

COROLLARY 3.2 *The variance of market price increases in investors' degree of coordination, α, such that it is the highest in a herding market and the lowest in a dispersing market, i.e., $Var(P^{Hh}) > Var(P^F) > Var(P^{Hd})$.*
Proof: See Appendix.

The intuition of Corollary 3.2 is straightforward. The more investors try to coordinate on each others' valuation, the more volatile the market price would be. In a herding market ($\alpha > 0$), investors assign less weight to the aggregated private signals, which is perfect; and more to the accounting report y. Since the accounting report is a noisy measure of the manager's effort, the overall variance of P is increased. The higher α is, the more volatile the performance measure P becomes. In a dispersing market, however, the investors assign more weight to the average private signal and less on the accounting report. The overall variance of the performance measure is therefore reduced. In summary, the variance of the firm's market price in the market with first-order beliefs, $Var(P^F)$, is higher than $Var(P^{Hd})$ but lower than $Var(P^{Hh})$.

We then proceed to compare the characteristics of the optimal contract in markets with different belief structures.

COROLLARY 3.3 (i) *The performance measure weight on market price, b_P, decreases in investors' degree of coordination, α, such that it is the lowest in a herding market and the highest in a dispersing market ($b_P^{Hd} > b_P^F > b_P^{Hh}$).*

(ii) *The weight on the accounting report, b_y, increases in α, such that it is the highest in a herding market and the lowest in a dispersing market ($b_y^{Hh} > b_y^F > b_y^{Hd}$).*

(iii) *The ratio of the weights on market price and on the accounting report, b_P/b_y decreases in α, such that it is the lowest in a herding market and the highest in a dispersing market.*

(iv) *The manager's equilibrium effort, e, decreases in α, such that it is the lowest in a herding market and the highest in a dispersing market ($e^{Hd} > e^F > e^{Hh}$).*

(v) *The board's expected utility, $E(U_B)$, decreases in α, such that it is the lowest in a herding market and the highest in a dispersing market ($E(U^{Hd}) > E(U^F) > E(U^{Hh})$).*

Proof: See Appendix.

The key driver of the results presented in Corollary 3.3 is $Var(P)$, the variance of the market price across different markets.[11] The higher $Var(P)$, the less precise P is as a measure of the manager's effort, and the more risk it imposes on the manager. Since the risk-averse manager must be compensated with a risk premium, a less precise performance measure results in a higher cost for the board. The board would thus put a lower b_P on a noisier P. This is reflected in part 1 of Corollary 3.3. At the same time, the board relies more on y, the accounting measure of the manager's performance. Accordingly, b_y is highest in a herding market. As a result, the ratio of performance measure weights, b_P/b_y, decreases in α. Note that a prerequisite for our comparative statics results on b_P and b_y to hold is that h_λ must be sufficiently small, that is, the market price cannot be too noisy.

Because y's precision in measuring the manager's effort remains the same across all market types, while P's precision changes, a herding market leads to overall less effort by the manager and thus a lower expected payoff for the board. A dispersing market generates the opposite: A lower $Var(P)$ makes price a more precise performance measure and prompts the board to rely more heavily on P in the manager's compensation contract. As a result, b_P increases while b_y decreases. Since the overall efficacy of the two performance measures in measuring managerial effort is still higher, more effort is induced, and the board enjoys a higher expected payoff.

4. Information Quality

The quality of information plays an important role in the design of optimal contracts. There are three sources of information in our model, and their respective qualities are 1) h_z, the precision of investors' private signals, 2) h_y, the precision of the public accounting report, and 3) h_λ, the precision of the noise term in the market price. In this section, we first examine the effects of

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[11] Although $Cov(P, y)$ is also part of the equilibrium results, it strictly decreases in h_y and its effect on b is subsumed in the effect of $Var(P)$.

information quality from all three sources, then focus on the effects of reporting quality h_y on the contract efficiency.

4.1. Effects of Different Sources of Information

The quality of information may affect both b_P and b_y, the bonus coefficients placed on the market price and the accounting report. Since b_P and b_y are always determined in conjunction with each other based on P and y's relative precisions, we examine the effects of different sources of information on the ratio of the two coefficients, b_P/b_y. This is equivalent to examining the effects on b_P scaled by the effects on b_y and has the advantage that any same degree of effects would cancel out and only differential effects would remain. The results are presented in Proposition 4.1.

PROPOSITION 4.1 *The ratio of the weights on market price and on the accounting report in the optimal compensation contract, b_P/b_y, (i) increases in h_z, the precision of the private signal; (ii) increases in h_λ, the precision of the noise term in market price; and (iii) decreases in h_y, the precision of the accounting report.*
Proof: See Appendix.

The results of these comparative statics are intuitive. A higher precision of the investors' private signals, h_z, leads the investors to assign less weight to the noisy accounting report and more to the aggregate average signal, thereby reducing the overall variance of the market price. Since the volatility of the accounting report is not impacted by h_z, the ratio b_P/b_y is increasing in h_z. A smaller variance of the noise term in market price, h_λ, decreases the variance of market price and leaves the accounting report's precision unchanged. Consequently, the ratio of performance measure weights is increasing in h_λ. The impact of a higher precision of the accounting report, h_y, is slightly more intricate. While a higher h_y results in a more precise accounting report and thus a higher weight on y, it has two countervailing effects on the precision of P. On the one hand, a more precise accounting report reduces P's variance; on the other hand, a higher h_y leads the investors to assign more weight to y, which is the noisier component of P and increases P's variance. Ultimately, it is h_y's latter effect on P together with its unambiguously positive effect on y that dominate h_y's first effect on P. Thus b_P/b_y decreases in h_y.

4.2. The Board's Preference for Reporting Quality

Proposition 4.1 provides some intuition about the effect of information quality on the variance of each performance measure. Among them, the reporting quality h_y is the most complex as well as the most important for the board, as a company could influence its own accounting system to some degree. If the board could determine the precision of the accounting system in the beginning of the game, it would choose a reporting quality that maximizes its total expected payoff.[12] The board's payoff is higher when the variances of the performance measures are lower, because more precise performance measures result in higher performance measure weights, which in turn elicit higher effort by the manager at the same cost.

Although the board could improve the precision of the accounting report y through a higher h_y, doing so may not always be optimal. This is because y and its precision h_y are also involved in the investors' price formation process, and a higher h_y may lead to a more volatile market price P and thus lower contracting efficiency. In particular, a higher h_y results in the

[12] Arguably, the main purpose of firms' accounting reports is to communicate with external stakeholders. In the following analyses, we focus on the partial equilibrium analyses on the effects of the precision of accounting reports on the managers' incentives, but acknowledge the limitation of this approach.

investors shifting more weight to y, which is the noisier component of P as compared to the aggregate private signals. The board thus must trade off the effects of a higher h_y on the improved contracting efficiency through y and a potential loss of efficiency through P. In this section, we examine the board's preference for reporting quality when both the accounting report y and market price P are used as performance measures in the manager's compensation contract.

We find that the board's payoff is U-shaped in h_y. This can be shown by taking the first-order derivative of $E(U_B)$ with regard to h_y and examining its sign around the extremum. The sign of the first-order condition switches from negative to positive, i.e., there exists a minimum level of $E(U_B)$ in $\overline{h}_y$. The minimum level occurs at the threshold

$$\overline{h}_y = \sqrt[3]{2h_z^2 h_\lambda (1-\alpha)^2} - h_z (1-\alpha). \tag{15}$$

When there are only first-order beliefs, i.e., $\alpha = 0$, the threshold simplifies to $\sqrt[3]{2h_z^2 h_\lambda} - h_z$.

PROPOSITION 4.2 *The board's payoff $E(U_B)$ is U-shaped in reporting quality h_y, and it increases in h_y when $h_y > \overline{h}_y$ and decreases in h_y when $h_y < \overline{h}_y$.*

Proof: See Appendix.

The result in Proposition 4.2 comes directly out of the two countervailing effects of h_y on *Var*(P). If the firm's reporting quality lies above the threshold point $\overline{h}_y$, improving reporting quality would lead to strictly higher contracting efficiency through performance measures y and P. If the firm's reporting quality lies below the threshold point, improving reporting quality would actually result in a net efficiency loss as the increase in *Var*(P) renders P a less useful performance measure. Even though y always becomes strictly more precise as h_y increases, the loss of contracting efficiency through P still dominates in equilibrium when $h_y < \overline{h}_y$. Of course, the highest level of $E(U_B)$ is reached when the financial reporting quality is infinitely high, i.e., $h_y = \infty$, which is a somewhat unrealistic goal.

Assuming that the firm has an established accounting system with a certain reporting quality, following the requirement of accounting regulation such as IFRS or US GAAP, in our setting the board would prefer to adjust the baseline reporting quality of the accounting system to help reduce the agency cost and improve contract efficiency. More precisely, if the baseline reporting quality is higher than $\overline{h}_y$, the board will have incentives to enhance the firm's reporting quality for the sake of more efficient contracting. However, if the baseline reporting quality is lower than $\overline{h}_y$, the board actually prefers to reduce the reporting quality.

We then compare the board's preference of reporting quality across markets with different types of beliefs formation and present the results in Corollary 4.3.

COROLLARY 4.3 *The threshold value of $\overline{h}_y$ that induces the minimum level of $E(U_B)$ increases in investors' degree of coordination, α, such that it is the highest in a herding market and the lowest in a dispersing market ($\overline{h}_y^{Hd} < \overline{h}_y^{F} < \overline{h}_y^{Hh}$).*

Proof: See Appendix.

Corollary 4.3 shows that the threshold level of reporting quality is lowest in a dispersing market and highest in a herding market, with the market without higher-order beliefs in the middle. Consequently, a firm in a herding market has a larger range of h_y in which its board may wish to reduce the baseline reporting quality, than a firm in a dispersing market or a market without higher-order beliefs. Or equivalently, a firm in a dispersing market has a larger range of h_y in which its board will try to improve its reporting quality for contracting efficiency than in a market with other belief structures. Interestingly, in the intermediate region $\overline{h}_y^{Hd} < h_y < \overline{h}_y^{Hh}$, a firm in a herding market prefers to have the lowest reporting quality possible while a firm in a dispersing market prefers to have the highest reporting quality.

Our results provide some insights into the regulatory implications of financial reporting. Although firms' reporting is always subject to the rules of accounting standards such as IFRS or US GAAP, the firms still have some discretion in adjusting their own reporting quality. When the reporting quality set by the standards is sufficiently high, firms have incentives to further increase the quality of their reports in all markets; when the standards do not yield sufficiently high information quality, firms may have incentives to lower their reporting quality even further. For intermediate levels, it depends on the higher-order beliefs formed by the market. Our results thus provide an example of the important yet complex stewardship role accounting information plays.

5. Conclusion

Higher-order beliefs exist in many markets and could result in asset bubbles, increased price volatility, and even market crises. When the board adopts market-based performance measures in the manager's compensation contract, the higher-order beliefs in the financial market inevitably enter the manager's incentives. We examine the effects of higher-order beliefs among investors on the agency problem within a firm.

We show that the use of market-based compensation decreases with the degree of interdependence among investors. That is, compensation contracts rely less on market-based performance measures in a herding market and more on them in a dispersing market. As a result, the manager's effort and the board's utility are also lower in a herding market and higher in a dispersing market. Further, the board's expected payoff is a U-shaped function of the reporting quality. That is, there exists a threshold level of reporting quality above which the board prefers to improve the firm's reporting and below which the board prefers to reduce it for higher contract efficiency. The threshold value that corresponds to the lowest board payoff strictly increases with the degree of investor interdependence.

Our study has important managerial implications. When a company uses market-based performance measures to evaluate its executives, the board or compensation committee should be aware of the investor sentiment that affects these market measures. Ideally, if the investors are likely herding toward the same assets, the market-based performance measures in the executive compensation should be given lower weight. In contrast, if the investors deliberately avoid making the same investments, the market-based measures should be given higher weight. Of course, investor sentiment in financial markets can be short-lived, compared to long-term managerial contracts. Nonetheless, companies could avoid being vulnerable to shifting investor sentiment by taking it into consideration.

Our study can be extended for future research. For example, managers often have some ability to bias their firms' accounting reports to the market. Assuming that managers prefer a high market price and could bias the report through earnings management, they would adopt different strategies in markets with different belief structures. Since the accounting report in our study is unbiased, the firm's market price only becomes more volatile but remains correct in expectation. An interesting avenue of future research would be to combine our setting with earnings management to study price bubbles and the managers' reporting strategies in the presence of higher-order beliefs.

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References

Allen, F., Morris, S., & Shin, H. S. (2006). Beauty contests and iterated expectations in asset markets. *The Review of Financial Studies*, *19*(3), 719–752. https://doi.org/10.1093/rfs/hhj036

Angeletos, G. M., & Pavan, A. (2004). Transparency of information and coordination in economies with investment complementarities. *American Economic Review*, *94*(2), 91–98. https://doi.org/10.1257/0002828041301641

Angeletos, G. M., & Pavan, A. (2007). Efficient use of information and social value of information. *Econometrica*, *75*(4), 1103–1142. https://doi.org/10.1111/ecta.2007.75.issue-4

Antle, R., & Smith, A. (1986). An empirical investigation of the relative performance evaluation of corporate executives. *Journal of Accounting Research*, *24*(1), 1–39. https://doi.org/10.2307/2490802

Arya, A., & Mittendorf, B. (2016). On the synergy between disclosure and investment beauty contests. *Journal of Accounting and Economics*, *61*(2–3), 255–273. https://doi.org/10.1016/j.jacceco.2015.11.003

Balakrishnan, K., Schrand, C., & Vashishtha, R.. (2020). Analyst recommendations and stock price bubbles. *Journal of Financial Reporting*, *5*(1), 1–24. https://doi.org/10.2308/jfir-10798

Banker, R. D., & Datar, S. M. (1989). Sensitivity, precision, and linear aggregation of signals for performance evaluation. *Journal of Accounting Research*, *27*(1), 21–39. https://doi.org/10.2307/2491205

Bushman, R. M., & Indjejikian, R. J. (1993). Accounting income, stock price, and managerial compensation. *Journal of Accounting and Economics*, *16*(1–3), 3–23. https://doi.org/10.1016/0165-4101(93)90003-X

Chen, Q., Huang, Z., & Zhang, Y. (2014). The effects of public information with asymmetrically informed short-horizon investors. *Journal of Accounting Research*, *52*(3), 635–669. https://doi.org/10.1111/joar.2014.52.issue-3

Chen, Q., Lewis, T., Schipper, K., & Zhang, Y. (2017). Uniform vs. discretionary regimes in reporting information with unverifiable precision and a coordination role. *Journal of Accounting Research*, *55*(1), 153–196. https://doi.org/10.1111/1475-679X.2017.55.issue-1

Cremers, M., Pareek, A., & Sautner, Z. (2021). Short-term institutions, analyst recommendations, and mispricing: The role of higher order beliefs. *Journal of Accounting Research*, *59*(3), 911–958. https://doi.org/10.1111/joar.v59.3

Dikolli, S., Hofmann, C, & Pfeiffer, T. (2013). Relative performance evaluation and peer- performance summarization errors. *Review of Accounting Studies*, *18*(1), 34–65. https://doi.org/10.1007/s11142-012-9212-9

Feltham, G., & Hofmann, C. (2012). Information suppression in multi-agent contracting. *Review of Accounting Studies*, *17*(2), 254–278. https://doi.org/10.1007/s11142-011-9175-2

Feltham, G. A., & Xie, J. (1994). Performance measure congruity and diversity in multi-task board/manager relations. *Accounting Review*, *69*(3), 429–453. http://links.jstor.org/sici?sici = 0001-4826%28199407%2969%3A3%3C429%3APMCADI%3E2.0.CO%3B2-8

Gao, P. (2008). Keynesian beauty contest, accounting disclosure, and market efficiency. *Journal of Accounting Research*, *46*(4), 785–807. https://doi.org/10.1111/joar.2008.46.issue-4

Hofmann, C., Huddart, S., & Pfeiffer, T. (2022). An analysis of net-outcome contracting with applications to equity-based compensation. *Review of Accounting Studies*, forthcoming. https://doi.org/10.1007/s11142-021-09666-w

Holmström, B. (1979). Moral hazard and observability. *Bell Journal of Economics*, *10*(1), 74–91. https://doi.org/10.2307/3003320

Jensen, M. C., & Murphy, K. J. (1990). Performance pay and top-management incentives. *Journal of Political Economy*, *98*(2), 225–264. https://doi.org/10.1086/261677

Keynes, J. M. (1936). *The general theory of employment, interest and money*. Macmillan.

Kim, O., & Suh, Y. (1993). Incentive efficiency of compensation based on accounting and market performance. *Journal of Accounting and Economics*, *16*(1–3), 25–53. https://doi.org/10.1016/0165-4101(93)90004-Y

Lambert, R. A., & Larcker, D. F. (1987). An analysis of the use of accounting and market measures of performance in executive compensation contracts. *Journal of Accounting Research*, *25*, 85–125. https://doi.org/10.2307/2491081

Liang, P. J., & Nan, L. (2014). Endogenous precision of performance measures and limited managerial attention. *European Accounting Review*, *23*(4), 693–727. https://doi.org/10.1080/09638180.2013.864568

Morris, S., & Shin, H. S. (2002). Social value of public information. *American Economic Review*, *92*(5), 1521–1534. https://doi.org/10.1257/000282802762024610

Schöndube-Pirchegger, B., & Schöndube, J. R. (2010). On the appropriateness of performance-based compensation for supervisory board members–An agency theoretic approach. *European Accounting Review*, *19*(4), 817–835. https://doi.org/10.1080/09638180903487784

Sloan, R. G. (1993). Accounting earnings and top executive compensation. *Journal of Accounting and Economics*, *16*(1–3), 55–100. https://doi.org/10.1016/0165-4101(93)90005-Z

Wagenhofer, A. (2003). Accrual-based compensation, depreciation and investment decisions. *European Accounting Review*, *12*(2), 287–309. https://doi.org/10.1080/0963818031000087835

Appendix.

A.1. Derivation of Investors' Average Valuation V

Each investor i's valuation $v_i = E_i(A)$ is dependent on $A = \alpha V + (1-\alpha)\theta$. The average valuation of the market, V, is the average of v_i, i.e.,

$$V = (1-\alpha)\int_0^1 E_i(\theta)\,\mathrm{d}i + \alpha\int_0^1 E_i(V)\,\mathrm{d}i. \tag{A1}$$

Substituting

$$E_i(V) = (1-\alpha)E_i\int_0^1 E_i(\theta)\,di + \alpha E_i\int_0^1 E_i(V)\,\mathrm{d}i \tag{A2}$$

into Equation (5), we obtain a new v_i:

$$v_i = (1-\alpha)E_i(\theta) + \alpha(1-\alpha)E_i\int_0^1 E_i(\theta)\,\mathrm{d}i + \alpha^2 E_i\int_0^1 E_i(V)\,\mathrm{d}i. \tag{A3}$$

The newly determined v_i triggers again a new average valuation V and a new $E_i(V)$, which can be substituted into Equation (A3). Repeated aggregation and substitution yields

$$V = (1-\alpha)\sum_{n=0}^{\infty}\alpha^n\theta^{(n+1)} \tag{A4}$$

as investors' average valuation, and

$$v_i = (1-\alpha)\sum_{n=0}^{\infty}\alpha^n E_i\left(\theta^{(n)}\right) \tag{A5}$$

as investor i's valuation of the firm.

We now define $E_i(\theta)$ as investor i's first-order belief, $\theta^{(1)} \equiv \int_0^1 E_i(\theta)di$ as investors' average first-order belief, $\theta^{(2)} \equiv \int_0^1 E_i \int_0^1 E_i(\theta)\,\mathrm{d}i\,\mathrm{d}i$ as investors' average second-order belief, and $\theta^{(n)}$ as investors' average nth-order belief about firm value.

If investors form first-order beliefs (i.e., if $\alpha = 0$), investor i's expectation of A simplifies to

$$E_i(\theta) = \delta z_i + (1-\delta)\, y \tag{A6}$$

Averaging over investors' first-order beliefs yields the average first-order belief

$$\theta^{(1)} = \delta\theta + (1-\delta)\, y. \tag{A7}$$

Assuming a coordination motive, investors form beliefs about other investors' beliefs about firm value. Let j be another investor from the unit interval. Investor j's belief about the average first-order belief is

$$E_j\left(\theta^{(1)}\right) = \delta^2 z_j + \left(1-\delta^2\right) y, \tag{A8}$$

the average second-order belief is

$$\theta^{(2)} = \delta^2\theta + \left(1-\delta^2\right) y, \tag{A9}$$

and in general, investors' average nth-order belief is

$$\theta^{(n)} = \delta^n\theta + (1-\delta^n)\, y. \tag{A10}$$

Substituting the average nth-order belief into Equation (A4) and applying geometric series, the initial average valuation can be re-expressed as

$$V = \left(\frac{(1-\alpha)\,\delta}{1-\alpha\delta}\right)\theta + \left(1 - \frac{(1-\alpha)\,\delta}{1-\alpha\delta}\right) y.$$

Analogously, by substituting $\theta^{(n)}$ into Equation (A5), investor i's valuation can be re-expressed as

$$v_i = \left(\frac{(1-\alpha)\,\delta}{1-\alpha\delta}\right) z_i + \left(1 - \frac{(1-\alpha)\,\delta}{1-\alpha\delta}\right) y.$$

A.2. *Proof of Proposition 3.1*

Taking the first-order condition of the manager's certainty equivalent

$$CE_M = a + b_P e + b_y e - c(e) - \frac{\rho}{2}\left(b_P\sigma_P^2 + b_y\sigma_y^2 + 2b_Pb_yCov(P,y)\right)$$

with respect to the manager's effort e and setting it equal to zero yields

$$b_P + b_y - c'(e) = 0. \tag{A11}$$

Since $c(e) = \frac{1}{2}e^2$, it follows that

$$e^* = b_P + b_y. \tag{A12}$$

Rearranging the manager's certainty equivalent for a and substituting $c(e) = \frac{1}{2}e^2$ and $e^* = b_P + b_y$, we obtain the optimal fixed pay

$$a^* = -\frac{1}{2}\left(b_P + b_y\right)^2 + \frac{\rho}{2}\left(b_P\sigma_P^2 + b_y\sigma_y^2 + 2b_Pb_yCov(P,y)\right). \tag{A13}$$

The board's objective function can be reexpressed as

$$\max E\left(\theta - a - b_PP - b_yy\right) = -a + e\left(1 - b_P - b_y\right). \tag{A14}$$

Plugging in e^* and a^*, the objective function becomes

$$\begin{aligned}&\max E\left(\theta - a - b_P P - b_y y\right)\\&= b_P + b_y - \frac{1}{2}\left(b_P + b_y\right)^2 - \frac{\rho}{2}\left(b_P\sigma_P^2 + b_y\sigma_y^2 + 2b_Pb_yCov\left(P,y\right)\right).\end{aligned} \tag{A15}$$

Taking the first-order condition of the board's payoff with respect to the weight on market price, b_P, and on the accounting report, b_y, setting them equal to zero, and rearranging for b_P and b_y, respectively, yields

$$b_P = -\frac{1}{1+\rho\sigma_P^2}\left(-1 + \rho b_y Cov\left(P,y\right) + b_y\right) \tag{A16}$$

and

$$b_y = -\frac{1}{1+\rho\sigma_y^2}\left(-1 + \rho b_P Cov\left(P,y\right) + b_P\right). \tag{A17}$$

Plugging b_P into b_y, we obtain

$$b_y = \frac{\sigma_P^2 - Cov\left(P,y\right)}{\sigma_P^2 + \sigma_y^2 + \rho\sigma_P^2\sigma_y^2 - 2Cov\left(P,y\right) - \rho Cov\left(P,y\right)^2}. \tag{A18}$$

Plugging b_y into b_P, we obtain

$$b_P = \frac{\sigma_y^2 - Cov\left(P,y\right)}{\sigma_P^2 + \sigma_y^2 + \rho\sigma_P^2\sigma_y^2 - 2Cov\left(P,y\right) - \rho Cov\left(P,y\right)^2}. \tag{A19}$$

The board's expected utility can be computed by substituting e^*, a^*, b_P, and b_y into its payoff function:

$$\begin{aligned}E\left(U_B\right) &= E\left(\theta - a - b_P P - b_y y\right)\\&= e - a - b_P e - b_y e\\&= \frac{1}{2}\frac{\sigma_P^2 + \sigma_y^2 - 2Cov\left(P,y\right)}{\sigma_P^2 + \sigma_y^2 + \rho\sigma_P^2\sigma_y^2 - 2Cov\left(P,y\right) - \rho Cov\left(P,y\right)^2}.\end{aligned} \tag{A20}$$

A.3. Proof of Corollary 3.2

Taking the first-order condition of the variance of the market price

$$\sigma_P^2 = \left(1 - \frac{\left(1-\alpha\right)\delta}{1-\alpha\delta}\right)^2\frac{1}{h_y} + \frac{1}{h_\lambda}$$

with respect to investors' degree of interdependence α yields

$$\frac{\partial\sigma_P^2}{\partial\alpha} = -2\frac{\delta}{h_y}\frac{\left(\delta-1\right)^2}{\left(\alpha\delta-1\right)^3}. \tag{A21}$$

The first-order condition is strictly positive, i.e., σ_P^2 is increasing in α.

Since $-1 < \alpha < 0$ holds in a dispersing market, $\alpha = 0$ in a market with first-order beliefs, and $0 < \alpha < 1$ in a herding market, it follows that market price's variance is lowest in a dispersing market and highest in a herding market. The variance of the market price in a market with first-order beliefs lies in between.

A.4. Proof of Corollary 3.3

Taking the first-order condition of the performance measure weight on price, b_P, with respect to investors' degree of interdependence α and simplifying yields that the derivative is negative if $(\rho + h_y)(\alpha\delta - 1)^2 > \delta^2 h_\lambda(\alpha - 1)^2$. This is satisfied for sufficiently small h_λ and proves (i).

Taking the first-order condition of the performance measure weight on the accounting report, b_y, with respect to α and simplifying yields that the derivative is positive if $-(\alpha\delta - 1)(\rho + h_y - 2\delta\rho + \alpha\delta\rho - \alpha\delta h_y) > \delta^2 h_\lambda(\alpha - 1)^2$. This is satisfied for sufficiently small h_λ and proves (ii).

If b_P decreases in α and b_y increases in α, then the ratio b_P/b_y must also decrease in α. This proves (iii).

Taking the first-order condition of the manager's effort, $e = b_P + b_y$, with respect to α yields

$$\frac{\partial e}{\partial \alpha} = \frac{2\delta^2 \rho h_\lambda (\alpha - 1)(\delta - 1)(\alpha\delta - 1)}{\left(\rho + h_y + \delta^2 h_\lambda - 2\alpha\delta^2 h_\lambda + \alpha^2\delta^2\rho - 2\alpha\delta\rho + \alpha^2\delta^2 h_y + \alpha^2\delta^2 h_\lambda - 2\alpha\delta h_y\right)^2},$$

which is always negative and proves (iv).

Taking the first-order condition of the board's expected utility, $E(U_B)$, with respect to α yields

$$\frac{\partial E(U_B)}{\partial \alpha} = \frac{\delta^2 \rho h_\lambda (\alpha - 1)(\delta - 1)(\alpha\delta - 1)}{\left(\rho + h_y + \delta^2 h_\lambda - 2\alpha\delta^2 h_\lambda + \alpha^2\delta^2\rho - 2\alpha\delta\rho + \alpha^2\delta^2 h_y + \alpha^2\delta^2 h_\lambda - 2\alpha\delta h_y\right)^2},$$

which is always negative and proves (v).

A.5. Proof of Proposition 4.1

Taking the first-order condition of the ratio of the performance measure weights, b_P/b_y, with respect to h_z and simplifying yields that the derivative is positive if $h_y(h_y + h_z(1 - \alpha))^2 > h_\lambda h_z^2(1 - \alpha)^2$. This is satisfied for sufficiently small h_λ and proves (i).

Taking the first-order condition of b_P/b_y with respect to h_λ yields

$$\frac{\partial b_P/b_y}{\partial h_\lambda} = \frac{-\frac{1}{h_y} h_z (\alpha - 1)\left(h_y + h_z - \alpha h_z\right)^3}{\left(\alpha^2 h_z^2 - 2\alpha h_y h_z - 2\alpha h_z^2 + h_\lambda \alpha h_z + h_y^2 + 2h_y h_z + h_z^2 - h_\lambda h_z\right)^2},$$

which is always positive and proves (ii).

Taking the first-order condition of b_P/b_y with respect to h_y and simplifying yields that the derivative is negative if $(2h_y + h_z(1 - \alpha))(h_y + h_z(1 - \alpha))^2 > h_\lambda h_z^2(1 - \alpha)^2$. This is satisfied for sufficiently small h_λ and proves (iii).

A.6. Proof of Proposition 4.2

Taking the first-order condition of the board's payoff in a market with higher-order beliefs

$$E(U_B) = \frac{1}{2}\frac{\sigma_P^2 + \sigma_y^2 - 2Cov(P, y)}{\sigma_P^2 + \sigma_y^2 + \rho\sigma_P^2\sigma_y^2 - 2Cov(P, y) - \rho Cov(P, y)^2} \tag{A22}$$

with respect to the accounting report's precision h_y and setting it equal to zero yields the solution

$$\bar{h}_y = \sqrt[3]{2h_z^2 h_\lambda (1 - \alpha)^2} - h_z(1 - \alpha). \tag{A23}$$

Since $\frac{\partial E(U_B)}{\partial h_y} < 0$ for $h_y < \sqrt[3]{2h_z^2 h_\lambda(1 - \alpha)^2} - h_z(1 - \alpha)$ and $\frac{\partial E(U_B)}{\partial h_y} > 0$ for $h_y > \sqrt[3]{2h_z^2 h_\lambda(1 - \alpha)^2} - h_z(1 - \alpha)$, the solution is a minimum, and $E(U_B)$ increases in h_y when

$h_y > \bar{h}_y$ and decreases in h_y when $h_y < \bar{h}_y$. The threshold in a market with first-order beliefs is obtained by setting $\alpha = 0$.

A.7. Proof of Corollary 4.3

Taking the first-order condition of the threshold value

$$\bar{h}_y = \sqrt[3]{2h_z^2 h_\lambda (1-\alpha)^2} - h_z (1-\alpha)$$

with respect to investors' degree of interdependence α yields

$$\frac{\partial \bar{h}_y}{\partial \alpha} = \frac{1}{3\alpha - 3}\left(3\alpha h_z - 3h_z + 2\sqrt[3]{2}\sqrt[3]{h_z^2 h_\lambda (\alpha-1)^2}\right),$$

which is always positive.