What Does the Market Know?*

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October 2023

Abstract

Investors' information about different aspects of financial reporting – firm fundamentals and managers' reporting objectives – affect earnings quality and price efficiency unambiguously (Fischer and Stocken (2004)), making proper measurement of investors' information important for researchers and policymakers. I develop a structural approach that uses firms' prices and analyst forecasts to measure how much fundamental and misreporting incentives information investors know. The new technique is used to estimate the amount of information an average U.S. investor has, and the magnitude of the trade-off between reporting quality and price efficiency faced by policymakers. Next, I apply the technique in two settings to obtain potentially policy-relevant insights. First, I measure how much misreporting incentives investors learned after the introduction of the Compensation Disclosure & Analysis (CD&A) section in 2007 and whether the regulation hurt the precision of reported earnings. Second, I measure the information spillover during an earnings cycle – the extent to which fundamental and incentives information disclosed by early reporters informs traders of later reporters' stocks.

*I appreciate helpful comments and suggestions from an anonymous referee, Gary Biddle, Tongqing Ding, Paul Fischer, Ian Gow, Wayne Guay, Luzi Hail, Mirko Heinle, Xue Jia, Chongho Kim, Jung Min Kim, Kevin Smith (discussant), Catherine Schrand, Stephen Taylor, Tong Liu, Frank Zhou, participants at the Junior Accounting Theory Conference, Duke Accounting Theory Summer Camp, the Melbourne Accounting Research Seminar, the Wharton-INSEAD Doctoral Consortium, the Financial Markets and Corporate Governance Conference, the Wharton School Workshop, the Wharton School Junior Faculty/PhD Student Summer Brown Bag Series, and at the Wharton School Finance/Accounting Doctoral Seminar.

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Introduction

Misreporting can undermine the efficiency of capital markets by blurring the information that economic agents can glean. However, investors rationally anticipate the bias in financial reports by acquiring knowledge about firms' fundamental characteristics and firm managers' reporting objectives. Investors' information has a non-trivial effect on financial markets. First, when investors know more about firm fundamentals, the earnings response coefficient (ERC) decreases, reducing financial misreporting. In contrast, more reporting incentives information increases ERC and financial misreporting. Second, both types of information may make stock prices more efficient (Fischer and Stocken (2004)). The unambiguous role of investors' information poses a challenge to regulators considering information-related policies, highlighting how important it is to know how much knowledge investors have and the extent to which this knowledge affects financial markets.

In this study, I develop a way to measure investors' information about firm fundamentals and managers' reporting incentives and their effect on reporting quality and firm prices. Estimating the aggregate amount of the market's information is challenging because investors may learn from multiple sources, including companies' filings, mass media, managers' and other employees' social media accounts, conference calls, or private meetings with companies' executives. Some of these sources can not be observed by researchers, and many of these sources can contain both fundamental and misreporting incentives information. I try to overcome these challenges by using structural estimation – an approach that attempts to uncover unobservable parameters from observed data.

As a first step, I use the new technique to estimate the average amount of information that investors on the U.S. stock market have and the magnitude of the trade-off between reporting quality and price efficiency faced by policymakers. Next, I apply the technique in two settings to obtain potentially policy-relevant insights. First, I evaluate how much new information about managers' incentives investors learned after the introduction of the Compensation Disclosure & Analysis (CD&A) section in 2007 and whether the regulation hurt the precision of reported earnings. Second, I measure the information spillover during an earnings cycle – the extent to which fundamental and incentives information disclosed by early reporters informs traders of later reporters' stocks.

I build a dynamic earnings management model based on Fischer and Verrecchia (2000) that features a manager who governs a company and reports earnings every year and the stock market. The manager cares about firm price and has full information about fundamentals – the actual value of the firm's earnings – and her misreporting incentives – the extent to which she cares about the stock price. The manager can bias the earnings she reports to investors; however, she has to bear the cost, which is a function of not just the current bias but cumulative bias in all reports the manager released in the past. The stock market prices the firm at the expected value of its past and future earnings. In contrast to the manager, investors do not know all the information, but only part of the fundamental and misreporting incentives information that the manager has.

In equilibrium, investors' information has a non-trivial effect on financial markets. The manager biases the earnings report more when the price response to her report is larger. ERC is decreasing in the amount of the market's fundamental information and increasing in the amount of the market's misreporting incentives information. As a result, when investors know more about firm fundamentals, earnings quality increases; and when investors know more about misreporting incentives, earnings quality decreases. At the same time, price efficiency is increasing in both types of information, suggesting policymakers' trade-off between financial reporting quality and efficiency of prices.

To identify unobserved investors' information from the data, I rely on the following intuition. If firm prices represent the market's expectation of firm value, the price is solely the function of investors' fundamental information. Investors' misreporting incentives information is uncovered in financial analysts' reports. I assume that when financial analysts predict the next earnings report, they aim to predict the number that will be reported as closely as possible (Mikhail et al. (1999), Hilary and Hsu (2013)), implying that analysts forecast the sum of true earnings and the bias that the manager will add to the report, where the bias is a function of the manager's misreporting incentives. Combined with investors' fundamental information identified from price dynamics, one can back out investors' misreporting incentives information from analyst forecasts.

Because companies provide a lot of information besides their earnings reports on their earnings report days, I separately estimate how much information investors learn on these days and on other days during a year. Short-window changes in firms' prices and analyst forecasts that are not explained by the earnings report help to identify the amount of information the market learned from other sources on the earnings report day. Prices' and analyst forecasts' movement during a year excluding the report day, in turn, measure new information that market participants acquired on other days.

The estimates of the structural model suggest that while firm earnings are volatile, investors already know a large portion of earnings before the report is disclosed. For 32% of companies, a yearly shock to true earnings deviates from its mean by more than 27% of the companies' book value. The market knows around 83% of this shock from sources other than the manager's report, and 12% of this 83% is learned about one year ahead, concurrently with the previous earnings report. Investors seem to know a lot about firm earnings, and only a small part of this knowledge is acquired when prior earnings are released, suggesting that sources other than managerial guidance or concurrent analyst reports are important for the market learning about fundamentals. Managers' misreporting incentives are more uncertain in general and more opaque to investors. In 32% of firms, a yearly shock to managers' incentives deviates from its mean by about 79% of the book value. Investors anticipate 60.7% of this shock, and 91.7% of this 60.7% is learned concurrently with the previous earnings report. Prior earnings report day is more significant for learning about reporting incentives than about fundamentals, perhaps because both company management and external analysts often disclose their expectations for next year's earnings on that day.

Estimated bias in reported earnings and deviation of the average company's market value is quite high. Reported earnings differ from true earnings by about 1.8 standard deviations of reported earnings. This conclusion is broadly consistent with Beyer et al. (2019) whose tests strongly reject a null hypothesis of zero reporting noise. The market value of a representative firm would be different by around two-thirds of the firm's book value if investors knew all the information available to the firm's management. Because investors already know a lot about fundamentals and firms' earnings are generally less volatile than managers' misreporting incentives, providing investors with extra fundamental information would not improve price efficiency by a lot. In contrast, if either managers' incentives were considerably less uncertain or investors learned all the information about managers' incentives,[1] the difference between corporations' actual market values and their values without information asymmetry would drop to less than a quarter of book value.

The approach that I develop has several advantages over reduced-form studies in informing regulators and evaluating policies' outcomes. First, because the structural approach uses a mathematical theory, it does not rely on plausibly exogenous shocks to identify the effects of changes in the information environment. Second, I can estimate the magnitudes of the economic environment's characteristics and not just their marginal effects. Finally, because structural estimation can uncover unobserved eco-

[1] These statements are conclusions from four counterfactual scenarios. In the first, the uncertainty about firm fundamentals is approaching zero; in the second, the variance of managers' misreporting incentives is approaching zero. In the third and the fourth, investors' fraction of information about earnings and managerial incentives, respectively, are set to one.

nomic parameters, one can quantify the welfare implications of information-related policies, which is hard to do using regressions (Leuz and Wysocki (2016)).

I demonstrate how the technique developed in this paper can be applied in two settings: (1) introduction of the CD&A section in 2007 and (2) information spillovers during the earnings reporting cycle. Model estimates before and after CD&A was in place suggest that investors indeed learned more about managers' reporting incentives: they used to know about 45% of managers' information, and currently know more than 90%. At the same time, in the post-2009 period, overall market uncertainty about firms' fundamentals declined substantially. The two effects combined led to an about 56% more efficient price without hurting earnings quality, which declined only by 0.9%. These statistics add to existing marginal-effect-reduced-form tests (e.g., Ferri et al. (2018)) and may give regulators a more complete picture of the CD&A policy outcome.

The second setting where I apply the model is the spillover of information during earnings reporting cycles. A number of researches documented that financial analysts and investors learn information relevant for companies announcing earnings later from companies announcing earnings earlier (e.g., Ramnath (2002), Savor and Wilson (2016)). However, it remains less clear whether these spillovers are economically meaningful and what kind of information market participants are learning. I find an unambiguous distinction between early and late reporters' information characteristics. On the one hand, spillover of fundamental information is significant: investors anticipate about 82% of earnings for firms reporting late and only almost 40% for firms reporting early. On the other hand, investors seem generally much more uncertain about the incentives of managers reporting later in the earnings cycle. This finding is consistent with a theory by Trueman (1990) who suggests that delayed reporting may be a signal of earnings management simply because manipulation takes time or because dishonest managers wait to see what the market's expectations are based on peer firms' reports. Information spillover is not enough to compensate for higher investors' uncertainty about misreporting incentives, resulting in about 80% lower quality of earnings for late reporters.

This study is broadly related to two streams of literature in accounting. The first aims to measure how informative accounting numbers are for different users. Following Ball and Brown (1968) and Beaver (1968)'s discovery that financial markets react to news in earnings announcements, researchers try to measure how meaningful is the information content of accounting reports. One of the intuitive metrics is the proportion of variance in returns that is explained by earnings announcements. Ball and Shivakumar (2008) find that quarterly announcements explain about 5-9% of companies' annual returns. My approach can not be directly mapped into theirs because I am not attempting to explain the variance of firms' returns in detail and thus avoid using return variance in the estimation. However, my estimates provide an upper bound of the effect that earnings reports have on stock prices: about 17% of fundamental information is privately known by the manager and disclosed (with bias) to the market on earnings announcement dates.

Other studies exploit statistical properties of accounting accruals to identify the amount of bias contained in reported earnings (e.g., Sloan and Sloan (1996), Dechow and Dichev (2002), Gerakos and Kovrijnykh (2013), Nikolaev (2019)). An earlier approach treated earnings with a high degree of persistence as high quality (e.g., Revsine et al. (2001), Penman (2012)). My paper shows why this method may not be accurate: bias in earnings driven by stock-price-related managerial incentives can also be persistent when managers' incentives to misreport are persistent. Gerakos and Kovrijnykh (2013) develop a novel way to measure misreporting, which is based on the notion that companies' misreporting must be correlated with their performance. Whereas this approach is a big step in our understanding and measurement of financial reporting bias, it does not account for the extent to which managers have incentives to misrepresent their companies' true performance. My study suggests that reporting objectives play a considerable role in explaining bias in financial reports. Perhaps this is the reason why our estimates of misreporting magnitude differ: Gerakos and Kovrijnykh (2013) find that median misreporting is about 0.7% of total assets, whereas my estimate is only about 0.18% of total assets.

The closest paper in this strand of literature is Beyer et al. (2019), which structurally estimates a model where earnings are biased due to exogenous factors, such as accounting system errors. My conclusions about the presence of reporting bias are generally consistent with the findings by Beyer et al. (2019), although the nature of the bias I study is different. Beyer et al. (2019) focus on broadly reporting noise that induces linear bias in earnings reports, whereas the center of my study is stock price-based misreporting incentives.

The second large stream of literature studies investors' uncertainty about managerial incentives and the implications of this uncertainty for financial misreporting (e.g., Ferri et al. (2018), Kim (2023), Bertomeu et al. (2019)). Ferri et al. (2018) use staggered adoption of the CD&A section in companies' proxy statements, and Kim (2023) uses investors' search for compensation-related disclosures to identify how investor uncertainty about managerial incentives affects financial reporting bias. The relative advantage of my approach is that I can distinguish fundamental and misreporting incentives information and their respective effects on misreporting, even if investors simultaneously learned both of these types of information during the CD&A adoption period or by searching for proxy statements online. Bertomeu et al. (2019) ask a question that is very close to mine – how to measure investors' uncertainty about managers' reporting objectives. However, our papers differ on multiple dimensions. I consider a dynamic problem that captures the inter-temporal trade-off that managers face when choosing misreporting amounts: overstating heavily today reduces the ability to boost prices in the future. The two studies also use different strategies to identify investor uncertainty about reporting objectives: Bertomeu et al. (2019) exploit observed earnings response to get to optimal misreporting, and I use analyst forecasts as a source of identification.

The rest of the paper is organized as follows. Section 1 presents the model and discusses the equilibrium and important insights. In section 2 I discuss the sample and show the main estimates of the model. Section 3 presents counterfactual analyses. In section 4, two applications of the technique are presented. Section 5 discusses how different assumptions affect model estimates. Section 6 concludes.

1 Model

This section discusses the model and equilibrium and presents theoretical moments that later will be used to estimate model parameters.

1.1 Setup

In what follows, I denote random variables by the $\tilde{}$ sign, and their realizations without the $\tilde{}$ sign.

The model is a dynamic version of the earnings management model with uncertain incentives as in Fischer and Stocken (2004). A long-lived manager cares about firm price and is required to report earnings to the firm's investors every year. The report does not have to be truthful: the manager can bias it at a cost. The manager has more information than investors about firm earnings and the extent to which she cares about the firm's price.

The firm's earnings in year t can be thought of as consisting of two parts, one observed by both the manager and the market, and another privately observed by the manager. Earnings are characterized by the following process:

$$\tilde{\epsilon}_t = \tilde{\epsilon}_{1,t} + \tilde{\epsilon}_{2,t}, \tag{1}$$

$$\tilde{\epsilon}_{1,t} = \tilde{v}_{1,t} + \tilde{v}_{1,t-1} + \tilde{v}_{1,t-2}, \quad \tilde{v}_{1,t} \sim N(0, q_v \sigma_v^2), \tag{2}$$

$$\tilde{\epsilon}_{2,t} = \tilde{v}_{2,t} + \tilde{v}_{2,t-1} + \tilde{v}_{2,t-2}, \quad \tilde{v}_{2,t} \sim N(0, (1-q_v)\sigma_v^2), \tag{3}$$

where $0 < q_v < 1$. The manager observes both parts, $\epsilon_{1,t}$ and $\epsilon_{2,t}$, and the market only observes $\epsilon_{1,t}$. The market learns $\epsilon_{1,t}$ from sources other than the manager's report. q_v represents the fraction of total fundamental information that the market knows.

I model firm earnings as a sum of the current and two prior-year shocks to, on the one hand, preserve important time-series properties of earnings, and on the other, keep the model tractable. The time series process for earnings in (2) and (3) ensures earnings are persistent and mean-revert (Gerakos and Kovrijnykh (2013)). Two prior-year shocks imply that to evaluate current earnings, investors mostly rely on information about earnings from the last two years. The number of relevant past earnings is consistent with prior studies (e.g., Albrecht et al. (1977)) finding that autocorrelation coefficients for earnings reports cross-sectionally vary between about 0.4 and 0.8. In addition, when earnings are a sum of a finite number of shocks rather than an AR(1) process, the manager's report in equilibrium is also a finite sum of shocks, allowing to derive a closed-form solution of the model.

The market learns its part of current earnings in two time periods. Some fraction is learned concurrently with the previous earnings report (e.g., from concurrent analyst reports), and another fraction is learned at other times during the year leading up to the earnings report. $\epsilon_{1,t}$ is divided into two parts:

$$\tilde{\epsilon}_{1,t} = \tilde{\epsilon}^0_{1,t} + \tilde{\epsilon}^1_{1,t}, \tag{4}$$

$$\tilde{\epsilon}^0_{1,t} = \tilde{v}^0_{1,t} + \tilde{v}^0_{1,t-1} + \tilde{v}^0_{1,t-2}, \quad \tilde{v}^0_{1,t} \sim N(0, q_v q_v^0 \sigma_v^2), \tag{5}$$

$$\tilde{\epsilon}^1_{1,t} = \tilde{v}^1_{1,t} + \tilde{v}^1_{1,t-1} + \tilde{v}^1_{1,t-2}, \quad \tilde{v}^1_{1,t} \sim N(0, q_v (1-q_v^0)\sigma_v^2), \tag{6}$$

where $0 < q_v^0 < 1$. $\epsilon^0_{1,t}$ is the fraction of the market's fundamental information that arrives concurrently with the previous earnings report, $\epsilon^1_{1,t}$ is the fraction of the market's fundamental information that arrives on other days during the year leading up to the current earnings report. The fraction of investors' earnings information that is learned together with the previous report is captured by q_v^0. The timing of information arrival is shown in figure 1.

The firm manager cares about stock price so that a \$1 increase in the price at time t gives her extra m_t units of utility. Misreporting incentives m_t are not just capturing the manager's compensation but can include non-monetary benefits such as reputation or happiness from governing a successful company. The incentives can be positive or negative. For example, if the manager urgently needs cash, she may prefer the company's price to fall next year so that she can sell her shares today and buy them back in a year for a lower price. Misreporting incentives evolve every year and are described by the following process:

$$\tilde{m}_t = \tilde{m}_{1,t} + \tilde{m}_{2,t}, \tag{7}$$

$$\tilde{m}_{1,t} = \tilde{\xi}_{1,t} + \tilde{\xi}_{1,t-1} + \tilde{\xi}_{1,t-2}, \quad \tilde{\xi}_{1,t} \sim N(0, q_\xi \sigma_\xi^2), \tag{8}$$

$$\tilde{m}_{2,t} = \tilde{\xi}_{2,t} + \tilde{\xi}_{2,t-1} + \tilde{\xi}_{2,t-2}, \quad \tilde{\xi}_{2,t} \sim N(0, (1-q_\xi)\sigma_\xi^2), \tag{9}$$

where $0 < q_\xi < 1$. Similarly to earnings, the manager knows both components of her incentives, $m_{1,t}$ and $m_{2,t}$, and the market knows only a part of them, $m_{1,t}$. q_ξ represents the share of misreporting incentives information that the market has.

Investors learn the manager's incentives for year t partially at the time of the year-$(t-1)$ earnings report and partially at other times between the year-$(t-1)$ and year-t reports. $m_{1,t}$ consists of two parts:

$$\tilde{m}_{1,t} = \tilde{m}^0_{1,t} + \tilde{m}^1_{1,t}, \tag{10}$$

$$\tilde{m}^0_{1,t} = \tilde{\xi}^0_{1,t} + \tilde{\xi}^0_{1,t-1} + \tilde{\xi}^0_{1,t-2}, \quad \tilde{\xi}^0_{1,t} \sim N(0, q_\xi q^0_\xi \sigma_\xi^2), \tag{11}$$

$$\tilde{m}^1_{1,t} = \tilde{\xi}^1_{1,t} + \tilde{\xi}^1_{1,t-1} + \tilde{\xi}^1_{1,t-2}, \quad \tilde{\xi}^1_{1,t} \sim N(0, q_\xi (1-q^0_\xi)\sigma_\xi^2). \tag{12}$$

where $0 < q^0_\xi < 1$. $m^0_{1,t}$ is the fraction of the market's misreporting incentives information that arrives concurrently with the manager's report, $m^1_{1,t}$ is the fraction of the market's misreporting incentives information that arrives on other days during the year preceding the current earnings report.

Every year, the manager releases a report (potentially biased), e_t, about the firm's earnings and is compensated based on the firm's stock price, p_t, net of personal cost of misreporting. The misreporting cost is a function of the current period's bias in earnings, as well as all other biases in prior period earnings. Such cost function, first, can capture the increasing likelihood of being caught and penalized when the manager misreports more cumulatively. Second, having to bear the cost of prior years' misreporting naturally introduces accrual reversal into earnings because, in order to exaggerate current earnings, the manager has to bias her report by an additional amount to compensate for the reversal rate, and thus bear a higher misreporting cost. The manager's utility at time t is

$$U_t = m_t p_t - \frac{\left(\sum_{k=0}^{t}(e_k - \varepsilon_k)\right)^2}{2}, \tag{13}$$ [2]

where m_t is the manager's misreporting incentives.[3]

The manager faces a dynamic trade-off: if her misreporting incentive is positive ($m_t > 0$), on the one hand, by overstating earnings today, she increases firm price and thus increases her utility. On the other hand, if she heavily overstates firm earnings today ($e_t > \varepsilon_t$), she will have little room for overstatement (and boosting firm price) going forward. If the manager understates earnings today ($e_t < \varepsilon_t$), it will be costlier for him to report a higher number in the future. The manager's problem at time t is

$$\max_{e_t} \quad E\left[\sum_{k=t}^{k=\infty} \delta_M^{k-t}\left(\tilde{m}_k p_k - \frac{\left(\sum_{\tau=0}^{k}(e_\tau - \varepsilon_\tau)\right)^2}{2}\right) | I_t^{\text{manager}}\right], \tag{14}$$

where $0 < \delta_M < 1$ is the extent to which the manager cares about his future utility, and $I_t^{\text{market}} = \{\epsilon_0, \epsilon_1, ..., \epsilon_t;$ $m_0, m_1, ..., m_t\}$ is all the information available to the manager at time t, which is simply all realizations of earnings and misreporting incentives.

The firm does not pay dividends, and thus all of its value will be realized upon liquidation in the future. The market prices the firm risk-neutrally at the expectation of its book value, equal to the sum of

[2]Other studies considered accounting system errors as another source of investors' uncertainty related to financial misreporting (e.g., Beyer et al. (2019)). The accounting system error can be incorporated in my model by changing the manager's misreporting cost to $\frac{\left(\sum_{k=0}^{t}(e_k - \varepsilon_k - \eta_k)\right)^2}{2}$, where η_k is the error introduced by the accounting system. Adding this feature to the model makes it considerably more complex without helping the main focus of this study – uncovering investors' uncertainty about managers' misreporting incentives, m_t. Since accounting error noise has been explored in detail in prior work (Beyer et al. (2019)), I leave the investigation of jointly misreporting incentives and accounting error uncertainty for future research.

[3]Note that the manager bears 1 unit of cost for the misreporting of size $\frac{\left(\sum_{k=0}^{t}(e_k - \varepsilon_k)\right)^2}{2}$. This implies that m_t is the manager's benefit of misreporting relative to the 1 unit of misreporting cost. Alternatively, the cost of misreporting can be modelled as $c\frac{\left(\sum_{k=0}^{t}(e_k - \varepsilon_k)\right)^2}{2}$ and the manager's misreporting incentives can be modelled as $M_t = cm_t$.

all past earnings, and the discounted sum of all expected future earnings:

$$p_t = E\left[\sum_{k=0}^{k=t} \tilde{e}_k + \sum_{k=t+1}^{k=\infty} \delta_I^{k-t} \tilde{e}_k | I_t^{\text{market}}\right], \tag{15}$$

where $0 < \delta_I < 1$ is investors' discount factor, and $I_t^{\text{market}} = \{r_0, r_1, ..., r_t; \epsilon_{1,0}, \epsilon_{1,1}, ..., \epsilon_{1,t}; m_{1,0}, m_{1,1}, ..., m_{1,t}\}$ is all the information available to the market at time t. It includes all past managerial reports and the history of fundamental and misreporting incentives information observed by the market.

The final element that I define is the market's expectations of the annual earnings report:

$$ME_t = E\left[\tilde{e}_t | I_t^{\text{market}}\right]. \tag{16}$$

I introduce the notion of the market's expectations because it allows me to glean investors' information about the manager's misreporting incentives. The expectation of the report is the expectation of the true earnings plus the intentional bias that the manager adds. The bias, in turn, is a function of the manager's incentives. Coupling market expectations with firm prices, which represent solely beliefs about firm earnings, we can disentangle investors' expectations of the reporting bias, and thus of the misreporting incentives.

1.2 Equilibrium

1.2.1 Equilibrium strategies and beliefs

I conjecture the following steady-state equilibrium strategies:

- The manager's earnings report is a linear function of the firm's true current earnings and the manager's misreporting incentives:

$$e_t = e_0 + e_\varepsilon \varepsilon_t + \sum_{k=0}^{k=t} e_{m_1^0,k} m_{1,t-k}^0 + \sum_{k=0}^{k=t} e_{m_1^1,k} m_{1,t-k}^1 + \sum_{k=0}^{k=t} e_{m_2,k} m_{2,t-k};$$

- Firm price is a linear function of the manager's current and prior reports, and the market's fundamental and misreporting incentives information:

$$p_t = p_0 + \sum_{j=0}^{j=t} \alpha_j^t e_j + \sum_{j=0}^{j=t} \beta_j^{0,t} \epsilon_{1,j}^0 + \sum_{j=0}^{j=t} \beta_j^{1,t} \epsilon_{1,j}^1 + \sum_{j=0}^{j=t} \gamma_j^{0,t} m_{1,j}^0 + \sum_{j=0}^{j=t} \gamma_j^{1,t} m_{1,j}^1;$$

- Market expectations of earnings report is a linear function of the manager's current and prior reports, and the market's fundamental and misreporting incentives information:

$$ME_t = ME_0 + \sum_{j=0}^{j=t} a_j^t e_j + \sum_{j=0}^{j=t} b_j^{0,t} \epsilon_{1,j}^0 + \sum_{j=0}^{j=t} b_j^{1,t} \epsilon_{1,j}^1 + \sum_{j=0}^{j=t} c_j^{0,t} m_{1,j}^0 + \sum_{j=0}^{j=t} c_j^{1,t} m_{1,j}^1.$$

α_j^t is price-t response to the managerial report, $\beta_j^{0,t}$ and $\beta_j^{1,t}$ are price-t responses to the fundamental information learned at the time of the manager's report and on other days, $\gamma_j^{0,t}$ and $\gamma_j^{1,t}$ are price-t responses to the misreporting incentives information learned at the time of the manager's report and on other days.

The firm's price and the market's expectations rely on all sources of information about true earnings and the manager's incentives. First, the market uses the unbiased information that investors learned from sources other than the manager's report. Second, the market forms beliefs about parts of earnings and the manager's incentives that it does not observe from the manager's earnings reports. Because a shock to earnings or incentives in one year persists in earnings or incentives for two more years, investors use two past reports when gleaning earnings and incentives from a manager's report in a given year.[4]

The proposition below describes the optimal earnings report chosen by the manager.

Proposition 1 *In equilibrium, the manager's earnings report is*

$$\begin{aligned} e_t &= \varepsilon_t + \alpha_t^t m_t + \sum_{k=1}^{\infty} \delta_M^k \alpha_t^{t+k} E_t[m_{t+k}] - \alpha_{t-1}^{t-1} m_{t-1} - \sum_{k=0}^{\infty} \delta_M^k \alpha_{t-1}^{t+k} E_{t-1}[m_{t+k}] \\ &= \varepsilon_t + (\alpha_0 + \delta_M \alpha_1 + \delta_M^2 \alpha_2)\xi_t - \alpha_0 \xi_{t-3} - \delta_M \alpha_1 \xi_{t-2} - \delta_M^2 \alpha_2 \xi_{t-1}, \end{aligned} \tag{17}$$

where α_0, α_1, and α_2 are the current, one-year-ahead, and two-year-ahead prices' responses to the manager's earnings report, defined in the Appendix.

The manager's optimal report is the sum of the firm's true earnings (ε_t), the bias added to the current earnings $\left(\alpha_t^t m_t + \sum_{k=1}^{\infty} \delta_M^k \alpha_t^{t+k} E_t[m_{t+k}]\right)$ net of the bias in the prior earnings report $\left(\alpha_{t-1}^{t-1} m_{t-1} + \sum_{k=0}^{\infty} \delta_M^k \alpha_{t-1}^{t+k} E_{t-1}[m_{t+k}]\right)$. In equilibrium, the manager chooses to (at least partially) reverse the bias she added to her report last year. If the product of her misreporting incentives and market response to

[4] In equilibrium, in the price equation, the coefficients in front of the current and past two earnings reports, $\alpha_j^t, j \in \{t-2, t-1, t\}$, will be non-zero, and the coefficients in front of earnings further in the past will be zero. Similarly, in the market's expectations equation, the coefficients in front of the current and past two earnings reports, $a_j^t, j \in \{t-2, t-1, t\}$, will be non-zero, and the coefficients in front of earnings further in the past will be zero.

the report are higher this year than last year, she will reverse last year's bias and also overstate current earnings.

To understand how the market's learning from the manager's report and other information sources is reflected in prices, let us analyze the firm's price at different times of the year: right before the time t report is issued, right after it is issued, and right before the time $t+1$ earnings report comes out. I denote by $p_t^{\text{pre-report}}$ the firm's price right before the earnings report e_t is released, and by $p_t^{\text{post-report}}$ the firm's price right after the report. I_t^{market} denotes the market's information at time t, which includes the time t earnings report. $I_t^{\text{market}} \setminus \{e_t\}$ is the market's information excluding the current earnings report and concurrent information. Before the earnings report at time t, the market's expectation of the cumulative sum of past, current, and discounted future earnings is

$$p_t^{\text{pre-report}} = \sum_{k+0}^{t} \varepsilon_{1,k} + \left(\delta_I \left(\nu_{1,t} + \nu_{1,t-1}\right) + E\left[\sum_{k=t+2}^{\infty} \delta_I^{k-t} \varepsilon_{1,k} | I_t^{\text{market}} \setminus \{e_t\}\right]\right) \tag{18}$$

$$+E\left[\sum_{k=0}^{t-1} \varepsilon_{2,k} | I_t^{\text{market}} \setminus \{e_t\}\right] + E\left[\sum_{k=t}^{\infty} \delta_I^{k-t} \varepsilon_{2,k} | I_t^{\text{market}} \setminus \{e_t\}\right] \tag{19}$$

The first summand $\left(\sum_{k+0}^{t} \varepsilon_{1,k}\right)$ represents the part of all earnings that investors learned perfectly from other information sources, and the second summand $\left(\delta_I \left(\nu_{1,t} + \nu_{1,t-1}\right) + E\left[\sum_{k=t+2}^{\infty} \delta_I^{k-t} \varepsilon_{1,k} | I_t^{\text{market}} \setminus \{e_t\}\right]\right)$ is investors' expectation of future part of earnings that they will eventually know. Since the two parts of earnings, ε_1 and ε_2, are independent and investors perfectly know the history of the first part, ε_1, investors do not rely on the manager's report to build their expectations about future first part of earnings, $E\left[\sum_{k=t+1}^{\infty} \delta_I^{k-t} \varepsilon_{1,k} | I_t^{\text{market}} \setminus \{e_t\}\right]$, but rather rely on their knowledge of the history of earnings. The third summand represents investors' belief about what the second part of earnings was in prior periods. Because investors do not observe this part of earnings, the only sources of information about it are the manager's earnings reports. For example, the information about the second part of yearnings at year $t-1$, $\varepsilon_{2,t-1} = \nu_{2,t-1} + \nu_{2,t-2} + \nu_{2,t-3}$, was contained in the most recent earnings report, e_{t-1}, the earnings report one year ago, e_{t-2}, because it contained ν_{t-2} and ν_{t-3}, and the earnings report two years ago, e_{t-3}, because it contained the earnings shock that persists for the next three years, ν_{t-3}. Finally, the fourth summand describes investors' expected second part of current and future earnings and similarly relies on the history of the earnings reports, which contain information about earnings shocks that will persist for some time in the future.

At the time of the earnings release, two types of information arrive. First, the earnings report itself, e_t, provides investors with information about the current earnings, which include shocks that will persist at time $t+1$ and $t+2$. Second, concurrent information sources (e.g., earnings calls) reveal some information about the next period's earnings, $v^0_{1,t+1}$. The firm's price right after the earnings report is released is

$$p_t^{\text{post-report}} = \sum_{k=0}^{t} \varepsilon_{1,k} + \left(\delta_I \left(v^0_{1,t+1} + v_{1,t} + v_{1,t-1} \right) + E\left[\sum_{k=t+2}^{\infty} \delta_I^{k-t} \varepsilon_{1,k} | I_t^{\text{market}} \right] \right) \tag{20}$$

$$+E\left[\sum_{k=0}^{t-1} \varepsilon_{2,k} | I_t^{\text{market}} \right] + E\left[\sum_{k=t}^{\infty} \delta_I^{k-t} \varepsilon_{2,k} | I_t^{\text{market}} \right] \tag{21}$$

This price differs from the price right before the earnings report in, first, the updated expectation of the first part of the next period's earnings, $\delta_I \left(v^0_{1,t+1} + v_{1,t} + v_{1,t-1} \right)$ and, second, investors' information set being expanded to include the current earnings report e_t. The analysis of the price change leads to the following proposition.

Proposition 2 *In the steady state, the change in firm price after the issuance of the manager's report is*

$$p_t^{\textit{post-report}} - p_t^{\textit{pre-report}} = (\delta_I + \delta_I^2 + \delta_I^3) v^0_{1,t+1} + \alpha_0 \left(e_t - E[\tilde{e}_t | I_t^{\textit{market}} \setminus \{e_t\}] \right). \tag{22}$$

The second round of price updating happens when the market acquires information throughout the year after the reporting day. The price of the firm right before the time $t+1$ earnings report release is

$$p_{t+1}^{\text{pre-report}} = \sum_{k=0}^{t} \varepsilon_{1,k} + \left(v_{1,t+1} + v_{1,t} + v_{1,t-1} \right) + E\left[\sum_{k=t+2}^{\infty} \delta_I^{k-(t+1)} \varepsilon_{1,k} | I_{t+1}^{\text{market}} \setminus \{e_{t+1}\} \right] \tag{23}$$

$$+E\left[\sum_{k=0}^{t} \varepsilon_{2,k} | I_{t+1}^{\text{market}} \setminus \{e_{t+1}\} \right] + E\left[\sum_{k=t+1}^{\infty} \delta_I^{k-(t+1)} \varepsilon_{2,k} | I_{t+1}^{\text{market}} \setminus \{e_{t+1}\} \right] \tag{24}$$

The price changes during the year because investors learn new information about earnings and misreporting incentives ($v^1_{1,t+1}$ and $\xi^1_{1,t+1}$) from other sources and also because one year passes and investors discount their expectations of current and future cash flows less.

Proposition 3 *In the steady-state, the change in firm price after the market learns* $\epsilon^1_{1,t+1}$ *and* $m^1_{1,t+1}$ *is*

$$p_{t+1}^{\textit{pre-report}} - p_t^{\textit{post-report}} = (1 + \delta_I + \delta_I^2)(v^0_{1,t+1} + v^1_{1,t+1}) - (\delta_I + \delta_I^2 + \delta_I^3) v^0_{1,t+1}$$

$$+(\alpha_1 - \alpha_0) \times (e_t - E[\tilde{e}_t | I_{t+1}^{\textit{market}} \setminus \{e_t\}]) \tag{25}$$

Next, I discuss how the market's expectations of the next earnings report evolve during a year. The market's expectation of the time-t earnings report right before its release is:

$$ME_t^{\text{pre-report}} = v_{1,t} + v_{1,t-1} + v_{1,t-2} \tag{26}$$

$$+E_t\left[v_{2,t-1} + v_{2,t-2} | I_t^{\text{market}} \setminus \{e_t\}\right] \tag{27}$$

$$+\left(\alpha_0 + \delta_M \alpha_1 + \delta_M^2 \alpha_2\right)\xi_{1,t} - \alpha_0 \xi_{1,t-3} - \delta_M \alpha_1 \xi_{1,t-2} - \delta_M^2 \alpha_2 \xi_{1,t-1} \tag{28}$$

$$-\alpha_0 E_t\left[\xi_{2,t-3} | I_t^{\text{market}} \setminus \{e_t\}\right] - \delta_M \alpha_1 E_t\left[\xi_{2,t-2} | I_t^{\text{market}} \setminus \{e_t\}\right] - \delta_M^2 \alpha_2 E_t\left[\xi_{2,t-1} | I_t^{\text{market}} \setminus \{e_t\}\right] \tag{29}$$

Similarly to the pre-report price, the market's expectation of true earnings consists of two parts: the one learned perfectly from other sources (26) and the one known imperfectly from the history of prior reports (27). The market's expectation of the bias in the earnings report, which is a function of misreporting incentives, has a similar structure. Investors know some part of the information (28) from other sources and use the history of reports to form beliefs about the other part (29).

When the earnings report is released, the market uses it to update its beliefs and also gets information about $v^0_{1,t+1}$ and $\xi^0_{1,t+1}$ from concurrent sources. The next proposition describes the market's expectation of the $t+1$ earnings report at time t, right after the earnings report e_t arrives.

Proposition 4 *In the steady-state, the market's expectation of the manager's next earnings report e_{t+1} after the issuance of the manager's report e_t is*

$$ME_t^{\textit{post-report}} = v^0_{1,t+1} + v_{1,t} + v_{1,t-1} \tag{30}$$

$$+\left(\alpha_0 + \delta_M \alpha_1 + \delta_M^2 \alpha_2\right)\xi^0_{1,t+1} - \alpha_0 \xi_{1,t-2} - \delta_M \alpha_1 \xi_{1,t-1} - \delta_M^2 \alpha_2 \xi_{1,t} \tag{31}$$

$$+\beta_0 \times \left(e_t - E[\tilde{e}_t | I_t^{\textit{market}} \setminus \{e_t\}]\right), \tag{32}$$

where β_0 is the regression coefficient of the market's expectations of the time-$t+1$ earnings report on the surprise in the time-t earnings report, defined in the Appendix.

Lines 30 and 31 show the market's known parts of true earnings and bias at time $t+1$, respectively. $v^0_{1,t+1}$ and $\xi^0_{1,t+1}$ were learned from sources concurrent with the time-t earnings report, and $v_{1,t}$, $v_{1,t-1}$, $\xi_{1,t}$, $\xi_{1,t-1}$, and $\xi_{1,t-2}$ were learned at earlier periods. The line 32 represents the market's updated beliefs about true earnings and bias at time $t+1$ based on the earnings report at time t.

During the year, investors learn information about fundamentals, $v^1_{1,t+1}$, and misreporting incentives, $\xi^1_{1,t+1}$ from sources other than earnings reports. This new information makes the market change its expectation of the earnings report at time $t+1$.

Proposition 5 *In the steady-state, the change in the market's expectation of the manager's next earnings report e_{t+1} during the year is*

$$ME^{\textit{pre-report}}_{t+1} - ME^{\textit{post-report}}_{t} = v^1_{1,t+1} + (\alpha_0 + \delta_M \alpha_1 + \delta_M^2 \alpha_2)\xi^1_{1,t+1} \tag{33}$$

1.2.2 Earnings Quality

I define earnings quality as the negative ratio of the expected bias in the manager's earnings report to the standard deviation of earnings:

$$EQ_t = \frac{-\sqrt{E[(\epsilon_t - e_t)^2]}}{\sqrt{Var[\epsilon_t]}} = \frac{-\sqrt{\sigma^2_\xi \left((\alpha_0 + \delta_M \alpha_1 + \delta_M^2 \alpha_2)^2 + \alpha_0^2 + \delta_M^2 \alpha_1^2 + \delta_M^4 \alpha_2^2 \right)}}{\sqrt{3\sigma^2_v}} \tag{34}$$

The market's information – q_v and q_ξ – affect the measure of earnings quality through the price responses to the manager's report, α_0, α_1, and α_2. Figures 2 and 3 plot firm price responses to the earnings report. In line with **?**, as investors know more fundamental information (q_v increases), prices become less responsive to the manager's report, reducing the reward that the manager gets per unit of manipulated earnings. As a result, earnings quality improves. Vice versa, when the market learns more information about the manager's misreporting incentives (q_ξ increases), investors are relying more on the earnings report, or become more responsive to it. The manager's reward for misreporting increases, and earnings quality declines. Figures 4 and 5 show how earnings quality changes with the amount of fundamental and misreporting incentives information that investors have, respectively.

[Insert Figure 2 around here]

[Insert Figure 3 around here]

[Insert Figure 4 around here]

[Insert Figure 5 around here]

1.2.3 Price Efficiency

I define price efficiency as the negative deviation of the firm's price from its hypothetical value if the market knew all the information that the manager knows:

$$
\begin{aligned}
PE_t &= -\sqrt{E[(p_t - \text{True Expected Value})^2]} \\
&= -\sqrt{E\left[\left(E\left[\sum_{k=0}^{k=t}\tilde{\epsilon}_k + \sum_{k=t+1}^{k=\infty}\delta_I^{k-t}\tilde{\epsilon}_k | I_t^{\text{market}}\right] - E\left[\sum_{k=0}^{k=t}\tilde{\epsilon}_k + \sum_{k=t+1}^{k=\infty}\delta_I^{k-t}\tilde{\epsilon}_k | I_t^{\text{manager}}\right]\right)^2\right]} \\
&= -\sqrt{(1-q_v)\sigma_v^2\left((\delta_I + \delta_I^2)^2 + \delta_I^2\right) + (1-q_\xi)\sigma_\xi^2\left((\alpha_0 + \delta_M\alpha_1 + \delta_M^2\alpha_2)^2 + (\alpha_0 + \delta_M\alpha_1)^2 + \alpha_0^2\right)}
\end{aligned}
\tag{35}
$$

In figures 6 and 7 I plot price efficiency as a function of the market's fundamental (q_v) and misreporting incentives (q_ξ) information, respectively. In contrast to earnings quality, price efficiency is increasing in both types of information: the more investors know, the more efficient is the price.

[Insert Figure 6 around here]

[Insert Figure 7 around here]

The fact that investors' misreporting incentives information affects earnings quality and price efficiency in opposite directions points to a trade-off faced by regulators. For example, a policy that requires corporations to disclose more information on executive compensation will make investors better off because companies will be traded closer to their fundamental values. At the same time, external users of financial information will be worse off because the information will get noisier. The regulators' ultimate decision will be determined by their objective function, or the extent to which they prioritize traders on the market versus the precision of reported earnings numbers.

1.2.4 The role of discount factors

Investors' response to earnings, and thus bias in earnings numbers and price efficiency are sensitive to discount rates of the manager and investors. Therefore, assumptions about discount factors might affect estimation results. Let us discuss how key statistics of the model vary with the extent to which investors and the manager care about the future.

Investors' discount factor affects ERC, earnings quality, and price efficiency monotonically. When market participants care more about the future, they react more strongly to earnings information (figure 8), reducing earnings quality (figure 9). Price efficiency also goes down as investors' discount factor increases (figure 10). When traders value future cash flows more, they put a higher weight on the expected financial performance of the firm, and the uncertainty about the fundamentals loads higher in price variance.

[Insert Figure 8 around here]

[Insert Figure 9 around here]

[Insert Figure 10 around here]

The impact of the manager's discount factor is more complicated. The ERC is decreasing when the manager cares more about her future utility (figure 11), implying an unambiguous effect on the quality of earnings. On the one hand, when the manager values future utility more, she values the effect of her bias on future prices more and misreports more. This positive effect is offset by the decreasing ERC: as the manager is more forward-looking, investors do not react as strongly to her report, reducing the value of the bias. The two forces generate an inverse-U-shaped earnings quality as a function of the manager's discount factor (figure 12). Price efficiency also changes non-monotonically when the manager's discount factor increases (figure 13). Similarly to the investors' discount factor, a higher manager's discount factor means the price varies more with investors' uncertainty. At the same time, this uncertainty is reduced when investors react less strongly to the earnings. For very myopic managers, the first effect dominates, and as the manager becomes more farsighted, the second effect wins.

[Insert Figure 11 around here]

[Insert Figure 12 around here]

[Insert Figure 13 around here]

1.3 Theoretical moments and identification

In this section, I list theoretical moments and explain how they help identify model parameters: the total fundamental and misreporting incentives uncertainty, σ_v^2 and σ_ξ^2, the fractions of fundamental and misreporting incentives information that the market knows, q_v and q_ξ, and the part of these fractions that investors learn from sources concurrent with earnings reports, q_v^0 and q_ξ^0. In total, I use ten theoretical moments. The first moment is a mean moment:

1. Earnings response coefficient:

$$E\left[p_t^{\text{post-report}} - p_t^{\text{pre-report}} - \alpha_0 \times \left(e_t - E\left[e_t | I_t^{\text{market}} \setminus \{e_t\}\right]\right)\right] = 0 \tag{36}$$

The next set of moments is variances of earnings reports and market's expectations:

2. Variance of earnings reports:

$$Var\left[e_t\right] = 3\sigma_v^2 + \left(\alpha_0 + \delta_M\alpha_1 + \delta_M^2\alpha_2\right)^2\sigma_\xi^2 + \alpha_0^2\sigma_\xi^2 + \delta_M^2\alpha_1^2\sigma_\xi^2 + \delta_M^4\alpha_2^2\sigma_\xi^2 \tag{37}$$

3. Residual variance of regressing the market's expectation of the time-$t+1$ earnings report on the time-t earnings report surprise:

$$\begin{aligned} &Var\left[ME_t^{\text{post-report}} - \beta_0 \times \left(e_t - E\left[e_t | I_t^{\text{market}} \setminus \{e_t\}\right]\right)\right] \\ &= q_v q_v^0\sigma_v^2 + 2q_v\sigma_v^2 + q_\xi q_\xi^0\sigma_\xi^2\left(\alpha_0 + \delta_M\alpha_1 + \delta_M^2\alpha_2\right)^2 + q_\xi\sigma_\xi^2\alpha_0^2 + q_\xi\sigma_\xi^2\delta_M^2\alpha_1^2 + q_\xi\sigma_\xi^2\delta_M^4\alpha_2^2 \end{aligned} \tag{38}$$

4. Variance of change in the market's expectation of the next earnings report during a year:

$$Var\left[ME_{t+1}^{\text{pre-report}} - ME_t^{\text{post-report}}\right] = q_v(1-q_v^0)\sigma_v^2 + q_\xi(1-q_\xi^0)\sigma_\xi^2\left(\alpha_0 + \delta_M\alpha_1 + \delta_M^2\alpha_2\right)^2 \tag{39}$$

Finally, I use covariances of earnings reports, the market's expectations of earnings reports, and firm prices with each other:

5. Covariance of time-$t+1$ earnings reports with residuals of the time-t "ERC" regression:

$$Cov\left[e_{t+1}, p_t^{\text{post-report}} - p_t^{\text{pre-report}} - \alpha_0 \times \left(e_t - E\left[e_t | I_t^{\text{market}} \setminus \{e_t\}\right]\right)\right] = q_v q_v^0\sigma_v^2\left(\delta_I + \delta_I^2 + \delta_I^3\right) \tag{40}$$

6. Covariance of time-$t+1$ earnings reports with residuals from regressing change in prices from right

after the time-t report to right before the time-$t+1$ report on the time-t earnings report surprise:

$$Cov\left[e_{t+1}, p_{t+1}^{\text{pre-report}} - p_t^{\text{post-report}} - (\alpha_1 - \alpha_0) \times \left(e_t - E\left[e_t | I_t^{\text{market}} \setminus \{e_t\}\right]\right)\right]$$
$$= q_v q_v^0 \sigma_v^2 (1 - \delta_I^3) + q_v (1 - q_v^0) \sigma_v^2 (1 + \delta_I + \delta_I^2) \tag{41}$$

7. Covariance of time-$t+1$ earnings reports with residuals from regressing the market's expectation of the time-$t+1$ earnings report on the time-t earnings report surprise:

$$Cov\left[e_{t+1}, ME_t^{\text{post-report}} - \beta_0 \times \left(e_t - E\left[e_t | I_t^{\text{market}} \setminus \{e_t\}\right]\right)\right]$$
$$= q_v q_v^0 \sigma_v^2 + 2 q_v \sigma_v^2 + q_\xi q_\xi^0 \sigma_\xi^2 \left(\alpha_0 + \delta_M \alpha_1 + \delta_M^2 \alpha_2\right)^2 + q_\xi \sigma_\xi^2 \alpha_0^2 + q_\xi \sigma_\xi^2 \delta_M^2 \alpha_1^2 + q_\xi \sigma_\xi^2 \delta_M^4 \alpha_2^2 \tag{42}$$

8. Covariance of time-$t+1$ earnings reports with changes in the market's expectations of the next earnings reports during a year:

$$Cov\left[e_{t+1}, ME_{t+1}^{\text{pre-report}} - ME_t^{\text{post-report}}\right] = q_v (1 - q_v^0) \sigma_v^2 + q_\xi (1 - q_\xi^0) \sigma_\xi^2 \left(\alpha_0 + \delta_M \alpha_1 + \delta_M^2 \alpha_2\right)^2 \tag{43}$$

9. Covariance of the residuals from regressing $\left(p_t^{\text{post-report}} - p_t^{\text{pre-report}}\right)$ on the time-t earnings surprise with residuals from regressing $ME_t^{\text{post-report}}$ on the same surprise:

$$Cov\left[p_t^{\text{post-report}} - p_t^{\text{pre-report}} - \alpha_0 \times \left(e_t - E\left[e_t | I_t^{\text{market}} \setminus \{e_t\}\right]\right), ME_t^{\text{post-report}} - \beta_0 \times \left(e_t - E\left[e_t | I_t^{\text{market}} \setminus \{e_t\}\right]\right)\right]$$
$$= q_v q_v^0 \sigma_v^2 \left(\delta_I + \delta_I^2 + \delta_I^3\right) \tag{44}$$

10. Covariance of the residuals from regressing $\left(p_{t+1}^{\text{pre-report}} - p_t^{\text{post-report}}\right)$ on the time-t earnings surprise with changes in the market's expectations of next earnings reports during a year:

$$Cov\left[p_{t+1}^{\text{pre-report}} - p_t^{\text{post-report}} - (\alpha_1 - \alpha_0) \times \left(e_t - E\left[e_t | I_t^{\text{market}} \setminus \{e_t\}\right]\right), ME_{t+1}^{\text{pre-report}} - ME_t^{\text{post-report}}\right]$$
$$= q_v (1 - q_v^0) \sigma_v^2 \left(1 + \delta_I + \delta_I^2\right) \tag{45}$$

The intuition for identification is the following. I need to disentangle, first, the manager's information from the market's information, which is a subset of the manager's. Second, fundamental information from incentives information. Third, within the market's fundamental and incentives information, information learned on earnings announcement days from information learned on other days. For the first part, for the manager's information, I use the variance of earnings reports (moment 2) since they are affected by all of the manager's information. In addition, I use the earnings response coefficient (moment 1) as it represents the amount of information contained in the manager's report that was not available to investors prior to the earnings release: if the report contains more new information, investors will react stronger to it. For the market's information – the part of the manager's information that investors learn from elsewhere – I use statistics that represent the evolution of price and the market's expectations of the next report (proxied by analyst forecasts) unexplained by the manager's report (moments 3-10). If prices and analyst forecasts evolve more even after "controlling" for earnings, the market learns more information from other sources.

For the second part, to distinguish the market's fundamental from the market's incentives information, I rely on two assumptions. First, I assume that a firm's price changes only when investors update their beliefs about firm fundamentals, but not about the firm manager's misreporting incentives.[5] Therefore, changes in firms' prices unexplained by earnings (moments 5, 6, 9, and 10) represent the amount of fundamental information known by the market. The second assumption is that when financial analysts try to predict the next earnings report, they forecast both true earnings and the bias that will be added to true earnings by the manager.[6] Since the bias is increasing in the manager's misreporting incentives, analyst forecasts represent a combination of the market's knowledge about fundamentals (true earnings) and the manager's incentives (bias). The evolution of analyst forecasts unexplained by earnings (moments 3, 4, 7, and 8), coupled with the knowledge of the market's fundamental information obtained from prices, helps identify the market's misreporting incentives information learned from other sources. For example, if analyst forecasts vary considerably during a year but prices do not, the market likely learned a lot of misreporting incentives information but not fundamental information.

For the third part, I exploit the timing of changes in firm prices and analyst forecasts. Residual changes in prices and analyst forecasts around earnings announcements after controlling for earnings

[5]This assumption implies that the manager's price-related misreporting incentives are orthogonal to the firm's fundamental characteristics. Any correlation between the manager's incentives to manage earnings and the firm's financial performance, such as the selection of managers that are more likely to manipulate into certain kinds of companies, would violate my assumption.

[6]This assumption is consistent with the evidence that analysts try to forecast the reported earnings number as closely as possible because forecast precision is the key driver in analysts' compensation and career (Mikhail et al. (1999), Hilary and Hsu (2013)).

(moments 3, 5, 7, and 9) represent information on fundamentals and incentives learned during the earnings announcement window from sources other than the earnings report. Changes in prices and analyst forecasts during the year excluding the earnings announcement window (moments 4, 6, 8, and 10) indicate the amount of information investors learned on other days of the year.

Finally, I discuss one important limitation of the model that precludes me from using price variances in estimation and only keeping covariances of prices with earnings reports and analyst forecasts. The model assumes that firms' prices are efficient and there is no volatility in returns due to factors not explained by the information about firm fundamentals.[7] Because price volatility may exceed fundamental volatility (LeRoy and Porter (1981), Shiller (1980)), one might worry that estimates of my model overstate the effect of the firm's reports and investors' information on prices. To avoid this upward bias, I do not use variances of firm prices as moments in the estimation. I only use covariance of price changes with earnings reports and changes in analyst forecasts. To the extent that additional noise in prices (such as discount rate variation) is uncorrelated with earnings or analyst forecasts, potential noise in prices does not affect parameter estimates.

2 Empirical analysis

This section describes the data I use to estimate the model, the estimation procedure, and the main results.

2.1 Data

Annual earnings reports are from the IBES database, balance sheet variables are from Compustat, and firm prices are from the CRSP database. For pre-report prices, I take firms' market values one day before earnings release dates; for post-report prices, I take firms' market values one day after earnings release dates. A proxy for the market's expectations is analyst earnings forecasts from IBES. For pre-report expectations, I take the last analyst forecast before an earnings release; for post-report expectations, I take the first analyst forecast after an earnings release. I multiply variables from IBES by the number of common shares outstanding on the corresponding date to obtain all the variables on the firm level. All the variables are divided by firms' three-year-lagged book values to make sure firm size does not mechanically

[7] One of these factors can be variation in discount rates. For example, Vuolteenaho (2002) finds that 33% of price variation in individual stocks is explained by discount rate variation.

drive firm-level volatility of earnings innovations.

I remove firms that have missing data on one or more variables and firms with negative book value, firms with market-to-book ratio above 10, and firms with stock prices below $1. I winsorize all the variables at the 0.1% level.

The final sample contains 6,754 public firms in the United States with fiscal years from 1993 to 2020, 47,819 observations in total. Table 1 describes the sample selection procedure; table 2 presents the percent of firms in each North American Industry Classification System (NAICS) sector. More than 20% of the sample comprise manufacturing companies, followed by finance and insurance. Firms' characteristics are presented in table 3. A median company is a large company with a market-to-book ratio slightly above 1 and a healthy leverage ratio.

[Insert Table 1 around here]

[Insert Table 2 around here]

[Insert Table 3 around here]

Summary statistics for the variables used in estimation are in Table 4. Reported earnings and changes in prices are positive on average. Analysts' forecasts generally go down during a year, consistent with the well-documented analyst forecast walk-down (e.g., Richardson et al. (2004), Bradshaw et al. (2016)): analysts tend to be more optimistic at the beginning of the forecasting period and gradually reduce their expectations as the date moves closer to the reporting date. This bias can be attributed to analysts' excessive optimism, desire to curry favor with companies' managers, or forecasting difficulty.

The standard deviation of price changes between two annual reports is about 4 (12) times greater than the standard deviation of earnings reports (analyst forecasts), consistent with the return volatility puzzle (Mehra and Prescott (1985)). Since my model is not primarily about companies' valuation, I do not aim to closely match the volatility of price changes in the data.

[Insert Table 4 around here]

2.2 Estimation Procedure

I use the two-step Generalized Method of Moments (GMM) to estimate the model (Hansen (1982)). The method looks for the values of theoretical parameters (σ_ν^2, q_ν, q_ν^0, σ_ξ^2, q_ξ, and q_ξ^0) that minimize the distance between theoretical moments (e.g., variance of earnings reports as a function of the theoretical parameters), and empirical moments (e.g., variance of earnings report calculated from the data). The distance is measured as a quadratic form of differences between theoretical and empirical moments with a weighting matrix. I describe the estimation procedure in more detail in Appendix.

Next I discuss how I choose the discount factors of investors and the manager. For investors' discount factor, I pick $\delta_I = 0.95$, which implies a discount rate of about 5%, which is close to discount rates assumed in prior literature (Cooper and Ejarque (2003), Hennessy and Whited (2005), Hennessy and Whited (2007)). For the manager's discount factor, I follow Bertomeu et al. (2022) and set $\delta_M = 0.7$. Bertomeu et al. (2022) compute this discount factor using median vesting duration (Gopalan et al. (2014)). I examine robustness of the model's estimates to the assumptions about discount in section 5.

2.3 Main Results and Model Fit

Table 5 presents the estimated parameters. The estimates suggest that while firm earnings are volatile, investors anticipate a high portion of earnings before the report is released. The total variance of annual innovations in firms' earnings is 0.074, implying that for 32% of companies, innovation of unbiased earnings deviates from the mean by more than 27.2% of these companies' three-year-lagged book value.[8] The market knows 82.8% of this innovation from sources other than the manager's report, and 12.3% of this 82.8% is learned about one year ahead, concurrently with the previous earnings report. Investors seem to know a lot about firm earnings, and only a small part of this knowledge is acquired when prior earnings are released, suggesting that sources other than managerial guidance or concurrent analyst reports are important for the market learning about fundamentals.

Managers' misreporting incentives are considerably more uncertain in general and opaque to investors. The total variance of innovations in the manager's misreporting incentives is 0.630. For 32% of firms, innovation of the manager's utility gain per $1 increase in firm prices deviates from its mean by 79.37% of the firm's 3-year-lagged book value. The market knows 60.7% of this innovation, and 91.7% of this 60.7% is learned concurrently with the previous earnings report. Compared to fundamentals, the market is less aware of managers' incentives to manipulate reported earnings. Interestingly, prior earnings report day is more significant for learning about reporting incentives than about fundamentals,

[8] This inference is calculated as the fraction of observations from a normal distribution not within one standard deviation of the mean.

perhaps because both company management and external analysts often disclose their expectations for next year's earnings on that day.

[Insert Table 5 around here]

Table 6 shows values of the empirical and theoretical moments at the estimated parameters and t-values of differences between the theoretical and empirical moments. For 8 out of 10 moments, differences between estimated theoretical and empirical values are statistically indistinguishable from zero. One of the other two estimated moments, the earnings response coefficient, is economically close to its data counterpart. The model fails to match one of the moments – covariance of price changes with the earnings report.

[Insert Table 6 around here]

The estimated parameters suggest that the level of earnings quality is -1.83, or reported earnings on average differ from true earnings by 183% of the standard deviation of true earnings. For a median company in my sample, misreporting is about 0.18% of the company's total assets.

Price efficiency is estimated to be low: for a representative company in my sample, the actual market value is different from a hypothetical market value without information asymmetry between investors and the manager by about 66.47% of the company's three-year lagged book value.

3 Counterfactual analyses

A structural model allows researchers to predict how financial markets would behave in different counterfactual scenarios without implementing these scenarios in real markets. In this section, I use this advantage of structural modeling to assess how different hypothetical regulations and other exogenous changes to the economic environment may affect the informativeness of financial information and the efficiency of firms' prices. First, I summarize the sensitivities of earnings quality and price efficiency to the overall uncertainty and the market's knowledge of firm fundamentals and managers' misreporting incentives. Next, I consider more substantial changes to the information environment.

3.1 Sensitivities of Earnings Quality and Price Efficiency

To better understand which factors affect the bias in reported earnings and deviation of firm prices from their fundamental values, I study several changes to the model's parameters. For every parameter governing overall uncertainty or investors' knowledge, I change the estimated value by 10% up and down while keeping other parameters fixed. I then look at the resulting changes in earnings quality and price efficiency. This analysis shows which factors (e.g., fundamental or misreporting incentives uncertainty or investors' knowledge) primarily move financial market outcomes.

Histograms of sensitivities are presented in figures 14 and 15. The analysis suggests that the factor that deserves regulators' attention the most is the amount of fundamental information known by investors. Both earnings quality and price efficiency are most sensitive to investors' fundamental information, and this sensitivity more than thrice exceeds sensitivities to other economic parameters. A policy that reduces stock market investors' information about firm fundamentals, such as decreased mandatory disclosure, by about 10%, will cause an almost 12% drop in price efficiency and about a 10% drop in earnings quality.

The non-trivial effects of investors' misreporting incentives information can be seen in the last bars of the histograms. When investors acquire more information about managers' incentives, price efficiency improves while the informativeness of reported earnings goes down. Changes in the two statistics are of similar magnitudes, showing a meaningful trade-off regulators face when deciding whether to increase the amount of misreporting incentives information provided to investors.

Earnings quality and price efficiency co-move when misreporting incentives uncertainty changes but move in opposite directions when fundamental uncertainty changes. A firm's price is closer to its fair value when investors are less uncertain about fundamentals or misreporting incentives. For earnings quality, this rule does not work. When misreporting incentives uncertainty is high, the noisy term in earnings reports is significant, making them less informative. In contrast, higher fundamental uncertainty increases the signal-to-noise ratio in earnings, providing users of earnings numbers with better information.

[Insert figures 14 and 15 around here.]

3.2 Fundamental changes in information environment

Next, I consider more profound changes to the information environment. First, I analyze and compare two economies: in one, fundamental uncertainty is a bigger concern than misreporting incentives uncertainty – perhaps an economy with high morality where firm managers try to be truthful with their investors, – and in another, misreporting incentives are much more volatile. The second set of counterfactuals is about markets with perfect information. In the first market, investors know everything about companies' fundamentals, and in the second, traders perfectly understand managers' incentives to misrepresent financial information.

3.2.1 Fundamental vs. misreporting incentives uncertainty

The first set of counterfactual analyses aims to understand to what extent two uncertainties – volatilities of companies' fundamentals and managers' incentives to misreport – affect financial markets. The results suggest that high misreporting incentives uncertainty is more harmful to earnings quality and price efficiency than fundamental uncertainty. The first two rows of table 7 show estimated earnings quality and price efficiency in scenarios where fundamental uncertainty is infinitely higher than misreporting incentives uncertainty and vice versa. In an economy where misreporting incentives are not a concern (first row of table 7), a representative company's earnings number is very close to its unbiased earnings. Even though investors in this economy obtain close to truthful financial information, the market price still deviates from its value without information asymmetry by about 23.45% of companies' book value. The reason is that at an arbitrary point in time, capital market participants do not know all fundamental information before the manager releases the annual report. For the economy with the opposite uncertainty concerns, where managers' misreporting incentives vary a lot, financial information quality and price efficiency are considerably worse. When investors are very uncertain about managers' incentives to misrepresent financial information, even a small piece of information about incentives from other sources makes traders think they understand reports much better, tremendously increasing the earnings response coefficient. As a result, managers benefit more from misreporting and bias earnings a lot. The bias can achieve a few hundred thousand percent of the standard deviation of true earnings. The price is also less efficient in such an economy: it deviates from the fair value by about 62% of companies' book value, suggesting that misreporting incentives uncertainty impacts prices more than fundamental uncertainty.

3.2.2 Perfect knowledge of fundamentals vs. of misreporting incentives

Next, let us consider scenarios where market participants know close to everything about companies' fundamentals (third row of table 7) and managers' incentives to misreport (fourth row of table 7). If a social planner were to choose between giving investors more fundamental or more misreporting incentives information, she would face a trade-off. Increasing fundamental information makes earnings numbers less biased; however, providing more information about incentives substantially improves price efficiency.

Counterfactual analyses demonstrate how nuanced the regulators' problem is when designing information provision systems. If we take overall fundamental and incentives uncertainties as fixed characteristics of the U.S. economy, whether to provide traders information about fundamentals or incentives depends on the regulators' objective function. A regulator who mostly cares about market participants' welfare, which can be measured with price efficiency, providing investors with as much information as possible about everything is the best strategy. Misreporting incentives information would have a greater positive effect, so the regulator should prioritize these disclosures. In contrast, a regulator who needs precise reported financial numbers would prefer investors who know little about misreporting incentives but can largely predict companies' performance.

[Insert table 7 around here.]

4 Applications: measuring policy outcome and information spillovers

Researchers face challenges when evaluating the effects of disclosure policies and thus can be limited in their ability to inform regulators. Leuz and Wysocki (2016) note that the reduced-form approach relies on proper identification to be able to provide magnitudes of policies' effects. Without the magnitudes, it is difficult for policymakers to weigh the benefits of potential regulations against their costs. Moreover, even if standard empirical methods find a credible identification strategy, it is hard for them to measure policies' externalities or economy-wide welfare implications. Policymakers, however, must consider the unintended consequences of their decisions and can not fully rely on studies that provide only evidence on local outcomes.

The structural estimation approach might help researchers better inform regulators by providing economic magnitudes and quantifying aggregate gains from policies and voluntary decisions by economic agents. First, because this method uses a mathematical theory of an economic system in equilibrium, it does not need a plausibly exogenous variation to quantify the effects of economic parameters. Furthermore, the theory accounts for potentially non-trivial relationships between different economic forces, and the estimated magnitudes may be more informative than linear coefficients. Second, structural estimation can estimate characteristics of economic systems that are not directly observed by researchers and can use these characteristics to compute the aggregate outcomes in the economy.

This section demonstrates how the method I develop can be used to quantify the effects of information-related regulations, which in turn can inform policymakers. I focus on two applications. First, I evaluate how introducing the Compensation Disclosure & Analysis (CD&A) section in corporations' proxy statements affected the quality of earnings and price efficiency in the U.S. stock market. Second, I quantify the disclosure spillover effect – or how much more information investors know about companies that report later in the earnings reporting cycle.

4.1 CD&A and the U.S. financial markets

The Securities and Exchange Commission (SEC) proposed revising rules for executive compensation disclosures in January 2006. The primary goal of the regulation was to provide investors with more information on managerial compensation and its sensitivity to company performance. Consistent with theory (**?**), reduced-form empirical evidence has confirmed that the introduction of CD&A has increased the earnings response coefficient (Ferri et al. (2018)), which may induce more earnings management.

The reduced-form approach has two limitations because of which regulators may rely on its results with caution. First, while regression coefficients can demonstrate direction and magnitude when an effect is linear, they can not measure the economic parameters of financial markets or quantify aggregate outcomes. Because the structural method can estimate abstract parameters and recover "true" earnings and "fair" prices, it allows us to measure the level of market imperfections and how they are affected by the regulation. The magnitudes are particularly valuable when a trade-off exists, like the choice between price efficiency and earnings quality when providing investors with misreporting incentives information.

Second, reduced-form estimation is limited in how it can account for other events that happen concurrently with a regulation. For instance, in the case of CD&A, fundamental uncertainty in the markets might change considerably from before 2007 to the current time. While more misreporting incentives information increases ERCs, lower fundamental uncertainty may drive ERCs down. As a result, we may not find the effect of CD&A on reporting bias in the data[9] and mistakenly conclude that the regulation did not have any effect. A regression can include multiple controls to keep omitted characteristics of the economic environment fixed, but it is limited by the quality of controls and the researcher's ability to think about all omitted factors. The benefit of structural estimation is that conditional on the model correctly describing processes we are interested in, we obtain estimates of all the characteristics of the economic environment and can evaluate which of those changed enough to explain the outcomes of the regulation.

I use my model to estimate the effect of CD&A. I evaluate all the parameters before and after the regulation to see how all economic system characteristics changed after 2006. The revisions of the proxy statements were released by the SEC in August 2006 and were effective for firms with the fiscal year ending on or after December 15, 2006. I divide my sample into two groups: before and after the compensation disclosure regulation. The "before" period is the fiscal year ends before the SEC proposal date, January 26, 2006, and the "after" period is the fiscal year ends after December 15, 2009.[10]

The results, presented in table 8, suggest that investors' misreporting incentives uncertainty indeed declined a lot in the post-CD&A period, improving price efficiency by a lot without sacrificing earnings quality. However, the more efficient price and unchanged earnings quality are not just the outcomes of the regulation, but also of the substantial changes in market-wide uncertainty. After CD&A was introduced, investors in fact started to better understand managers' misreporting incentives: the proportion of incentives information known by market participants has more than doubled, from 44.8% to 92.1%. At the same time, fundamental variance declined substantially, by about a half. Lower incentives volatility coupled with investors being generally less uncertain about firm fundamentals improved price efficiency by 56.2% without hurting the precision of reported earnings, which declined by only 0.9%. We can conclude that the CD&A introduction achieved its main goal of providing market participants with incentives information and, due to other processes in the economy at the time time, did not cause a

[9] Ferri et al. (2018) indeed only find the effect of CD&A on ERCs, but not on discretionary accruals.

[10] Since in my model every shock to firm fundamentals or misreporting incentives persists for three periods, the model needs at least three periods after a shock to converge to a new steady-state.

worrisome decline in the precision of earnings reports.

[Insert table 8 around here.]

4.2 Information spillover in the earnings reporting cycle

Empirical studies have widely documented information spillovers from companies that announce earnings earlier to their later-announcing peers. Ramnath (2002) shows that financial analysts and investors seem to better predict the earnings of firms announcing later in the reporting cycle, and the prediction partially comes from earlier reports. Savor and Wilson (2016) document higher abnormal returns for early earnings announcers. The authors posit that investors use announcers' disclosures to revise their beliefs about non-announcers, which increases covariance between early announcers' and market-wide cash flow news – early announcers' systematic risk.

It remains less clear whether the documented spillovers are economically meaningful or what kind of information market participants learn. Both Ramnath (2002) and Savor and Wilson (2016) note that investors and financial analysts do not fully incorporate earnings news from early announcing companies. The studies are also limited in providing welfare implications of information spillovers for firms later in the earnings cycle. I try to fill this void and evaluate investors' information, earnings quality, and price efficiency for companies reporting earnings at different times.

I split my sample into early and late reporters. A company is classified as a late reporter if it reported earnings later than a median company in a given year. Table 9 presents the estimation results.

[Insert table 9 around here.]

The estimated parameters for early and late reporters suggest that, while investors indeed seem to know more information about firms reporting earnings later, these firms' misreporting incentives are much more opaque, and as a result, late reporters have worse earnings quality than early reporters. Spillover of fundamental information during the reporting cycle is sizeable: for companies reporting later, investors know 81.6% of fundamental information available to firm managers, almost 40% larger than for companies reporting early. However, perhaps surprisingly, the quality of earnings of late reporters is about 80% smaller. The reason is that these companies have more uncertain misreporting incentives. Managers' incentives for late reporters are about 16 times more volatile.

Late reporters' incentives may be more opaque because firms that report later in the earnings cycle tend to (or a believed to) manage earnings more. Trueman (1990) offers a theory that connects companies' earnings management to their choice of disclosure timing. First, earnings management itself may result in delayed reporting and second, a manager who wants to manipulate may choose to observe other reports first to better understand what the market's expectations are for the earnings of her firm. Whether late firms have incentives to misreport may therefore be unclear to investors, and this uncertainty seems to outweigh the gain from learning more about fundamentals from other companies' early reports.

5 Alternative discount factors

Section 1.2.4 demonstrated that the market statistics about earnings and prices are sensitive to the manager's and investors' discount factors. As a result, the estimates of other parameters in the model likely change when I assume different discount factors. To test how the results of the study vary with the assumptions, I estimate two alternative specifications of the model. In the first specification, I reduce the investors' discount factor and set it below the manager's. In the second specification, I increase the manager's discount factor.

For both alternative specifications, the primary difference from the baseline results is the lower variance of managers' incentives. The technical explanation is that since both lower investors' discount factor and higher manager's discount factor decrease the ERC, the model makes up to match the ERC in the data by estimating that investors are generally less uncertain about the manager's incentives. Therefore, the estimated variance of misreporting incentives is higher when either investors are assumed more myopic or the manager is assumed more forward-looking. I invite the reader to use their own judgment in deciding what discount factors, and thus what variance of the managers' misreporting incentives, are descriptive of the current economic environment.

[Insert table 10 around here.]

6 Conclusion

The unambiguous effect of different types of investors' information on financial reporting quality and price efficiency makes the measurement of investors' knowledge an important question for researchers and regulators. This paper develops a technique to measure how much information the market knows about firm fundamentals and managers' misreporting incentives, the implications of this information for firms' prices, and the usefulness of accounting numbers for external users.

I apply the structural estimation approach to provide insights into what capital market investors currently know about their companies and quantify the trade-off between the quality of earnings and price efficiency. I also demonstrate how the technique can be used for assessing outcomes of information-related policies or economic agents' choices. First, I measure how much misreporting incentives investors learned after the introduction of the Compensation Disclosure & Analysis (CD&A) section in 2007 and conclude that they learned a lot and, due to simultaneous decline in the overall market's fundamental uncertainty, significantly improved price efficiency without hurting reporting quality. Second, I measure the information spillover during an earnings cycle and find that while investors indeed know more fundamental information about late reporters, the market is also more uncertain about these reporters' reporting objectives, resulting in considerably worse accounting quality for firms that report earnings later than some of their peers.

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Table 1: Sample selection procedure

Sample reduction reason	Sample size
Initial sample, containing all the variables needed from I/B/E/S and CRSP	81,138
Non-missing book value in Compustat	65,183
Positive book value	62,004
Market-to-book ratio less than or equal to 10	56,900
Price above or equal to $1	56,060
Firms with non-missing lagged reports	47,819

Table 2: Percent of firms in NAICS sectors in the sample

NAICS	% of total sample
Agriculture, Forestry, Fishing and Hunting	0.15
Mining	2.90
Utilities	1.87
Construction	0.78
Manufacturing	22.88
Wholesale Trade	1.35
Retail Trade	3.25
Transportation and Warehousing	2.32
Information	4.46
Finance and Insurance	12.61
Real Estate Rental and Leasing	2.28
Professional, Scientific, and Technical Services	3.62
Management of Companies and Enterprises	1.21
Administrative and Support and Waste Management and Remediation Services	1.13
Educational Services	0.35
Health Care and Social Assistance	0.99
Arts, Entertainment, and Recreation	0.48
Accommodation and Food Services	0.98
Other Services (except Public Administration)	0.24
Missing NAICS	36.15

Table 3: Descriptive statistics

Statistic	N	Mean	St. Dev.	Pctl(25)	Median	Pctl(75)
Book value (in $ 100 millions)	47,819	30.358	116.147	1.491	4.561	15.215
Market value (in $ 100 millions)	47,819	58.063	214.488	2.305	7.829	29.349
Total assets (in $ 100 millions)	47,297	172.535	1,176.706	3.334	12.444	47.700
Market-to-book ratio	47,819	2.218	1.726	1.078	1.697	2.758
ROA	47,293	0.020	0.138	0.006	0.032	0.070
Leverage ratio	35,142	0.735	1.676	0.032	0.356	0.847

Table 4: Summary statistics for the variables used in estimation

Statistic	N	Mean	St. Dev.	Pctl(25)	Median	Pctl(75)
Reported earnings, e_t	47,819	0.254	1.002	0.045	0.140	0.282
Earnings surprise, $e_t - E[\tilde{e}_t \mid I_t^{\text{market}} \setminus \{e_t\}]$	47,819	−0.003	0.160	−0.005	0.001	0.009
Price change around earnings announcements, $p_t^{\text{post-report}} - p_t^{\text{pre-report}}$	47,819	0.008	0.772	−0.072	0.001	0.089
Price change during a year, $p_{t+1}^{\text{pre-report}} - p_t^{\text{post-report}}$	47,819	0.564	4.893	−0.303	0.131	0.777
First analyst forecast after an earnings announcement, $ME_t^{\text{post-report}}$	47,819	0.278	0.938	0.062	0.150	0.289
Analyst forecast during a year, $ME_{t+1}^{\text{pre-report}} - ME_t^{\text{post-report}}$	47,819	−0.018	0.326	−0.035	−0.002	0.017

Table 5: Estimated model parameters

Parameter	Estimate
Fundamental variance, σ_v^2	0.074 (0.022)
Market's total share of fundamental information, q_v	0.828 (0.206)
Market's share of fundamental information received concurrently with the manager's report, q_v^0	0.123 (0.070)
Incentives variance, σ_ξ^2	0.630 (0.917)
Market's total share of incentives information, q_ξ	0.607 (0.094)
Market's total share of incentives information received concurrently with the manager's report, q_ξ^0	0.917 (0.035)
J-statistic	21.635

Note: Standard errors are in parentheses. The parameters are estimated assuming discount rates $\delta_M = 0.7$ and $\delta_I = 0.95$.

Table 6: Data moments and theoretical moments at the estimated parameters

	Moment	Empirical value	Theoretical value	t-statistic [p-value]
1	Earnings response coefficient moment	0.51789	0.42069	2.598 [0.009]
2	Variance of earnings reports	1.00411	0.96461	-0.686 [0.493]
3	Residual variance of regressing the market's expectation of the time-$t+1$ earnings report on the time-t earnings report surprise	0.61929	0.55364	-1.443 [0.149]
4	Variance of change in the market's expectation of the next earnings report during a year	0.08526	0.08125	-0.787 [0.431]
5	Covariance of time-$t+1$ earnings reports with residuals of the time-t "ERC" regression	0.03112	0.02039	-0.775 [0.439]
6	Covariance of time-$t+1$ earnings reports with residuals from regressing change in prices from right after the time-t report to right before the time-$t+1$ report on the time-t earnings report surprise	0.52588	0.15428	-2.733 [0.006]
7	Covariance of time-$t+1$ earnings reports with residuals from regressing the market's expectation of the time-$t+1$ earnings report on the time-t earnings report surprise	0.59363	0.55364	-0.909 [0.363]
8	Covariance of time-$t+1$ earnings reports with changes in the market's expectations of the next earnings reports during a year	0.06768	0.08125	1.322 [0.186]
9	Covariance of the residuals from regressing $\left(p_t^{\text{post-report}} - p_t^{\text{pre-report}}\right)$ on the time-t earnings surprise with residuals from regressing $ME_t^{\text{post-report}}$ on the same surprise	0.02807	0.02039	-0.591 [0.555]
10	Covariance of the residuals from regressing $\left(p_{t+1}^{\text{pre-report}} - p_t^{\text{post-report}}\right)$ on the time-t earnings surprise with changes in the market's expectations of next earnings reports during a year	0.17897	0.15321	-0.636 [0.525]

Table 7: Earnings quality and price efficiency in counterfactual scenarios

Scenario	Difference between reported and unbiased earnings, % of st.dev. of unbiased earnings	Difference between actual and no-info-asymmetry price, % of the company's book value
1. Fundamental uncertainty is much greater than misreporting incentives uncertainty, $\sigma_\xi^2 \to 0$.	0.14	23.45
2. Misreporting incentives uncertainty is much greater than fundamental uncertainty, $\sigma_v^2 \to 0$.	493,471.79	61.83
3. Investors perfectly know fundamentals, $q_v \to 1$.	181.56	61.84
4. Investors perfectly know misreporting incentives, $q_\xi \to 1$.	1,132.77	23.46

Table 8: Estimated model parameters before and after the introduction of CD&A

Parameter estimate	Before CD&A	After CD&A
Fundamental variance, σ_v^2	0.100 (0.114)	0.053 (0.026)
Market's total share of fundamental information, q_v	0.789 (0.914)	0.550 (0.258)
Market's share of fundamental information received concurrently with the manager's report, q_v^0	0.044 (0.100)	0.153 (0.208)
Incentives variance, σ_ξ^2	0.973 (4.301)	0.030 (0.014)
Market's total share of incentives information, q_ξ	0.448 (0.331)	0.921 (0.051)
Market's total share of incentives information received concurrently with the manager's report, q_ξ^0	0.996 (0.058)	0.826 (0.041)
Earnings quality, negative bias in earnings, % of st.dev. of unbiased earnings	−1.849	−1.866
Price efficiency, negative deviation of price from fair value, % of the company's book value	−0.917	−0.402

Note: Standard errors are in parentheses. The parameters are estimated assuming discount rates $\delta_M = 0.7$ and $\delta_I = 0.95$.

Table 9: Estimated model parameters for early and late earnings reporters

Parameter estimate	**Early reporters**	**Late reporters**
Fundamental variance, σ_v^2	0.111 (0.026)	0.068 (0.024)
Market's total share of fundamental information, q_v	0.591 (0.127)	0.816 (0.189)
Market's share of fundamental information received concurrently with the manager's report, q_v^0	0.024 (0.095)	0.207 (0.120)
Incentives variance, σ_ξ^2	0.052 (0.039)	0.827 (0.851)
Market's total share of incentives information, q_ξ	0.591 (0.103)	0.653 (0.101)
Market's total share of incentives information received concurrently with the manager's report, q_ξ^0	0.999 (0.090)	0.875 (0.036)
Earnings quality, negative bias in earnings, % of st.dev. of unbiased earnings	−1.170	−2.109
Price efficiency, negative deviation of price from fair value, % of the company's book value	−0.665	−0.688

Note: Standard errors are in parentheses. The parameters are estimated assuming discount rates $\delta_M = 0.7$ and $\delta_I = 0.95$.

Table 10: Estimated model parameters for alternative values of discount rates

Parameter estimate	$\delta_I = 0.6, \delta_M = 0.7$	$\delta_I = 0.95, \delta_M = 0.99$
Fundamental variance, σ_v^2	0.141 (0.027)	0.091 (0.021)
Market's total share of fundamental information, q_v	0.646 (0.103)	0.645 (0.142)
Market's share of fundamental information received concurrently with the manager's report, q_v^0	0.128 (0.106)	0.096 (0.075)
Incentives variance, σ_ξ^2	0.070 (0.044)	0.085 (0.084)
Market's total share of incentives information, q_ξ	0.656 (0.080)	0.661 (0.067)
Market's total share of incentives information received concurrently with the manager's report, q_ξ^0	0.990 (0.072)	0.918 (0.037)
Earnings quality, negative bias in earnings, % of st.dev. of unbiased earnings	−1.145	−1.586
Price efficiency, negative deviation of price from fair value, % of the company's book value	−0.556	−0.643

Note: Standard errors are in parentheses.

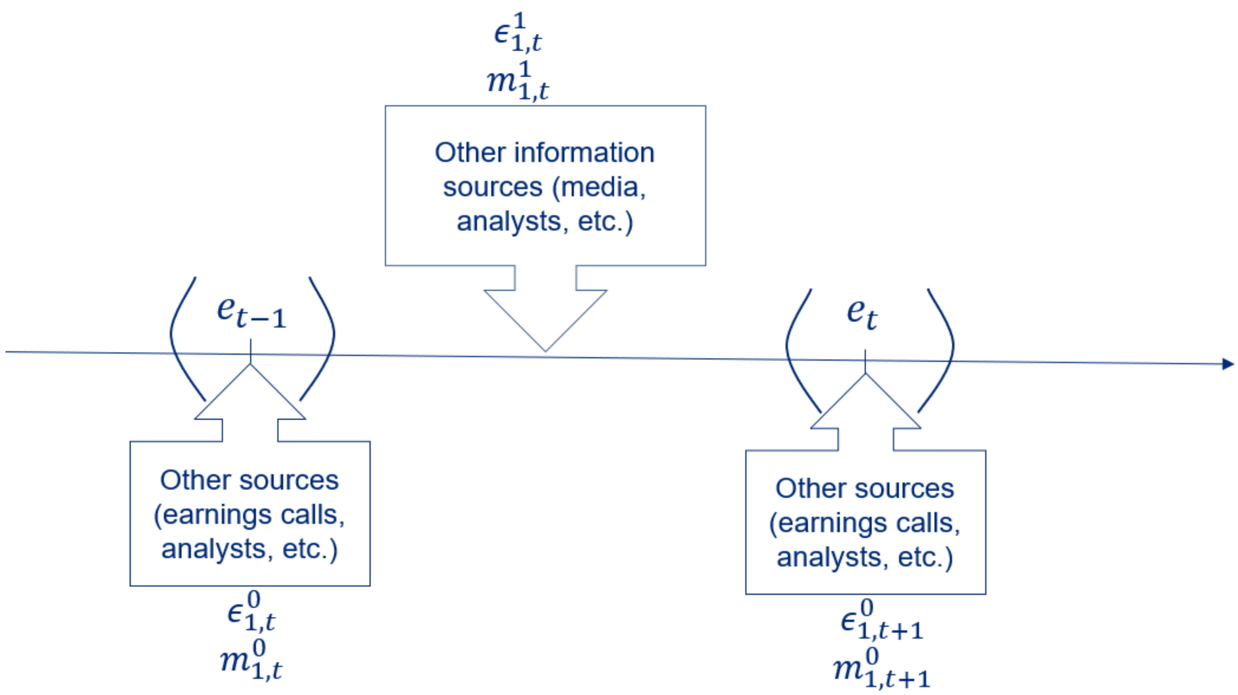

Figure 1: Timing of information arrivals to investors in the model. e_τ is an earnings report issued at time τ, ϵ_τ and m_τ are investors' earnings and misreporting incentives information related to the earnings report at time τ.

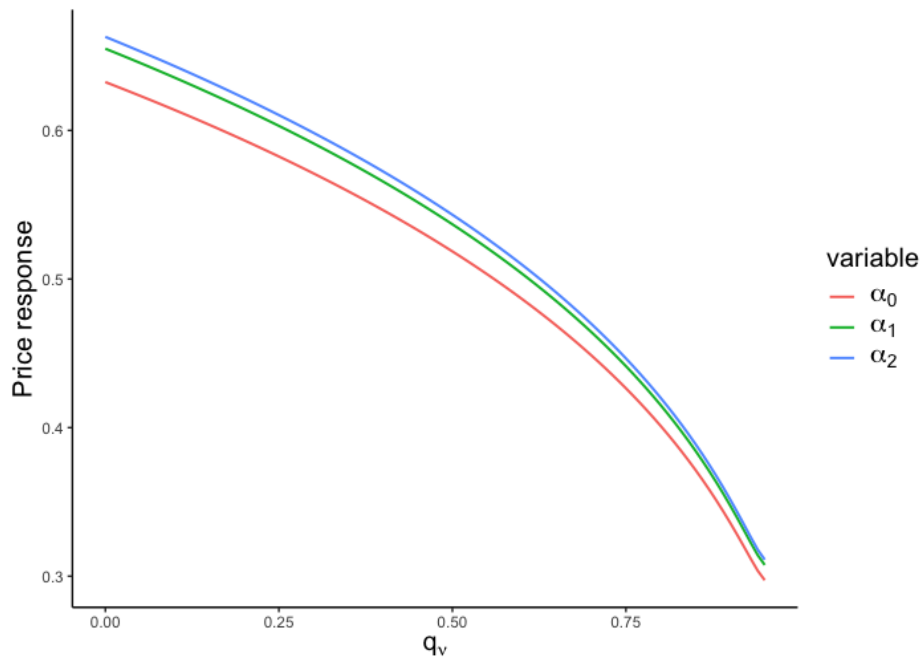

Figure 2: Price responses to the manager's report as a function of the market's fundamental information, q_v. $\sigma_v^2 = 0.8$, $q_\xi = 0.6$, $\sigma_\xi^2 = 0.5$, $\delta_M = 0.9$, $\delta_I = 0.9$.

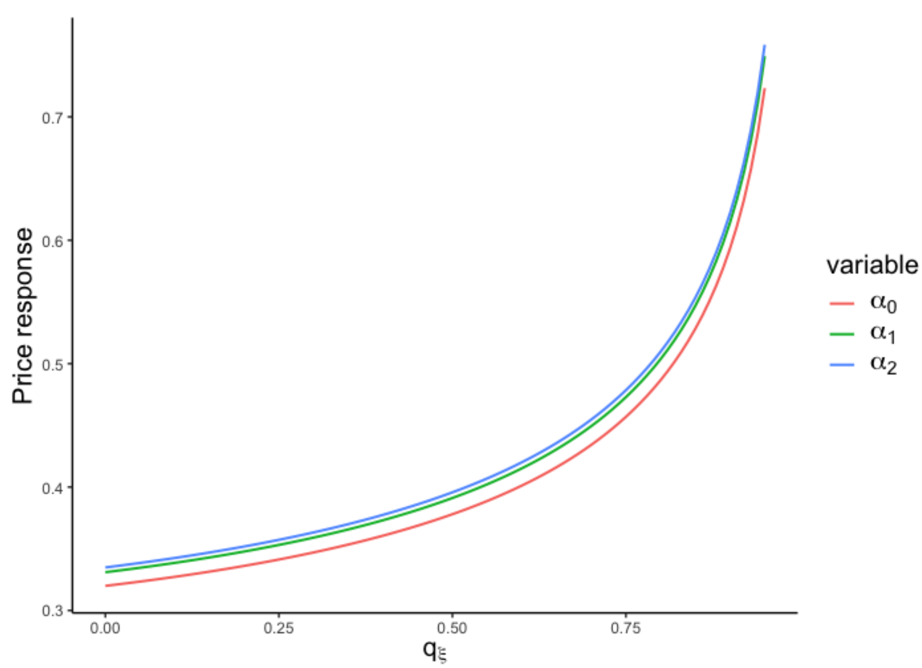

Figure 3: Price responses to the manager's report as a function of the market's misreporting incentives information, q_ξ. $q_v = 0.8$, $\sigma_v^2 = 0.08$, $\sigma_\xi^2 = 0.5$, $\delta_M = 0.9$, $\delta_I = 0.9$.

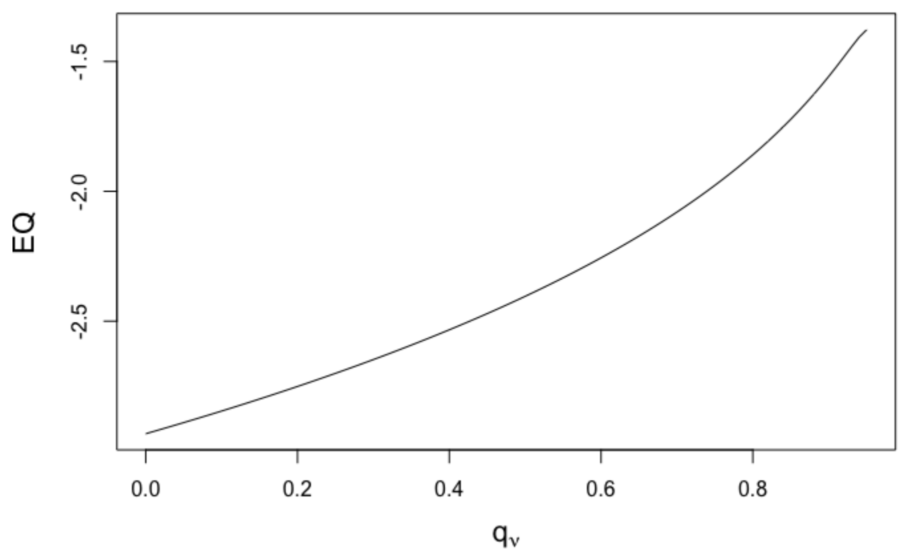

Figure 4: Earnings quality as a function of the market's fundamental information, q_ν. $\sigma_\nu^2 = 0.08$, $q_\xi = 0.6$, $\sigma_\xi^2 = 0.5$, $\delta_M = 0.9$, $\delta_I = 0.9$.

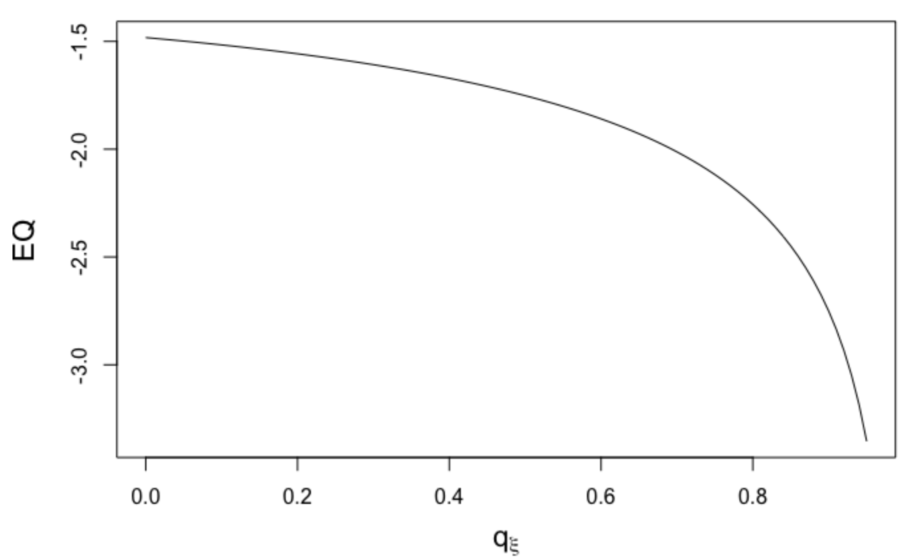

Figure 5: Earnings quality as a function of the market's misreporting incentives information, q_ξ. $q_\nu = 0.8$, $\sigma_\nu^2 = 0.08$, $\sigma_\xi^2 = 0.5$, $\delta_M = 0.9$, $\delta_I = 0.9$.

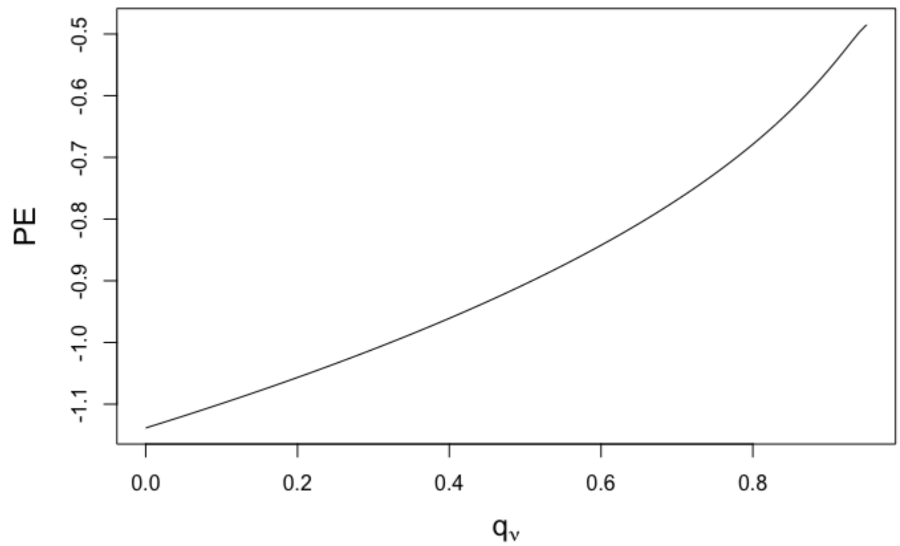

Figure 6: Price efficiency as a function of the market's fundamental information, q_ν. $\sigma_\nu^2 = 0.08$, $q_\xi = 0.6$, $\sigma_\xi^2 = 0.5$, $\delta_M = 0.9$, $\delta_I = 0.9$.

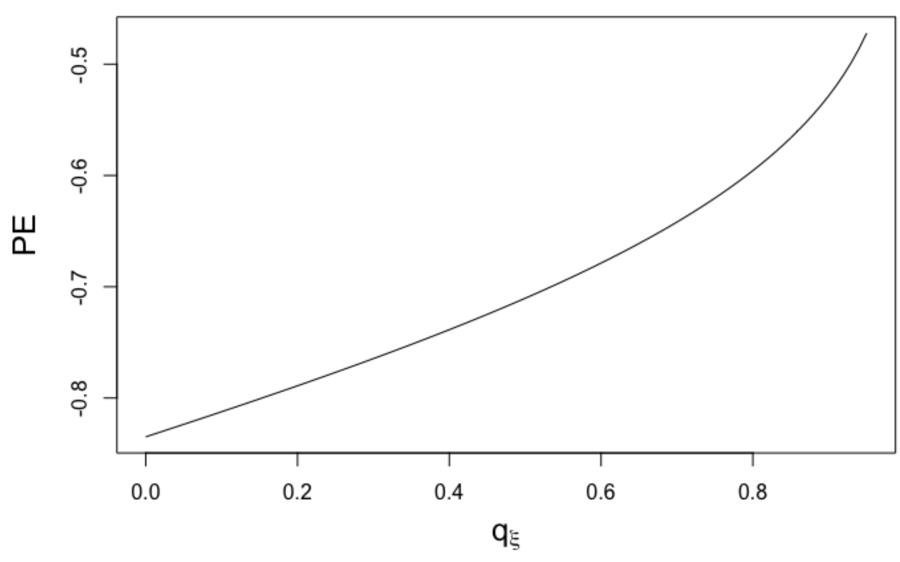

Figure 7: Price efficiency as a function of the market's misreporting incentives information, q_ξ. $q_\nu = 0.8$, $\sigma_\nu^2 = 0.08$, $\sigma_\xi^2 = 0.5$, $\delta_M = 0.9$, $\delta_I = 0.9$.

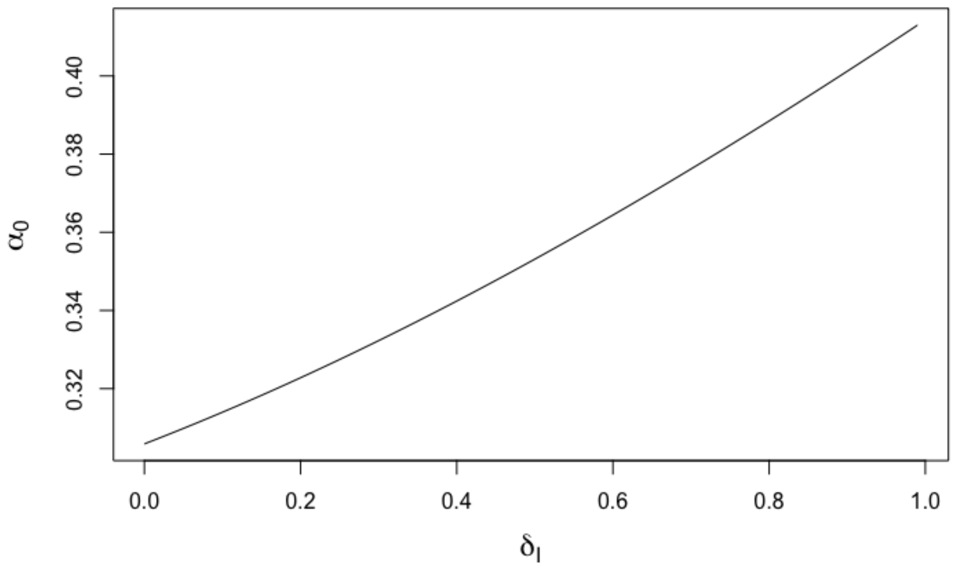

Figure 8: Earnings response coefficient as a function of investors' discount factor, δ_I. $q_\nu = 0.8, \sigma_\nu^2 = 0.08$, $q_\xi = 0.6$, $\sigma_\xi^2 = 0.5$, $\delta_M = 0.9$.

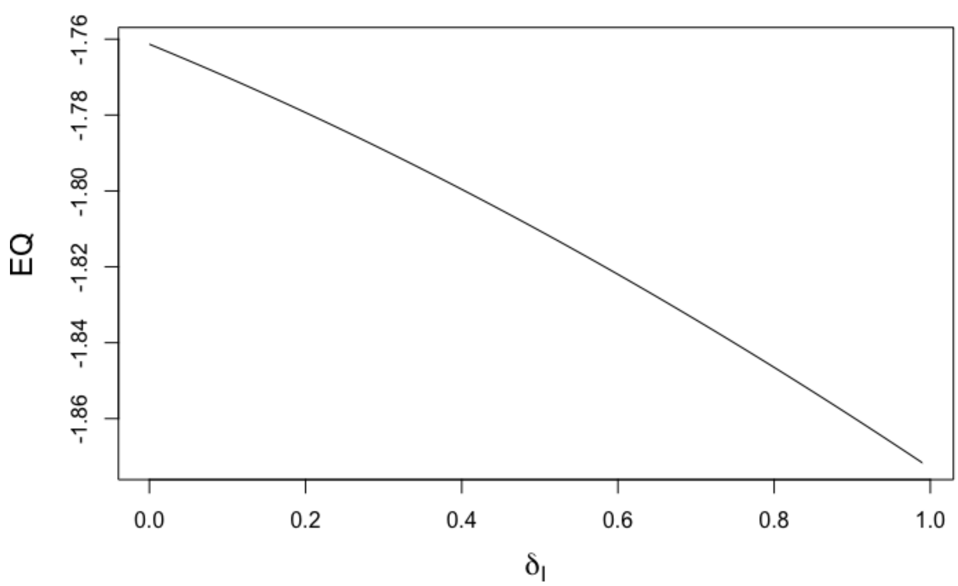

Figure 9: Earnings quality as a function of investors' discount factor, δ_I. $q_\nu = 0.8, \sigma_\nu^2 = 0.08$, $q_\xi = 0.6$, $\sigma_\xi^2 = 0.5$, $\delta_M = 0.9$.

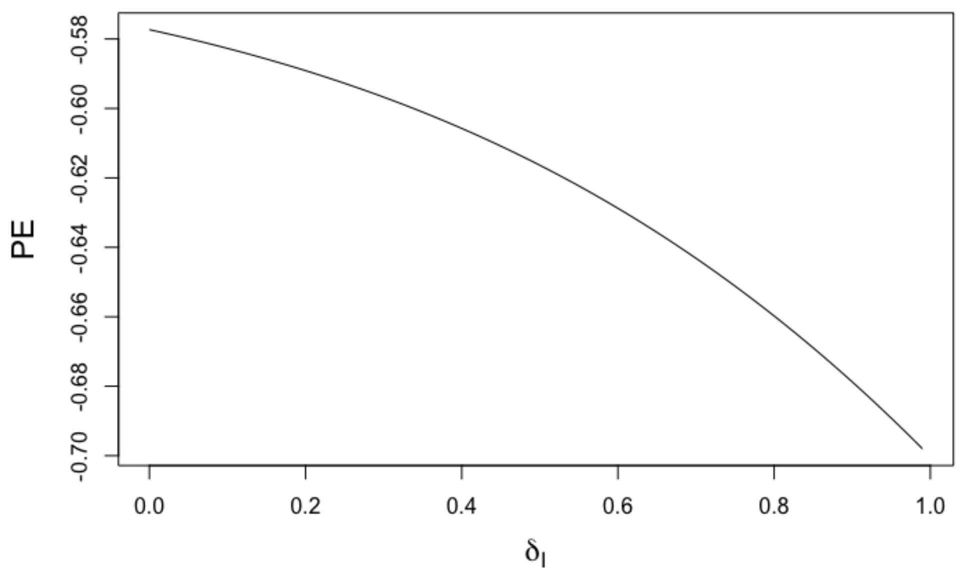

Figure 10: Price efficiency as a function of investors' discount factor, δ_I. $q_\nu = 0.8, \sigma_\nu^2 = 0.08$, $q_\xi = 0.6$, $\sigma_\xi^2 = 0.5$, $\delta_M = 0.9$.

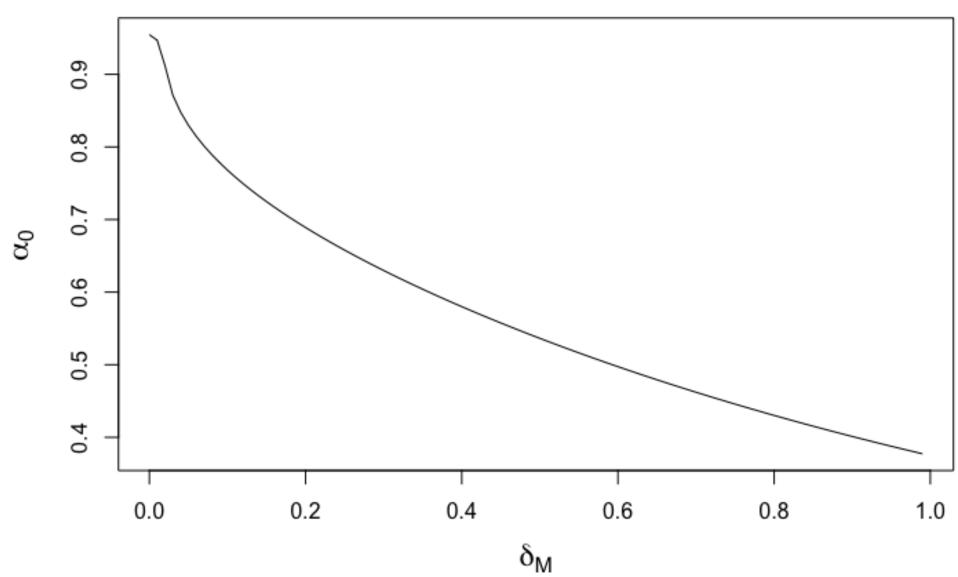

Figure 11: Earnings response coefficient as a function of the manager's discount factor, δ_M. $q_\nu = 0.8, \sigma_\nu^2 = 0.08$, $q_\xi = 0.6$, $\sigma_\xi^2 = 0.5$, $\delta_I = 0.9$.

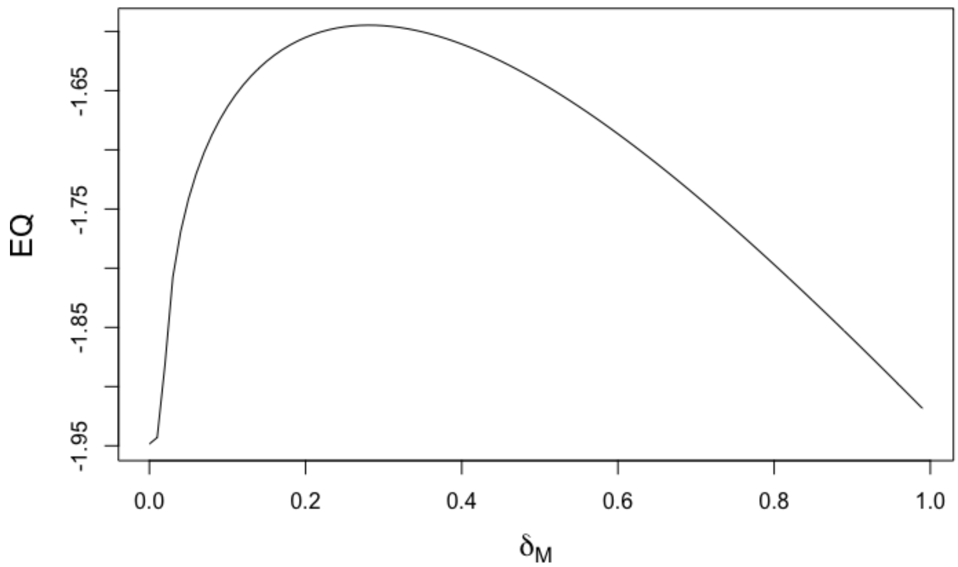

Figure 12: Earnings quality as a function of the manager's discount factor, δ_M. $q_\nu = 0.8, \sigma_\nu^2 = 0.08$, $q_\xi = 0.6$, $\sigma_\xi^2 = 0.5$, $\delta_I = 0.9$.

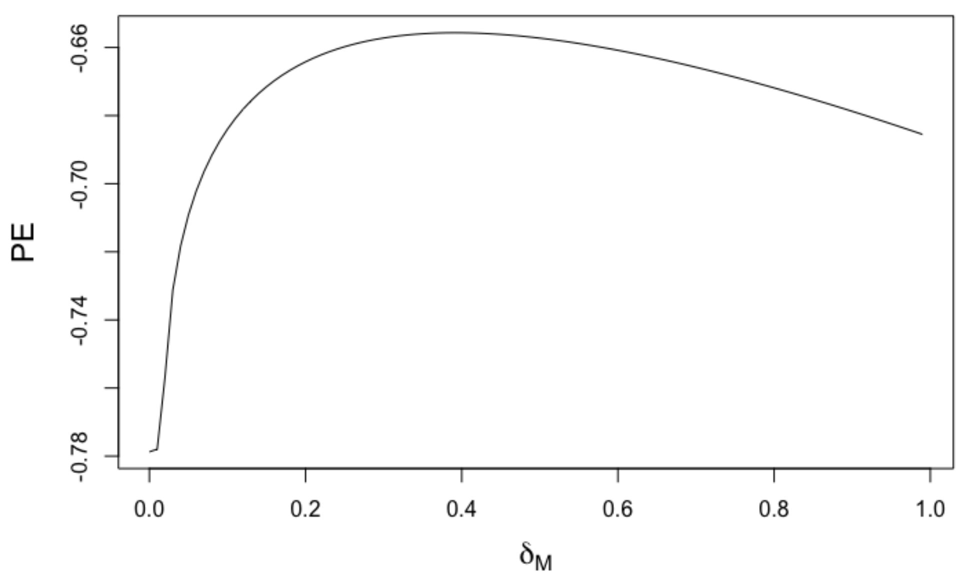

Figure 13: Price efficiency as a function of the manager's discount factor, δ_M. $q_\nu = 0.8, \sigma_\nu^2 = 0.08$, $q_\xi = 0.6$, $\sigma_\xi^2 = 0.5$, $\delta_I = 0.9$.

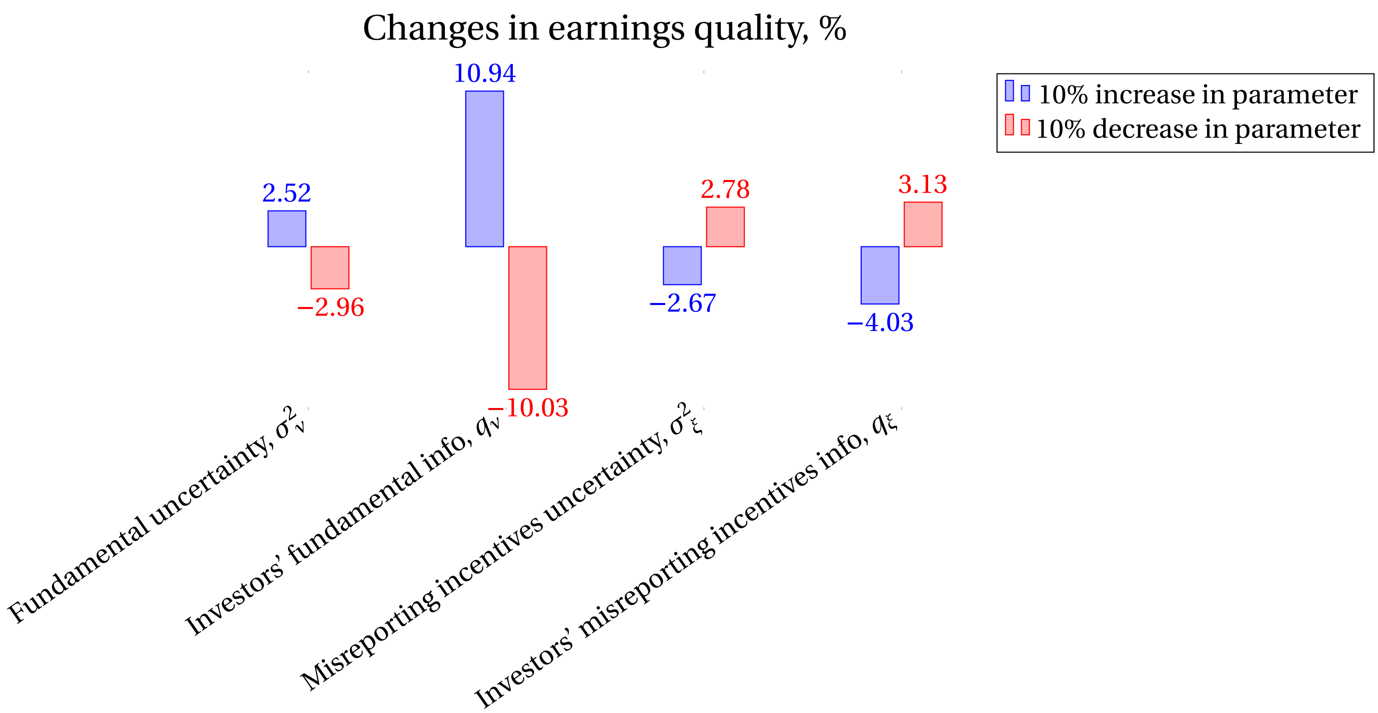

Figure 14: Sensitivity of earnings quality to model parameters. The values of parameters are as estimated (see Table 5).

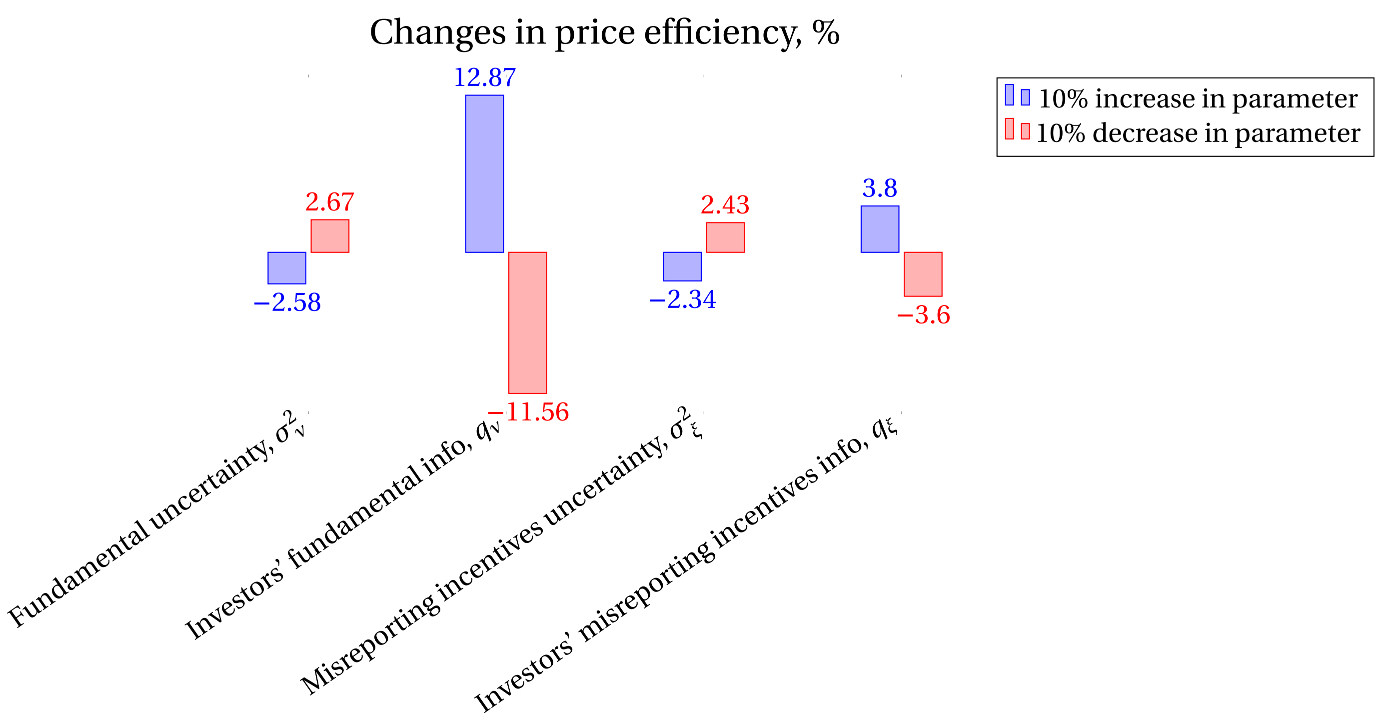

Figure 15: Sensitivity of price efficiency to model parameters. The values of parameters are as estimated (see Table 5).

Appendix

A.1 Proof of Proposition 1

Let us start with a manager who has finite tenure, that is, works at a firm with certainty up until time T.

At time T, the manager's problem is:

$$\max_{r_T} \quad m_T p_T - \frac{\left(e_T - \varepsilon_T + \sum_{k=0}^{T-1}(e_k - \varepsilon_k)\right)^2}{2} \tag{A46}$$

$$= m_T(p_0 + \sum_{j=0}^{j=T} \alpha_j^T e_j + \sum_{j=0}^{j=T} \beta_j^{0,T} \epsilon_{1,j}^0 + \sum_{j=0}^{j=T} \beta_j^{1,T} \epsilon_{1,j}^1 + \sum_{j=0}^{j=T} \gamma_j^{0,T} m_{1,j}^0 + \sum_{j=0}^{j=T} \gamma_j^{1,T} m_{1,j}^1) - \frac{\left(e_T - \varepsilon_T + \sum_{k=0}^{T-1}(e_k - \varepsilon_k)\right)^2}{2} \tag{A47}$$

The optimal report is:

$$e_T^* = \varepsilon_T - \sum_{k=0}^{T-1}(e_k - \varepsilon_k) + m_T \alpha_T^T \tag{A48}$$

Given the optimal choice at time T, the manager's problem at time $T-1$ is:

$$\max_{r_{T-1}} \quad m_{T-1} p_{T-1} - \frac{\left(e_{T-1} - \varepsilon_{T-1} + \sum_{k=0}^{T-2}(e_k - \varepsilon_k)\right)^2}{2} + \delta_M E_{T-1}[U_T] \tag{A49}$$

The expected utility at time T is

$$E_{T-1}[U_T] = E_{T-1}[m_T p_T + \frac{(m_T \alpha_T^T)^2}{2}]$$
$$= E_{T-1}[m_T]\left(p_0 + \sum_{j=0}^{j=T-1} \alpha_j^{T-1} e_j + \sum_{j=0}^{j=T-1} \beta_j^{0,T-1} \epsilon_{1,j}^0 + \sum_{j=0}^{j=T-1} \beta_j^{1,T-1} \epsilon_{1,j}^1 + \sum_{j=0}^{j=T-1} \gamma_j^{0,T-1} m_{1,j}^0 + \sum_{j=0}^{j=T-1} \gamma_j^{1,T-1} m_{1,j}^1\right) + E_{T-1}[\frac{(m_T \alpha_T^T)^2}{2}] \tag{A50}$$

The optimal report at time $T-1$ is

$$e_{T-1} = \varepsilon_{T-1} - \sum_{k=0}^{T-2}(e_k - \varepsilon_k) + m_{T-1}\alpha_{T-1}^{T-1} + \delta_M E_{T-1}[m_T]\alpha_{T-1}^T \tag{A51}$$

By induction, the manager's optimal report at time t is

$$e_t = \varepsilon_t - \sum_{k=0}^{t-1}(e_k - \varepsilon_k) + m_t\alpha_t^t + \delta_M\alpha_t^{t+1}E_t[m_{t+1}] + \delta_M^2\alpha_t^{t+2}E_t[m_{t+2}] \tag{A52}$$

Now work forwards starting from $t = 0$:

$$e_0 = \varepsilon_0 + \alpha_0^0 m_0 + \delta_M\alpha_0^1 E_0[m_1] + \delta_M^2\alpha_0^2 E_0[m_2] \tag{A53}$$

$$\begin{aligned} e_1 = \varepsilon_1 &- \left(\alpha_0^0 m_0 + \delta_M\alpha_0^1 E_0[m_1] + \delta_M^2\alpha_0^2 E_0[m_2]\right) \\ &+ \alpha_1^1 m_1 + \delta_M\alpha_1^2 E_1[m_2] + \delta_M^2\alpha_1^3 E_1[m_3] \end{aligned} \tag{A54}$$

$$\begin{aligned} e_2 = \varepsilon_2 - \big(-\left(\alpha_0^0 m_0 + \delta_M\alpha_0^1 E_0[m_1] + \delta_M^2\alpha_0^2 E_0[m_2]\right) + \alpha_1^1 m_1 + \delta_M\alpha_1^2 E_1[m_2] + \delta_M^2\alpha_1^3 E_1[m_3]\big) \\ - \left(\alpha_0^0 m_0 + \delta_M\alpha_0^1 E_0[m_1] + \delta_M^2\alpha_0^2 E_0[m_2]\right) \\ + \alpha_2^2 m_2 + \delta_M\alpha_2^3 E_2[m_3] + \delta_M^2\alpha_2^4 E_2[m_4] \\ = \varepsilon_2 - \left(\alpha_1^1 m_1 + \delta_M\alpha_1^2 E_1[m_2] + \delta_M^2\alpha_1^3 E_1[m_3]\right) \\ + \alpha_2^2 m_2 + \delta_M\alpha_2^3 E_2[m_3] + \delta_M^2\alpha_2^4 E_2[m_4] \end{aligned} \tag{A55}$$

Finally,

$$e_t = \varepsilon_t + \alpha_t^t m_t + \sum_{k=0}^{\infty}\delta_M^k\alpha_t^{t+k}E_t[m_{t+k}] - \alpha_{t-1}^{t-1}m_{t-1} - \sum_{k=0}^{\infty}\delta_M^k\alpha_{t-1}^{t+k}E_{t-1}[m_{t+k}] \tag{A56}$$

A.2 Proof of Proposition 2

Denote by α_0, α_1 and α_2 the steady-state responses of current, one-year ahead and two-years ahead prices' to a current managerial report. Managerial report in steady-state is then:

$$e_t = \varepsilon_t + (\alpha_0 + \delta_M\alpha_1 + \delta_M^2\alpha_2)\xi_t - \alpha_0\xi_{t-3} - \delta_M\alpha_1\xi_{t-2} - \delta_M^2\alpha_2\xi_{t-1} \tag{A57}$$

Right before the report e_t is released, variance of the report from investors' perspective is

$$\begin{aligned} Var[e_t] = (1-q_v)\sigma_v^2 + Var[v_{2,t-1}|e_{t-1}] + Var[v_{2,t-2}|e_{t-1}, e_{t-2}] \\ + (1-q_\xi)\sigma_\xi^2(\alpha_0 + \delta_M\alpha_1 + \delta_M^2\alpha_2)^2 + Var[\xi_{2,t-1}|e_{t-1}]\delta_M^4\alpha_2^2 \\ + Var[\xi_{2,t-2}|e_{t-1}, e_{t-2}]\delta_M^2\alpha_1^2 + Var[\xi_{2,t-3}|e_{t-1}, e_{t-2}, e_{t-3}]\alpha_0^2 \end{aligned} \tag{A58}$$

Denote $\sigma^2_{\nu 1} \equiv Var[\nu_{2,t-1}|e_{t-1}]$, $\sigma^2_{\nu 2} \equiv Var[\nu_{2,t-2}|e_{t-1}, e_{t-2}]$, $\sigma^2_{\xi 1} \equiv Var[\xi_{2,t-1}|e_{t-1}]$, $\sigma^2_{\xi 2} \equiv Var[\xi_{2,t-2}|e_{t-1}, e_{t-2}]$, and $\sigma^2_{\xi 3} \equiv Var[\xi_{2,t-3}|e_{t-1}, e_{t-2}, e_{t-3}]$. In this notation,

$$Var[e_t] = (1-q_\nu)\sigma^2_\nu + \sigma^2_{\nu 1} + \sigma^2_{\nu 2} + (1-q_\xi)\sigma^2_\xi(\alpha_0 + \delta_M\alpha_1 + \delta^2_M\alpha_2)^2 + \sigma^2_{\xi 1}\delta^4_M\alpha^2_2 + \sigma^2_{\xi 2}\delta^2_M\alpha^2_1 + \sigma^2_{\xi 3}\alpha^2_0 \quad \text{(A59)}$$

$$cov[e_t, \nu_t] = \sigma^2_\nu(1-q_\nu) \quad \text{(A60)}$$

Therefore,

$$Var[\nu_t|e_t] = (1-q_\nu)\sigma^2_\nu - \frac{(1-q_\nu)^2\sigma^4_\nu}{(1-q_\nu)\sigma^2_\nu + \sigma^2_{\nu 1} + \sigma^2_{\nu 2} + (1-q_\xi)\sigma^2_\xi(\alpha_0 + \delta_M\alpha_1 + \delta^2_M\alpha_2)^2 + \sigma^2_{\xi 1}\delta^4_M\alpha^2_2 + \sigma^2_{\xi 2}\delta^2_M\alpha^2_1 + \sigma^2_{\xi 3}\alpha^2_0} \quad \text{(A61)}$$

In the steady-state, $\sigma^2_{\nu 1}$, $\sigma^2_{\nu 2}$, $\sigma^2_{\xi 1}$, $\sigma^2_{\xi 2}$, and $\sigma^2_{\xi 3}$ are the solution to:

$$\sigma^2_{\nu 1} = (1-q_\nu)\sigma^2_\nu - \frac{(1-q_\nu)^2\sigma^4_\nu}{(1-q_\nu)\sigma^2_\nu + \sigma^2_{\nu 1} + \sigma^2_{\nu 2} + (1-q_\xi)\sigma^2_\xi(\alpha_0 + \delta_M\alpha_1 + \delta^2_M\alpha_2)^2 + \sigma^2_{\xi 1}\delta^4_M\alpha^2_2 + \sigma^2_{\xi 2}\delta^2_M\alpha^2_1 + \sigma^2_{\xi 3}\alpha^2_0} \quad \text{(A62)}$$

$$\sigma^2_{\nu 2} = \sigma^2_{\nu 1} - \frac{\sigma^4_{\nu 1}}{(1-q_\nu)\sigma^2_\nu + \sigma^2_{\nu 1} + \sigma^2_{\nu 2} + (1-q_\xi)\sigma^2_\xi(\alpha_0 + \delta_M\alpha_1 + \delta^2_M\alpha_2)^2 + \sigma^2_{\xi 1}\delta^4_M\alpha^2_2 + \sigma^2_{\xi 2}\delta^2_M\alpha^2_1 + \sigma^2_{\xi 3}\alpha^2_0} \quad \text{(A63)}$$

$$\sigma^2_{\xi 1} = (1-q_\xi)\sigma^2_\xi - \frac{(1-q_\xi)^2\sigma^4_\xi}{(1-q_\nu)\sigma^2_\nu + \sigma^2_{\nu 1} + \sigma^2_{\nu 2} + (1-q_\xi)\sigma^2_\xi(\alpha_0 + \delta_M\alpha_1 + \delta^2_M\alpha_2)^2 + \sigma^2_{\xi 1}\delta^4_M\alpha^2_2 + \sigma^2_{\xi 2}\delta^2_M\alpha^2_1 + \sigma^2_{\xi 3}\alpha^2_0} \quad \text{(A64)}$$

$$\sigma^2_{\xi 2} = \sigma^2_{\xi 1} - \frac{\sigma^4_{\xi 1}\delta^8_M\alpha^4_2}{(1-q_\nu)\sigma^2_\nu + \sigma^2_{\nu 1} + \sigma^2_{\nu 2} + (1-q_\xi)\sigma^2_\xi(\alpha_0 + \delta_M\alpha_1 + \delta^2_M\alpha_2)^2 + \sigma^2_{\xi 1}\delta^4_M\alpha^2_2 + \sigma^2_{\xi 2}\delta^2_M\alpha^2_1 + \sigma^2_{\xi 3}\alpha^2_0} \quad \text{(A65)}$$

$$\sigma^2_{\xi 3} = \sigma^2_{\xi 2} - \frac{\sigma^4_{\xi 2}\delta^4_M\alpha^4_1}{(1-q_\nu)\sigma^2_\nu + \sigma^2_{\nu 1} + \sigma^2_{\nu 2} + (1-q_\xi)\sigma^2_\xi(\alpha_0 + \delta_M\alpha_1 + \delta^2_M\alpha_2)^2 + \sigma^2_{\xi 1}\delta^4_M\alpha^2_2 + \sigma^2_{\xi 2}\delta^2_M\alpha^2_1 + \sigma^2_{\xi 3}\alpha^2_0} \quad \text{(A66)}$$

The change in the firm's price around the earnings report release includes updating based on the report and on the concurrent information. The concurrent information provides $\nu^0_{1,t+1}$, and the earnings report provides information about $v_{2,t}$, $v_{2,t-1}$, and $v_{2,t-2}$.

$$p_t^{\text{post-report}} - p_t^{\text{pre-report}} = \left(\delta_I + \delta_I^2 + \delta_I^3\right) v_{1,t+1}^0 \tag{A67}$$

$$+(1+\delta_I+\delta_I^2)\left(e_t - E\left[e_t | I_t^{\text{market}} \setminus \{e_t\}\right]\right)$$

$$\times \frac{(1-q_v)\sigma_v^2}{(1-q_v)\sigma_v^2 + \sigma_{v1}^2 + \sigma_{v2}^2 + (1-q_\xi)\sigma_\xi^2(\alpha_0 + \delta_M\alpha_1 + \delta_M^2\alpha_2)^2 + \sigma_{\xi1}^2\delta_M^4\alpha_2^2 + \sigma_{\xi2}^2\delta_M^2\alpha_1^2 + \sigma_{\xi3}^2\alpha_0^2} \tag{A68}$$

$$+(1+1+\delta_I)\left(e_t - E\left[e_t | I_t^{\text{market}} \setminus \{e_t\}\right]\right)$$

$$\times \frac{\sigma_{v1}^2}{(1-q_v)\sigma_v^2 + \sigma_{v1}^2 + \sigma_{v2}^2 + (1-q_\xi)\sigma_\xi^2(\alpha_0 + \delta_M\alpha_1 + \delta_M^2\alpha_2)^2 + \sigma_{\xi1}^2\delta_M^4\alpha_2^2 + \sigma_{\xi2}^2\delta_M^2\alpha_1^2 + \sigma_{\xi3}^2\alpha_0^2} \tag{A69}$$

$$+3\left(e_t - E\left[e_t | I_t^{\text{market}} \setminus \{e_t\}\right]\right)$$

$$\times \frac{\sigma_{v2}^2}{(1-q_v)\sigma_v^2 + \sigma_{v1}^2 + \sigma_{v2}^2 + (1-q_\xi)\sigma_\xi^2(\alpha_0 + \delta_M\alpha_1 + \delta_M^2\alpha_2)^2 + \sigma_{\xi1}^2\delta_M^4\alpha_2^2 + \sigma_{\xi2}^2\delta_M^2\alpha_1^2 + \sigma_{\xi3}^2\alpha_0^2}, \tag{A70}$$

where $\left(e_t - E\left[e_t | I_t^{\text{market}} \setminus \{e_t\}\right]\right) \times \frac{(1-q_v)\sigma_v^2}{(1-q_v)\sigma_v^2 + \sigma_{v1}^2 + \sigma_{v2}^2 + (1-q_\xi)\sigma_\xi^2(\alpha_0 + \delta_M\alpha_1 + \delta_M^2\alpha_2)^2 + \sigma_{\xi1}^2\delta_M^4\alpha_2^2 + \sigma_{\xi2}^2\delta_M^2\alpha_1^2 + \sigma_{\xi3}^2\alpha_0^2} = E[v_{2,t}|e_t]$, $\left(e_t - E\left[e_t | I_t^{\text{market}} \setminus \{e_t\}\right]\right) \times \frac{\sigma_{v1}^2}{(1-q_v)\sigma_v^2 + \sigma_{v1}^2 + \sigma_{v2}^2 + (1-q_\xi)\sigma_\xi^2(\alpha_0 + \delta_M\alpha_1 + \delta_M^2\alpha_2)^2 + \sigma_{\xi1}^2\delta_M^4\alpha_2^2 + \sigma_{\xi2}^2\delta_M^2\alpha_1^2 + \sigma_{\xi3}^2\alpha_0^2} = E[v_{2,t-1}|e_t, e_{t-1}]$, and $\left(e_t - E\left[e_t | I_t^{\text{market}} \setminus \{e_t\}\right]\right) \times \frac{\sigma_{v2}^2}{(1-q_v)\sigma_v^2 + \sigma_{v1}^2 + \sigma_{v2}^2 + (1-q_\xi)\sigma_\xi^2(\alpha_0 + \delta_M\alpha_1 + \delta_M^2\alpha_2)^2 + \sigma_{\xi1}^2\delta_M^4\alpha_2^2 + \sigma_{\xi2}^2\delta_M^2\alpha_1^2 + \sigma_{\xi3}^2\alpha_0^2} = E[v_{2,t-2}|e_t, e_{t-1}, e_{t-2}]$. The earnings response coefficients solve

$$\alpha_0 = \frac{(1+\delta_I+\delta_I^2)(1-q_v)\sigma_v^2 + (2+\delta_I)\sigma_{v1}^2 + 3\sigma_{v2}^2}{(1-q_v)\sigma_v^2 + \sigma_{v1}^2 + \sigma_{v2}^2 + (1-q_\xi)\sigma_\xi^2(\alpha_0 + \delta_M\alpha_1 + \delta_M^2\alpha_2)^2 + \sigma_{\xi1}^2\delta_M^4\alpha_2^2 + \sigma_{\xi2}^2\delta_M^2\alpha_1^2 + \sigma_{\xi3}^2\alpha_0^2} \tag{A71}$$

$$\alpha_1 = \frac{(2+\delta_I)(1-q_v)\sigma_v^2 + 3\sigma_{v1}^2 + 3\sigma_{v2}^2}{(1-q_v)\sigma_v^2 + \sigma_{v1}^2 + \sigma_{v2}^2 + (1-q_\xi)\sigma_\xi^2(\alpha_0 + \delta_M\alpha_1 + \delta_M^2\alpha_2)^2 + \sigma_{\xi1}^2\delta_M^4\alpha_2^2 + \sigma_{\xi2}^2\delta_M^2\alpha_1^2 + \sigma_{\xi3}^2\alpha_0^2} \tag{A72}$$

$$\alpha_2 = \frac{3\left((1-q_v)\sigma_v^2\sigma_{v1}^2 + \sigma_{v2}^2\right)}{(1-q_v)\sigma_v^2 + \sigma_{v1}^2 + \sigma_{v2}^2 + (1-q_\xi)\sigma_\xi^2(\alpha_0 + \delta_M\alpha_1 + \delta_M^2\alpha_2)^2 + \sigma_{\xi1}^2\delta_M^4\alpha_2^2 + \sigma_{\xi2}^2\delta_M^2\alpha_1^2 + \sigma_{\xi3}^2\alpha_0^2} \tag{A73}$$

A.3 Proof of Proposition 3

Between any two earnings reports, the market only learns about ε_1^1 and m_1^1. Since ε_1 and ε_2 and m_1 and m_2 are independent, the market's beliefs about ε_2 and m_2 remain unchanged: $E[e_t|I_{t+1}^{\text{market}} \setminus \{e_t\}] = E[e_t|I_t^{\text{market}}]$.

The change in the firm price during a year between two earnings reports is

$$p_{t+1}^{\text{pre-report}} - p_t^{\text{post-report}} = \left(v_{1,t+1}^1 + v_{1,t+1}^0\right) + \left(\delta_I v_{1,t+1}^1 + \delta_I v_{1,t+1}^0\right)$$

$$+ \left(\delta_I^2 v_{1,t+1}^1 + \delta_I^2 v_{1,t+1}^0\right) - \left(\delta_I + \delta_I^2 + \delta_I^3\right) v_{1,t+1}^0$$

$$+ (e_t - E[e_t]) \times (\alpha_1 - \alpha_0) \tag{A74}$$

A.4 Proof of Proposition 4

$$E_t[\xi_{2,t-2}|e_t, e_{t-1}, e_{t-2}] = \left(e_t - E\left[e_t|I_t^{\text{market}} \setminus \{e_t\}\right]\right)$$

$$\times \frac{\sigma_{\xi 2}^2}{(1-q_v)\sigma_v^2 + \sigma_{v1}^2 + \sigma_{v2}^2 + (1-q_\xi)\sigma_\xi^2(\alpha_0 + \delta_M\alpha_1 + \delta_M^2\alpha_2)^2 + \sigma_{\xi 1}^2\delta_M^4\alpha_2^2 + \sigma_{\xi 2}^2\delta_M^2\alpha_1^2 + \sigma_{\xi 3}^2\alpha_0^2} \tag{A75}$$

$$E_t[\xi_{2,t-1}|e_t, e_{t-1}] = \left(e_t - E\left[e_t|I_t^{\text{market}} \setminus \{e_t\}\right]\right)$$

$$\times \frac{\sigma_{\xi 1}^2}{(1-q_v)\sigma_v^2 + \sigma_{v1}^2 + \sigma_{v2}^2 + (1-q_\xi)\sigma_\xi^2(\alpha_0 + \delta_M\alpha_1 + \delta_M^2\alpha_2)^2 + \sigma_{\xi 1}^2\delta_M^4\alpha_2^2 + \sigma_{\xi 2}^2\delta_M^2\alpha_1^2 + \sigma_{\xi 3}^2\alpha_0^2} \tag{A76}$$

$$E_t[\xi_{2,t}|e_t] = \left(e_t - E\left[e_t|I_t^{\text{market}} \setminus \{e_t\}\right]\right)$$

$$\times \frac{(1-q_\xi)\sigma_\xi^2}{(1-q_v)\sigma_v^2 + \sigma_{v1}^2 + \sigma_{v2}^2 + (1-q_\xi)\sigma_\xi^2(\alpha_0 + \delta_M\alpha_1 + \delta_M^2\alpha_2)^2 + \sigma_{\xi 1}^2\delta_M^4\alpha_2^2 + \sigma_{\xi 2}^2\delta_M^2\alpha_1^2 + \sigma_{\xi 3}^2\alpha_0^2} \tag{A77}$$

$$ME_t^{\text{post-report}} = v_{1,t+1}^0 + v_{1,t} + v_{1,t-1} \tag{A78}$$

$$+(\alpha_0 + \delta_M\alpha_1 + \delta_M^2\alpha_2)\xi_{1,t+1}^0 - \alpha_0\xi_{1,t-2} - \delta_M\alpha_1\xi_{1,t-1} - \delta_M^2\alpha_2\xi_{1,t} \tag{A79}$$

$$+E_t[v_{2,t} + v_{2,t-1}|e_t, e_{t-1}] \tag{A80}$$

$$E_t[(\alpha_0 + \delta_M\alpha_1 + \delta_M^2\alpha_2)\xi_{2,t+1}^0 - \alpha_0\xi_{2,t-2} - \delta_M\alpha_1\xi_{2,t-1} - \delta_M^2\alpha_2\xi_{2,t}|e_t, e_{t-1}, e_{t-2}] \tag{A81}$$

or

$$ME_t^{\text{post-report}} = v_{1,t+1}^0 + v_{1,t} + v_{1,t-1} \tag{A82}$$

$$+(\alpha_0 + \delta_M\alpha_1 + \delta_M^2\alpha_2)\xi_{1,t+1}^0 - \alpha_0\xi_{1,t-2} - \delta_M\alpha_1\xi_{1,t-1} - \delta_M^2\alpha_2\xi_{1,t} \tag{A83}$$

$$+\beta_0 \times \left(e_t - E\left[e_t|I_t^{\text{market}} \setminus \{e_t\}\right]\right), \tag{A84}$$

where $\beta_0 = \frac{(1-q_v)\sigma_v^2 + \sigma_{v1}^2 - \alpha_0\sigma_{\xi 2}^2 - \delta_M\alpha_1\sigma_{\xi 1}^2 - \delta_M^2\alpha_2(1-q_\xi)\sigma_\xi^2}{(1-q_v)\sigma_v^2 + \sigma_{v1}^2 + \sigma_{v2}^2 + (1-q_\xi)\sigma_\xi^2(\alpha_0 + \delta_M\alpha_1 + \delta_M^2\alpha_2)^2 + \sigma_{\xi 1}^2\delta_M^4\alpha_2^2 + \sigma_{\xi 2}^2\delta_M^2\alpha_1^2 + \sigma_{\xi 3}^2\alpha_0^2}$.

A.5 Proof of Proposition 5

Since the market's beliefs about ε_2 and m_2 remain unchanged during a year between two reports, the market's expectation of the next earnings report changes only because investors learn $\nu^1_{1,t+1}$ and $\xi^1_{1,t+1}$:

$$ME^{\text{pre-report}}_{t+1} - ME^{\text{post-report}}_{t} = \nu^1_{1,t+1} + \left(\alpha_0 + \delta_M \alpha_1 + \delta^2_M \alpha_2\right) \xi^1_{1,t+1} \tag{A85}$$

A.6 Estimation procedure

The objective of the GMM procedure is to minimize the distance between the theoretical moments, which are functions of the model parameters, and empirical moments, which are calculated from the data. In other words, the goal is to find a set of parameters $\hat{\theta}$ such that

$$\hat{\theta} = \text{argmin}_{\theta \in \Theta} \quad \left(\frac{1}{N}\sum_{i=1}^{N} g(Y_i,\theta)\right)^T \hat{W} \left(\frac{1}{N}\sum_{i=1}^{N} g(Y_i,\theta)\right), \tag{A86}$$

where $\frac{1}{N}\sum_{i=1}^{N} g(Y_i,\theta) = m(d) - \hat{m}(\theta)$ is the vector of average differences between moments computed from the data $m(d)$ – a function of data d – and their counterparts computed from the model $\hat{m}(\theta)$ the model – a function of the model's parameters θ. I show how each element of this vector is calculated in table 11 below. The matrix W is the weighting matrix.

The estimation is conducted in two steps. In the first step, the algorithm searches for $\hat{\theta}_1$ that minimizes A86 with an identity matrix as the weighting matrix $\hat{W}_1 = E$. Next, I take the obtained estimates $\hat{\theta}_1$, plug them into the vector $\frac{1}{N}\sum_{i=1}^{N} g(Y_i,\theta)$, and calculate the covariance matrix of this vector, $\hat{\Omega} \equiv \frac{1}{N}\sum_{i=1}^{N} \left[g(Y_i,\theta)\right]\left[g(Y_i,\theta)\right]'$. In the second step, the algorithm searches for $\hat{\theta}_2$ that minimizes A86 where the weighting matrix is the inverse of the covariance matrix: $\hat{W}_2 = \hat{\Omega}^{-1}$. The parameter estimates obtained in the second step $\hat{\theta}_2$ are the ultimate estimates. I use the Controlled Random Search algorithm (Price (1983), Kaelo and Ali (2006)) to search for $\hat{\theta}$ in both steps.

I calculate standard errors of the estimates using the formula for the asymptotic covariance matrix of estimates:

$$\mathbf{V} \equiv \frac{1}{N}\left[\hat{G}\hat{\Omega}^{-1}\hat{G}^T\right]^{-1}, \tag{A87}$$

where $\hat{G} \equiv \frac{\partial\left(\frac{1}{N}\sum_{i=1}^{N} g(Y_i,\theta)\right)}{\partial\theta}$ is the Jacobian matrix, evaluated at $\hat{\theta}_2$. The derivative of moment k with respect to parameter p, $\frac{\partial\left(\frac{1}{N}\sum_{i=1}^{N} g(Y_i,\theta)\right)_k}{\partial\theta_p}$, is calculated by increasing parameter $\hat{\theta}_p$ by 0.01% (keeping other parameters constant) and dividing the difference between the new value of the moment and the value of the moment at the $\hat{\theta}_p$, $\left(\frac{1}{N}\sum_{i=1}^{N} g(Y_i,\theta)\right)_k \left(1.0001\hat{\theta}_p\right) - \left(\frac{1}{N}\sum_{i=1}^{N} g(Y_i,\theta)\right)_k \left(\hat{\theta}_p\right)$ by 0.01% of $\hat{\theta}_p$.

The J-statistic is $J = N\left(\frac{1}{N}\sum_{i=1}^{N} g(Y_i,\theta)\right)^T \hat{\Omega}^{-1}\left(\frac{1}{N}\sum_{i=1}^{N} g(Y_i,\theta)\right)$ and follows a χ^2 distribution with the degrees of freedom equal to the number of moments in excess of the number of parameters (10-6=4 in my case) under the null hypothesis that the model does not fail to match all moments.

A.7 Calculation of differences between empirical and theoretical moments

In this Appendix, I explain how the empirical moments used to fit the model are computed. The paper uses 10 moments: one mean moment (earning response coefficient), three variance moments (variances of earnings reports, residuals from regressing market expectations immediately after a report on the report surprise, and changes in market expectations during a year), and six covariance moments.

The data series used in estimation are reported annual earnings and analyst forecasts of annual earnings from the IBES database, firm prices from the CRSP database, and book values (for normalization) from the Compustat database.

I start by computing aggregate reported earnings, analyst forecasts, and firm value by multiplying IBES earnings-per-share, forecasts of earnings-per-share, and prices, respectively, by the total number of shares outstanding. Next, I normalize the aggregate values by dividing them by 3-year lagged book values.

I treat my data as cross-sectional. For each observation i, I have 7 columns:

1. Reported earnings, e_t^i, – earnings reported at time t.
2. 1-year-lead reported earnings, e_{t+1}^i, – earnings reported at time $t+1$.
3. Earnings surprise, $e_t^i - LAF_t^i$, – the difference between the reported earnings number at time t and the last analyst forecast before the earnings announcement.
4. Change in firm prices around an earnings announcement, $p_t^{\text{post-report}\,i} - p_t^{\text{pre-report}\,i}$, – firm price on the first trading day after an earnings announcement at time t minus firm price on the last trading day before the earnings announcement.
5. Change in firm prices during the year following an earnings announcement, $p_{t+1}^{\text{pre-report}\,i} - p_t^{\text{post-report}\,i}$, – firm price on the last trading day before an earnings announcement at time $t+1$ minus firm price

on the first trading day after an earnings announcement at time t.

6. First analyst forecast after an earnings announcement, FAF_t^i, – the first analyst forecast of time-$t+1$ earnings issued after the earnings report at time t.

7. Change in analyst forecasts during a year following an earnings announcement, $LAF_{t+1}^i - FAF_t^i$, – the last analyst forecast of time-$t+1$ earnings issued before the $t+1$ earnings announcement minus the first analyst forecast of time-$t+1$ earnings issued after the t earnings announcement.

In the table 11 below, I provide formulas used to calculate differences between empirical and theoretical moments. To save the space, instead of $^{\text{pre-report}}$ and $^{\text{post-report}}$ superscripts, I write $^{\text{pre}}$ and $^{\text{post}}$.

Table 11: Formulas to calculate differences between empirical and theoretical moments

Moment	**Formula for difference between empirical and theoretical moments**
Earnings response coefficient moment	$\frac{1}{N}\sum_{i=1}^{N}\left(\left(p_t^{\text{post}\,i}-p_t^{\text{pre}\,i}\right)-\alpha_0\times\left(e_t^i-LAF_t^i\right)\right)$
Variance of earnings reports	$\frac{1}{N}\sum_{i=1}^{N}\left(e_i-\left(\frac{1}{N}\sum_{i=1}^{N}e_i\right)\right)^2-$ $\left[3\sigma_v^2+\left(\alpha_0+\delta_M\alpha_1+\delta_M^2\alpha_2\right)^2\sigma_\xi^2+\alpha_0^2\sigma_\xi^2+\delta_M^2\alpha_1^2\sigma_\xi^2+\delta_M^4\alpha_2^2\sigma_\xi^2\right]$
Residual variance of regressing the market's expectation of the time-$t+1$ earnings report on the time-t earnings report surprise	$\frac{1}{N}\sum_{i=1}^{N}\left(FAF_t^i-\beta_0\left(e_t^i-LAF_t^i\right)-\frac{1}{N}\sum_{i=1}^{N}\left(FAF_t^i-\beta_0\left(e_t^i-LAF_t^i\right)\right)\right)^2-$ $\left[q_vq_v^0\sigma_v^2+2q_v\sigma_v^2+q_\xi q_\xi^0\sigma_\xi^2\left(\alpha_0+\delta_M\alpha_1+\delta_M^2\alpha_2\right)^2+q_\xi\sigma_\xi^2\alpha_0^2+q_\xi\sigma_\xi^2\delta_M^2\alpha_1^2+q_\xi\sigma_\xi^2\delta_M^4\alpha_2^2\right]$
Variance of change in the market's expectation of the next earnings report during a year	$\frac{1}{N}\sum_{i=1}^{N}\left(LAF_{t+1}^i-FAF_t^i-\frac{1}{N}\sum_{i=1}^{N}\left(LAF_{t+1}^i-FAF_t^i\right)\right)^2-$ $\left[q_v(1-q_v^0)\sigma_v^2+q_\xi(1-q_\xi^0)\sigma_\xi^2\left(\alpha_0+\delta_M\alpha_1+\delta_M^2\alpha_2\right)^2\right]$
Covariance of time-$t+1$ earnings reports with residuals of the time-t "ERC" regression	$\frac{1}{N}\sum_{i=1}^{N}\left[e_{t+1}^i-\frac{1}{N}\sum_{i=1}^{N}e_{t+1}^i\right]$ $\left[\left(p_t^{\text{post}\,i}-p_t^{\text{pre}\,i}\right)-\alpha_0\times\left(e_t^i-LAF_t^i\right)-\left(\frac{1}{N}\sum_{i=1}^{N}\left(\left(p_t^{\text{post}\,i}-p_t^{\text{pre}\,i}\right)-\alpha_0\times\left(e_t^i-LAF_t^i\right)\right)\right)\right]-$ $\left[q_vq_v^0\sigma_v^2\left(\delta_I+\delta_I^2+\delta_I^3\right)\right]$
Covariance of time-$t+1$ earnings reports with residuals from regressing change in prices from right after the time-t report to right before the time-$t+1$ report on the time-t earnings report surprise	$\frac{1}{N}\sum_{i=1}^{N}\left[e_{t+1}^i-\frac{1}{N}\sum_{i=1}^{N}e_{t+1}^i\right]$ $\left[\left(p_{t+1}^{\text{pre}\,i}-p_t^{\text{post}\,i}\right)-(\alpha_1-\alpha_0)\times\left(e_t^i-LAF_t^i\right)-\left(\frac{1}{N}\sum_{i=1}^{N}\left(\left(p_{t+1}^{\text{pre}\,i}-p_t^{\text{post}\,i}\right)-(\alpha_1-\alpha_0)\times\left(e_t^i-LAF_t^i\right)\right)\right)\right]-$ $\left[q_vq_v^0\sigma_v^2(1-\delta_I^3)+q_v(1-q_v^0)\sigma_v^2(1+\delta_I+\delta_I^2)\right]$
Covariance of time-$t+1$ earnings reports with residuals from regressing the market's expectation of the time-$t+1$ earnings report on the time-t earnings report surprise	$\frac{1}{N}\sum_{i=1}^{N}\left[e_{t+1}^i-\frac{1}{N}\sum_{i=1}^{N}e_{t+1}^i\right]\left[FAF_t^i-\beta_0\times\left(e_t^i-LAF_t^i\right)-\left(\frac{1}{N}\sum_{i=1}^{N}\left(FAF_t^i-\beta_0\times\left(e_t^i-LAF_t^i\right)\right)\right)\right]-$ $\left[q_vq_v^0\sigma_v^2+2q_v\sigma_v^2+q_\xi q_\xi^0\sigma_\xi^2\left(\alpha_0+\delta_M\alpha_1+\delta_M^2\alpha_2\right)^2+q_\xi\sigma_\xi^2\alpha_0^2+q_\xi\sigma_\xi^2\delta_M^2\alpha_1^2+q_\xi\sigma_\xi^2\delta_M^4\alpha_2^2\right]$
Covariance of time-$t+1$ earnings reports with changes in the market's expectations of the next earnings reports during a year	$\frac{1}{N}\sum_{i=1}^{N}\left[LAF_{t+1}^i-FAF_t^i-\frac{1}{N}\sum_{i=1}^{N}\left(LAF_{t+1}^i-FAF_t^i\right)\right]\left[e_{t+1}^i-\frac{1}{N}\sum_{i=1}^{N}e_{t+1}^i\right]-$ $\left[q_v(1-q_v^0)\sigma_v^2+q_\xi(1-q_\xi^0)\sigma_\xi^2\left(\alpha_0+\delta_M\alpha_1+\delta_M^2\alpha_2\right)^2\right]$
Covariance of the residuals from regressing $\left(p_t^{\text{post-report}}-p_t^{\text{pre-report}}\right)$ on the time-t earnings surprise with residuals from regressing $ME_t^{\text{post-report}}$ on the same surprise	$\frac{1}{N}\sum_{i=1}^{N}\left[\left(p_t^{\text{post}\,i}-p_t^{\text{pre}\,i}\right)-\alpha_0\times\left(e_t^i-LAF_t^i\right)-\left(\frac{1}{N}\sum_{i=1}^{N}\left(\left(p_t^{\text{post}\,i}-p_t^{\text{pre}\,i}\right)-\alpha_0\times\left(e_t^i-LAF_t^i\right)\right)\right)\right]$ $\left[FAF_t^i-\beta_0\times\left(e_t^i-LAF_t^i\right)-\left(\frac{1}{N}\sum_{i=1}^{N}\left(FAF_t^i-\beta_0\times\left(e_t^i-LAF_t^i\right)\right)\right)\right]-$ $\left[q_vq_v^0\sigma_v^2\left(\delta_I+\delta_I^2+\delta_I^3\right)\right]$
Covariance of the residuals from regressing $\left(p_{t+1}^{\text{pre-report}}-p_t^{\text{post-report}}\right)$ on the time-t earnings surprise with changes in the market's expectations of next earnings reports during a year	$\frac{1}{N}\sum_{i=1}^{N}\left[\left(p_{t+1}^{\text{pre}\,i}-p_t^{\text{post}\,i}\right)-(\alpha_1-\alpha_0)\left(e_t^i-LAF_t^i\right)-\left(\frac{1}{N}\sum_{i=1}^{N}\left(\left(p_{t+1}^{\text{pre}\,i}-p_t^{\text{post}\,i}\right)-(\alpha_1-\alpha_0)\left(e_t^i-LAF_t^i\right)\right)\right)\right]$ $\left[LAF_{t+1}^i-FAF_t^i-\frac{1}{N}\sum_{i=1}^{N}\left(LAF_{t+1}^i-FAF_t^i\right)\right]-$ $\left[q_v(1-q_v^0)\sigma_v^2\left(1+\delta_I+\delta_I^2\right)\right]$