Informational Feedback and ESG Growth Opportunities: Optimal Public Disclosure

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Abstract

We develop a rational expectations model to study the optimal precision of firm's public disclosure when traders have heterogeneous preferences and the firm learns from market prices to guide its ESG investment decisions. In our model, the firm's payoff combines financial and ESG components, while traders differ in the component they value. The firm's manager can publicly disclose noisy signals about these components and uses stock prices to infer the value of an ESG-linked growth opportunity. We show that when the manager's private information is imprecise, the investment opportunity is large, and prices are more informative about the value of the ESG component that the manager wants to learn about, greater precision of public disclosure may impair firm's ability to learn from prices and may reduce firm value. In contrast, when manager's information is highly precise, the investment opportunity is small, and prices are more informative about the financial component, full disclosure increases firm value. Thus, the firms' optimal disclosure policy balances the benefits of price efficiency against the costs of reduced market-based learning, generating a non-monotonic relationship between disclosure and firm value. Our findings uncover novel trade-offs in public disclosure design and offer policy implications for firms and policymakers navigating evolving transparency mandates.

JEL codes: G11; G20; G23.

Keywords: ESG preferences; Public disclosure; Feedback Effects

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1. Introduction

The rapid growth of environmental, social, and governance (ESG) investment has transformed how firms engage with capital markets. A rising share of traders, driven by both financial and non-pecuniary motives, demand more information about firms' ESG-related activities. In response, firms increasingly include ESG disclosures in financial reports, sustainability reports, or third-party ratings, either voluntarily or under growing regulatory pressure (e.g., EU CSRD, SEC climate disclosure rules). While greater transparency can reduce information asymmetries between firms and traders and improve capital allocation (Verrecchia, 2001; Easley and O'Hara, 2004), it may also have unintended consequences. In particular, excessive disclosure can discourage private information acquisition by investors (Diamond, 1985; Goldstein and Yang, 2017), weakening the market's feedback mechanism—the ability of prices to convey information back to the firm. This feedback is especially valuable when the firm uses price signals to learn about uncertain investment opportunities (Dow et al., 2017; Goldstein and Yang, 2019). As firms face increasing pressure to disclose more ESG-related data, it becomes essential to understand how these two opposite effects of public information precision impact firm value in equilibrium.

In this paper, we develop a rational expectations model to examine how the precision of public information affects firm value when traders have heterogeneous preferences and the firm learns from prices to guide its ESG investment decision. We consider a setting where the firm's payoff consists of two components, financial and ESG, and where two types of risk-averse traders value only one component each. The firm faces an investment opportunity whose payoff depends solely on the ESG component, and uses the stock price to infer the expected value of this opportunity. The overall value of the firm that it aims to maximize is the weighted average of its short-term value, i.e., its expected price of

the asset-in-place, and the long-term value, i.e., its expected growth opportunity value (Langberg and Sivaramakrishnan, 2010). More precise public disclosure, on the one hand, improves the expected price by reducing the uncertainty faced by traders, thereby increases the short-term value of the firm. On the other hand, greater precision may weaken the feedback that the firm receives from the price about the value of its ESG payoff component that determines its expected growth value, thereby impairing its investment efficiency. We show how, depending on the firm's own information precision, the magnitude of the investment opportunity, and the prevailing market equilibrium, the optimal level of public information disclosure balances the benefits of improved expected price against the costs of diminished learning opportunities.

We find that, even when disclosure is costless and there is no crowding-out effect in financial markets, there may still arise a case where higher precision of public disclosure reduces the overall value of the firm. The precision of public information disclosure has a non-trivial effect on firm value due to a feedback loop between disclosure, trading behavior, and firm learning. First, we show that when the precision of the firm's own information, based on which the manager chooses the precision of public disclosure, is sufficiently large, it is always optimal for the firm to choose full disclosure, as greater transparency unambiguously increases firm value by increasing both the expected price and the expected growth opportunity value. In such cases, the manager has already enough information about the growth opportunity and thus, does not need to learn much from the market.

Second, when the firm's own information is not sufficiently precise, the optimal precision of disclosure depends on the magnitude of the ESG growth opportunity. If the investment opportunity is small, it is still optimal for the firm to fully disclose its information, as more precise information increases both the expected price and the expected value on the investment opportunity. However, if the investment opportunity is large, then

the optimal precision of public information depends on the prevailing equilibrium in the market. In the equilibria where prices are not specifically informative regarding the value of the ESG component of the payoff, the firm can not learn much from the prices about this component that guides its ESG investment decision. In such cases, as before, the more precise information increases both the expected price and the expected growth value and thus, the firm's optimal disclosure policy would be full disclosure.

Finally, in the equilibrium where prices are more informative about the value of the ESG component, the firm can learn much about the private information of traders by observing the price. In this case, high precision of public disclosure reduces the informativeness of the price regarding the ESG component. This negative effect may outweigh the positive effect on the short-term value of the firm, giving rise to an interior optimal level of disclosure precision: more precise disclosure beyond this optimal precision improves pricing in the short-term but may deprive the firm from valuable market-based information. The interaction between heterogeneous traders' preferences and market feedback thus generates novel conditions under which greater disclosure can reduce firm value.

Several mechanisms in our model give rise to these results. First, the firm's payoff consists of two components, financial and ESG, and two types of risk-neutral traders differ in the utility they derive from each: traditional traders value only the financial component, while ESG traders care exclusively about the ESG component. This separation gives rise to differential incentives across trader types, and creates a new dimension of strategic disclosure for the firm. Both types receive exogenous private signals about each payoff component, and the firm's manager issues public disclosures with a chosen precision level. Traders trade based on their posterior beliefs, and equilibrium prices aggregate both public and private information. In addition to its assets-in-place, the firm has a growth opportunity that is tied specifically to the ESG component of its payoff. Crucially, the firm learns

about the expected value of this growth option by observing prices, which reflect the private information of ESG traders, making the informativeness of price a key determinant of investment efficiency.[1]

Hayek (1945) argued that prices are an important source of information for the decision-makers in the real side of the economy because they aggregate disperse information from many market participants through the trading process. The price, as a signal generated from the information aggregation process, provides valuable insights for capital allocation decisions on the real side of the economy. Modern finance literature has explored the implications of this market information feedback effect (Bond et al., 2012; Goldstein, 2023). In our model, the firm's manager wants to learn from its stock price in the market to update her belief about the expected value of the ESG growth opportunity. As the manager increases the precision of public disclosure, ESG traders will trade less based on their private signals and thus, the price would be less informative about the value of the ESG payoff component that determines the final value of the firm. Lower informativeness means that the manager learns less from the market, reducing the efficiency of her investment decision.

Moreover, as Goldstein and Yang (2017) argue, public information disclosure can have complicated effects on different measures of the firm performance, e.g., on its cost of capital, liquidity, return volatility, and market efficiency. These measures do not necessarily translate into a clear objective function to determine the desirability of public disclosure directly. Some papers have addressed this issue by employing certain objective functions (Gao and Liang, 2013; Han et al., 2016; Bond and Goldstein, 2015; Goldstein and Yang, 2019). In this paper, we follow Langberg and Sivaramakrishnan (2010) and assume that

[1]This is the information feedback from the market, through which the firm learns valuable information from its stock price about the expected outcome of its investment opportunity (Subrahmanyam and Titman, 1999; Foucault and Gehrig, 2008).

the firm value is a weighted average of the expected value of its price and the expected value of its ESG growth opportunity. This can be interpreted as the firm trying to balance the interests of short-term traders, who care about the price, and long-term traders who care about both the price and the long-term growth. Goldstein and Yang (2017) shows that in this scenario, on the one hand, higher precision of public information disclosure reduces the uncertainty faced by traders and thus, reduces the firm's cost of capital. On the other hand, higher precision of public disclosure crowds out private information production and thus, reduces the information that firm can learn from the market, thereby lowering the efficiency of its investment decision.[2] Optimal precision of public disclosure trades off these two opposite effects on the firm's final value, i.e., its objective function. We complement this argument by considering a case where traders have heterogeneous preferences. We show that, in our model, a similar trade-off arises only when the firm's manager wants to learn about a specific dimension of the firm performance, and by disclosing too much public information, loses valuable feedback from the market.

Our paper contributes to the growing literature on the optimal precision of information disclosure in settings with heterogeneous preferences and informational feedback. Gao and Liang (2013) analyze optimal public disclosure when firms learn from prices, but in a framework with a single payoff component and homogeneous investor preferences. More generally, a firm's payoff may consist of multiple dimensions, e.g., financial, operational, or ESG-related, over which market participants may differ in valuation (Goldstein and Yang, 2015). Goldstein and Yang (2019) study optimal disclosure in such environments, showing how public signals affect real decisions through price informativeness, but assume that all traders value each component equally. In contrast, Goldstein et al. (2024) introduce hetero-

[2]We do not endogenize private information acquisition and thus, crowding out mechanism does not apply to our model. In future work, we will extend our model to include this feature, as better disclosure of public information will reduce the traders' incentives to acquire private information.

geneous investor preferences across payoff components, yet abstract from public disclosure and exclude informational feedback effects.

We build on and connect these models by developing one in which (i) the firm's payoff has two components, (ii) traders have heterogeneous preferences over these components, (iii) the manager can choose the precision of public disclosure, and (iv) the firm learns from prices to guide investment into a growth opportunity linked to one component. This richer framework allows us to characterize how the optimal disclosure precision varies across equilibria, and to identify conditions under which more precise public information can either enhance or diminish firm value. Not only do we find opposite effects of more precise disclosure on the different dimensions of a firm value (Goldstein and Yang, 2019), but also characterize the optimal disclosure precision, and explore its relationship with manager's own information precision, magnitude of the investment opportunity, and the prevailing equilibrium in the market. In doing so, we uncover novel trade-offs between transparency and market-based learning in the presence of heterogeneous beliefs and multidimensional firm value, highlighting that greater disclosure precision can, under certain conditions, reduce the firm's ability to learn from prices and ultimately lower firm value—an insight that represents the core contribution of our theoretical framework.

2. The Model

We consider an economy with a firm that seeks to create value not only for its shareholders but also for a broader set of stakeholders. The firm provides both financial and ESG-related information, which traders incorporate into their trading decisions in the firm's equity market. The market is competitive and populated by risk-neutral traders, and features two assets: a risk-free asset and a risky asset. We model this setting using the noisy rational-expectations framework (Grossman and Stiglitz, 1980; Hellwig, 1980; Ver-

recchia, 1982). The risk-free asset yields a gross return of one and is priced at unity. The risky asset represents a claim on the firm's output, denoted by $\widetilde{v}$, which corresponds to the value of the firm's assets-in-place. This output is composed of two independent stochastic components: a financial component $\widetilde{z}$, and an ESG component $\widetilde{\delta}$. The financial component $\widetilde{z}$ captures the cash flows generated by the firm, while the ESG component $\widetilde{\delta}$, following the interpretation of Goldstein et al. (2024), reflects the firm's contribution to social good or the financial materiality of its ESG activities. Both components are modeled as uncorrelated normal random variables, with $\widetilde{\delta} \sim \mathcal{N}(0, \tau_{\delta}^{-1})$ and $\widetilde{z} \sim \mathcal{N}(0, \tau_{z}^{-1})$. Throughout the analysis, we assume $\tau_z = \tau_\delta = \tau$.

In addition to the asset-in-place (with the risky payoff $\widetilde{v}$), the firm has a growth opportunity generated by its contribution to the public good. This growth opportunity arises from ESG investments and activities, and its productivity depends on $\widetilde{\delta}$. The firm does not observe $\widetilde{\delta}$ directly, but receives its own private signal about this component, and also, learns about it indirectly through its market price, which aggregates all traders' information. To undertake this investment, the firm must raise additional funds, denoted by I. Following Subrahmanyam and Titman (1999) and Foucault and Gehrig (2008), and to maintain tractability, we assume that this growth opportunity is distinct from the firm's assets in place and are non-tradable.

The model unfolds over four stages, as illustrated in Figure 1:

- $t = 0$: The firm's manager commits to a disclosure policy aimed at maximizing the firm's overall value. This decision balances short-term value, derived from the expected market price of the firm's assets-in-place, and long-term value, arising from the expected return on its ESG investment opportunity.

- $t = 1$: Traders receive signals and trade the firm's shares in the financial market,

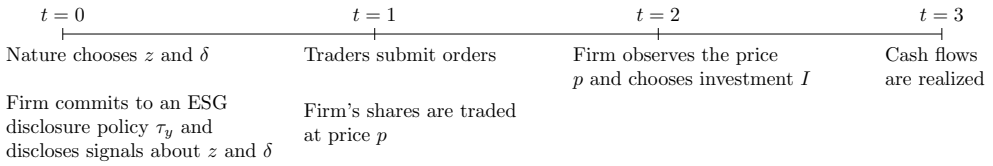


Figure 1: Timeline of the model

determining the equilibrium price $\widetilde{p}$.

- $t = 2$: After observing the market price, the manager chooses her ESG investment level, I, to maximize the value of the growth opportunity.

- $t = 3$: The firm's cash flows are realized.

2.1. Traders

The financial market is populated by both rational and liquidity traders. Among the rational traders, we distinguish between two types: traditional traders, denoted by t, and ESG traders, denoted by g. For simplicity, we assume that the mass of these two trader types are equal, and normalize the total mass of rational traders to 1. Traditional traders derive utility solely from the firm's financial performance, valuing only the financial component of the payoff, $\widetilde{z}$. In contrast, ESG traders derive utility exclusively from the firm's ESG performance (non-pecuniary utility), and therefore value only the ESG component, $\widetilde{\delta}$. Both types of traders exhibit constant absolute risk aversion (CARA) preferences, with a common risk aversion coefficient $\gamma > 0$. The expected utility of a trader of type $j \in \{t, g\}$ with initial wealth W_0 who holds q shares is given by

$$\mathbb{E}\left\{-\exp\left(-\gamma\left[W_0 + q\left(\beta_z^j \widetilde{z} + \beta_\delta^j \widetilde{\delta} - \widetilde{p}\right)\right]\right)\right\}, \tag{1}$$

where β_z^j and β_δ^j denote the weights that traders of type j assign to the financial and ESG components of the asset's return, respectively. Therefore, in our model, $\beta_z^t = 1$, $\beta_\delta^t = 0$, $\beta_z^g = 0$, and $\beta_\delta^g = 1$. Traders have rational expectations: they know the price function, which reflects the aggregate valuations of all traders, and condition their decisions on the observed price. Accordingly, each trader selects a demand function that maximizes expected utility based on all available information. Liquidity traders, by contrast, have an exogenously specified demand, $\widetilde{x} \sim \mathcal{N}(0, \tau_x^{-1})$, with $\tau_x > 0$.

2.2. Information Structure

The firm's manager is endowed with information about both the financial and ESG components of the payoff, with common precision τ_f:

$$\begin{aligned} \widetilde{s}_{Fz} &= \widetilde{z} + \widetilde{\varepsilon}_{Fz}, \\ \widetilde{s}_{F\delta} &= \widetilde{\delta} + \widetilde{\varepsilon}_{F\delta}, \end{aligned}$$

where $\widetilde{\varepsilon}_{Fz}, \widetilde{\varepsilon}_{F\delta} \sim \mathcal{N}(0, \tau_f^{-1})$. The manager discloses publicly noisy signals based on her information: $\widetilde{w} = \widetilde{s}_{Fz} + \widetilde{\varepsilon}_w$ and $\widetilde{y} = \widetilde{s}_{F\delta} + \widetilde{\varepsilon}_y$, where $\widetilde{\varepsilon}_w \sim \mathcal{N}(0, \tau_{\eta w}^{-1})$ and $\widetilde{\varepsilon}_y \sim \mathcal{N}(0, \tau_{\eta y}^{-1})$ are uncorrelated noise terms. The financial disclosure can thus be rewritten as:

$$\widetilde{w} = \widetilde{z} + \widetilde{\eta}_z,$$

where $\widetilde{\eta}_z = \widetilde{\varepsilon}_{Fz} + \widetilde{\varepsilon}_w$ and $\widetilde{\eta}_z \sim \mathcal{N}(0, \tau_w^{-1})$, with $\tau_w = (\tau_f^{-1} + \tau_{\eta w}^{-1})^{-1} \in [0, \tau_f]$. Similarly, the ESG disclosure takes the form:

$$\widetilde{y} = \widetilde{\delta} + \widetilde{\eta}_y,$$

where $\widetilde{\eta}_y = \widetilde{\varepsilon}_{F\delta} + \widetilde{\varepsilon}_y$ and $\widetilde{\eta}_y \sim \mathcal{N}(0, \tau_y^{-1})$, with $\tau_y = (\tau_f^{-1} + \tau_{\eta y}^{-1})^{-1} \in [0, \tau_f]$. Notice that the precision of the public signal is smaller than the precision of the information that the manager has, i.e., $\tau_w, \tau_y < \tau_f$. The financial disclosure $\widetilde{w}$, may be interpreted as the firm's announcements regarding future financial prospects, while the ESG disclosure, $\widetilde{y}$, reflects information about the firm's sustainability practices, such as sustainability reports or ESG ratings. For tractability, we assume the precision of public information is equal across components, i.e., $\tau_w = \tau_y$. The precision of the disclosure, τ_y, governs the quality of the public signal: the greater the precision, the more informative the disclosure. When $\tau_y = 0$, no information is disclosed by the manager; when $\tau_y = \tau_f$, she fully reveals her information.

In addition to these public signals, rational traders also receive private signals about both payoff components. Following Goldstein et al. (2024), we assume each trader i observes:

$$\begin{aligned} \widetilde{s}_z^i &= \widetilde{z} + \widetilde{\varepsilon}_z, \\ \widetilde{s}_\delta^i &= \widetilde{\delta} + \widetilde{\varepsilon}_\delta, \end{aligned}$$

where $\widetilde{\varepsilon}_z \sim \mathcal{N}(0, \tau_s^{-1})$ and $\widetilde{\varepsilon}_\delta \sim \mathcal{N}(0, \tau_s^{-1})$. For simplicity, in the rest of the paper we discard the i superscript from the private signal notation.

These private signals represent idiosyncratic information acquired by individual traders through proprietary analysis or research. Although noisy, they play a critical role in traders' portfolio decisions. Through the trading process, this dispersed private information is aggregated and reflected in the market price. As a result, the price serves as an informative signal about the firm's fundamentals, and provides valuable feedback to the manager for guiding her investment decisions.

2.3. Manager's Decisions

The stakeholders' value is determined by both the firm's assets-in-place and its ESG growth opportunity. The manager faces two key decisions. At time $t = 0$, she chooses the optimal disclosure policy, i.e., the precision of the public disclosure τ_y, to maximize the expected value of the firm for all stakeholders. At time $t = 2$, she chooses the level of ESG investment I to maximize the value of the ESG growth opportunity, conditional on the information she has gathered from the signals and the observed market price $\widetilde{p}$ at time $t = 1$.

To model optimal disclosure, we follow Diamond (1985), Verrecchia (2001), Lambert et al. (2007), and Gao and Liang (2013). As in these studies, we focus on the ex-ante disclosure decision, meaning the manager commits to a disclosure precision τ_y before any realization of its signals.[3]

Following Langberg and Sivaramakrishnan (2010), we assume that the overall value of the firm is a weighted average of the expected market price of the firm's assets-in-place and the expected value of the ESG growth opportunity:

$$V(\tau_y) = \alpha \mathbb{E}(\widetilde{p}) + (1 - \alpha)\mathbb{E}(\widetilde{G}), \tag{2}$$

where α is a weight determined by the firm's board of directors. By varying α, the board balances the interests of short-term shareholders, who focus on the price $\widetilde{p}$, and long-term shareholders, who are concerned with realized cash flows (see Goldstein and Yang, 2017).[4]

[3]We do not consider strategic ex-post disclosure, where the manager chooses to disclose based on her realized signal (see Grossman, 1981; Milgrom, 1981; and Dye, 1985, among others). We also abstract from issues related to market transparency, which involve disclosure of trading orders and prices (e.g., Madhavan, 1995; Pagano and Röell, 1996; Bloomfield and O'Hara, 1999; and Dumitrescu, 2010).

[4]One could alternatively treat α as a policy variable, especially in the context of comparative statics on stakeholder priorities.

The ESG growth opportunity payoff $\widetilde{G}$ is realized at $t = 3$, and takes the form:

$$\widetilde{G} = \sqrt{\Phi}\,\widetilde{\delta}\,I - \frac{I^2}{2}, \tag{3}$$

where the parameter Φ captures the scale or magnitude of the growth opportunity. It captures the economic significance of the ESG investment opportunity, which may vary across firms depending on factors such as industry context, firm size, or the materiality of ESG performance to stakeholders. As we will show later, this variable plays an important role in deriving our results. This functional form for $\tilde{G}$ captures the idea of diminishing returns to ESG investment: while the expected benefit increases linearly with the ESG signal $\widetilde{\delta}$, the cost of investment increases quadratically in I, ensuring concavity of the objective.

At $t = 2$, the manager chooses the level of investment I to maximize the expected value of $\widetilde{G}$, conditional on the information available to her at that time:

$$I^* = \arg\max_I \mathbb{E}\left[\widetilde{G}\,\middle|\,\mathcal{I}_F\right] = \sqrt{\Phi}\,\mathbb{E}\left[\widetilde{\delta}\,\middle|\,\mathcal{I}_F\right], \tag{4}$$

where $\mathcal{I}_F = \{\widetilde{s}_{Fz}, \widetilde{s}_{F\delta}, \widetilde{w}, \widetilde{y}, \widetilde{p}\}$ denotes the manager's information set at time $t = 2$.

2.4. Trading and Market Clearing

Rational trader i of type $j \in \{t, g\}$ choose their demand $d^{ij}(\mathcal{I}_i)$ to maximize expected utility as defined in equation (1). Each trader submits an order based on their available information, which includes private signals, public signals, and the observed price: $\mathcal{I}_i = \{\widetilde{s}_z, \widetilde{s}_\delta, \widetilde{w}, \widetilde{y}, \widetilde{p}\}$. Accordingly, the trader's strategy is a function mapping their information set to a portfolio choice, i.e., $d^{ij}(\cdot) : \mathbb{R}^5 \to \mathbb{R}$ for all traders.

We denote by:

$$D^j\left(\mathcal{I}_i\right) = \int_{i \in T_j} d^{ij}(\mathcal{I}_i)\, di$$

the aggregate demand for the stock from traders of type j, where T_j denotes the set of traders of type j.

The market-clearing price $\widetilde{p}$ equates the total demand from traditional traders, ESG traders, and liquidity traders with the fixed supply of shares, which is normalized to 1. Given traders' strategies, the price schedule is a mapping from the signals and noise trading space to the price space, $p(\cdot) : \mathbb{R}^5 \to \mathbb{R}$. We assume a rational expectations equilibrium with a linear price function:

$$\widetilde{p} = p_0 + p_z\widetilde{z} + p_\delta\widetilde{\delta} + p_w\widetilde{w} + p_y\widetilde{y} + p_x\widetilde{x} = p_0 + p_x\left(k_z\widetilde{z} + k_\delta\widetilde{\delta} + k_w\widetilde{w} + k_y\widetilde{y} + \widetilde{x}\right), \tag{5}$$

where we define the normalized price coefficients as $k_z = \dfrac{p_z}{p_x}$, $k_\delta = \dfrac{p_\delta}{p_x}$, $k_w = \dfrac{p_w}{p_x}$, and $k_y = \dfrac{p_y}{p_x}$. This linear pricing form arises naturally from the assumptions of normally distributed signals and CARA preferences, which ensure that equilibrium prices are linear functions of the underlying signals (Grossman and Stiglitz, 1980; Hellwig, 1980). The normalized coefficients k_z, k_δ, k_w, and k_y capture the relative sensitivity of the market price reaction to each signal relative to its reaction to noise trading. This normalization simplifies the characterization of equilibrium by allowing us to express price informativeness independently of the absolute scale of noise trading. Economically, these coefficients reflect how strongly the market incorporates each source of information into the price, and play a key role in determining both trader behavior and the manager's ability to learn from the market.

Definition 1 (Equilibrium)**.** *An equilibrium consists of a disclosure precision τ_y^*, an in-*

vestment level I^*, trader strategy functions $d^t(\cdot)$ and $d^g(\cdot)$ for traditional and ESG traders, respectively, and a price function $p(\cdot)$, such that the following conditions are satisfied:

1. ***Firm's Optimization.*** *The manager chooses τ_y^* at time $t = 0$ to maximize the expected stakeholders' value as defined in equation (2). At time $t = 2$, conditional on her information set, she selects I^* to maximize the expected value of the firm's ESG growth opportunity, as specified in equation (3).*
2. ***Traders' Optimization.*** *Given the price function and public signals, each trader of type $j \in \{t, g\}$ selects a demand function $d^j(\cdot)$ so as to maximize expected utility, as defined in equation (1), taking prices and the strategies of other traders as given.*
3. ***Market Clearing.*** *The price $\widetilde{p}$ satisfies the market-clearing condition almost surely:*

$$D^t\left(\widetilde{z}, \widetilde{\delta}, \widetilde{w}, \widetilde{y}, \widetilde{p}\right) + D^g\left(\widetilde{z}, \widetilde{\delta}, \widetilde{w}, \widetilde{y}, \widetilde{p}\right) + \widetilde{x} = 1, \tag{6}$$

where $D^j(\cdot)$ denotes the aggregate demand of traders of type j, and $\widetilde{x}$ is the exogenous demand from liquidity traders.

3. Equilibrium Characterization

We solve the model by backward induction, reflecting the sequential decisions of the manager and traders, in three steps: (i) the manager's investment decision at time $t = 2$; (ii) the trading game and price formation at time $t = 1$; and (iii) the manager's disclosure precision choice at time $t = 0$. This structure mirrors the timeline of the model and highlights the informational feedback loop that links the firm's disclosure policy to the investment efficiency via market prices.

At time $t = 2$, after observing the market price, the manager updates her belief about the ESG component of the payoff. This belief is formed using all available information,

including the price, which aggregates traders' private signals, and the manager's own internal signals and disclosures. Based on this updated belief, she selects her ESG investment level to maximize the expected value of the growth opportunity. This decision captures the core feedback channel of the model: the market's aggregation of information affects the firm's real investment behavior.

To determine how the market price conveys information, we analyze the trading game at time $t = 1$. Rational traders, both traditional and ESG-oriented, form demands based on their private signals, the firm's public disclosures, and their expectations about how these signals affect prices. Given the price conjecture (5), we derive traders' optimal demand functions and impose market-clearing to solve for the equilibrium price coefficients. This yields an expression for the price as a function of the underlying signals and liquidity noise.

Finally, at time $t = 0$, the manager anticipates how the disclosure policy affects the informativeness of prices, the information that she can extract from the price at $t = 2$, and ultimately the value she can generate for stakeholders. The manager selects the precision of public disclosure to maximize expected stakeholder value (2). The optimal disclosure policy thus trades off the benefits of improved price efficiency against the potential loss of valuable market-based information.

This equilibrium characterization highlights the dual role of disclosure: while it improves traders' pricing, it may also reduce the informativeness of market prices and impair the manager's ability to learn from them. The interaction between these forces determines the endogenous level of transparency chosen by the manager and gives rise to novel insights on the optimal precision of public information in capital markets.

3.1. Optimal Investment Policy

We begin by deriving the firm's optimal investment strategy at date $t = 2$, conditional on the information available to the manager, including both private signals and the information revealed through the equilibrium price.[5]

Lemma 1. *The optimal investment strategy is given by:*

$$I^* = \iota_z \widetilde{s}_{Fz} + \iota_\delta \widetilde{s}_{F\delta} + \iota_w \widetilde{w} + \iota_y \widetilde{y} + \iota_p \widetilde{p}, \tag{7}$$

where $\mathcal{I}_F = \{\widetilde{s}_{Fz}, \widetilde{s}_{F\delta}, \widetilde{w}, \widetilde{y}, \widetilde{p}\}$ *denotes the firm's information set at the time of investment, and the coefficients* ι_z, ι_δ, ι_w, ι_y, *and* ι_p *are given explicitly in equation* (12) *in* 5.

The key insight from Lemma 1 is that the market price $\widetilde{p}$ serves as an additional signal that improves the manager's inference about the ESG component $\widetilde{\delta}$. Because traders act on their private signals when submitting orders, and the price aggregates these orders through the market-clearing condition, $\widetilde{p}$ implicitly embeds information about $\widetilde{\delta}$ that is not fully captured by the manager's own signals or disclosures. This informational feedback allows her to refine the investment decision using market-based learning.

The coefficients ι_z, ι_δ, ι_w, ι_y, and ι_p represent the weights that the manager places on each information source when forming her posterior belief about the ESG component $\widetilde{\delta}$. These weights are determined by the relative precision and correlation structure of the signals. In particular, ι_p is the weight that the manager assigns to the price in updating her expectation about the value of $\widetilde{\delta}$, and plays a critical role in the feedback mechanism:

[5]The expression for the firm's optimal investment follows from standard Bayesian updating under multivariate normality. Since all signals and underlying variables are jointly normally distributed, the conditional expectation of $\widetilde{\delta}$ given the firm's information set $\mathcal{I}_F$ is linear in the observed signals. The weights on each signal, denoted by $\iota_z, \iota_\delta, \iota_w, \iota_y$, and ι_p, are obtained from Bayesian updating using the variance-covariance matrix of the fundamental values and the signals and their correlation with $\widetilde{\delta}$. See, for example, DeGroot (1970, Chapter 9) for the general derivation of posterior distributions in Gaussian models.

the higher ι_p, the more the manager relies on the market price to learn about the ESG payoff. The magnitude of ι_p is itself endogenous, as it depends on the equilibrium precision of public disclosure and the precision of traders' signals.

3.2. Optimal Trading Strategies

We now derive the optimal trading strategies of rational traders. Each trader chooses their demand based on their private signals, the public disclosures, and the observed price. The price is taken as given and follows the linear form conjectured in equation (5). From the CARA-Normal setup, each trader of type $j \in \{t, g\}$ maximizes expected utility by choosing the demand function given by:

$$d^{j*}(\mathcal{I}_i) = \frac{\mathbb{E}\left[\beta_z^j \widetilde{z} + \beta_\delta^j \widetilde{\delta} \,\middle|\, \mathcal{I}_i\right] - \widetilde{p}}{\gamma \,\mathbb{V}\left[\beta_z^j \widetilde{z} + \beta_\delta^j \widetilde{\delta} \,\middle|\, \mathcal{I}_i\right]}, \tag{8}$$

where $\mathcal{I}_i = \{\widetilde{s}_z, \widetilde{s}_\delta, \widetilde{w}, \widetilde{y}, \widetilde{p}\}$ denotes the information available to trader i.

Lemma 2. *In a symmetric linear equilibrium, the optimal demand of a trader i of type $j \in \{t, g\}$ is given by:*

$$d^{j*}(\mathcal{I}_i) = i_z^j \widetilde{s}_z + i_\delta^j \widetilde{s}_\delta + i_w^j \widetilde{w} + i_y^j \widetilde{y} + i_p^j \widetilde{p}, \tag{9}$$

where the coefficients for traditional and ESG traders are given in equations (17) and (18) in 5, respectively.

The expression in Lemma 2 presents each trader's optimal demand. The numerator captures the expected payoff of the asset from the perspective of trader i of type j, conditional on their information set. This expected payoff reflects the trader's subjective valuation, weighted by their preferences for the financial and ESG components. The denominator reflects the perceived risk, specifically the conditional variance of the payoff,

scaled by the trader's risk aversion parameter γ. Thus, the demand is increasing in the perceived underpricing of the asset relative to its expected value, and decreasing in the associated risk. The resulting linear demand in the signals follows from the assumption of CARA utility and normally distributed payoffs.

3.3. Trading Intensities

Equilibrium price coefficients k_z, k_δ, k_w, and k_y are determined endogenously through the aggregation of trades by rational traders, who respond to both public and private signals about the two payoff components. Heterogeneous traders' preferences play a central role in shaping posterior beliefs and trading intensities. While each trader type ultimately derives utility from only one component, the posterior expectation of that component depends on signals about both $\widetilde{z}$ and $\widetilde{\delta}$. This reflects an important feature of the model: even signals about the component a trader does not directly value can affect their demand. This is due to the informational content of these signals that is embedded in the price and the correlation structure of signals.

To illustrate, consider a traditional trader forming an expectation about the financial payoff $\widetilde{z}$ based on their private signals $\widetilde{s}_z$ and $\widetilde{s}_\delta$, the public signals $\widetilde{w}$ and $\widetilde{y}$, and the market price $\widetilde{p}$. From equation (15), this posterior can be decomposed into two components:

$$\mathbb{E}[\widetilde{z} \mid \mathcal{I}_i] = \underbrace{\frac{\tau_s}{\tau+\tau_s+\tau_y}\cdot\widetilde{s}_z + \frac{\tau_y}{\tau+\tau_s+\tau_y}\cdot\widetilde{w}}_{\text{Direct Signal Inference}} + \underbrace{\frac{\frac{1}{\tau+\tau_s+\tau_y}\cdot p_z\left(\widetilde{p} - \left[p_w\widetilde{w} + p_y\widetilde{y} + p_z\cdot\frac{\tau_y\widetilde{w}+\tau_s\widetilde{s}_z}{\tau+\tau_s+\tau_y} + p_\delta\cdot\frac{\tau_y\widetilde{y}+\tau_s\widetilde{s}_\delta}{\tau+\tau_s+\tau_y}\right]\right)}{\frac{1}{\tau+\tau_s+\tau_y}\cdot p_z^2 + \frac{1}{\tau+\tau_s+\tau_y}\cdot p_\delta^2 + \frac{1}{\tau_x}\cdot p_x^2}}_{\text{Price Inference}}. \tag{10}$$

The first term, direct signal inference, summarizes the informational content from

signals directly related to $\widetilde{z}$: the trader's private signal $\widetilde{s}_z$ and the public signal $\widetilde{w}$. As expected, a higher signal about the valued component increases expected payoff and thus demand. Moreover, when forming their full posterior via the price, traditional traders must infer what portion of the price reflects $\widetilde{z}$ versus $\widetilde{\delta}$. This is reflected in the second term, indirect price inference. Higher values of $\widetilde{s}_z$ and $\widetilde{w}$ reduce the informativeness of the price component of the posterior. Intuitively, for a given observed price $\widetilde{p}$, receiving stronger direct signals leads the trader to infer that other market participants must have received weaker signals about $\widetilde{z}$, thereby diminishing the marginal informational content of the price.[6]

From equation (13), the posterior uncertainty about $\widetilde{z}$ for a traditional trader consists of the residual uncertainty after incorporating direct signal information, minus a correction term that reflects learning from the price. Formally,

$$\mathbb{V}[\widetilde{z} \mid \mathcal{I}_i] = \frac{1}{\tau + \tau_s + \tau_y} - \frac{\left(\frac{1}{\tau + \tau_s + \tau_y} \cdot p_z\right)^2}{\frac{1}{\tau + \tau_s + \tau_y} \cdot p_z^2 + \frac{1}{\tau + \tau_s + \tau_y} \cdot p_\delta^2 + \frac{1}{\tau_x} \cdot p_x^2}.$$

Differentiating this expression with respect to τ_y, we find that $\dfrac{\partial \mathbb{V}[\widetilde{z} \mid \mathcal{I}_i]}{\partial \tau_y} < 0$, i.e., increasing the precision of public signals always reduces posterior uncertainty about $\widetilde{z}$.

To understand how this affects trading behavior, we substitute both the posterior expectation and variance into the optimal demand expression in equation (9). Taking the derivative of d^t with respect to the private signal $\widetilde{s}_z$ yields:

$$i_z^t = \frac{\partial d^t}{\partial \widetilde{s}_z} > 0.$$

[6]This mechanism is consistent with the discussion in Goldstein et al. (2024), which highlights how private signals affect the intensity of trading and the relative contribution of price versus signal inference.

This inequality reflects the fact that, although a higher $\widetilde{s}_z$ reduces the trader's reliance on the price (i.e., weakens the price inference channel), its direct effect on the signal inference term is sufficiently strong to dominate. In other words, traditional traders always increase their demand for the firm's shares as they receive more favorable private signals about the financial component they value.

In contrast, the effect of a higher public signal $\widetilde{w}$ is ambiguous. While $\widetilde{w}$ directly improves signal inference, it also reduces the informational content of the price. As a result, the sign of $i_w^t = \dfrac{\partial d^t}{\partial \widetilde{w}}$ depends on the relative magnitude of the equilibrium price coefficients and cannot be determined ex ante.

We next examine the effect of higher public and private signals about $\tilde{\delta}$, the payoff component that traditional traders do not directly care about, on their trading intensity. Since ESG traders act on $\widetilde{s}_\delta$ and $\widetilde{y}$, traditional traders learn about $\widetilde{z}$ by conditioning on these variables as well. Therefore, private and public signals about $\widetilde{\delta}$ (i.e., $\widetilde{s}_\delta$ and $\widetilde{y}$) influence the beliefs and trading behavior of traditional traders, even though they do not derive utility from $\widetilde{\delta}$.

This interdependence arises due to the endogenous information aggregation in the price and is a distinctive feature of models with heterogeneous trader preferences. It implies that disclosure policies and signal structures about one component can have general equilibrium effects on trading activity and market outcomes, even for traders who "ignore"that component.

In equation (10), higher values of $\widetilde{s}_\delta$ or $\widetilde{y}$ do not enter the signal inference term, as traditional traders place no intrinsic value on ESG-related payoffs. However, these signals do enter the price inference term and affect beliefs indirectly through inference about the information embedded in the price.

Specifically, for a fixed observed price $\widetilde{p}$, a higher realization of $\widetilde{s}_\delta$ or $\widetilde{y}$ leads traditional

traders to infer that ESG-oriented traders received stronger signals about $\widetilde{\delta}$ and therefore exerted upward pressure on the price. Holding $\widetilde{p}$ constant, this implies that the remaining portion of the price, attributable to information about $\widetilde{z}$, must be lower. As a result, the informational content of the price regarding $\widetilde{z}$ is weakened. Since the price inference term in equation (10) is reduced, the overall posterior expectation of $\widetilde{z}$ declines.

Importantly, because this effect only operates through the price channel and has no offsetting positive contribution from direct signal inference, the impact of $\widetilde{s}_\delta$ and $\widetilde{y}$ on traditional traders' demand is unambiguously negative. We show that:

$$i_y^t = \frac{\partial d^t}{\partial \widetilde{y}} < 0 \quad \text{and} \quad i_\delta^t = \frac{\partial d^t}{\partial \widetilde{s}_\delta} < 0.$$

Thus, traditional traders always reduce their demand for the firm's shares when they receive stronger private or public signals about the ESG component of the payoff, even though they do not value it directly. This result highlights the general equilibrium effect of heterogeneous preferences: in a market where the price aggregates information from all traders, even signals about irrelevant components influence trading behavior through the learning embedded in prices.

Notice that similar to Goldstein et al. (2024), because traditional and green traders value different components, they trade in opposite directions based on the same signals. Both trader groups trade with equal and constant intensities on signals about the output components they value: $i_z^t = i_\delta^g = \frac{\tau_s}{\gamma}$. At the same time, their trading intensities on signals about the output components they do not value, i_δ^t and i_z^g depend on the equilibrium price coefficients and on the riskiness of the stock payoff. Traders of type-j trade more intensively on signals about the fundamental they do not value when facing a smaller residual uncertainty or, equivalently, when the equilibrium price is more informative to

them.

Defining the price informativeness to a type-j trader similar to Goldstein et al. (2024), as $PI_j \equiv \mathbb{V}\left(\beta_z^j \widetilde{z} + \beta_\delta^j \widetilde{\delta} \middle| \mathcal{I}_i\right)$, it is easy to see that:

$$\frac{i_\delta^t}{i_z^g} = \frac{\frac{\tau + \tau_s + \tau_y}{\tau_x} + k_z^2}{\frac{\tau + \tau_s + \tau_y}{\tau_x} + k_\delta^2} = \frac{PI_t}{PI_g} \equiv \nu, \tag{11}$$

where ν is the relative price informativeness. If $\nu = 1$, the price is equally informative to traditional and green traders. If $\nu > 1$, the price is more informative to traditional traders than to green traders and they trade against their $\widetilde{\delta}$ -signals more intensively than green traders trade against their $\widetilde{z}$-signals. The opposite is true if $\nu < 1$.

In summary, our model builds on the framework of Goldstein et al. (2024), who study how heterogeneous ESG preferences affect trading behavior and the informational content of prices. We extend this framework by introducing an endogenous public disclosure policy: the manager chooses the precision of public information in order to maximize the overall value of the firm. This setup allows us to examine how disclosure precision influences traders' posterior beliefs and, through them, equilibrium outcomes. A key insight of our model is that more precise public information improves traders' direct signal inference, but simultaneously reduces the informativeness of the price. This, in turn, affects the firm's ability to learn from the market and alters its investment decision. The interaction between these forces creates a novel feedback channel that links disclosure policy to both traders' behavior and real outcomes, and generates an endogenous trade-off that determines the optimal level of transparency.

3.4. Firm's Growth Opportunity

We next compute the expected value of the firm at time $t = 0$, which is given by the weighted average of the expected market price of the firm's assets-in-place and the

expected value of its ESG growth opportunity, as defined in equation (2).

Lemma 1 characterizes the firm's optimal investment policy at time $t = 2$. Substituting the optimal investment I^* into the growth opportunity function in equation (3), and applying the law of iterated expectations, we obtain the unconditional expected value of the growth opportunity at time $t = 0$.

Lemma 3. *The expected value at time $t = 0$ of the firm's growth opportunity is given by:*

$$\mathbb{E}[\widetilde{G}^*] = \frac{1}{2}\Phi\left(\mathbb{V}[\widetilde{\delta}] - \mathbb{V}[\widetilde{\delta} \mid \mathcal{I}_F]\right) = \frac{1}{2}\Phi\left(\tau^{-1} - \frac{1}{\tau + \tau_f + \tau_y} \cdot \frac{\frac{\tau + \tau_f + \tau_y}{\tau_x} + k_z^2}{\frac{\tau + \tau_f + \tau_y}{\tau_x} + k_\delta^2 + k_z^2}\right).$$

This expression highlights that the expected value of the firm's growth opportunity increases with the precision of the firm's posterior about $\widetilde{\delta}$. Greater public disclosure may reduce $\mathbb{V}[\widetilde{\delta} \mid \mathcal{I}_F]$, thereby increasing the firm's ability to invest efficiently. However, as discussed earlier, higher disclosure precision may reduce price informativeness, which can increase the conditional variance and thus lower expected value. This trade-off underpins the firm's optimal disclosure decision.

3.5. Equilibrium

We now characterize the equilibrium of the model. A key insight is that the interaction between traders' heterogeneous preferences and the firm's disclosure policy leads to the possibility of multiple equilibria, depending on the precision of the public ESG signal, τ_y. The central mechanism at play is the role of strategic substitution between public and private information in shaping price informativeness. When τ_y is sufficiently high, public information dominates and both types of traders rely heavily on the disclosed signal. In this regime, the incentives to acquire and trade on private information are symmetric and relatively weak, resulting in a unique equilibrium where both trader types contribute

equally to price informativeness.

However, when the public signal becomes less precise, asymmetric equilibria emerge. Traders face a coordination problem: whichever group believes it has greater informational advantage will trade more aggressively, leading prices to reflect more of their private information. This endogenous selection of dominant information type, either financial or ESG, creates multiple equilibria.

Formally, we show that there exists a threshold value $\tau_y^c \equiv \frac{\tau_x}{4}\left(\frac{\tau_s}{2\gamma}\right)^2 - \tau - \tau_s$, such that when $\tau_y < \tau_y^c$ three equilibria can emerge: one symmetric and two asymmetric. For $\tau_y \geq \tau_y^c$, the coordination friction disappears and only the symmetric equilibrium survives. This is summarized in the proposition below.

Proposition 1 (Equilibrium Characterization)**.** *There exists an equilibrium* $(\tau_y^*, I^*, d^{t*}, d^{g*}, p^*)$*, such that* τ_y^* *maximizes the expected firm value (2),* I^**maximizes the expected growth opportunity and is given by (7),* d^{t*}, d^{g*} *maximize the expected profits from trading of green and traditional traders, respectively, and are given by (9), and the equilibrium price is given by (5), where the coefficients solve the system of equations (20)-(25).*

For given values of parameters, we have partial disclosure $(\tau_y^* < \tau_y^c)$*. Otherwise, we have full disclosure* $(\tau_y^* = \tau_f)$*.*

Proposition 1 characterizes the equilibrium of the game and shows how the informativeness of public disclosure interacts with the market's endogenous information structure. When the precision of the information chosen by the firm is high $(\tau_y \geq \tau_y^c)$ there is a unique equilibrium. The equilibrium is symmetric in the sense that the information revealed in the price about the financial and ESG components is the same, i.e., $k_z = k_\delta$ and thus, $\nu = 1$. In this case the optimal precision disclosure is full disclosure, i.e., $\tau_y^* = \tau_f$. If the precision of public disclosure is lower than τ_y^c, we need to distinguish two cases. If $V(\tau_y^*) > V(\tau_f)$,

then the local optimum is the global optimum and the firm partially disclose its information, i.e., $\tau_y^* < \tau_f$. Otherwise, the global optimum is $\tau_y^* = \tau_f$, and therefore we have full disclosure of information.

Notice that when it is optimal for the firm to fully disclose its information and $\tau_y^c < \tau_f$, we have a unique equilibrium. However, when it is optimal to have partial disclosure ($\tau_y^* \leq \tau_f$), or full disclosure and $\tau_f \leq \tau_y^c$, we have multiplicity of equilibria. Thus, when $\tau_y^* < \tau_y^c$, in addition to the symmetric equilibrium ($k_z = k_\delta$), there are also two asymmetric equilibria: one in which $k_z > k_\delta$, and another one in which $k_z < k_\delta$. Following Goldstein et al. (2024), we will denote the equilibrium where $k_z = k_\delta$ as the M-equilibrium, the one in which $k_z > k_\delta$ as the T-equilibrium, and the one in which $k_z < k_\delta$ as the G-equilibrium. Notice that in the M-equilibrium the price is equally informative about the financial component and ESG component ($\nu = 1$), in the T-equilibrium, the price is more informative about the financial component ($\nu > 1$), and in the G-equilibrium, the price is more informative about the ESG component ($\nu < 1$).

4. Optimal Precision of Public Information

4.1. Firm's Learning from the Price

A central feature of our model is that the firm learns from the stock price when making its investment decision. Specifically, the market price aggregates the beliefs of heterogeneous traders who possess private information about both payoff components, financial ($\widetilde{z}$) and ESG ($\widetilde{\delta}$), and thereby conveys signals about these components that the firm's manager can use to guide her real decisions.

In particular, although the manager observes its own private signals about both payoff components ($\widetilde{s}_{Fz}$ and $\widetilde{s}_{F\delta}$), the price contains additional information inferred from the aggregated trading behavior of informed investors. This makes the price a valuable source

of feedback, especially regarding the ESG component, which directly determines the payoff of the firm's growth opportunity.

In equilibrium, the market price can be interpreted as delivering two separate informational signals: one about the value of $\widetilde{z}$ component, and another about the value of $\widetilde{\delta}$ component. Given that the manager already knows $\widetilde{s}_{Fz}$, $\widetilde{s}_{F\delta}$, $\widetilde{w}$, and $\widetilde{y}$, the incremental information of the price regarding each payoff component lies in the new information it conveys beyond these internal signals. Formally, conditional on the manager's information set, the price is equivalent to the signals of the form indicated in equations (39) and (40). The precision of the signals about the $\widetilde{z}$ and $\widetilde{\delta}$ components are denoted by $\tau_{p,z}$ and $\tau_{p,\delta}$, respectively.

The effect of τ_y on the informativeness of these price signals is highly sensitive to the prevailing equilibrium in the market. In the symmetric M-equilibrium, as we show in equation (43), increasing τ_y always improves the informativeness of the price about both payoff components. This enhances the manager's ability to learn from prices and supports a higher investment efficiency, making full disclosure optimal.

In asymmetric equilibria, however, the relationship is more nuanced. In the T-equilibrium, we find that increasing τ_y improves the information content of the price about the ESG component ($\widetilde{\delta}$), which directly affects the firm's investment. Hence, in this case too, as we show in equation (45), greater disclosure enhances the manager's decision-making. In contrast, as shown in equation (47), in the G-equilibrium, increasing τ_y reduces the informativeness of the price about $\widetilde{\delta}$. In this case, greater transparency may reduce firm value, and an interior optimal level of disclosure may emerge. In section 4.2, we explore further the possibility of emerging an optimal level of public information precision.

4.2. Precision of Public Information and Firm's Value

We now investigate in more detail how the precision of public information affects the firm's overall value. As shown in Equation (2), the firm's value is composed of two distinct components: the expected market price of the firm's assets-in-place, $\mathbb{E}[\tilde{p}] = p_0$, reflecting its short-term value, and the expected value of the growth opportunity, $\mathbb{E}[\tilde{\tilde{G}}]$, which captures its long-term value. Importantly, as we demonstrate in the proof of Proposition 1 (5), the impact of increasing public information precision on these two components is not uniform and depends critically on the prevailing market equilibrium. In particular, higher precision always enhances the informativeness of prices, thereby raising $\mathbb{E}[\tilde{p}]$. At the same time, it may impair the firm's ability to learn from market prices, potentially reducing $\mathbb{E}[\tilde{G}]$. The interplay between these opposing forces governs whether greater disclosure improves or diminishes the firm's value, and may give rise to an interior optimal level of public signal precision. Figure 2 illustrates the interaction between public information precision and firm value under certain parameter configurations. In this figure, we fix $\tau = \tau_s = \tau_x = 1$ and set the risk aversion parameter to $\gamma = 0.1$. As derived in Proposition 1, in this scenario, the critical threshold for the precision of public information is $\tau_y^c = 4.25$. Panels (a) and (c) correspond to the case where the precision of the firm's endowed information is relatively low ($\tau_f = 4.5$), while panels (b) and (d) depict the case with relatively high precision ($\tau_f = 10$). In terms of the investment opportunity, panels (a) and (b) consider a modest growth potential ($\Phi = 1$), whereas panels (c) and (d) examine scenarios with a large investment opportunity ($\Phi = 100$).

Figure 2 illustrate that when the magnitude of the investment opportunity is relatively small ($\Phi = 1$), increasing the precision of public information enhances the firm's overall value. In these cases, greater disclosure increases both the expected market price, $\mathbb{E}[\tilde{p}]$, and the expected value of the growth opportunity, $\mathbb{E}[\tilde{G}]$. As a result, in such cases, it is

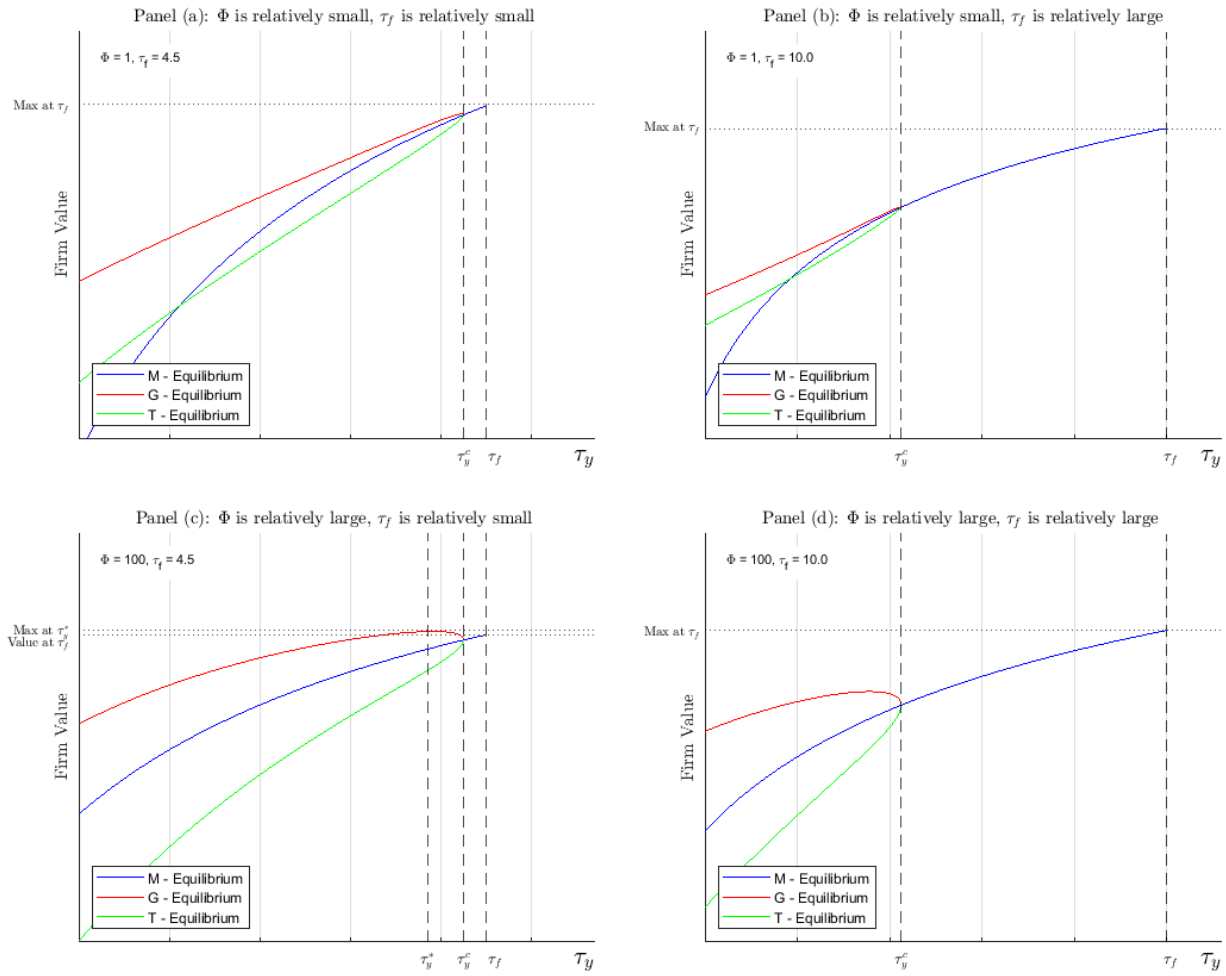


Figure 2: Public Information Precision and Firm Value

This figure shows how the value of the firm varies with the precision of public information disclosure (τ_y) under different market equilibria, investment magnitudes, and firm's information precision. In all panels, we assume $\alpha = 0.5$, i.e., the firm assigns equal weights to its short-term and long-term dimensions of its value in its objective function (2). $\tau_y^c = 4.25$ is the cutoff in the precision of public information disclosure below which several equilibria may arise (Equation 34). In panels (a) and (c), the precision of firm's information, τ_f, is relatively small, while in panels (b) and (d), the precision of firm's information is relatively large. Panels (a) and (b) illustrate the case where the magnitude of the ESG investment option, Φ, is relatively low. In these cases, higher disclosure precision always increases firm value and thus, full disclosure is the optimal choice, i.e., $\tau_y^* = \tau_f$. Panels (c) and (d) correspond to settings where the magnitude of the ESG investment option is relatively high. Panel (c) shows that when the precision of the firm's information is low and G-equilibrium prevails, there is an internal optimal level of public information precision that maximizes the value of the firm, i.e., $\tau_y^* < \tau_f$. Panel (d) shows that when the precision of the firm's information is large, again, full disclosure is the optimal choice, i.e., $\tau_y^* = \tau_f$.

always optimal for the firm to fully disclose its endowed information, i.e., $\tau_y^* = \tau_f$.

In contrast, when the magnitude of the investment opportunity is large ($\Phi = 100$), the negative effect of increasing public information precision on the value of the growth opportunity, $\mathbb{E}[\tilde{G}]$, can outweigh the positive effect on the expected price, p_0. This occurs in the G-equilibrium, an outcome of particular relevance given that the firm's investment opportunity is a function of the ESG component of its payoff, $\tilde{\delta}$. In this equilibrium, the market price aggregates ESG traders' private information more effectively and becomes more informative about the ESG component, which the firm relies on to guide its investment decision. However, as the precision of the public signal increases, ESG traders face a diminished informational advantage over traditional traders and thus reduce their trading intensity. As a consequence, the price becomes less reflective of their private information, impairing the firm's ability to learn from the market. This deterioration in the feedback channel lowers the expected value of the growth opportunity, and can ultimately reduce the overall value of the firm.

However, as the firm increases the precision of its public signal beyond the threshold τ_y^c, the G-equilibrium gives way to an interior equilibrium in which the price is equally informative about both payoff components. In this new equilibrium, higher public information precision once again unambiguously increases the firm's value, as the increasing effect of disclosure on $\mathbb{E}[\tilde{p}]$ outweighs the decreasing effect on $\mathbb{E}[\tilde{G}]$. Nevertheless, the firm's disclosure precision is constrained above by its own information endowment, i.e., τ_f. If the firm's value at this upper bound is lower than the maximum value attained within the G-equilibrium, where disclosure was less precise, then the optimal disclosure level will be interior, equal to the precision that maximized firm value in that regime. This is the case when τ_f is relatively small, as illustrated in panel (c) of Figure 2. Conversely, when τ_f is sufficiently large, as in panel (d), full disclosure again maximizes the firm's overall value.

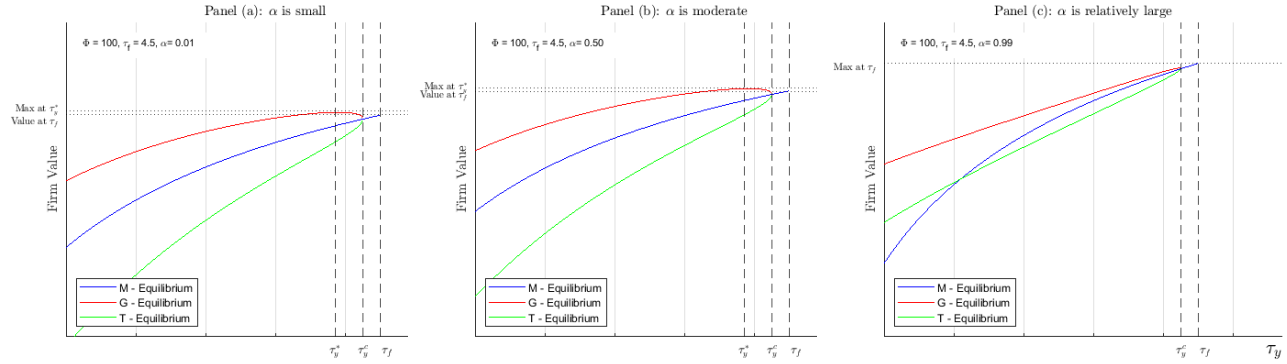


Figure 3: Firm Value as a Function of Public Information Precision for Varying Weights on Short-Term Value (α)
This figure illustrates how the firm's value changes with the precision of public disclosure (τ_y) for different values of α, which determines the weight the firm places on short-term value (expected price) relative to long-term value (expected growth opportunity). τ_f is the precision of firm's information and Φ is the magnitude of the firm's ESG investment opportunity. $\tau_y^c = 4.25$ is the cutoff in the precision of public information disclosure below which several equilibria may arise (Equation 34), and τ_y^* is the precision of public information that maximizes the overall value of the firm. In Panel (a), where $\alpha = 0.01$, the firm primarily values its long-term performance. In this case, increasing disclosure precision can reduce price-based learning and lower the value of the growth opportunity, resulting in a non-monotonic relationship and an interior optimum. In Panel (b), with $\alpha = 0.5$, the firm values both components equally, which in our model, leads to the existence of an optimal level of public information disclosure. In Panel (c), where $\alpha = 0.99$, the firm is primarily focused on its short-term value; here, greater precision monotonically increases firm value as the benefits from improved pricing dominate the loss in learning. The optimal disclosure policy for the firm would be full disclosure.

The firm's optimal disclosure policy is also shaped by the relative weight it assigns to short-term versus long-term value in its objective function (2), as captured by the parameter α. Figure 3 plots this relationship. When α is small, the firm places greater emphasis on its long-term value, which is driven by the value of the ESG-related growth opportunity. In this case, the potential negative effect of greater disclosure precision becomes more pronounced. As a result, the firm may find it optimal to withhold some information in order to preserve the learning channel from prices and improve investment efficiency.

In contrast, when α is large, the firm's objective is dominated by short-term considerations, specifically the expected price of its assets-in-place. Since public disclosure reduces uncertainty and improves pricing accuracy, a higher transparency is beneficial to this component. In this case, the negative impact of disclosure on price-based learning becomes less relevant for the firm's objective, and full disclosure once again emerges as the optimal

strategy. Thus, the optimal level of public information precision depends on α, reflecting the shifting importance of price informativeness versus learning in determining overall firm value.

Finally, note that when the precision of the manager's information is lower than the threshold precision, i.e., $\tau_f < \tau_y^c$, the firm always operates in the region where multiple equilibria are possible. In this regime, the informativeness of the market price, and therefore, the firm's ability to learn from it, is highly sensitive to the prevailing equilibrium and the precision of public disclosure.

In this case, as can be inferred from Figure 2, when the magnitude of the ESG investment opportunity is relatively small (Panels a and b), increasing the precision of public information continues to improve both components of firm value, and as a result, full disclosure remains the optimal policy. However, when the investment opportunity is large (Panel c), the relationship between disclosure precision and firm value becomes non-monotonic. In particular, whether full disclosure remains optimal depends on whether τ_f falls below or above the turning point beyond which further increases in precision begin to reduce the firm's ability to learn from the price. If τ_f falls below this point, then full disclosure remains optimal. Otherwise, increasing precision beyond this point diminishes the value of the firm's growth opportunity more than it improves pricing, and the firm maximizes its value by choosing $\tau_y = \tau_y^*$.

In sum, the relationship between public information precision and firm value is shaped by a subtle interplay between price informativeness and the firm's ability to learn from the market. When the investment opportunity is modest, or the precision of the manager's private information is sufficiently large, greater disclosure consistently enhances firm value, and full transparency is optimal. However, when the investment opportunity is large and the precision of the manager's private information is not sufficiently large, excessive public

disclosure can impair market-based learning. This leads to a decline in the value of the firm's growth option, potentially making partial disclosure optimal. These results highlight that optimal disclosure is neither maximal nor minimal by default, but context-dependent, balancing short-term pricing benefits against long-term informational feedback that shapes real investment decisions.

The dependence of disclosure precision on the equilibrium in the market is a novel result in the literature on information design and market feedback. While prior work (e.g., Goldstein et al., 2024) highlights how heterogeneous preferences shape equilibrium informativeness, our model endogenizes disclosure policy and shows how it can affect the value of the firm. This result has implications for regulatory debates on ESG transparency and corporate reporting mandates.

From a policy perspective, our results suggest that mandatory ESG disclosure may have unintended consequences in environments where market prices are more informative about the ESG payoff component and the firm, faced with an ESG investment opportunity, wants to learn from traders' information about this component. These results point to the importance of calibrating disclosure mandates with attention to the endogenous response of the market participants.

5. Conclusions

We studied how a firm should optimally disclose public information when it relies on market prices to guide its investment decisions. The interaction between heterogeneous traders' preferences and the firm's learning from prices creates a novel trade-off: while public disclosure improves the short-term value of the firm, it may also weaken the valuable feedback that the firm can receive from the market to guide its investment and thus, may lower the long-term value.

Our model shows that when the precision of public information is relatively high, the price is not specifically informative about the component about which the firm wants to learn. Therefore, higher precision of public information improves the overall value of the firm and thus, full disclosure maximizes the overall value of the firm. However, at lower levels of public information precision and when the price is more informative about the value of the ESG component about which the firm wants to learn, a trade-off may arise. In such cases, more precise public information may reduce the learning opportunity of the firm about the ESG growth opportunity from the market prices. In this case, we show that there is an optimal level of precision that balances out the increasing effect of public disclosure on the short-term value and its decreasing effect on the long-term value of the firm.

Our results have direct implications for both firms and policymakers engaged in the design and evaluation of ESG disclosure frameworks. While disclosure is often promoted as a mechanism for reducing information asymmetry and aligning firm behavior with stakeholder preferences, our model shows that, aligned with the findings of Goldstein and Yang (2019), this intuition may be incomplete when market prices also guide real decisions. In particular, when traders with heterogeneous preferences trade based on both public and private signals, greater transparency can weaken the information aggregation role of prices. For firms that rely on prices to evaluate ESG investment opportunities, this effect can distort resource allocation, especially when ESG performance is difficult to measure or forecast internally. These findings caution against one-size-fits-all disclosure mandates and suggest that optimal disclosure policies may depend critically on the traders' preferences and the firm's reliance on price-based learning.

This paper opens several avenues for future research. A promising direction is to allow for endogenous information acquisition by traders, where disclosure not only affects

price informativeness but also the precision of private information. This will allow us to incorporate crowding-out effect of private information in our model. We also aim to generalize the model to cases where ESG traders value both financial and ESG payoff components, or the growth opportunity of the firm depends on both the financial and the ESG payoff components. However, in the current model, we do not obtain closed-form analytical solutions for these cases. Finally, future work could examine how disclosure affects firm value in the presence of rating agencies, index inclusion, or other intermediaries that aggregate ESG-related signals on behalf of investors with diverse objectives.

Appendix

Proof of Lemma 1. We derive the firm's optimal investment policy at time $t = 2$ by computing its posterior expectation of $\widetilde{\delta}$ conditional on its information set $\mathcal{I}_F = \{\widetilde{s}_{Fz}, \widetilde{s}_{F\delta}, \widetilde{w}, \widetilde{y}, \widetilde{p}\}$. By the projection theorem for multivariate normal distributions, the conditional expectation is a linear function of the observed signals.[7] Thus, the optimal investment is given by:

$$I^* = \sqrt{\Phi}\,\mathbb{E}\left[\widetilde{\delta}\,\middle|\,\mathcal{I}_F\right] = \sqrt{\Phi}(\iota_z\,\widetilde{s}_{Fz} + \iota_\delta\,\widetilde{s}_{F\delta} + \iota_w\,\widetilde{w} + \iota_y\,\widetilde{y} + \iota_p\,\widetilde{p}),$$

where the coefficients $\iota_\bullet$ are determined by the covariances between $\widetilde{\delta}$ and each signal in $\mathcal{I}_F$, and are given by:

$$\begin{aligned}
\iota_z &= -\tau_f\tau_x p_z p_\delta,\\
\iota_\delta &= \tau_f(\tau+\tau_f+\tau_y)p_x^2 + \tau_f\tau_x p_z^2,\\
\iota_w &= -\tau_x(\tau+\tau_f+\tau_y)p_w p_\delta - \tau_x\tau_y p_z p_\delta,\\
\iota_y &= \tau_y(\tau+\tau_f+\tau_y)p_x^2 + \tau_x\tau_y p_z^2 - \tau_x(\tau+\tau_f+\tau_y)p_y p_\delta,\\
\iota_p &= \tau_x(\tau+\tau_f+\tau_y)p_\delta.
\end{aligned} \tag{12}$$

■

Proof of Lemma 2. We compute the conditional variance terms using the projection theorem. The posterior variances are:

$$\mathbb{V}[\widetilde{z}\mid\mathcal{I}_i] = \frac{1}{\tau+\tau_s+\tau_y} - \frac{\left(p_z/(\tau+\tau_s+\tau_y)\right)^2}{p_x^2/\tau_x + p_z^2/(\tau+\tau_s+\tau_y) + p_\delta^2/(\tau+\tau_s+\tau_y)}, \tag{13}$$

[7] The projection theorem implies that when all variables are jointly normally distributed, the conditional expectation of any variable on a set of observed variables is the best linear predictor and is given by the linear projection based on covariances. See, e.g., DeGroot (1970, Chapter 9).

$$\mathbb{V}[\widetilde{\delta} \mid \mathcal{I}_i] = \frac{1}{\tau + \tau_s + \tau_y} - \frac{\left(p_\delta/(\tau + \tau_s + \tau_y)\right)^2}{p_x^2/\tau_x + p_z^2/(\tau + \tau_s + \tau_y) + p_\delta^2/(\tau + \tau_s + \tau_y)}. \tag{14}$$

Next, we calculate the posterior expectations of $\widetilde{z}$ and $\widetilde{\delta}$ using the projection theorem for jointly normal random variables. After simplification, we have:

$$\begin{aligned} E[\widetilde{z}|\mathcal{I}_i] = \widetilde{s}_z \frac{\tau_s}{\tau + \tau_s + \tau_y} + \widetilde{w} \frac{\tau_y}{\tau + \tau_s + \tau_y} \\ + \frac{p_z \frac{1}{\tau + \tau_s + \tau_y} \left[p - \left(\widetilde{w} p_w + \widetilde{y} p_y + p_\delta \frac{\widetilde{y}\tau_y + \widetilde{s}_\delta \tau_s}{\tau + \tau_s + \tau_y} + p_z \frac{\widetilde{w}\tau_y + \widetilde{s}_z \tau_s}{\tau + \tau_s + \tau_y} \right) \right]}{p_x^2 \frac{1}{\tau_x} + p_z^2 \frac{1}{\tau + \tau_s + \tau_y} + p_\delta^2 \frac{1}{\tau + \tau_s + \tau_y}}. \end{aligned} \tag{15}$$

A similar expression holds for $\mathbb{E}[\widetilde{\delta} \mid \mathcal{I}_i]$,

$$\begin{aligned} E[\widetilde{\delta}|\mathcal{I}_i] = \widetilde{s}_\delta \frac{\tau_s}{\tau + \tau_s + \tau_y} + \widetilde{y} \frac{\tau_y}{\tau + \tau_s + \tau_y} \\ + \frac{p_\delta \frac{1}{\tau + \tau_s + \tau_y} \left[\widetilde{p} - \left(\widetilde{w} p_w + \widetilde{y} p_y + p_\delta \frac{\widetilde{y}\tau_y + \widetilde{s}_\delta \tau_s}{\tau + \tau_s + \tau_y} + p_z \frac{\widetilde{w}\tau_y + \widetilde{s}_z \tau_s}{\tau + \tau_s + \tau_y} \right) \right]}{p_x^2 \frac{1}{\tau_x} + p_z^2 \frac{1}{\tau + \tau_s + \tau_y} + p_\delta^2 \frac{1}{\tau + \tau_s + \tau_y}}. \end{aligned} \tag{16}$$

Substituting these expectations and the variances into equation (8) and simplifying, we obtain a linear demand function. We conjecture that the demand functions for traditional ($j = t$) and ESG ($j = g$) traders are equal to

$$d^{j*}(\mathcal{I}_i) = i_z^j \widetilde{s}_z + i_\delta^j \widetilde{s}_\delta + i_w^j \widetilde{w} + i_y^j \widetilde{y} + i_p^j \widetilde{p}.$$

We identify the coefficients $i_\bullet^j$ for traditional ($j = t$) and ESG ($j = g$) traders and we

obtain that they are equal to the equations (17) and (18), respectively.

$$
\begin{aligned}
i_z^t &= \frac{\partial d^t}{\partial \widetilde{s}_z} = \frac{\tau_s}{\gamma}, \\
i_\delta^t &= \frac{\partial d^t}{\partial \widetilde{s}_\delta} = -\frac{1}{\gamma}\frac{\tau_s \tau_x p_z p_\delta}{(\tau+\tau_s+\tau_y)\,p_x^2+\tau_x p_\delta^2}, \\
i_w^t &= \frac{\partial d^t}{\partial \widetilde{w}} = \frac{1}{\gamma}\frac{\tau_y\,(\tau+\tau_s+\tau_y)\,p_x^2+\tau_x\tau_y p_\delta^2-\tau_x\,(\tau+\tau_s+\tau_y)\,p_w p_z}{(\tau+\tau_s+\tau_y)\,p_x^2+\tau_x p_\delta^2}, \\
i_y^t &= \frac{\partial d^t}{\partial \widetilde{y}} = -\frac{\tau_x p_z}{\gamma}\frac{(\tau+\tau_s+\tau_y)\,p_y+\tau_y p_\delta}{(\tau+\tau_s+\tau_y)\,p_x^2+\tau_x p_\delta^2}, \\
i_p^t &= \frac{\partial d^t}{\partial \widetilde{p}} = -\frac{\tau+\tau_s+\tau_y}{\gamma}\frac{(\tau+\tau_s+\tau_y)\,p_x^2+\tau_x\,(p_z^2+p_\delta^2)-\tau_x p_z}{(\tau+\tau_s+\tau_y)\,p_x^2+\tau_x p_\delta^2},
\end{aligned}
\tag{17}
$$

and,

$$
\begin{aligned}
i_z^g &= \frac{\partial d^g}{\partial \widetilde{s}_z} = -\frac{1}{\gamma}\frac{\tau_s \tau_x p_z p_\delta}{(\tau+\tau_s+\tau_y)\,p_x^2+\tau_x p_z^2}, \\
i_\delta^g &= \frac{\partial d^g}{\partial \widetilde{s}_\delta} = \frac{\tau_s}{\gamma} \\
i_w^g &= \frac{\partial d^g}{\partial \widetilde{w}} = -\frac{1}{\gamma}\frac{\tau_x\,(\tau+\tau_s+\tau_y)\,p_w p_\delta+\tau_x\tau_y p_z p_\delta}{(\tau+\tau_s+\tau_y)\,p_x^2+\tau_x p_z^2}, \\
i_y^g &= \frac{\partial d^g}{\partial \widetilde{y}} = \frac{1}{\gamma}\frac{\tau_y\,(\tau+\tau_s+\tau_y)\,p_x^2-\tau_x\,(\tau+\tau_s+\tau_y)\,p_y p_\delta+\tau_x\tau_y p_z^2}{(\tau+\tau_s+\tau_y)\,p_x^2+\tau_x p_z^2}, \\
i_p^g &= \frac{\partial d^t}{\partial \widetilde{p}} = -\frac{1}{\gamma}\frac{(\tau+\tau_s+\tau_y)\,((\tau+\tau_s+\tau_y)\,p_x^2+\tau_x\,(p_z^2+p_\delta^2)-\tau_x p_\delta)}{(\tau+\tau_s+\tau_y)\,p_x^2+\tau_x p_z^2}
\end{aligned}
\tag{18}
$$

■

Proof of Lemma 3. As explained before, at $t = 2$, the manager chooses the level of investment I to maximize the expected value of the growth opportunity conditional on her information set $\mathcal{I}_\mathcal{F} = \{\tilde{s}_{Fz}, \tilde{s}_{F\delta}, \tilde{w}, \tilde{y}, \tilde{p}\}$. We obtained that the optimal investment strategy is given by (4):

$$I^*(\mathcal{I}_\mathcal{F}) = \sqrt{\Phi}E(\tilde{\delta}|\mathcal{I}_\mathcal{F}).$$

Inserting the optimal investment into the growth opportunity (3), it can be shown that:

$$E[\tilde{G}^*] = \frac{1}{2}\Phi\left(\tau^{-1} - \frac{1}{\tau+\tau_f+\tau_y}\cdot\frac{\frac{\tau+\tau_f+\tau_y}{\tau_x}+k_z^2}{\frac{\tau+\tau_f+\tau_y}{\tau_x}+k_\delta^2+k_z^2}\right). \tag{19}$$

■

Proof of Proposition 1. To solve for the equilibrium, we first compute the aggregate demands of traditional and ESG traders, defined as $D^t = \int_{i\in T_t} d^t\, di$ and $D^g = \int_{i\in T_g} d^g\, di$, where d^j is given in Lemma 2. Substituting these into the market-clearing condition,

$$\frac{1}{2}D^t + \frac{1}{2}D^g + \widetilde{x} = 1,$$

and simplifying, we obtain an equilibrium condition in terms of the fundamental variables $\widetilde{z}$, $\widetilde{\delta}$, $\widetilde{w}$, $\widetilde{y}$, and $\widetilde{p}$. We identify the coefficients p_0, p_x and the normalized coefficients k_z, k_δ, k_w, k_y in the linear price conjecture

$$\widetilde{p} = p_0 + p_x\left(k_z\widetilde{z} + k_\delta\widetilde{\delta} + k_w\widetilde{w} + k_y\widetilde{y} + \widetilde{x}\right).$$

The market clearing condition implies that the coefficients are such that:

$$\begin{aligned}
k_z &= \frac{1}{2}\left(i_z^g + i_z^t\right)\\
k_\delta &= \frac{1}{2}\left(i_\delta^g + i_\delta^t\right)\\
k_w &= \frac{1}{2}\left(i_w^g + i_w^t\right)\\
k_y &= \frac{1}{2}\left(i_y^g + i_y^t\right)\\
1 &= \frac{1}{2}\left(i_p^g + i_p^t\right)p_0\\
-1 &= \frac{1}{2}\left(i_p^g + i_p^t\right)p_x
\end{aligned}$$

Plugging in the demand coefficients given by (17) and (18) we obtain the following system for the price coefficients:

$$k_z = \frac{1}{2}\frac{\tau_s}{\gamma}\left(1 - \frac{k_z k_\delta}{\Upsilon + k_z^2}\right) \tag{20}$$

$$k_\delta = \frac{1}{2}\frac{\tau_s}{\gamma}\left(1 - \frac{k_z k_\delta}{\Upsilon + k_\delta^2}\right) \tag{21}$$

$$k_w = \frac{1}{2\gamma}\left(\tau_y - \frac{\Upsilon \tau_x k_z k_w}{\Upsilon + k_\delta^2} - \frac{\left(\Upsilon \tau_x k_w + \tau_y k_z\right) k_\delta}{\Upsilon + k_z^2}\right) \tag{22}$$

$$k_y = \frac{1}{2\gamma}\left(\tau_y - \frac{\Upsilon \tau_x k_\delta k_y}{\Upsilon + k_z^2} - \frac{\Upsilon\left(\tau_x k_y + \tau_y k_\delta\right) k_z}{\Upsilon + k_\delta^2}\right) \tag{23}$$

$$p_x = \frac{2\gamma}{\Upsilon \tau_x}\left(\frac{\left(\Upsilon + (k_z^2 + k_\delta^2)\right)}{\Upsilon + k_z^2} + \frac{\left(\Upsilon + (k_z^2 + k_\delta^2)\right)}{\Upsilon + k_\delta^2}\right)^{-1} \tag{24}$$

$$p_0 = -p_x \tag{25}$$

The remaining price coefficients follow directly:

$$p_z = k_z p_x, \tag{26}$$

$$p_\delta = k_\delta p_x, \tag{27}$$

$$p_w = k_w p_x, \tag{28}$$

$$p_y = k_y p_x. \tag{29}$$

To find k_δ, we solve equation (21) for k_z in terms of k_δ and substitute it into equation (20). This yields a single equation in k_δ:

$$\left(k_\delta^3 + \Upsilon k_\delta - \frac{\Upsilon \tau_s}{2\gamma}\right) \cdot \left(-2\gamma k_\delta^2 + \tau_s k_\delta - 2\gamma\Upsilon\right) = 0. \tag{30}$$

Each real positive solution to equation (30) corresponds to a candidate equilibrium. The roots of the first polynomial correspond to a symmetric equilibrium in which both types

of traders have equal price informativeness. The second factor captures the coordination problem between the two types of traders. Multiple equilibria arise when the second factor has multiple positive real roots, corresponding to cases where the information of a given component of the liquidation value dominates in the price formation. Each positive real root of these expressions corresponds to a possible equilibrium. We have the following cases:

Case 1. ***Symmetric Equilibrium***

We begin by analyzing the first factor on the left-hand side of equation (30), which corresponds to the symmetric case where $k_z = k_\delta$.[8] Substituting into equation (30), we obtain a cubic polynomial in k_δ. Its discriminant is:

$$\Delta = -\left(4\Upsilon^3 + 27\left(\frac{\Upsilon\tau_s}{2\gamma}\right)^2\right) < 0,$$

implying that the cubic has exactly one real root. Applying Cardano's formula, we obtain this root in closed form as:

$$k_\delta = \sqrt[3]{\frac{\Upsilon\tau_s}{4\gamma} + \sqrt{\frac{1}{4}\left(\frac{\Upsilon\tau_s}{2\gamma}\right)^2 + \frac{1}{27}\Upsilon^3}} + \sqrt[3]{\frac{\Upsilon\tau_s}{4\gamma} - \sqrt{\frac{1}{4}\left(\frac{\Upsilon\tau_s}{2\gamma}\right)^2 + \frac{1}{27}\Upsilon^3}}, \tag{31}$$

which is always strictly positive. Hence, the first factor in equation (30) always admits a unique positive real root. Replacing k_δ from equation (31) into the recursive price coeffi-

[8] This condition can be imposed by substituting $k_z = k_\delta$ into either equation (20) or (21).

cients, we find that:

$$\begin{aligned} k_z &= k_\delta, \\ k_y &= k_w = \frac{1}{2}\frac{\Upsilon\tau_y}{\gamma k_\delta^2 + \Upsilon\tau_x k_\delta + \gamma\Upsilon}, \\ p_x &= -p_0 = \frac{\gamma k_\delta^2 + \Upsilon\tau_x k_\delta + \gamma\Upsilon}{\Upsilon\tau_x\left(\Upsilon + 2k_\delta^2\right)}. \end{aligned}$$

The remaining coefficients follow from (26)-(29).

Since $k_z = k_\delta$, we obtain that in this equilibrium the relative price informativeness defined in (11) is $\nu = 1$, so the price is equally informative to traditional and green traders.

Case 2. ***Degenerate Multiple Equilibrium***

We now consider the second factor on the left-hand side of equation (30). This term is a quadratic polynomial in k_δ:

$$-2\gamma k_\delta^2 + \tau_s k_\delta - 2\gamma\Upsilon = 0.$$

Solving this yields:

$$k_\delta = \frac{1}{4\gamma}\left(\tau_s \pm \sqrt{\tau_s^2 - 16\gamma^2\Upsilon}\right). \tag{32}$$

Two equal real roots arise when the discriminant equals zero, i.e., when:

$$\tau_s^2 - 16\gamma^2\Upsilon = 0 \quad \Leftrightarrow \quad \tau_y = \tau_y^c = \frac{\tau_x}{4}\left(\frac{\tau_s}{2\gamma}\right)^2 - \tau - \tau_s.$$

In this special case, we obtain:

$$k_\delta = k_z = \frac{\tau_s}{4\gamma}.$$

Substituting into the recursive expressions for the remaining price coefficients, we find:

$$k_w = k_y = \frac{8\gamma\tau_y\Upsilon}{16\gamma^2\Upsilon + \tau_s\left(\tau_s + 4\Upsilon\tau_x\right)},$$

and

$$p_0 = -p_x = -\frac{1}{2}\gamma\frac{16\gamma^2\Upsilon + \tau_s\left(\tau_s + 4\Upsilon\tau_x\right)}{\Upsilon\tau_x\left(\tau_s^2 + 8\gamma^2\Upsilon\right)}. \tag{33}$$

The remaining coefficients follow from (26)-(29).

Notice that in this case $k_\delta = k_z = \frac{\tau_s}{4\gamma}$, the equilibrium is also unique, as the three possible equilibria are the same. Notice also that since $k_z = k_\delta$, we have again that $\nu = 1$, so here also the price is equally informative to traditional and green traders.

Case 3. ***Asymmetric Equilibria***

We now consider the case where the discriminant in equation (32) is strictly positive. This occurs if:

$$\tau_s^2 - 16\Upsilon\gamma^2 > 0 \quad \Leftrightarrow \quad \tau_y < \tau_y^c = \frac{\tau_x}{4}\left(\frac{\tau_s}{2\gamma}\right)^2 - \tau - \tau_s. \tag{34}$$

Under this condition, equation (30) admits three equilibria: one symmetric equilibrium (as in Case 1), and two asymmetric equilibria in which prices are more informative either about traditional or ESG information.[9]

Let us consider first the T-equilibrium, where:

$$k_\delta = \frac{1}{4\gamma}\left(\tau_s - \sqrt{\tau_s^2 - 16\gamma^2\Upsilon}\right),$$
$$k_z = \frac{1}{4\gamma}\left(\tau_s + \sqrt{\tau_s^2 - 16\gamma^2\Upsilon}\right).$$

[9]See also Equation (18) in Goldstein et al. (2024), where similar multiplicity arises. However, note that in their model, $\tau_y = 0$.

The normalized price coefficients for the public signals are therefore:

$$k_y = \gamma\tau_y \frac{\tau_s - \sqrt{\tau_s^2 - 16\gamma^2\Upsilon}}{4\gamma^2\tau_s + \tau_x\tau_s^2 - 8\gamma^2\Upsilon\tau_x},$$
$$k_w = \gamma\tau_y \cdot \frac{\tau_s + \sqrt{\tau_s^2 - 16\gamma^2\Upsilon}}{4\gamma^2\tau_s + \tau_x\tau_s^2 - 8\gamma^2\Upsilon\tau_x}.$$

The price coefficients follow from the market clearing:

$$p_0 = -p_x = 2\gamma \frac{4\gamma^2\tau_s + \tau_s^2\tau_x - 8\gamma^2\Upsilon\tau_x}{\tau_s\tau_x\left(4\gamma^2\Upsilon - \tau_s^2\right)}. \tag{35}$$

The remaining coefficients follow from (26)-(29).

Notice that since $k_z > k_\delta$ we have that $\nu > 1$ and therefore the price is more informative to traditional traders, and they trade against their $\widetilde{\delta}$-signals more intensively than green traders trade against their $\widetilde{z}$-signals. We will call this equilibrium the T-equilibrium.

We now turn to the second asymmetric equilibrium, i.e., G-equilibrium, where:

$$k_\delta = \frac{1}{4\gamma}\left(\tau_s + \sqrt{\tau_s^2 - 16\Upsilon\gamma^2}\right), \tag{36}$$
$$k_z = \frac{1}{4\gamma}\left(\tau_s - \sqrt{\tau_s^2 - 16\Upsilon\gamma^2}\right), \tag{37}$$

which implies that $k_z < k_\delta$. Notice that since $k_z < k_\delta$ we have that $\nu < 1$ and therefore the price is less informative to traditional traders, and they trade against their $\widetilde{\delta}$-signals less intensively than green traders trade against their $\widetilde{z}$-signals. We will call this equilibrium the G-equilibrium and here the price is more informative about the ESG component of the firm's payoff than about its financial component. The normalized price coefficients

associated with the public signals are:

$$k_y = \gamma\tau_y \cdot \frac{\tau_s + \sqrt{\tau_s^2 - 16\gamma^2\Upsilon}}{4\gamma^2\tau_s - 8\gamma^2\Upsilon\tau_x + \tau_x\tau_s^2},$$
$$k_w = \gamma\tau_y \cdot \frac{\tau_s - \sqrt{\tau_s^2 - 16\gamma^2\Upsilon}}{4\gamma^2\tau_s - 8\gamma^2\Upsilon\tau_x + \tau_x\tau_s^2}.$$

The intercept of the price function remains the same as in the T-equilibrium:

$$p_0 = -p_x = -\frac{8\gamma^3 \cdot \frac{\tau_s}{\tau_x} + 2\gamma\tau_s^2 - 16\gamma^3\Upsilon}{\tau_s^3 - 4\gamma^2\Upsilon\tau_s}. \tag{38}$$

As before, the remaining price coefficients are obtained from (26)-(29).

Firm's Learning from the Price

Considering the manager's information set $\mathcal{I}_F = \{\widetilde{s}_{Fz}, \widetilde{s}_{F\delta}, \widetilde{w}, \widetilde{y}, \widetilde{p}\}$, the price provides the additional signals:

$$\widetilde{s}_{p,z} = \frac{p - p_0 - p_w\widetilde{w} - p_y\widetilde{y} - p_\delta\mathbb{E}[\widetilde{\delta}|\widetilde{s}_{F\delta}]}{p_z} = \widetilde{z} + \underbrace{\frac{p_\delta}{p_z}\left(\widetilde{\delta} - \mathbb{E}[\widetilde{\delta}|\widetilde{s}_{F\delta}]\right) + \frac{p_x}{p_z}\widetilde{x}}_{\widetilde{\varepsilon}_{p,z}}, \tag{39}$$

and

$$\widetilde{s}_{p,\delta} = \frac{p - p_0 - p_w\widetilde{w} - p_y\widetilde{y} - p_z\mathbb{E}[\widetilde{z}|\widetilde{s}_{Fz}]}{p_\delta} = \widetilde{\delta} + \underbrace{\frac{p_z}{p_\delta}\left(\widetilde{\delta} - \mathbb{E}[\widetilde{z}|\widetilde{s}_{Fz}]\right) + \frac{p_x}{p_\delta}\widetilde{x}}_{\widetilde{\varepsilon}_{p,\delta}}, \tag{40}$$

where $\tau_{p,z} = \widetilde{\varepsilon}_{p,z}^{-1}$ and $\tau_{p,\delta} = \widetilde{\varepsilon}_{p,\delta}^{-1}$ indicate the precision of the information that the price provides to the manager about the value of $\widetilde{z}$ and $\widetilde{\delta}$, respectively.[10] We can show that:

$$\tau_{p,z} = \tau_x k_z^2 \frac{\tau + \tau_f}{\tau_x k_\delta^2 + \tau + \tau_f} = M_1\left(k_z, k_\delta\right), \tag{41}$$

[10]To extract the price signal about each component, we have subtracted the expected value of all terms besides that component from the price, and divided it by the price coefficient of that component, as in Zhou and Kang (2023).

and

$$\tau_{p,\delta} = \tau_x k_\delta^2 \frac{\tau + \tau_f}{\tau_x k_z^2 + \tau + \tau_f} = M_2\left(k_z, k_\delta\right). \tag{42}$$

To analyze the effect of the precision pf public information, τ_y on the information that the manager can learn from the price, we take the derivative of equations 41 and 42, with respect to τ_y, in each equilibrium.

Case 1 M**-equilibrium** $k_z = k_\delta$

In this case, it can be shown that:

$$\frac{\partial \tau_{p,z}}{\partial \tau_y} = \frac{\partial \tau_{p,\delta}}{\partial \tau_y} > 0, \tag{43}$$

i.e., higher precision of public information always increases the manager's learning from the price, about the value of both payoff components.

Asymmetric Equilibria $k_z \neq k_\delta$ In **Case 2** T**-equilibrium** $(k_z > k_\delta)$, we can show that:

$$\frac{\partial \tau_{p,z}}{\partial \tau_y} < 0, \tag{44}$$

i.e., in the T-equilibrium, higher precision of public information reduces the additional information that the price provides to the manager regarding the value of the $\widetilde{z}$ component. However, the manager does not need to learn about this component, because her investment opportunity is a function of $\widetilde{\delta}$ component.

Also:

$$\frac{\partial \tau_{p,\delta}}{\partial \tau_y} > 0, \tag{45}$$

i.e., in the T-equilibrium, higher precision of public information improves the additional information that the price provides to the manager regarding the value of the $\widetilde{\delta}$ component. It is important, because the manager wants to learn about the $\widetilde{\delta}$ component to guide her

investment decision. Thus, we expect the manager to increase the precision of public information when the T-equilibrium prevails in the market.

In **Case 3** G**-equilibrium** ($k_z < k_\delta$), we show that:

$$\frac{\partial \tau_{p,z}}{\partial \tau_y} > 0, \tag{46}$$

i.e., in the G-equilibrium, higher precision of public information improves the additional information that the price provides to the manager regarding the value of the $\widetilde{z}$ component. However, the manager does not need to learn about this component, because her investment opportunity is a function of $\widetilde{\delta}$ component. Thus, increasing the precision of public information does not necessarily improves the investment decision.

Also:

$$\frac{\partial \tau_{p,\delta}}{\partial \tau_y} < 0, \tag{47}$$

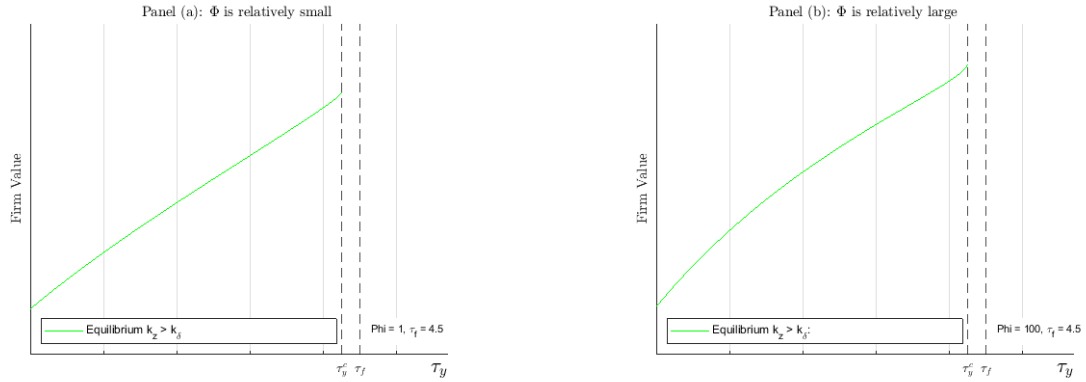
i.e., in the G-equilibrium, higher precision of public information reduces the additional information that the price provides to the manager regarding the value of the $\widetilde{\delta}$ component. Since the manager wants to learn about the $\widetilde{\delta}$ component to guide her investment decision, it is not necessarily optimal for her to improve the precision of public information in this equilibrium.

Optimal Disclosure Precision

Next, we evaluate the firm's optimal disclosure policy that maximizes its value $V = \alpha \mathbb{E}[\tilde{p}] + (1-\alpha)\,\mathbb{E}[\tilde{G}] = \alpha p_0 + (1-\alpha)\,\mathbb{E}[\tilde{G}]$. To do this, we first analyze the effect of higher precision of public information on the two components of the firm value separately.

First, we see that for all the three equilibria $\dfrac{\partial p_0}{\partial \tau_y} > 0$.

In **Case 1** M**-equilibrium** ($k_z = k_\delta$), $\dfrac{\partial \mathbb{E}[\tilde{G}]}{\partial \tau_y} > 0$



(a) Small investment option: $\Phi = 1$

(b) Large investment option: $\Phi = 100$

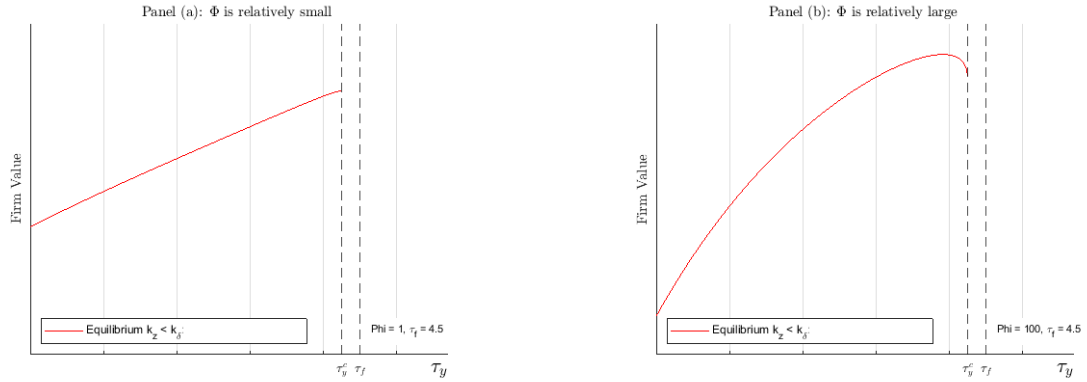
Figure 4: Firm Value and ESG Disclosure Precision in T-equilibrium

These plots illustrate how the firm's total value varies with the precision of public disclosure τ_y, in the T-equilibrium. In both cases, the firm's signal precision is $\tau_f = 4.5$. Φ is the magnitude of the ESG investment opportunity. $\tau_y^c = 4.25$ is the cutoff in the precision of public information disclosure below which several equilibria may arise (Equation 34). We observe that in T-equilibrium, higher τ_y always leads to higher firm value, both for large and small magnitudes of investment opportunity Φ.

In **Case 2** T**-equilibrium** $(k_z > k_\delta)$ $\dfrac{\partial \mathbb{E}[\tilde{G}]}{\partial \tau_y} > 0$. That is, in this equilibrium, increasing the precision of public disclosure increases the firm's ability to learn from market prices and thereby increases the expected value of the ESG growth option. At the same time, we have shown that $\dfrac{\partial p_0}{\partial \tau_y} > 0$, meaning that more precise public information improves the short-term component of firm value by lowering uncertainty and increasing price informativeness. Therefore, higher disclosure precision improves both p_0 and $\mathbb{E}[\widetilde{G}]$ and thus, always increases the value of the firm. We display this relationship in Figure 4, which plots firm value as a function of τ_y for two different values of Φ.

We let $\tau = \tau_s = \tau_x = 1$ and $\gamma = 0.1$. Panel (a) corresponds to a relatively small investment opportunity ($\Phi = 1$), while Panel (b) shows the case of a large investment opportunity ($\Phi = 100$). In both cases, the firm's own signal precision is set to $\tau_f = 4.5$.

In **Case 3** G**-equilibrium** $(k_z < k_\delta)$, however, it is possible that $\dfrac{\partial \mathbb{E}[\tilde{G}]}{\partial \tau_y} < 0$ for some values of the parameters. Therefore, there may be cases where increasing τ_y improves p_0 but reduces $\mathbb{E}[\widetilde{G}]$. Depending on the relative magnitudes of these effects, firm value may



(a) Small investment option: $\Phi = 1$

(b) Large investment option: $\Phi = 100$

Figure 5: Firm Value and ESG Disclosure Precision In G-equilibrium

This figure illustrates how the firm's value varies with public ESG disclosure precision τ_y, in the G-equilibrium. In both cases, the firm's signal precision is $\tau_f = 4.5$. Φ is the magnitude of the ESG investment opportunity. $\tau_y^c = 4.25$ is the cutoff in the precision of public information disclosure below which several equilibria may arise (Equation 34). We observe that in G-equilibrium, while firm value increases monotonically with disclosure when Φ is small, an interior optimum arises when Φ is large.

exhibit a non-monotonic relationship with disclosure precision. Specifically, there may exist an interior optimum $\tau_y^* < \tau_f$ that maximizes firm value. Figure 5 illustrates this relationship numerically for two values of the investment opportunity Φ. As before, we fix $\tau = \tau_s = \tau_x = 1$, $\gamma = 0.1$, and $\tau_f = 4.5$.

Panel (a) corresponds to a small investment opportunity ($\Phi = 1$). In this case, firm value increases monotonically with τ_y, as the gain from improved p_0 dominates the loss from reduced $\mathbb{E}[\widetilde{G}]$. In contrast, Panel (b) shows the case of a large investment opportunity ($\Phi = 100$), where an interior maximum emerges: initially, increasing τ_y raises firm value, but beyond a certain point, the negative effect on learning dominates, and further disclosure reduces total value. This confirms the existence of an interior solution for the optimal disclosure level.

Finally, we need to check that our Perfect Bayesian Equilibrium satisfies both the sequential rationality and belief consistency conditions. The firm selects its disclosure policy strategically, anticipating how its chosen level of precision will influence traders' beliefs and, ultimately, the equilibrium price in the market. Traders observe the publicly

disclosed signals and, given the disclosure policy, update their beliefs about the firm's fundamentals using Bayes' rule for the signals that are on the equilibrium path. These beliefs then inform their trading decisions, which in turn determine the market-clearing price. In equilibrium, the firm's disclosure choice, traders' belief updating, and the resulting price must be mutually consistent: traders' beliefs must be rational given the disclosure strategy, and the firm manager must choose the policy optimally, taking into account how it will affect the price through these belief dynamics.

To prove sequential rationality we need that each player's strategy is optimal given their information and beliefs. Thus, at $t = 2$ the firm uses Bayesian updating to form an expectation of $\tilde{\delta}$ which is optimal given its information. The investment I^* maximizes expected value of the ESG opportunity (a concave function), conditional on this belief. Then at $t = 1$, traders choose their demand strategies based on the expectations about $\tilde{z}$ and $\tilde{\delta}$, conditional on their beliefs. Finally, at $t = 0$ the firm choice is sequentially rational because the manager chooses the disclosure precision that balances short-term versus long-term value (higher expected price from more precise disclosure benefits short-term value), lower informativeness of price due to crowding out of private signals hurts learning, and long-term value). Finally, our equilibrium satisfies the belief consistency since agents updated their beliefs using Bayes' rule, given the equilibrium strategies and observed signals. Thus, the traders use correct Bayesian inference to combine public and private signals (as derived in Lemma 2) and price aggregates private information via equilibrium coefficients that reflect market-clearing (6). ■

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