THE ACCOUNTING REVIEW
Vol. XX, No. XX
MONTH YEAR
pp. 1–29

American Accounting Association
DOI: 10.2308/TAR-2023-0707

ESG Disclosure, Market Forces, and Investment Efficiency

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ABSTRACT: This paper examines the impact of environmental, social, and governance (ESG) disclosure on firm investment. The analysis characterizes the optimal precision of ESG disclosure that channels investors' tastes for ESG into firm investment. Although it is tempting to think that the optimal ESG disclosure becomes more precise when investors care more about ESG, I show this intuition is incomplete because it overlooks the fact that stronger tastes for ESG change how investors use information. Applying the analysis to a large economy, I show that mandating more precise climate disclosure than would be voluntarily provided motivates self-interested firms to act on common interests in reducing emissions. That is, a regulator can leverage market forces and a disclosure mandate to achieve a similar result as a Pigovian tax in motivating firms to internalize the externalities created by their climate-related investments.

JEL Classifications: D82; G14; M41.

Keywords: ESG investing; delegated philanthropy; real effects; tragedy of the commons; mandatory versus voluntary climate disclosure.

I. INTRODUCTION

In 1970, Milton Friedman published his famous essay "The social responsibility of business is to increase its profits." It has been recognized that Friedman's view is consistent with many social goals, such as investing in employees and suppliers, to the extent that these goals generate long-term value. Subsequent studies have identified situations where corporate social responsibility (CSR) goes beyond maximizing profits, be it short-term or long-term. One such situation is where it is more efficient to restrain firms from certain actions that impose negative consequences on society. For example, it is often more efficient for companies to avoid pollution in the first place than to have someone clean it up afterward. This is perhaps why we see companies like Amazon and Microsoft investing in nuclear energy to lower their emissions. Another argument for firms to undertake socially responsible investments pertains to information and transaction costs (Bénabou and Tirole 2010). For example, steel producer Cleveland-Cliffs can draw on its expertise to determine the most effective way to replace its coal-based blast furnaces with cleaner alternatives, whereas outside organizations cannot do so without incurring significant transaction costs.[1]

I am grateful to Brian Mittendorf (editor) and two anonymous referees for their constructive comments. The paper benefits from discussions with Anne Beyer, Jeremy Bertomeu, Qi Chen, Scott Dyreng, Henry Friedman (discussant), Jonathan Glover, Ilan Guttman, Campbell Harvey, Mirko Heinle, Thomas Hemmer (discussant), Chandra Kanodia, Volker Laux, Florin Sabac, Kevin Smith, Jack Stecher, and Sang Wu. I also thank workshop participants at Columbia University, The University of Texas at Austin, Duke University, the University of Houston, the University of Alberta, the University of Zurich, the 2022 Dopuch Conference at Washington University in St. Louis, the 2023 Accounting and Economics Society Winter Retreat, the 2023 Utah Winter Conference, and the 2024 Yale Accounting Conference for their helpful comments. The author has no conflicts to disclose.

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Supplemental material is available online, as linked in the text.

Editor's note: Accepted by Brian Mittendorf, under the Senior Editorship of Kathryn Kadous.

Submitted: December 2023
Accepted: March 2025
Early Access: April 2025

[1] The Amazon and Microsoft example is based on Blunt (2024). For the Cleveland-Cliffs example, see the news release on March 25, 2024: https://www.businesswire.com/news/home/20240325479918/en/

Many environmentally related investments share the features discussed above. As shareholders have become increasingly concerned about environmental, social, and governance (ESG) issues in recent years, it is conceivable that they have some desire for corporations to engage in ESG-friendly activities on their behalf. The question is how to ensure that firms take actions in accordance with shareholders' tastes for ESG issues. One solution is to rely on market forces. For example, Fama (2020) argues that when investors value environmental issues, "dirty" firms are punished by lower stock prices, which incentivize firms to become "clean" and, hence, be rewarded via higher prices.

The growing interest in ESG issues has also triggered a call for ESG disclosure. Starting in October 2022, the European Union (EU) requires large companies to publish regular reports on the social and environmental impacts of their activities. The call for ESG disclosures is driven in part by the belief that they help move firm actions toward more sustainable goals. For example, the final report regarding climate-related disclosure submitted to European Commission states that "[climate-related disclosure] will help smooth the transition to a more sustainable, low-carbon and climate-resilient economy."[2] In 2022, the U.S. Securities and Exchange Commission (SEC) proposed rule changes that would require registrants to include climate-related disclosures in their registration statements and periodic reports.[3]

Although the focus on disclosure is intuitively appealing, the real effects of ESG disclosure are not well understood and difficult to predict (Christensen, Hail, and Leuz 2021). Many important questions remain unanswered. First, when, if at all, is ESG disclosure needed to ensure the firm makes investment in accordance with stakeholders' tastes for ESG? Second, does an increasing emphasis on ESG necessarily mean we need more precise ESG disclosure? Third, under what circumstances should ESG disclosure be mandated rather than left to the discretion of individual firms? This paper presents a model intended to address these questions.

To elaborate on the main model, a firm chooses an investment that affects its profits and ESG performance. Profits are maximized when the marginal return of investment equals its marginal cost. Larger investments are assumed to have a greater impact on emissions, capturing the dual impact of firm investment on profits and ESG. The investment can be either "green" (e.g., reducing emissions) or "dirty" (e.g., increasing emissions). Investors care about both financial and environmental implications of the investment, as in Hart and Zingales (2017). The firm chooses its investment to maximize its stock price, which is formed in a competitive market populated with a continuum of risk-averse investors. Investors do not observe firm investment, and they rely on private and public signals to assess firm profit and ESG performance prior to trading.

Consistent with prior studies, I show that "dirty" firms are punished with a lower stock price, and the price drop is more severe when investors place a higher weight on ESG factors. However, if investors do not observe the firm's ESG performance (say, reported emissions), an increase in the investors' tastes for ESG lowers stock price but *fails* to change firm investment. This disconnect is caused by investors not observing firm investment.[4] If there is no signal about the firm's emissions, investors' disutility regarding emissions can only be priced based on their conjectured level of emissions that the firm takes as given and cannot change. In other words, the lack of information on actual emissions disconnects the firm's investment choice from the "green" premium/discount it expects to see. The firm responds by choosing a profit-maximizing investment regardless of how strongly investors care about ESG. Investors anticipate this choice and price the firm accordingly, resulting in a prisoner's dilemma type outcome.

ESG disclosure helps restore the connection between firm investment and the investors' tastes. Specifically, disclosing emissions gives the firm a means of influencing investors' valuation by changing its investment choice. The analysis shows how ESG disclosure (but not disclosures about the investment) can channel investors' ESG tastes into the firm's investment decision. I characterize the optimal precision of ESG disclosure. The optimal disclosure ensures that the firm, by maximizing its stock price, makes the same investment that its ESG-concerned investors would have chosen themselves to balance the financial and environmental implications of the investment. To the extent that "[CSR] is the delegated exercise of prosocial behaviour on behalf of stakeholders" (Bénabou and Tirole 2010), this paper shows that ESG disclosure plays a crucial role in determining the efficiency of that delegation.

It is tempting to think that the optimal ESG disclosure to sustain efficient investment is more precise when investors care more about ESG (i.e., place a higher weight on environmental factors). I show this intuitive thinking is incomplete: the fact that improving ESG disclosure *can* move investments toward the efficient level does not mean that one should improve the disclosure. What is missing in the intuitive thinking is the role of market forces (i.e., pricing of tastes and

[2] Sustainable finance teg report climate related disclosures, published in January 2019.
[3] https://www.sec.gov/news/press-release/2022-46
[4] The challenge for outside stakeholders to identify firms' ESG investments is commonly noted. For instance, Cleveland-Cliffs' 2023 Sustainability Report discusses its clean steel transition and emissions reduction initiatives without releasing specific dollar amounts for those activities. Similarly, Apple's 2024 Carbon Removal Strategy White Paper reports using carbon offsets for achieving carbon neutrality, but omits investment figures for these efforts. In financial statements, companies often pool ESG investments within other capital expenditures, making it difficult to isolate these investments.

information). Once we account for interactions with market forces, the optimal precision of ESG disclosure often decreases as investors become more ESG concerned. Intuitively, if we fix the quality of ESG disclosure at a level that is optimal for a given preference, a stronger taste for ESG changes how investors use their information (hence, pricing of information) in a way that inflates the firm's perceived cost of emissions more than the underlying change in the investors' tastes. Therefore, the precision of the optimal ESG disclosure decreases to undo the inflated perception that market forces impose on the firm. The result cautions against the temptation to focus on regulating ESG disclosures to *directly* change firm behaviors. A better approach seems to be to think of ESG disclosures as interventions designed to iron out inefficiencies that market forces would otherwise experience. More precise ESG disclosure is needed if market forces fail to move investment sufficiently, whereas less ESG disclosure is justified if market forces have gone overboard.

The model is then applied to shed light on the ongoing debate about mandating climate disclosure. In particular, I extend the analysis to a large economy and model the externalities associated with emissions by assuming that an increase in *total* emissions decreases economy-wide productivity. Although a lower total emissions would benefit all firms, each firm has incentives to free-ride on others' emission-cutting efforts. The equilibrium has firms pollute more than the socially optimal level—a standard result akin to "the tragedy of the commons." I show that the free-rider problem underlying firms' investment decisions percolates into their voluntary disclosure choices. That is, even if a firm's disclosure is costless and is uninformative about other firms, there will still be an underprovision of climate disclosure and overpollution if disclosure is voluntary. In this case, mandating a more precise climate disclosure than would be voluntarily provided motivates self-interested firms to act on common interests in reducing emissions. The result indicates that the regulator can leverage a disclosure mandate and market forces jointly to achieve similar results as a Pigovian tax in motivating firms to internalize the externalities of their climate-related investments. This finding has regulatory implications as a reporting mandate is often viewed as "less intrusive" than imposing taxes (Christensen et al. 2021).

A common challenge faced by models studying ESG-related issues is whether the model is about ESG or a broader setup that has an ESG interpretation. Three features of the model are intended to capture characteristics of firms' ESG investments and disclosures. First, for a given firm, the dual impacts of investment capture the notion that "profit and social consequences are inextricably connected" emphasized by Hart and Zingales (2020). Second, on the macro level, the model captures the free-rider problem firms face in reducing emissions and the resulting "tragedy of the commons" (Hardin 1968). Third, the paper embeds ESG-conscious investors' nonpecuniary preferences into a trading model, a defining feature in models studying ESG investing (e.g., Pástor, Stambaugh, and Taylor 2021). Together, the paper addresses questions regarding the demand, design, and implementation of ESG disclosure under one framework.

Prior studies have examined mechanisms that investors with pro-social preferences can use to influence firm actions. One line of the literature examines how shareholders influence firm actions through "engagement." Hart and Zingales (2017) study a firm's choice between a "clean" project with less profits and a "dirty" project with higher profits. They show that polling the investors through a referendum allows shareholders to honestly express their social objectives. Gollier and Pouget (2014) show that a pro-social large investor can convert nonresponsible firms into responsible ones (and make positive abnormal returns in doing so) if the investor can commit to a long-term investing horizon. Chowdhry, Davies, and Waters (2019) study how a pro-social investor counters a profit-focused owner's tendency to overemphasize profits via joint financing. Friedman and Heinle (2021) study the free-riding problem atomistic shareholders face in carrying out costly governance activities. Bonham and Riggs-Cragun (2022) show ESG efforts can be motivated by incorporating ESG metrics in executive compensation contracts.[5]

Another line of research focuses on managerial incentives provided through stock price. Friedman, Heinle, and Luneva (2021) study a price-based mechanism, in which a manager exerts unobservable efforts that affect the firm's ESG and cash flow. They introduce uncertainty about the manager's objective function and study strategic misreporting of the ESG performance in a way analogous to earnings management. Aghamolla and An (2023) study a voluntary disclosure model with uncertainty about information endowment and examine how the manager's investment choice is affected by his ability to withhold bad signals. I do not consider misreporting or withholding bad signals. My focus is to study how the precision of ESG disclosure affects firm investment, and highlight the interdependency between ESG disclosure and market forces in motivating sustainable investments.

Responsible investors can also influence firm decisions by changing its ability to raise capital or its cost of capital. Notable examples include Heinkel, Kraus, and Zechner (2001) and Berk and van Binsbergen (2024), who study the efficacy of impact investors' divestment in changing firms' cost of capital. In the current model, the firm has a "deep" pocket in that it can ensure the funding for its investment. The way disclosure affects firm investment in this paper does not work through the firm's cost of capital, which is related to the stock price *level* (and correlations across firms' values

[5] De Bettignies and Robinson (2018) study a model in which a government imposes a cap on "pollution." They show the profit-seeking firm can simultaneously lobby for a loose cap and hire socially responsible employees.

in a large economy). Instead, the argument here works through incentives tied to the *sensitivity* of stock price to the disclosed ESG performance.

My results on mandatory climate disclosure are related to Admati and Pfleiderer (2000) and Dye (1990) who show the value of mandating more precise disclosure than firms' voluntary choice. In their studies, one firm's disclosure is informative about other firms' valuation. Smith (2023) compares mandatory and voluntary disclosure from a risk-sharing perspective. The mechanism in this paper is different because a firm's disclosure is uninformative about others and there is no diversification benefit in the model. Instead, it is the free-rider problem underlying firms' investment decisions that causes an underprovision of voluntary disclosure. This mechanism complements prior studies and speaks specifically to the challenge that firms face in reducing emissions. In this regard, Ostrom (1990) reviews models studying problems that individuals face when governing the common good, as is the case with reducing emissions, and concludes that: "At the heart of each of these models is the free-rider problem."

In the remainder of the paper, Section II presents the model. Section III illustrates the demand for ESG disclosure. Section IV derives the optimal precision of ESG disclosure, and illustrates why investors caring more about ESG does not mean that more precise disclosure is optimal. Extending to a large economy, Section V offers a rationale for mandating more precise climate disclosure than would be voluntarily provided. Section VI introduces heterogeneous investors and Section VII presents a nonshareholder-centric adaptation of the model. Section VIII concludes.

II. MODEL SETUP

The model consists of a continuum of investors and a firm that chooses an investment $k \geq 0$. (A multifirm setting is analyzed in Section V.) Firm profit v depends on its investment k as

$$v(k) = \lambda k - \frac{k^2}{2} + \psi, \tag{1}$$

where $\lambda > 0$ is the marginal return of the investment and $\frac{k^2}{2}$ is the cost of investment. The noise term $\psi \sim N(0, \tau_v^{-1})$ in Equation (1) is normally distributed with precision τ_v.

Firm investment k also affects its ESG performance. This dual impact of investment is intended to model "situations where profit and social consequences are inextricably connected" (Hart and Zingales 2020).[6] To capture the dual impact simply, I assume that, on average, larger investments impose a greater impact on the firm's ESG performance F as follows:

$$F(k) = f(k) + \phi, \text{ and } f(k) \text{ is monotonic.} \tag{2}$$

The noise term ϕ in Equation (2) is normally distributed with a zero mean and variance τ_F^{-1}. This random variable captures the effect of unknown factors outside the firm's control at the time of investment. Think of k as the amount of renewable energy generated from wind or nuclear power. Given a production target k, the emission $F(k)$ is also affected by random factors, such as weather and technology uncertainties, which are unknown *ex ante*. These uncertainties are realized over time, and the firm can measure their impact on emissions during the process.

The paper makes minimal assumptions on the functional form of $f(k)$. The investment could impose negative ESG consequences or have a positive impact on ESG. To make the exposition concrete, I present the main model under the case of $f'(k) < 0$. Examples of such "green" investments include Amazon and Microsoft investing in nuclear-powered energy and Cleveland-Cliffs replacing coal-based blast furnaces with cleaner options. The assumption $f'(k) < 0$ captures the fact that such investments are aimed to reduce emissions. I allow for any non-negative $f(k)$ satisfying $f'(k) < 0$ and $f''(k) \geq 0$ (i.e., a weakly diminishing return). As will be noted throughout the analysis, results in this paper also hold for "dirty" investments (i.e., $f'(k) > 0$), such as producing fossil fuels, that increase emissions.[7]

The firm chooses the investment k to maximize its stock price p, which is determined in a rational expectations equilibrium (REE) similar to Diamond and Verrecchia (1981). There is a continuum of investors $i \in [0, 1]$ and a risk-free asset that serves as the numeraire. Investors are assumed to have a constant absolute risk averse utility function with a

[6] The tension between financial and environmental implications is common. In an interview with *Politico* in September 2024, the CEO of Cleveland-Cliffs said that the company might abandon "green steel" production, and forgo up to $500 million federal support, due to the high costs of investment and their financial implications.

[7] For "dirty" investments, the assumption becomes $f'(k) > 0$ and $f''(k) \geq 0$. In both cases, assuming $f''(k) \geq 0$ ensures that Equation (4) is concave in k so that the first-best investment is unique.

common risk-aversion parameter $\rho > 0$. The mean supply of the asset is $M \geq 0$. Noise traders supply ϵ share per capita, and $\epsilon \sim N(0, \tau_\epsilon^{-1})$ is normally distributed with a precision τ_ϵ.

In standard REE models, the investor utility function is $-\exp(-\rho x_i)$, where $x_i = (v - p)q_i$ is investor i's wealth if she invests q_i shares at the price p and receives the profit v. Following Pástor et al. (2021) and Goldstein, Kopytov, Shen, and Xiang (2022), I use the following specification to incorporate investors' disutility associated with investing q_i shares into a firm with emissions F:

$$x_i = \underbrace{(v - p)q_i}_{\text{Financial Returns}} - \underbrace{s \times Fq_i}_{\text{ESG Consideration}}. \quad (3)$$

The parameter $s \geq 0$ captures investor ESG tastes/awareness, and canonical REE models correspond to the case of $s = 0$. One can think of Fq_i in Equation (3) as investor i's "share" of the firm's total emissions F. The baseline model assumes that all investors share the same ESG preference. In Section VI, I introduce heterogeneous investors—some are ESG-conscious, whereas others are purely profit-motivated—and obtain qualitatively similar results.

Note that "ESG Consideration" in Equation (3) is not about how much pollution an investor consumes, but about investors disliking investing in a company that pollutes. One can incorporate the disutility that investor i suffers due to her physical consumption of emissions into Equation (3) by subtracting another term that is tied to the emissions F but is *independent* of her shareholding q_i. I have verified that this additional term does not change the equilibrium analysis.[8] Further, substituting x_i in Equation (3) into the utility function $-\exp(-\rho x_i)$ implicitly assumes that investors are averse to the risks in their exposure to the firm's ESG performance. The risk-averse assumption is consistent with Avramov, Cheng, Lioui, and Tarelli (2022), who provide evidence that uncertainty about corporate ESG performance reduces the demand of ESG-sensitive institutional investors. Modeling investors' risk concern about firm ESG performance seems to be also consistent with regulators' view, such as the SEC, that a main role of ESG disclosure is to help investors better understand their exposures to ESG-related risks.

Investors do not directly observe the firm's investment k in the model, as in Kanodia and Lee (1998) and Kurlat and Veldkamp (2015). Instead, investors rely on public and private signals to assess the firm's profit v and ESG performance F for their trading decisions. The firm issues an earnings report $R = v + \zeta$ prior to trading. I assume $\zeta \sim N(0, \tau_R^{-1})$, and the precision τ_R captures the quality of the earnings report. Each investor $i \in [0, 1]$ also observes a private signal $y_i = v + \eta_i$ about profit v, where $\eta_i \sim N(0, \tau_\eta^{-1})$ is independently distributed across all investors. To highlight the role of ESG disclosure and to maintain tractability, I assume in the main model that information about the firm's ESG performance F comes solely from its ESG disclosure. Online Appendix A considers investors' private signals about F and demonstrates the robustness of the main results. The sequence of events is as follows.

- At $t = 0$, a regulator sets the disclosure quality.
- At $t = 1$, the firm chooses an investment k.
- At $t = 2$, investors observe signals about v and F; a market-clearing price p is formed.
- At $t = 3$, payoffs are realized.

The firm chooses k to maximize $E[p]$. One way to motivate this objective is through a forced sale: the current owner sells the firm to the next generation of investors for life-cycle reasons. The implicit assumption is that the future generation of investors cares more about the environmental implications of the investment than the current owner. Alternatively, one can embed the investing party's focus on the short-term price within a principal-agent setting. The investors/principal value the long-term financial and environmental implications of the investment as in Equation (3). The manager/agent is tasked with making investment decisions and is concerned with the short-term stock price (or at least more so than the principal).

III. DEMAND FOR ESG DISCLOSURE

Benchmark Analysis

Incentive frictions in the model stem from the fact that investors do not choose k themselves. Hence, there is no guarantee that the k the firm chooses to maximize its price will reflect the investors' tastes. In the first benchmark, I examine a (hypothetical) single-person optimization problem in which investors form a new firm and choose k directly as owners to maximize their payoffs $\mathbb{E}[-\exp(-\rho[v(k) - sF(k)])]$, which is equivalent to maximizing the certainty

[8] Incorporating the extra term will not change the investor's demand function (5) and, therefore, does not affect the price function, the equilibrium investment, or the design of ESG disclosure.

equivalent, $E[v(k) - sF(k)] - \frac{\rho}{2}\text{var}[v(k) - sF(k)]$. Because the variance $\text{var}[v(k) - sF(k)] = \frac{1}{\tau_v} + \frac{s^2}{\tau_F}$ depends only on the exogenous parameters, the certainty equivalent is maximized when the investment k maximizes $\lambda k - \frac{k^2}{2} - sf(k)$.[9] The investors would choose k^{FB} as follows in this optimization problem:

$$\lambda = k^{FB} + sf'(k^{FB}). \tag{4}$$

The second benchmark introduces incentive frictions and stock market, as in the main model, but assumes perfect information. That is, firm investment k is publicly observed, and investors know the firm's profit $v(k)$ and emissions $F(k)$ perfectly prior to trading. When the investment k is public, one can capture this perfect-information benchmark by setting $\tau_v = \tau_F = \infty$, i.e., assuming away the noise terms ψ and ϕ in Equation (1) and Equation (2).[10] In this case, a publicly chosen k results in common knowledge that the firm's profit is $\lambda k - \frac{k^2}{2}$ and its emission is $f(k)$. The market-clearing price under perfect information is $p = \lambda k - \frac{k^2}{2} - sf(k)$, which is a deterministic function of the investment that the firm chooses publicly at $t = 1$. It is clear that the price-maximizing firm will choose k^{FB} shown in Equation (4) under perfect information. Alternatively, one can think of k^{FB} in Equation (4) as the investment preferred by a social planner who assigns a weight of s to the ESG factor and treats secondary market trading as zero-sum, thereby maximizing $E[v(k) - sF(k)]$.

The main model further incorporates information frictions. Throughout the analysis, I say that investors' tastes for ESG are perfectly channeled into firm investment if the firm, by maximizing its stock price, chooses the same investment k^{FB} that its investors would choose themselves to balance the financial and environmental implications of the investment. By focusing on incentive congruity, this paper takes the view that "[CSR] is the delegated exercise of prosocial behaviour on behalf of stakeholders" (Bénabou and Tirole 2010). The main model focuses on shareholders' interests, as is standard in models studying ESG investing (e.g., Zerbib 2019; Pástor et al. 2021).[11] In Section VII, I present a nonshareholder-centric approach of defining the first-best investment and explain how it relates to the results in the main model.

Demand for ESG Disclosure

This section assumes away any ESG disclosure, and illustrates why such a disclosure is needed to ensure the firm makes investment in accordance with the investors' tastes. I start the analysis with taking the distributions of the firm profit v and carbon emissions F as given and examining the effect of investor tastes on the stock price.

Because investors care about the firm's financial profit v as well as its emissions F, it is not surprising that an investor i's demand q_i for the firm's share depends on both factors and can be expressed as

$$q_i = \frac{\mathbb{E}(v - sF|\mathcal{F}_i) - p}{\rho\,\text{var}(v - sF|\mathcal{F}_i)}, \tag{5}$$

where $\mathcal{F}_i$ is investor i's information set. All else equal, the demand for the firm's share increases if the investor expects a higher profit v or a lower carbon emission F.

The equilibrium price function is obtained from analyzing the market-clearing condition $\int_i q_i\, di = M + \varepsilon$, where $M \geq 0$ is the mean asset supply and ϵ is the supply shock. The steps used to determine the linear price function are standard and, hence, are omitted in the text. The result below summarizes the price impact of the investors' ESG tastes given the distribution of the firm profits $v \sim N(\mu_v, \tau_v^{-1})$ and its carbon emission $F \sim N(\mu_F, \tau_F^{-1})$.

Lemma 1: Given the distributions of profit v and emissions F, the linear price function satisfies $E[p] = \mu_v - s\,\mu_F - \alpha_M M$. An increase in the investors' ESG taste lowers price in that $\frac{dE[p]}{ds} < 0$.

Proof. All proofs are in Appendix A.

The result is intuitive and consistent with Pástor et al. (2021). The expected price, $E[p] = E[v] - s\,E[F] - \rho\text{var}(v - sF|\mathcal{F}_i)M$, is increasing in the expected profits and decreasing in expected emissions. The weight, s, placed on the emissions matches the investors' tastes for ESG in Equation (3). The *taste-driven price reaction* $\frac{dE[p]}{ds} < 0$ is consistent with the

[9] The model takes prior uncertainties, such as τ_F, as given. In the Online Appendix B, I further endogenize prior uncertainty by relating it to firm investment. This additional element changes the level of investment that risk-averse investors would choose themselves, but the driving forces studied in the main model carry over.

[10] Alternatively, one can assume that realizations of ψ and ϕ are observed perfectly and obtain the same k^{FB}.

[11] The idea of incentive congruity can be extended when one interprets the model as a sale from the current owner to the next generation of investors (see the discussion at the end of Section II). This overlapping-generations sale abstracts away from the agency problem within the firm, and instead focuses on how to channel the future generation's ESG tastes into the investment choices of the current owner who aims to maximize the sale price.

intuition that emissions will be punished more severely when investors are more ESG concerned. It seems intuitive that the firm will respond to more ESG-concerned investors by investing more in cutting emissions. The following result challenges the connection between the taste-driven price reaction $\frac{dE[p]}{ds} < 0$ and firm investment in the absence of ESG disclosure.

Proposition 1: In the absence of ESG disclosure, an increase in the investors' ESG awareness s lowers the expected price $E[p]$ but does not change firm investment. The firm chooses $k^{\emptyset} \equiv \lambda$ no matter how strongly its investors care about ESG.

The result may appear surprising. If more ESG-concerned investors punish a "dirty" firm via a steeper price drop, why would not the firm invest more in cutting emissions? The breakdown is caused by investors not directly observing firm investment. The idea can be seen by examining the price function $p = \alpha_0 + \alpha_v v + \alpha_R \zeta - \alpha_M M - \alpha_\epsilon \epsilon$ and expressing $E[p] = \alpha_0(\hat{k}) + \alpha_v E[v|k] - \alpha_M M$, where $\hat{k}$ is the investors' conjectured investment. If there is no signal about firm's actual/realized emissions F, emissions can only be priced based on the conjectured level via the intercept $\alpha_0(\hat{k})$ as a function of the conjectured investment, $\hat{k}$. Because the firm takes investors' conjecture $\hat{k}$ as given and cannot change it, the firm ends up choosing a profit-maximizing investment, $k = \lambda$. Investors anticipates this choice and price the firm accordingly.[12]

Information asymmetry regarding firm investment is critical in the argument. Because firms discuss their investments in public fillings, one may wonder if such a public report would qualitatively change the argument above. To address the question, suppose that the firm reports $I = k + \theta$ about its investment k, with $\theta \sim N(0, \tau_\theta^{-1})$. The corollary below shows that the dilemma caused by the lack of ESG disclosure cannot be resolved by disclosing noisy measures about the investment itself.

Corollary 1: Proposition 1 holds whenever investment k is reported with noise, i.e., $\tau_\theta < \infty$.

To understand this result, note that the firm's ESG performance $F = f(k) + \phi$ and reported investment $I = k + \theta$ are related through the investment k. If k were drawn from an exogenous distribution by nature, investors would use the reported I to update their beliefs of k, and, hence, their expected carbon footprint F. The difference here is that k is an endogenous choice. When the equilibrium is in *pure strategies*, the investors view their conjecture $\hat{k}$ as a constant, and attribute any difference between the reported investment I and their conjecture $\hat{k}$ to the noise, θ. In other words, because investors know the firm's strategy on-the-equilibrium path, they do not use signals to revise their beliefs about the firm's equilibrium strategy. This simple yet thought-provoking reasoning is formalized in Bagwell (1995) and Kanodia, Singh, and Spero (2005), who summarize the idea as "noisy signals of endogenous actions have no information content."

Unlike signals about the investment choice, disclosing the firm's emissions/ESG performance has the potential to change its investment strategy. Denote by D a ESG disclosure that measures firm's emission F as follows

$$D = F + \xi, \tag{6}$$

and $\xi \sim N(0, \tau_\xi^{-1})$ is normally distributed with a precision τ_ξ. To see why such a disclosure may change firm investment, recall from Equation (2) that the firm's emission $F(k) = f(k) + \phi$ depends not only on its investment but also on the realization of ϕ—the unknown component capturing the impact of weather or technology uncertainties on emissions. Disclosing D allows the investors to revise their assessment of ϕ : a low reported emission D revises the investors' inferences about ϕ downward, leading to a higher valuation.[13] The firm is therefore tempted to jam the report D by investing more in reducing emissions, similar to the thinking in "signal jamming" models (e.g., Holmström 1999). Consequently, disclosing emissions provides the firm both the incentive and, more importantly, a means to influence investors' inferences and firm valuation by changing its emission-cutting investment.

It is worth reconciling my results to prior studies that argue the disciplinary role of market forces (e.g., Fama 2020; Friedman and Heinle 2016). All these models assume that the prior distribution of ESG performance is publicly observed, which, in a model with endogenous investments, is equivalent to assuming that investments are observed by external investors. What I have shown in this section is that, for investments that are not perfectly observed by outside investors, taste-driven market forces *alone* have trouble changing firm investment choices, and this is where ESG disclosure is needed. Moreover, the value of disclosing a firm's ESG performance cannot be substituted by non-ESG

[12] Adding private signals about F would partially restore the connection between the investors' tastes and firm's investment choice. The point here is that the taste-driven price reaction $\frac{dE[p]}{ds} < 0$ *alone* cannot change firm actions and, for that to happen, it is necessary for investors to observe signals about the realized ESG performance, F. In Online Appendix A, I show that considering private signals about F does not qualitatively change the design of the public ESG disclosure.

[13] Let $z = D - \hat{f}(k) = \phi + \xi$, where $\hat{f}(k)$ is the expected emission given the firm's equilibrium choice. One can see that observing D provides information about ϕ.

disclosures even if they are correlated in equilibrium. These results provide a theoretical basis for a separate disclosure of firms' ESG performance, which is relevant to standard setters since changes in disclosure requirements involve a cost-benefit analysis (Schipper 2010).

IV. DESIGN OF ESG DISCLOSURE

Optimal ESG Disclosure

Different ESG disclosure policies in the model are characterized by different precisions, $\tau_\xi \geq 0$. Can we choose the precision of ESG disclosure so that the firm, by maximizing its price, undertakes the efficient investment k^{FB} in Equation (4)? To answer the question, I first establish the equilibrium for a given precision $\tau_\xi > 0$ of ESG disclosure and study how a change in τ_ξ would affect the investment the firm chooses in equilibrium. The next result summarizes the subgame equilibrium for a given precision of ESG disclosure.

Lemma 2: Given a ESG disclosure quality $\tau_\xi \geq 0$, the linear price function is $p = \alpha_0 + \alpha_v v + \alpha_R \zeta - \alpha_F D - a_M M - \alpha_\epsilon \epsilon$, and the investment is the solution to $\alpha_v(\lambda - k) - \alpha_F f'(k) = 0$. The price coefficients satisfy

$$\frac{d\alpha_F}{d\tau_\xi} > 0 \text{ and } \frac{d\alpha_v}{d\tau_\xi} > 0. \tag{7}$$

It is intuitive that the price function will be more responsive to ESG disclosure D when it becomes more precise, i.e., $\frac{d\alpha_F}{d\tau_\xi} > 0$. In comparison, the result $\frac{d\alpha_v}{d\tau_\xi} > 0$ may appear surprising. Why would more precise ESG disclosure make price more responsive to firm profits v, even though the ESG disclosure $D = F + \xi$ contains no information about profits? The thinking behind the spillover effect rests on the investors' risk considerations. More precise ESG disclosure lowers the uncertainty investors face regarding their exposures to firm's ESG performance, F. In response to the lower uncertainty, investors trade more aggressively on their information, be it financial-related or ESG-related. The intensive trading better aggregates investors' signals $y_i = v + \eta_i$ about firm profits and explains the spillover result $\frac{d\alpha_v}{d\tau_\xi} > 0$ in Equation (7).

Lemma 2 also shows that firm investment is independent of the mean supply M even though a higher M lowers the price by $\alpha_M M$. This independent result arises because the firm takes the price coefficient $\alpha_M = \rho \text{var}(v - sF|\mathcal{F}_i)$ as given when choosing k.[14]

The two price coefficients α_F and α_v in Equation (7) are important in determining firm investments. This can be seen by expressing expected stock price, $E[p|k,\hat{k}] = \alpha_0(\hat{k}) + \alpha_v E[v|k] - \alpha_F E[F|k] - \alpha_M M$, as a function of the actual investment k chosen by the firm and the investors' conjecture $\hat{k}$ that the firm takes as given. It follows that

$$\frac{dE[p|k,\hat{k}]}{dk} = \alpha_v \frac{dE[v|k]}{dk} - \alpha_F \frac{dE[F|k]}{dk}.$$

The price-maximizing firm internalizes the investors' tastes against emissions to the extent captured by the *sensitivity* of price to the reported emissions, i.e., the price coefficient α_F. Similarly, the price coefficient α_v is the sensitivity of price to profits v and it captures the extent to which the firm internalizes the investors' utility derived from a higher profit.

The result $\frac{d\alpha_F}{d\tau_\xi} > 0$ and $\frac{d\alpha_v}{d\tau_\xi} > 0$ in Equation (7) suggests that improving the quality τ_ξ of ESG disclosure provides countervailing incentives to the firm's investment decision. Specifically, an increase in τ_ξ provides the firm with stronger incentives to cut emissions (by increasing α_F), but also raises the firm's perceived benefit of earning a higher profit (by increasing α_v). The net effect on investment depends on how fast a more precise ESG disclosure increases the firm's perceived marginal value of reducing emissions (via α_F) *relative to* increasing profits (via α_v). This can be seen by rewriting the first-order condition in Lemma 2 as:

$$\lambda = k^* + \frac{\alpha_F(\tau_\xi, s)}{\alpha_v(\tau_\xi, s)} f'(k^*). \tag{8}$$

[14] In Online Appendix B, I show that the firm's unobservable investment choice k is independent of M even if k affects prior risk, such as τ_F. A similar independence result is shown by Xue (2025), who studies a model in which higher investment increases prior uncertainty.

One can think of the ratio, $\frac{\alpha_F(\tau_\xi^*, s)}{\alpha_v(\tau_\xi^*, s)}$, as the weight that the firm places on the environmental implication of its investment relative to its financial implication. The notation $\frac{\alpha_F(\tau_\xi^*, s)}{\alpha_v(\tau_\xi^*, s)}$ emphasizes its dependence on the quality of ESG quality τ_ξ and on the investor tastes, s. If there exists a precision τ_ξ^* under which $\frac{\alpha_F(\tau_\xi^*, s)}{\alpha_v(\tau_\xi^*, s)} = s$, the condition Equation (8) used to determine the firm's investment k^* will coincide with Equation (4) used to determine k^{FB}. In this case, τ_ξ^* perfectly aligns the firm's incentive in maximizing price to the investors' underlying preferences. The proposition below verifies the existence of such ESG-disclosure quality τ_ξ^* and presents its closed-form expression.

Proposition 2: A unique ESG disclosure precision $0 < \tau_\xi^* < \infty$ incentivizes the firm to choose the investment k^{FB} and

$$\tau_\xi^* = \tau_F \left(\frac{r^2 \tau_F^2 \tau_\eta^2 \tau_\epsilon}{(s^2 \tau_v + \tau_F)^2} + \tau_\eta + \tau_R \right) \tau_v^{-1}. \tag{9}$$

It is worth noting that the optimal τ_ξ^* is the same, whether the investment in question is "green" (i.e., $f'(k) < 0$) or "dirty" (i.e., $f'(k) > 0$). What matters is that τ_ξ^* ensures the price-maximizing firm values the financial-versus-ESG tradeoff the same way as investors do, i.e., $\frac{\alpha_F(\tau_\xi^*, s)}{\alpha_v(\tau_\xi^*, s)} f'(k) = s f'(k)$. The sign of $f'(k)$ is not important to the argument. The thinking is reminiscent of the goal congruency literature that studies the design of performance measures to align incentives in principal-agent settings. For example, the principal uses residual income in contracts to ensure that agents with different horizons will make the investment that is optimal from the principal's point of view (e.g., Dutta and Reichelstein 2005). To the extent that "[CSR] is the delegated exercise of prosocial behaviour on behalf of stakeholders" (Bénabou and Tirole 2010), this paper shows that ESG disclosure plays a crucial role in determining the efficiency of the delegation and, hence, the sustainable investment chosen in equilibrium.

A limitation of the analysis above is that it overlooks the interests of noise traders, a common critique of noisy REE models.[15] Because of this limitation, it is best to view the paper as focusing on the effect of ESG disclosure on investment efficiency (i.e., implementing k^{FB}) rather than attempting to study welfare or broader market efficiency. The paper's focus on disclosure and investment efficiency aligns with Fishman and Hagerty (1989); Gao and Liang (2013); and Goldstein and Yang (2019), who study the effect of disclosure on firm investment in models where noise traders are used to prevent price from being fully revealing. For robustness, Section VI presents an extension where I assume away noise traders and obtain similar results to those in the main model.

Tastes and the Optimal Disclosure

In this section, I study how the optimal precision τ_ξ^* of ESG disclosure would change if investors care more about the environmental impact of firm actions, i.e., a higher s. This question has immediate regulatory implications because the proliferation of ESG disclosures stems partly from heightened investor awareness of corporate social and environmental impacts.

It is tempting to think that the optimal ESG disclosure becomes more precise when investors care more about ESG. Figure 1, Panel A illustrates this intuitive thinking using a numerical example in which $f(k) = 3 - k$, $\lambda = 1.5$, $\tau_v = 0.5$, $\tau_R = 0$, $\tau_F = 0.2$, $\rho = \tau_\eta = \tau_\epsilon = 1$, and $s = 0.1$. The upward curve plots the firm's investment choice as a function of the quality of ESG disclosure. The optimal precision $\tau_\xi^* = 0.78$ is determined when the equilibrium investment intersects with $k^{FB} = 1.6$ from Equation (4). Two facts in the figure are noteworthy. First, more ESG-concerned investors prefer a higher green investment k^{FB}. (That is, the horizontal line in Panel A is increasing in s.) Second, increasing the quality of ESG disclosure will incentivize the firm to invest more in cutting emissions, as indicated by the upward-sloping curve. It is therefore tempting to conclude that the optimal disclosure τ_ξ^* is increasing in the investors' tastes for ESG, s.

However, the next result shows the fact that improving ESG disclosure *can* move firm investment toward the efficient level does not mean that we should improve the disclosure.

Proposition 3: The precision of the optimal ESG disclosure decreases in investors' ESG tastes. That is, $\frac{d\tau_\xi^*}{ds} < 0$.

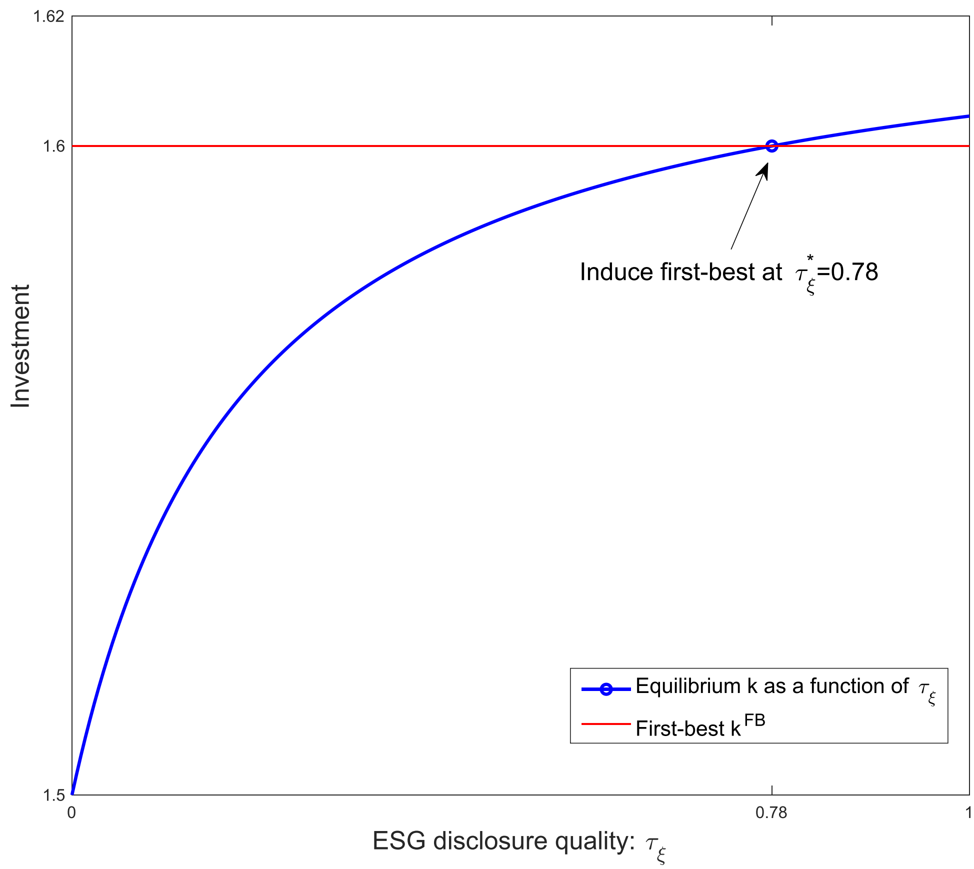
The key to understanding the counter-intuitive result is that stronger tastes for ESG change how investors use information. Figure 1, Panel B illustrates the intuition. The 45-degree line plots the firm's perceived ESG tradeoff, captured

[15] Vives (2010) presents a standard critique: "This [the use of noise traders in REE] is unsatisfactory because the decisions of noise traders are not modeled, it is not explained why these traders are willing to lose money in the market, and consequently a proper welfare analysis cannot be performed."

FIGURE 1

Numerical Examples Illustrating Proposition 3

Panel A: Optimal ESG Disclosure Given $s = 0.1$



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by $\frac{\alpha_F}{\alpha_v}$ in Equation (8), under the optimal τ_ξ^*. The fact that it is a 45-degree line indicates that τ_ξ^* fully aligns the firm's perceived ESG tradeoff with the investors' tastes s. The dotted line in Panel B is a counterfactual analysis: it plots what the firm's ESG tradeoff would have been had I fixed the quality of disclosure precision at $\tau_\xi = 0.78$, which is the optimal ESG disclosure for $s = 0.1$ shown in Panel A. Note that the dotted line lies everywhere above the 45-degree line, suggesting that market forces have caused the firm paying "too much" attention to ESG. That is, if I fix ESG-disclosure quality $\tau_\xi = 0.78$, an increase in investors' ESG taste s changes their trading (hence, stock price) in ways that inflate the firm's focus on ESG beyond what is justified by the underlying change in s. Therefore, the optimal ESG disclosure quality decreases, which will lower the firm's ESG tradeoff to the level warranted by the underlying investor taste, s.

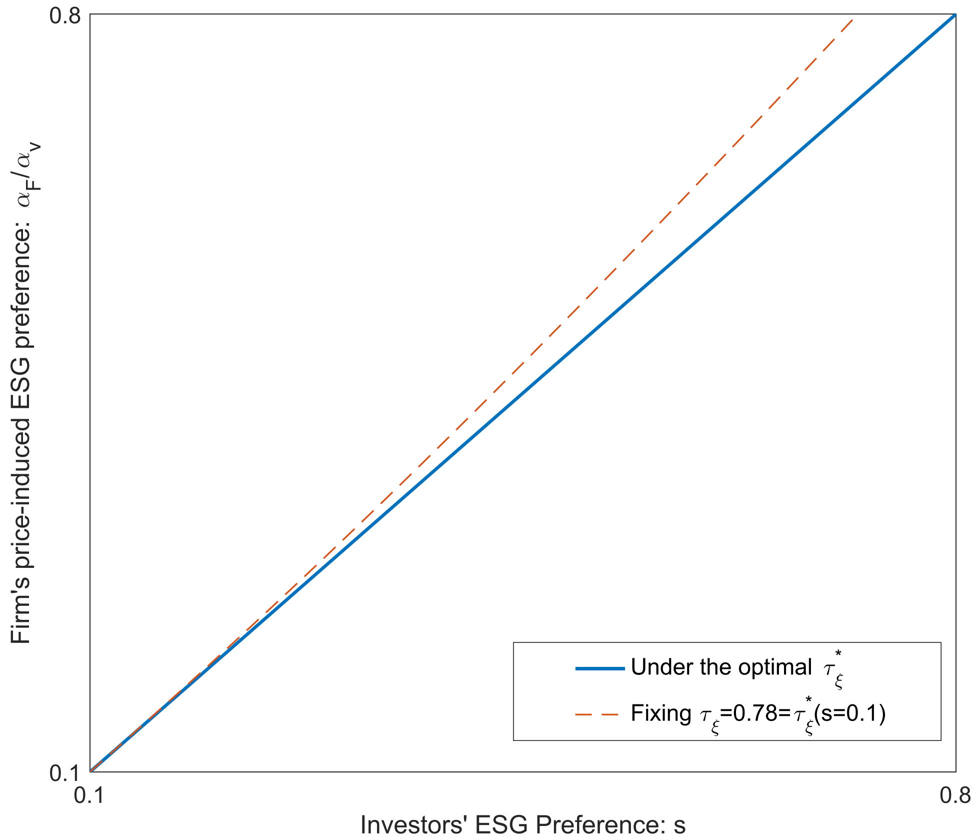
Formally, recall that τ_ξ^* is chosen to align the firm's emissions-versus-profit tradeoff to the tradeoff in the eyes of the investors, i.e.,

$$\underbrace{\frac{\alpha_F(\tau_\xi^*, s)}{\alpha_v(\tau_\xi^*, s)}}_{\text{Firm's ESG tradeoff}} = \underbrace{s}_{\text{Investors' ESG tradeoff}}. \tag{10}$$

Fixing the quality of disclosure, it follows from $\alpha_F = s\frac{\tau_\xi^*}{\tau_\xi^* + \tau_F}$ that an increase in s already makes price more responsive to the reported emissions and, hence, raises the "Firm's ESG tradeoff" in Equation (10). This is because a higher s

FIGURE 1 (continued)

Panel B: Investors' versus Firm's ESG Tradeoff



(The full-color version is available online.)

increases the relevance of emission F in investors' portfolio decisions, and investors rationally rely more on the reported emissions. The result $\frac{d\tau_\xi^*}{ds} < 0$ occurs because a higher s increases "Firm's ESG tradeoff" *faster* than "Investors' ESG tradeoff," as seen in Figure 1, Panel B. To understand the intuition, note that a higher s not only increases the numerator $\alpha_F = \frac{\tau_\xi^*}{\tau_\xi^* + \tau_F} s$ in Equation (10) but also reduces the denominator $\alpha_v = \frac{\tau_p + \tau_\eta + \tau_R}{\tau_p + \tau_\eta + \tau_R + \tau_v}$ by lowering τ_p, that is, by reducing the information that price contains about profit v. This is because an increase in ESG tastes has two effects: it decreases the *relevance* of profit v and increases the *risk* investors face by raising $\text{var}(v - sF|\mathcal{F})$. Both effects make the investors trade less intensively on their private signals about v, reducing the information content of price τ_p and, hence, the price sensitivity to profit α_v.

Note that I am *not* claiming a stronger taste for ESG would always call for a lower quality of ESG disclosure. The unconditional result $\frac{d\tau_\xi^*}{ds} < 0$ shown in Proposition 3 is due to the lack of private signals about emissions. In Online Appendix A, I examine an alternative setting in which the investors observe private signals about F and show $\frac{d\tau_\xi^*}{ds} < 0$ holds for $s < \sqrt{\tau_F / \tau_v}$. My goal is to point out the incompleteness behind the conventional wisdom that firms should improve ESG disclosure simply because investors care more about ESG. Although intuitive, this argument overlooks the fact that a change in investors' tastes also changes how they use information. In particular, stronger tastes for ESG (1) increase (and decrease) the relevance of information about emissions (and profit, respectively), and (2) increases the risks investors face by raising $\text{var}(v - sF|\mathcal{F})$. These two effects determine how intensively investors trade on their information, which, in turn, influences the design of ESG disclosure.

More broadly, the analysis cautions against the temptation to focus on regulating ESG disclosures in order to *directly* change firm behaviors. In particular, the fact that improving ESG disclosure can move investment toward efficient goals does not mean that one should improve the disclosure. A better approach seems to be to think of ESG disclosures as interventions designed to iron out inefficiency that (taste-driven) market forces would otherwise experience. More precise ESG disclosure is needed if market forces fail to move investment sufficiently, whereas less ESG disclosure is justified if market forces have gone overboard.

A main feature captured in this section is that firm investment k simultaneously affects two performances that investors care about. Stepping back from the financial-versus-ESG interpretation, one can also think of $v(k)$ and $sF(k)$ as current and future profits, where s measures the importance of future profits in determining firm value. Under this alternative interpretation, the analysis above can be thought of as examining the tradeoffs for disclosing forecasts of future profits. Thus, the result in this section is not unique to ESG disclosure. The next two sections introduce additional features intended to bring the model more specific to ESG-related investment and disclosure.

V. A THEORY FOR MANDATING CLIMATE DISCLOSURE

The model can be applied to shed light on the debate about mandating climate disclosure. Such a mandate has been in place in the EU since 2022 (e.g., Directive 2022/2464). In 2022, the SEC issued a proposal "The Enhancement and Standardization of Climate-Related Disclosures for Investors," which would require registrants to disclose emissions in their periodic reports. Christensen et al. (2021) note that: "the current policy debate in the U.S. revolves largely around the question of a mandate that explicitly imposes CSR reporting requirements on companies."

This section offers a rationale for mandating climate disclosure by explicitly modeling the negative externalities of emissions in lowering economy-wide productivity. Extend the main model to a large economy with a continuum of firms. Each firm $i \in [0, 1]$ chooses an investment $k_i \geq 0$, and its financial profit $v(k_i) = \lambda k_i - \frac{k_i^2}{2} + \psi_i$ and emissions $F(k_i) = f(k_i) + \phi_i$ are determined as in Equation (1) and Equation (2). Firm i's earnings report $R_i = v(k_i) + \zeta_i$ and ESG disclosure $D_i = F(k_i) + \xi_i$ are defined as before. All the noise terms (i.e., $\psi_i, \phi_i, \zeta_i, \xi_i$ and ϵ_i) are independent of each other and across different firms.

The fact that noise terms are independent across firms assumes away information spillover between firms, which has been proposed in prior studies as a rationale for mandating disclosure. The argument here exploits the externalities caused by firms' investments and the free-rider problem they face in reducing emissions. To introduce the externalities created by firms' investments, I assume that the marginal return of investment, λ, is decreasing in the *aggregated* emissions, $\overline{F} = \int_j F(k_j)dj$. That is,

$$\overline{\lambda} \equiv \overline{\lambda}(\overline{F}) \geq 0, \text{ with } \overline{\lambda}'(\cdot) < 0. \tag{11}$$

Tying aggregated emissions to firm productivity is a standard approach to modeling externalities of emissions (e.g., Nordhaus 2019; Tresch 2022). As the efficient benchmark, suppose a single conglomerate owned all the firms $i \in [0, 1]$ and chose a *socially optimal* investment k^S to balance its financial and environmental impacts at the aggregated level. That is, k^S is chosen to maximize $\int_i [v_i(k) - sF_i(k)]di = \overline{\lambda}k - \frac{k^2}{2} - sf(k)$.[16] Substituting $\overline{F} = \int_j F(k)dj = f(k)$ into $\overline{\lambda} \equiv \overline{\lambda}(\overline{F})$, one obtains the following first-order condition that characterizes k^S:

$$\overline{\lambda}(f(k^S)) = k^S + sf'(k^S) + \left|\frac{d\overline{\lambda}}{d\overline{F}}\right| f'(k^S)\, k^S. \tag{12}$$

The term $|\frac{d\overline{\lambda}}{d\overline{F}}| f'(k^S)$ captures the externality of a higher investment on economy-wide productivity $\overline{\lambda}$ by changing aggregate emissions, $\overline{F}$.

The focus of this section is to show that mandating more precise climate disclosures than would be voluntarily provided motivates self-interested firms to act on common interests in reducing emissions. That is, regulators can use a disclosure mandate to create *tax-like incentives* in addressing the externalities created by firm investment. Since taxes are used mainly to target actions with negative externalities, the exposition in this large-economy application focuses on "dirty" investments (i.e., $f'(k) > 0$) that lower productivity $\overline{\lambda}$. As will be explained prior to Proposition 5, the reasoning also applies to "green" investments that impose positive externalities.

It is helpful to first analyze the equilibrium under *voluntary disclosure*, in which firm $i \in [0, 1]$ chooses the quality τ_ξ^i of its climate disclosure at $t = 0$ and invests k_i at $t = 1$ to maximize its price. To focus on the real effect of disclosure on

[16] This condition can be obtained if one extends either benchmark presented in Section III to a large economy, and let the conglomerate choose k for all firms.

firm investment, I set the mean supply $M = 0$ in this large economy.[17] The result below summarizes the symmetric equilibrium under voluntary disclosure.

Lemma 3: Under voluntary disclosure, each firm chooses the quality of its climate disclosure $\tau_\xi^V = \tau_\xi^*$ as in Proposition 2. The equilibrium investment k^V under voluntary disclosure results in overpollution relative to the socially optimal k^S.

To understand firms' voluntary climate disclosure choice τ_ξ^V, note that firm i takes other firms' investment choices and, hence, the equilibrium $\overline{\lambda}$ in Equation (11) as given. Recall from Equation (8) that the firm chooses its investment according to $\overline{\lambda} = k + \frac{\alpha_F(\tau_\xi)}{\alpha_v(\tau_\xi)} f'(k)$, and Proposition 2 shows that setting $\tau_\xi = \tau_\xi^*$ ensures $\frac{\alpha_F(\tau_\xi)}{\alpha_v(\tau_\xi)} = s$. Intuitively, a firm aiming to maximize its valuation has incentives to commit to its shareholders that it will invest in accordance to their tastes, and the way to commit is to choose the quality of disclosure τ_ξ^* upfront as in Proposition 2 because it ensures incentive congruity, i.e., $\frac{\alpha_F(\tau_\xi^*)}{\alpha_v(\tau_\xi^*)} = s$. Given $\frac{\alpha_F(\tau_\xi^*)}{\alpha_v(\tau_\xi^*)} = s$, we know a firm that anticipates an investment k^V from others will choose its investment k_i so that $\overline{\lambda}(f(k^V)) = k_i + s \times f'(k_i)$. The symmetric equilibrium is determined when the firm's best response, k_i, coincides with the investment k^V it expects from others. That is,

$$\overline{\lambda}(f(k^V)) = k^V + s \times f'(k^V). \tag{13}$$

The fact that firms overpollutes follows by comparing Equation (12) and Equation (13). The term $|\frac{d\overline{\lambda}}{d\overline{F}}| f'(k^S) k^S$ in Equation (12) is the externality associated with firm investment in affecting economy-wide productivity. This externality is overlooked in an individual firm's decision Equation (13) because each firm takes others' investments (hence, $\overline{\lambda}$) as given when choosing its own investment. Although a reduction in total emissions benefits all firms, each firm has incentives to free ride on others' emission-cutting efforts. The result is that all firms invest too much in "dirty" investments relative to the socially optimal level, i.e., $k^V > k^S$. This is a standard result akin to "the tragedy of the commons," referring to the degradation of the environment whenever many individuals use a resource in common (Hardin 1968).

A regulator can mitigate the tragedy of the commons by mandating more precise climate disclosure, τ_ξ^M, than would be voluntarily provided. Recall from Equation (8) that a firm chooses its investment according to $\lambda = k + \frac{\alpha_F}{\alpha_v} f'(k)$. Hence, a regulator aiming to implement the socially optimal k^S in a decentralized economy must ensure that k^S satisfies an individual firm's first-order condition:

$$\overline{\lambda}(f(k^S)) = k^S + \frac{\alpha_F(\tau_\xi^M)}{\alpha_v(\tau_\xi^M)} f'(k^S), \tag{14}$$

To implement k^S, the regulator needs to align the private cost of investment with its social cost, i.e., to align the right-hand sides of Equation (14) and Equation (12). That is,

$$\underbrace{\frac{\alpha_F(\tau_\xi^M)}{\alpha_v(\tau_\xi^M)} \times f'(k^S)}_{\text{Private cost}} = \underbrace{\left(s + \left|\frac{d\overline{\lambda}}{d\overline{F}}\right| k^S\right) \times f'(k^S)}_{\text{Social cost}}. \tag{15}$$

A sufficient condition to ensure a solution to Equation (15) is $\frac{\tau_v s}{\tau_R + \tau_\eta + \tau_p} > -\frac{d\overline{\lambda}}{d\overline{F}} k|_{k=k^S}$, that is, the left-hand side of Equation (15) is greater than its right-hand side as the mandate $\tau_\xi^M \to \infty$.[18] I assume the condition is satisfied so that k^S can be implemented in the next result. (Even if the condition is not satisfied, it is still valuable to mandate a more precise climate disclosure than would be voluntarily provided because doing so moves k^V toward the socially optimal k^S.)

Proposition 4: A regulator avoids the tragedy of the commons by mandating τ_ξ^M, which is more precise than would be voluntarily provided (i.e., $\tau_\xi^M > \tau_\xi^V$) and implements the socially optimal k^S. Moving from voluntary disclosure τ_ξ^V to mandating τ_ξ^M increases stock valuation $E[p]$.

[17] For $M > 0$, disclosure also affects the cost of capital, $\alpha_M M$, which is minimized as the disclosure is infinitely precise. Note that the effect of disclosure on cost of capital does *not* interact with its effect on firm investment. This can be seen by noting that neither the firm investment in Lemma 2 nor the k^{FB}-inducing disclosure τ_ξ^* in Proposition 2 depends on the mean asset supply, M. Hence, setting $M > 0$ simply adds an effect that is independent of the investment effect presented in the text, and one obtains similar results as Proposition 4.

[18] Because the socially optimal k^S in Equation (12) is independent of signal precisions, the sufficient condition imposes restrictions on exogenous precision parameters, such as τ_η and τ_v.

Figure 2 illustrates Proposition 4 using a numerical example in which $\rho = \tau_v = \tau_\epsilon = 1, \tau_F = 0.5,$ and $\tau_\eta = 0.2$. Panel A plots the socially optimal investment k^S and the mandatory disclosure quality τ_ξ^M that implements k^S. It is intuitive that investors who place a higher weight s on emissions prefer a smaller k^S, i.e., less "dirty" investment. Echoing the surprising result in Proposition 3, the fact that investors care more about emissions does *not* mean we need to mandate more precise climate disclosures. Panel B shows that mandating more precise disclosure than would be voluntarily provided increases stock valuations. This is because the mandate avoids the tragedy of commons: it results in lower total emissions and, hence, a higher productivity $\overline{\lambda}$. This result offers a rationale for Downar, Ernstberger, Reichelstein, Schwenen, and Zaklan (2021) who show that mandatory reporting of greenhouse gas emissions results in a decrease in aggregate emissions among affected firms, without adversely affecting their financial operating results.

It is worth comparing Proposition 4 to Admati and Pfleiderer (2000) and Dye (1990), who show the value of mandating more precise disclosure than firms' voluntary choice. Their argument is based on the assumption that one firm's disclosure is informative about other firms. The mechanism here is different because one firm's disclosure is uninformative about others. Instead, it is the free-rider problem underlying firms' endogenous investments that causes an underprovision of voluntary disclosure, i.e., $\tau_\xi^V < \tau_\xi^M$. Examining Equation (15) shows that $\frac{\alpha_F}{\alpha_v} > s$ is necessary for firms to internalize the *social value* of investments. Although $\frac{\alpha_F}{\alpha_v} > s$ is achievable through improved climate disclosure, a firm has no incentive to voluntarily enhance disclosure since it would lead to an investment that deviates from private-value maximization.

FIGURE 2

Illustration of Proposition 4, Assuming $f(k) = k$ and $\bar{\lambda} = \frac{1}{1+F}$.

Panel A: Implementing k^S by Mandating τ_ξ^M

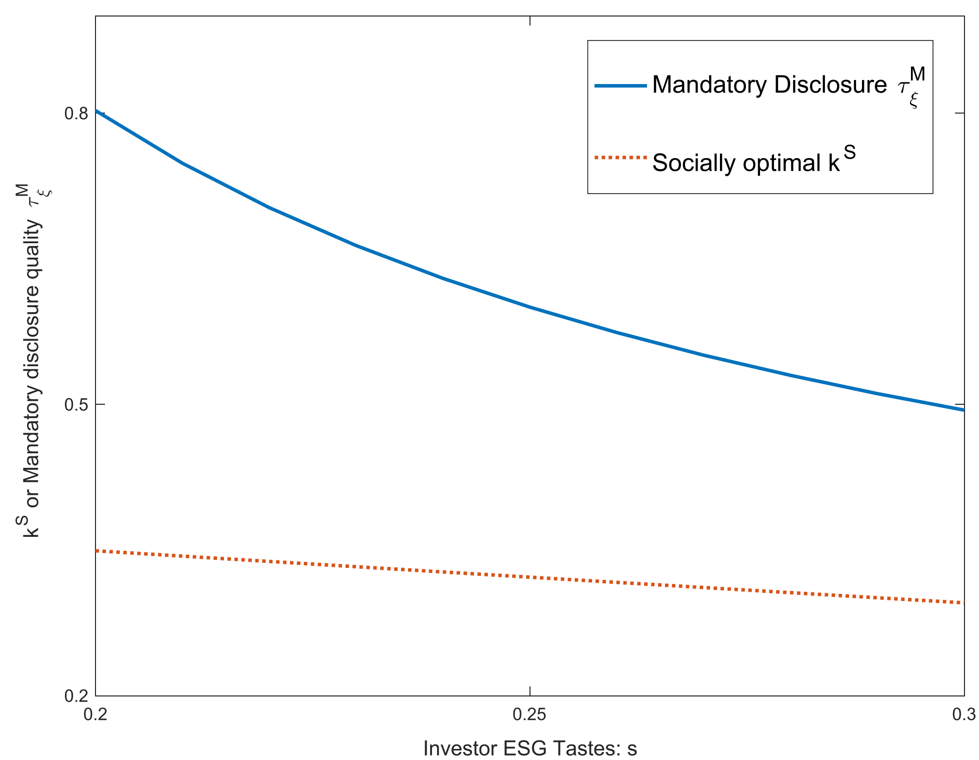


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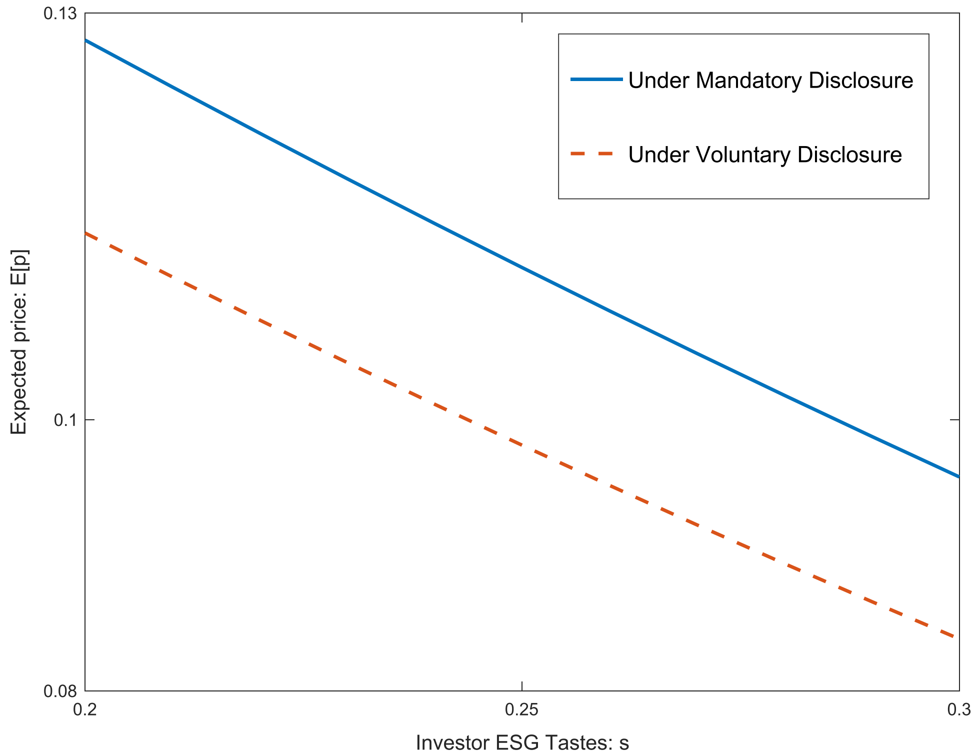
FIGURE 2 (continued)

Panel B: Price Impacts



(The full-color version is available online.)

The argument above applies to both "dirty" investments (i.e., $f'(k) > 0$) and green investments (i.e., $f'(k) < 0$). The reasoning relies on the fact that an individual firm fails to internalize the externality its investment imposes on others, whether that externality is positive (for "green" investment) or negative (for "dirty" investment). Because of the free-rider problem, firms invest too little in "green" and too much in "dirty" investments under voluntary disclosure, i.e., $k^V < k^S$ for $f'(k) < 0$ and $k^V > k^S$ for $f'(k) > 0$. A regulator can implement the socially optimal k^S by mandating a more precise ESG disclosure τ_ξ^M so that $\frac{\alpha_F}{\alpha_v} = s + |\frac{d\bar{\lambda}}{dF}|k^S$.[19] Intuitively, setting $\frac{\alpha_F}{\alpha_v} > s$ raises a firm's perceived marginal cost of a "dirty" investment (or marginal benefit of a "green" investment), thereby motivating the firm to lower its "dirty" investment (or increase its "green" investment) toward the socially optimal level.

The next result follows Proposition 4. It shows how the mandated climate disclosure would change with respect to the quality of traditional, financial information that investors observe.

Proposition 5: The precision of the mandatory climate disclosure increases in the quality of earnings reports and private information about profits. That is, $\frac{d\tau_\xi^M}{d\tau_\eta} > 0$ and $\frac{d\tau_\xi^M}{d\tau_R} > 0$.

The result is fairly intuitive. It predicts stricter (more precise) climate disclosures in countries that historically feature high quality financial reports. This result adds to Christensen et al. (2021) who point out that institutional arrangements impose constraints on the mandate of climate disclosure and noted "intricate complementarities among the many institutions in a market or country." In fact, if a country has an opaque financial information environment, this model predicts that mandating strict climate disclosure has the risk of inducing firms to sacrifice too much financial returns in exchange for favorable climate performance.

[19] For $f'(k) < 0$, it is helpful to express Equations (12) and (14) as $k^S = \bar{\lambda}(f(k^S)) + s|f'(k^S)| + |\frac{d\bar{\lambda}}{dF}||f'(k^S)|k^S$ and $k^S = \bar{\lambda}(f(k^S)) + \frac{\alpha_F(\tau_\xi^M)}{\alpha_v(\tau_\xi^M)}|f'(k^S)|$. Hence, a mandate τ_ξ^M implements k^S if and only if $\frac{\alpha_F(\tau_\xi^M)}{\alpha_v(\tau_\xi^M)} = s + |\frac{d\bar{\lambda}}{dF}|k^S$.

VI. INCORPORATING HETEROGENEOUS INVESTORS

The analysis so far assumes that all investors care about a firm's ESG performance. This section incorporates investor heterogeneity. Assume that $\omega \in [0,1]$ fraction of investors share the ESG taste Equation (3) analyzed before, i.e., they care about the firm's emissions in addition to its financial profits. The remaining $1-\omega$ fraction of investors are purely profit-motivated. I denote the ω fraction as *ESG-conscious investors* and the $1-\omega$ fraction as *profit-only investors*.

We know from Equation (5) that an ESG-conscious investor's demand for the firm's share is $q_i^E = \frac{\mathbb{E}(v - sF|\mathcal{F}_i) - p}{\rho\,\mathrm{var}(v - sF|\mathcal{F}_i)}$. In comparison, a profit-only investor's demand, $q_j = \frac{\mathbb{E}(v|\mathcal{F}_j) - p}{\rho\,\mathrm{var}(v|\mathcal{F}_j)}$, only pertains to her assessment of firm profit v. The linear price function is determined from the market-clearing condition:

$$\omega \int_i q_i^E \, di + (1-\omega)\int_j q_j \, dj = M + \varepsilon.$$

The firm's emission $F(k)$ affects the ESG-conscious investor's holding q_i^E through $s * F(k)$. Because the paper allows for a general functional form $F(k)$, I redefine $\tilde{F}(k) = sF(k)$ in this section to suppress the explicit reference to the taste parameter s, and instead focus on the role played by the fraction ω of ESG-conscious investors. As will become clear, ω plays a similar role as the ESG-taste parameter $s \geq 0$ in the model with homogeneous investors. The result below summarizes the linear price function that clears the market at $t = 2$.

Lemma 4: A unique linear price function is $p = \alpha_0 + \alpha_v v + \alpha_R \zeta - \alpha_F D - \alpha_M M - \alpha_\epsilon \epsilon$, and the price coefficients are functions of the fraction ω of ESG-conscious investors. Given the distributions of firm profit v and emissions F, an increase in ω lowers the expected stock price.

This result resembles Lemma 1. It is intuitive that a higher fraction of ESG-conscious investors lowers the valuation of firms with positive emissions. Analyzing the price coefficient α_F reveals a novel force arising from incorporating heterogeneous investors. As noted before, α_F is the sensitivity of price to reported emissions. I show in the proof that

$$\alpha_F = \omega \times \frac{\tau_\xi}{\tau_\xi + \tau_F} \times \underbrace{\frac{\mathrm{var}(v|\mathcal{F})}{\omega \mathrm{var}(v|\mathcal{F}) + (1-\omega)\mathrm{var}(v - F|\mathcal{F})}}_{\text{Representation factor:}\mathbf{R}}. \tag{16}$$

It is easy to see that $\alpha_F = \frac{\tau_\xi}{\tau_\xi + \tau_F}$ for $\omega = 1$, which is the case analyzed in previous sections. Examining Equation (16) reveals that ESG-conscious investors' preference is under-represented in the stock price. The under-representation is captured by the last term $\mathrm{R} \leq 1$ in Equation (16). What causes this under-representation of ESG-conscious investors is that they face a higher uncertainty than profit-only investors, i.e., $\mathrm{var}(v - F|\mathcal{F}) > \mathrm{var}(v|\mathcal{F})$. Therefore, ESG-conscious investors trade less aggressively than profit-only investors, causing ESG-conscious investors' preferences to be under-represented in the capital market.[20]

At $t = 1$, the manager chooses an investment to maximize the expected price. It is shown in Equation (8) that the firm chooses its investment k according to

$$\lambda = k + \frac{\alpha_F}{\alpha_v}(\tau_\xi, \omega) \times f'(k). \tag{17}$$

The notation $\frac{\alpha_F}{\alpha_v}(\tau_\xi, \omega)$ highlights that $\frac{\alpha_F}{\alpha_v}$ is a function of the quality of ESG disclosure τ_ξ and the fraction of ESG-conscious investors ω.

The optimal ESG disclosure τ_ξ^* is chosen to channel investors' tastes into firm investment. I start by determining the investment k^{FB} that the investors would choose themselves in a benchmark analogous to the single-person optimization problem discussed in the section "Benchmark Analysis."[21] To aggregate the expectations of different exponential utility functions, I follow Eyster, Rabin, and Vayanos (2019) and calculate the geometric average of the expected utilities of the two types of investors as:

[20] As will be shown in Corollary 2 later, the intuition is readily extended to alternative model specifications where ESG-conscious investors can be either under- or over-represented.

[21] Alternatively, one can obtain k^{FB} in Equation (20) by assuming away the model's information friction, i.e., assuming that the firm chooses k publicly, and setting $\tau_F = \infty$ and $\tau_v \to \infty$. Because investors with heterogeneous preferences value the firm differently, τ_v is set to be finite so that $\mathrm{var}(v|\mathcal{F}_j) > 0$. This condition ensures that the investors' demand is bounded at the market-clearing price.

$$\overline{U} \equiv \mathbb{E}[-\exp(-\rho\,[v(k) - F(k)])]^{\omega} \times \mathbb{E}[-\exp(-\rho\, v(k))]^{1-\omega}. \tag{18}$$

The weights ω and $1-\omega$ are the fraction of the ESG-conscious and profit-only investors, respectively. Substituting $\mathbb{E}[-\exp(-\rho[v(k) - F(k)])] = -\exp[-\rho(\lambda k - \frac{k^2}{2} - f(k) - \frac{\rho}{2}(\frac{1}{\tau_v} + \frac{1}{\tau_F}))]$ and $\mathbb{E}[-\exp(-\rho v(k))] = -\exp[-\rho(\lambda k - \frac{k^2}{2} - \frac{\rho}{2}\frac{1}{\tau_v})]$, one can rewrite $\overline{U}$ as

$$\overline{U} = -\exp\left[-\rho\left(\lambda k - \frac{k^2}{2} - \omega f(k) - \frac{\rho}{2}\left(\frac{1}{\tau_v} + \frac{\omega}{\tau_F}\right)\right)\right]. \tag{19}$$

The investment k^{FB} that maximizes $\overline{U}$ is determined from the following condition:

$$\lambda = k^{FB} + \omega f'(k^{FB}). \tag{20}$$

Comparing Equation (20) to the firm's first-order condition Equation (17), we know that setting the precision of ESG disclosure τ_ξ^* as follows would motivate the price-maximizing firm to chooses k^{FB} shown above:

$$\frac{\alpha_F(\tau_\xi^*, \omega)}{\alpha_v(\tau_\xi^*, \omega)} = \omega. \tag{21}$$

This condition resembles $\frac{\alpha_F(\tau_\xi^*, s)}{\alpha_v(\tau_\xi^*, s)} = s$ shown in Equation (10) under homogeneous investors. Just as a stronger ESG-taste s reduces the information that price contains about firm profits (i.e., a lower τ_p), a higher fraction ω of ESG-conscious also reduces τ_p. Hence, a higher ω not only increases the numerator $\alpha_F = \omega\frac{\tau_\xi}{\tau_\xi + \tau_F + (1-\omega)(\tau_p + \tau_\eta + \tau_R + \tau_v)}$ in Equation (21) but also lowers its denominator $\alpha_v = \frac{\tau_p + \tau_\eta + \tau_R}{\tau_p + \tau_\eta + \tau_R + \tau_v}$ by reducing τ_p. As argued following Equation (10), the fact that an increase in ω reduces τ_p (hence, α_v) will result in a counter-intuitive result $\frac{d\tau_\xi^*}{d\omega} < 0$. That argument relies on how investors use their *private* signals $y_i = v + \eta_i$, and is the driving force behind Proposition 3 with homogeneous investors.

To focus on the novel force from modeling heterogeneous investors, we can assume away private signals by setting $\tau_\eta = 0$. This will shut down the price-informativeness channel (i.e., $\tau_p \equiv 0$) as price does not contain information in the absence of private signals. Setting $\tau_\eta = 0$ also removes the need for noise traders ϵ, which was needed previously to prevent the price from fully revealing firm profit v. One can now set noise traders $\epsilon \equiv 0$ because the results are independent of the distribution of ϵ.

Proposition 6: Without private signals (i.e., $\tau_\eta = 0$), a unique $\tau_\xi^* = \frac{\tau_R(\tau_F + (1-\omega)(\tau_R + \tau_v))}{\tau_v}$ motivates the firm to invest k^{FB} in Equation (20). The optimal disclosure satisfies $\frac{d\tau_\xi^*}{d\omega} < 0$.

The result $\frac{d\tau_\xi^*}{d\omega} < 0$ can be compared to $\frac{d\tau_\xi^*}{ds} < 0$ in Proposition 3. To understand the novel driving force due to heterogeneous investors, one can use α_F from Equation (16) and $\alpha_v = \frac{\tau_R}{\tau_R + \tau_v}$ to rewrite the condition Equation (21) used to determine τ_ξ^* as follows:

$$\omega \times \left(\frac{\tau_\xi^*}{\tau_\xi^* + \tau_F} \Bigg/ \frac{\tau_R}{\tau_R + \tau_v}\right) \times \frac{\tau_\xi^* + \tau_F}{\tau_\xi^* + \tau_F + (1-\omega)(\tau_R + \tau_v)} = \omega. \tag{22}$$

The last term $\frac{\tau_\xi^* + \tau_F}{\tau_\xi^* + \tau_F + (1-\omega)(\tau_R + \tau_v)}$ on the left-hand side is the representation factor $\mathrm{R} \le 1$ in Equation (16). The key to understanding $\frac{d\tau_\xi^*}{d\omega} < 0$ is that the representation factor R is increasing in ω. That is, the extent to which ESG-conscious investors are under-represented in the stock price is diminishing as ω increases. Intuitively, the representation factor measures the ESG-conscious investors' trading intensity relative to the average trading intensity in the market, and it is less than one because profit-only investors perceive less risks and trade more aggressively. An increase in ω moves the average trading intensity in the market toward that of the ESG-conscious investors, narrowing the extent to which these investors are misrepresented. Because the optimal ESG disclosure τ_ξ^* is chosen to compensate the under-representation of ESG-conscious investors, it is not surprising that less correction is needed when the under-representation problem is less severe as a result of a higher ω.

The fact $\frac{d\tau_\xi^*}{d\omega} < 0$ holds unconditionally in Proposition 6 warrants further discussion about its underlying assumptions. In keeping with prior studies, the model assumes that all investors value \$1 gain/loss from trading equally (see, for example, Equation (2) in Pástor et al. 2021). Although intuitive, this specification implies that ESG-conscious investors always face higher risks than value-only investors because the former are also concerned about the uncertainties in F. In a more general specification, one can modify the ESG-conscious investors' utility by assuming they care about $x_i = [(1-s)(v-p) - sF]q_i$ for a $s \in [0,1)$ instead of $x_i = [(v-p) - sF]q_i$ in Equation (3). This generalization makes it possible for the ESG-conscious investors to face greater or lesser risks than value-only investors at the trading stage, i.e., $\text{var}((1-s)v - sF|\mathcal{F}_i) \gtrless \text{var}(v|\mathcal{F}_i)$.

Corollary 2: Assuming $x_i = [(1-s)(v-p) - sF]q_i$ for ESG-conscious investors, the unique τ_ξ^* that implements k^{FB} satisfies $\frac{d\tau_\xi^*}{d\omega} < 0$ if and only if $\text{var}((1-s)v - sF|\mathcal{F}_i) > \text{var}(v|\mathcal{F}_i)$, which is equivalent to $\tau_F < \frac{s\tau_v}{2-s}$ in terms of model parameters.

The thinking behind this result follows that of Proposition 6 closely. The optimal quality of ESG disclosure τ_ξ^* aligns firm's perceived ESG tradeoff with that of the investors, i.e., $\frac{\alpha_F(\tau_\xi^*, \omega)}{\alpha_v(\tau_\xi^*, \omega)} = \frac{\omega s}{\omega(1-s) + (1-\omega)}$, where the right-hand side is the investors' mass-adjusted tastes for ESG performance relative to profits. One can use the price coefficients (derived in Appendix A) and rewrite the condition as:

$$\omega s \left(\frac{\tau_\xi^*}{\tau_\xi^* + \tau_F} \Big/ \frac{\tau_R}{\tau_R + \tau_v} \right) \times \frac{1}{\omega(1-s) + (1-\omega)\frac{\text{var}((1-s)v - sF|\mathcal{F}_i)}{\text{var}(v|\mathcal{F}_i)}} = \frac{\omega s}{\omega(1-s) + (1-\omega)}. \tag{23}$$

This condition extends Equation (22) naturally. The difference is that ESG-conscious investors' tastes can now be either under-represented ($\frac{1}{\omega(1-s)+(1-\omega)\frac{\text{var}((1-s)v-sF|\mathcal{F}_i)}{\text{var}(v|\mathcal{F}_i)}} < \frac{1}{\omega(1-s)+(1-\omega)}$) or over-represented ($\frac{1}{\omega(1-s)+(1-\omega)\frac{\text{var}((1-s)v-sF|\mathcal{F}_i)}{\text{var}(v|\mathcal{F}_i)}} > \frac{1}{\omega(1-s)+(1-\omega)}$) in the stock price. In particular, ESG-conscious investors are under-represented when they face higher risks than value-only investors at the trading stage (i.e., $\frac{\text{var}((1-s)v-sF|\mathcal{F}_i)}{\text{var}(v|\mathcal{F}_i)} > 1$) and, hence, trade less aggressively; whereas over-representation occurs when ESG-conscious investors face lesser risk than their value-only counterparts, i.e., $\frac{\text{var}((1-s)v-sF|\mathcal{F}_i)}{\text{var}(v|\mathcal{F}_i)} < 1$. The optimal ESG disclosure τ_ξ^* in Equation (23) corrects any misrepresentation of ESG-conscious investors: a high (or low) τ_ξ^* is used to compensate an under-representation (or undo an over-representation). We observe $\frac{d\tau_\xi^*}{d\omega} < 0$ when ESG-investors are otherwise under-represented (and $\frac{d\tau_\xi^*}{d\omega} > 0$ when they are over-represented) because an increase in ω mitigates the misrepresentation problem that ESG disclosure is used to correct.[22] Corollary 2 shows that, in equilibrium, ESG-conscious investors face higher risks than value-only investors if and only if the prior beliefs about emissions are noisy: $\tau_F < \frac{s\tau_v}{2-s}$.

Echoing Proposition 3, Proposition 6 and its corollary caution against the temptation to focus on regulating ESG disclosures to directly change firm behaviors. A better approach is to view ESG disclosures as interventions designed to iron out inefficiency that market would otherwise experience. In this regard, the paper identifies two factors central to understanding market forces. The first factor relates to how a change in investors' tastes affects the intensity with which they use private signals and, hence, the extent to which price aggregates private information. The second factor is the representation of ESG-conscious investors, i.e., their ability to move price relative to profit-only investors. These two factors determine the extent to which a given information—private or public—is picked up by the capital market, which, in turn, influences the design of public disclosure.[23]

VII. A NONSHAREHOLDER-CENTRIC VIEW OF ESG INVESTING

The analysis so far has taken a shareholder-centric view in defining the efficient investment level. This can be seen by noting that k^{FB} is increasing in the percentage of (or the extent to which) investors care about emissions. The focus on shareholders is common in practice and economic analysis (e.g., Hart and Zingales 2017; Zerbib 2019; Pástor et al. 2021). In this section, I relate the model to an alternative view that ESG investing is to move firm investment toward some socially optimal target that is *independent* of how many investors share that social objective. This alternative view seems to be consistent with Berk and van Binsbergen (2024), who study the efficacy of divestment in moving firm investment toward some (exogenous) socially optimal level.

[22] Any misrepresentation, be it under- or over-representation, disappears in the limit of $\omega = 1$.
[23] Proposition 3 highlights the first factor while shutting down the second (by assuming homogeneous investors). Proposition 6 highlights the second factor while shutting down the first (by assuming away private signals).

One way to incorporate a nonshareholder-centric view is to assume that a social planner aims to implement an investment k that balances its financial profit and the externality $F(k)$. The investment that the social planner would like to implement is obtained from:

$$\lambda = k^* + f'(k^*). \tag{24}$$

Unlike Equation (20) in the main model, the efficient investment k^* above is independent of the fraction ω of the investors who share the planner's concern for externality.

Although the efficient investment is defined differently under the nonshareholder-centric view, the firm's investment decision is still determined by the same condition, $\lambda = k + \frac{\alpha_F}{\alpha_v}(\tau_\xi, \omega) \times f'(k)$, as previously shown in Equation (17). The question is, can the social planner choose a disclosure precision τ_ξ^* that will motivate the price-maximizing firm to pick the socially optimal investment defined in Equation (24), knowing that only a subset of the investors share the planner's concern about emissions? The proposition below summarizes the result.

Proposition 7: Assuming away private signals, a planner can implement k^* defined in Equation (24) by setting a ESG disclosure quality τ_ξ^* if and only if there is enough ESG-conscious investors, i.e., for $\omega > \frac{\tau_R}{\tau_R + \tau_v}$. The disclosure policy that induces k^* is $\tau_\xi^* = \frac{\tau_R(\tau_F + (1-\omega)(\tau_R + \tau_v))}{\omega\tau_v - (1-\omega)\tau_R}$, and $\frac{d\tau_\xi^*}{d\omega} < 0$.

The main difference between Propositions 6 and 7 is whether a ESG disclosure policy can always be used to motivate the firm to choose the efficient investment target. Such a ESG disclosure policy τ_ξ always exists when the efficient investment is defined from the shareholders' point of view in Proposition 6. Instead, such a disclosure policy may not exist if the targeted investment is defined from a social planner's point of view independent of the investors' average tastes. Proposition 7 shows that the planner can use a disclosure policy to implement its own investment target if and only if its social objective is shared by enough investors, i.e., ω is high enough. This result is consistent with Berk and van Binsbergen (2024) who show that divestment cannot have a meaningful impact on firm decision unless the mass of impact investors is sufficiently high. Berk and van Binsbergen (2024) build their argument on how ESG investing affects the firm's cost of capital, and there is no disclosure in their paper. In contrast, the argument in this paper works through incentives that are tied to the sensitivity of price to the reported emissions. The paper therefore offers a different channel through which ESG investing can affect firm investment, and ESG reporting is crucial in this channel.

The nonshareholder-centric analysis in this section can be viewed as a reduced way of modeling a firm's failure to internalize the externalities it generates. One literal interpretation is that the firm's emissions costs the society $F(k)$ in the eyes of the social planner, but the firm only internalizes $\omega < 1$ fraction of the cost. We observe similar results under this reduced form of modeling externalities. For example, ESG disclosure is needed, but the optimal quality of ESG disclosure can actually satisfy $\frac{d\tau_\xi^*}{d\omega} < 0$. In addition, the analysis provides a rationale for the planner to mandate a ESG disclosure more precise than what would be voluntarily provided. The latter can be seen by noting that the optimal τ_ξ^* in Proposition 7 (under a nonshareholder-centric view) is higher than that in Proposition 6 (under a shareholder-centric view). That is, the social planner has to mandate a more precise ESG disclosure if the firm only internalizes a fraction $\omega < 1$ of the externality its investment generates. Modeling externalities in a multifirm setting as in Section V has an advantage of capturing the free-rider problem firms face, which is at the heart of the models studying common good (Ostrom 1990).

VIII. CONCLUSION

This paper studies the role of ESG disclosure in transforming firm investment decisions. The way I model ESG investment follows the view that CSR is a delegated philanthropy (Tirole 2017).[24] The analysis shows that, as long as investors do not perfectly observe firm investment, measuring and disclosing ESG performance is necessary in motivating the firm to undertake sustainable investments. Moreover, the value of disclosing ESG performance cannot be replaced by non-ESG disclosures even if they are correlated in equilibrium.

I characterize the optimal precision of ESG disclosure, which induces the price-maximizing firm to choose the investment that balances its financial and environmental implications. Although it is tempting to think that more precise ESG disclosures are needed (to ensure efficient investment) when shareholders care more about ESG issues, I show this intuition is incomplete because it overlooks the fact that a stronger taste for ESG changes how investors use their information. The analysis cautions against the temptation to focus on regulating ESG disclosures to directly change firm

[24] Arya, Mittendorf, and Ramanan (2022) examine the information content of a specific tax-motivated philanthropic behavior—insiders' share donations.

behaviors. A better approach seems to be to think of ESG disclosures as interventions used to iron out inefficiency that market would otherwise experience. More precise ESG disclosure is needed if market forces fail to move investment sufficiently whereas less ESG disclosure is justified if market forces have gone overboard.

The paper also adds to the ongoing policy debate regarding mandatory climate disclosure. I illustrate why a mandatory climate disclosure can be valuable. The argument exploits the free-rider problem underlying firms' efforts to reduce emissions. I show that the free-rider problem underlying firms' climate-related investments extends to their disclosure incentives. As a result, there will be an underprovision of climate disclosure if disclosure is voluntary. Mandating a climate disclosure that is more precise than what firms would voluntarily provide can motivate self-interested firms to act on common interests in reducing emissions and avoid the tragedy of the commons. The finding that a disclosure mandate generates a tax-like incentive seems to have the potential to offer valuable insights on the policy debate about mandatory climate disclosure.

The paper takes the quality of the firm's financial reporting as given. Although the assumption can be motivated by existing regulatory requirements for financial reporting, it seems interesting to study a bigger game in which the regulator jointly determines the quality of both financial and ESG reporting. Such an expanded model would need to incorporate additional frictions, such as debt contracting, to separately create the demand for financial reporting. In addition, the firm does not possess pre-investment private information in the model, and ESG disclosure pertains to information realized after the investment decision. It might be useful to adapt/expand the model to study scenarios where ESG disclosure is used to reveal private information that firms possess before making an investment, such as risk exposure of a potential investment. Finally, the model features *ex ante* identical firms and, hence, is agnostic about the potential shift of "dirty" activities from public companies to private sectors. Exploring how ESG disclosures influence this shift could be an interesting avenue for future research.

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APPENDIX A

Proof of Lemma 1

Investor utility function is $-\exp(-\rho x_i)$, where $x_i = (v-p)q_i - sFq_i = (v-p-sF)q_i$ follows Equation (3). Denote by $\mathcal{F}_i$ the information set investor i observes prior to trade. We know $\mathbb{E}(x_i|\mathcal{F}_i) = q_i[E(v-sF|\mathcal{F}_i)-p]$, and $\text{var}(x_i|\mathcal{F}_i) = q_i^2\text{var}(v-sF|\mathcal{F}_i)$. It is a known result that $\mathbb{E}[-\exp(-\rho x_i)|\mathcal{F}_i] = -\exp(-\rho\, CE_i)$, and $CE_i = \mathbb{E}(x_i|\mathcal{F}_i) - \frac{\rho}{2}\text{var}(x_i|\mathcal{F}_i)$ is the certainty equivalent. One can use the expressions above to obtain the following:

$$\mathbb{E}[-\exp(-\rho x_i)|\mathcal{F}_i] = -\exp[-\rho q_i(\mathbb{E}(v-sF|\mathcal{F}_i)-p) + \frac{\rho^2}{2}q_i^2\text{var}(v-sF|\mathcal{F}_i)].$$

Taking the first-order condition, I obtain agent i's demand conditional on her information $\mathcal{F}_i$ as

$$q_i = \frac{\mathbb{E}(v - sF|\mathcal{F}_i) - p}{\rho\,\text{var}(v - sF|\mathcal{F}_i)}. \tag{A.1}$$

For $\mathcal{F}_i = \{p, y_i, R, D\}$, I guess and verify the following linear price function:

$$p = \alpha_0 + \beta v + \gamma R - \alpha_F D - \alpha_M M - \alpha_\epsilon \epsilon, \tag{A.2}$$

where the coefficients can depend on the investors' conjecture $\hat{k}$ but not on k, which is unobservable by assumption. Note that the price p is informationally equivalent to $m \doteq \frac{p-\alpha_0-\gamma R+\alpha_F D+\alpha_M M}{\beta} = v - \frac{\alpha_\epsilon}{\beta}\epsilon$, which is a noisy signal of v with a precision $\tau_p = (\frac{\beta}{\alpha_\epsilon})^2\tau_\epsilon$. To determine Equation (A.1), note that $(v-sF, y_i, m, D, R)$ follows a multivariate normal distribution as follows:

$$\begin{bmatrix} v-sF \\ y_i \\ m \\ D \\ R \end{bmatrix} \sim N\left(\begin{bmatrix} \lambda\hat{k} - \frac{\hat{k}^2}{2} - sf(\hat{k}) \\ \lambda\hat{k} - \frac{\hat{k}^2}{2} \\ \lambda\hat{k} - \frac{\hat{k}^2}{2} \\ f(\hat{k}) \\ \lambda\hat{k} - \frac{\hat{k}^2}{2} \end{bmatrix}, \begin{bmatrix} \frac{1}{\tau_v}+\frac{s^2}{\tau_F} & \frac{1}{\tau_v} & \frac{1}{\tau_v} & -s\frac{1}{\tau_F} & \frac{1}{\tau_v} \\ \frac{1}{\tau_v} & \frac{1}{\tau_v}+\frac{1}{\tau_\eta} & \frac{1}{\tau_v} & 0 & \frac{1}{\tau_v} \\ \frac{1}{\tau_v} & \frac{1}{\tau_v} & \frac{1}{\tau_v}+\frac{\alpha_\epsilon^2}{\beta^2\tau_\epsilon} & 0 & \frac{1}{\tau_v} \\ -s\frac{1}{\tau_F} & 0 & 0 & \frac{1}{\tau_F}+\frac{1}{\tau_\xi} & 0 \\ \frac{1}{\tau_v} & \frac{1}{\tau_v} & \frac{1}{\tau_v} & 0 & \frac{1}{\tau_v}+\frac{1}{\tau_R} \end{bmatrix}\right).$$

One can calculate the conditional mean $\mathbb{E}(v-sF|\mathcal{F}_i)$ and conditional variance $\text{var}(v-sF|\mathcal{F}_i)$ given $\mathcal{F}_i = (y_i, m, R, D)$. Substituting the conditional mean and variance into Equation (A.1), I solve for the market-clearing price p from the following market-clearing condition

$$\int_i q_i\, di = M + \epsilon. \tag{A.3}$$

The equilibrium price function is determined by comparing the coefficients in the market-clearing price p obtained above to those in the conjectured Equation (A.2). Denote by $\tau_\Sigma = \tau_v + \tau_R + \tau_\eta + \tau_p$. The price coefficients can be characterized as:

$$\begin{aligned} &\alpha_0 = \frac{\tau_v}{\tau_\Sigma}\mu_v - s\frac{\tau_F}{\tau_F+\tau_\xi}\mu_F, \quad \beta = \frac{\tau_\eta+\tau_p}{\tau_\Sigma}, \quad \gamma = \frac{\tau_R}{\tau_\Sigma}, \quad \alpha_F = \frac{\tau_\xi}{\tau_F+\tau_\xi}s, \\ &\alpha_M = \rho\text{var}(v-sF|\mathcal{F}_i), \quad \alpha_\epsilon = \rho\text{var}(v-sF|\mathcal{F}_i) + \frac{\tau_p \Big/ \left(\frac{\beta}{\alpha_\epsilon}\right)}{\tau_\Sigma}, \end{aligned} \tag{A.4}$$

where $\text{var}(v-sF|\mathcal{F}_i) = \frac{1}{\tau_\Sigma} + \frac{s^2}{\tau_F+\tau_\xi}$.

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These price coefficients are fully characterized once we determine the value $\frac{\beta}{\alpha_\epsilon}$ (recall $\tau_p = (\frac{\beta}{\alpha_\epsilon})^2\tau_\epsilon$). Let $X = \frac{\beta}{\alpha_\epsilon}$. Note that β and α_ϵ shown above are functions of X. Setting $\frac{\beta}{\alpha_\epsilon} = X$, one can show that X is the unique (positive) real root to the cubic function below:

$$s^2\tau_\epsilon X^3 + [\tau_F + \tau_\xi + s^2(\tau_v + \tau_R + \tau_\eta)]X - \frac{1}{\rho}(\tau_F + \tau_\xi)\tau_\eta = 0. \quad (A.5)$$

Applying the implicit function theorem to Equation (A.5) verifies $\frac{dX}{ds} < 0$ and, hence, $\frac{d\tau_p}{ds} < 0$. Substituting $R = v + \zeta$ into Equation (A.2) and letting $\alpha_v = \beta + \gamma$ and $\alpha_R = \gamma$, I rewrite the price function as:

$$p = \alpha_0 + \alpha_v v + \alpha_R\zeta - \alpha_F D - \alpha_M M - \alpha_\epsilon\epsilon. \quad (A.6)$$

Straightforward algebra verifies $E[p] = \mu_v - s\mu_F - \alpha_M M$. To prove $\frac{dE[p]}{ds} < 0$, it is sufficient to show that $\alpha_M = \rho(\frac{1}{\tau_\Sigma} + \frac{s^2}{\tau_F+\tau_\xi})$ is increasing in s. The fact that $\frac{d\alpha_M}{ds} > 0$ follows by noting that a higher s not only increases $\frac{s^2}{\tau_F+\tau_\xi}$ but also lowers $\tau_\Sigma = \tau_v + \tau_R + \tau_\eta + \tau_p$ (recall $\frac{d\tau_p}{ds} < 0$). This verifies the claim that $\frac{dE[p]}{ds} < 0$. ■

Proof of Proposition 1

When there is no ESG disclosure (i.e., $\tau_\xi = 0$), the price function Equation (A.6) becomes $p = \alpha_0 + \alpha_v v + \alpha_R\zeta - \alpha_M M - \alpha_\epsilon\epsilon$ because $\alpha_F = 0$. The expected price is

$$E[p|k,\hat{k}] = \alpha_0(\hat{k}) + \alpha_v E[v|k] - \alpha_M M.$$

The expression is a function of the actual investment k chosen by the firm and the investors' conjecture $\hat{k}$, which enters the intercept $\alpha_0 = \frac{\tau_v}{\tau_\Sigma}\mu_v - s\mu_F$ via $\mu_v(\hat{k}) = \lambda\hat{k} - \frac{\hat{k}^2}{2}$ and $\mu_F(\hat{k}) = f(\hat{k})$. It follows that

$$\frac{dE[p|k,\hat{k}]}{dk} = \alpha_v\frac{dE[v|k]}{dk}.$$

Substituting $E[v|k] = \lambda k - \frac{k^2}{2}$ from Equation (1), I rewrite the first-order condition characterizing investment without ESG disclosure, $k^\emptyset$, as

$$\alpha_v(\lambda - k^\emptyset) = 0, \quad (A.7)$$

from which I conclude $k^\emptyset = \lambda$. To complete the characterization of the equilibrium, I apply rational expectations by letting $\hat{k} = k^\emptyset = \lambda$ solved above. This ensures that the endogenous beliefs $\mu_v(\hat{k}) = \lambda\hat{k} - \frac{\hat{k}^2}{2}$ and $\mu_F(\hat{k}) = f(\hat{k})$ that investors hold are correct in equilibrium. ■

Proof of Corollary 1

Reasoning follows Bagwell (1995) and is summarized in the text. ■

Proof of Lemma 2

The equilibrium for a given $\tau_\xi \geq 0$ is solved in three steps. I first obtain the linear price function, taking the market conjecture $\hat{k}$ as given. In the second step, I endogenize the firm's investment choice k, taking the investors' conjecture $\hat{k}$ and the price function as given. The equilibrium is then determined after imposing rational expectations, i.e., $\hat{k} = k$.

For a given precision $\tau_\xi \geq 0$, the linear price function below is proved in Lemma 1 (see Equation (A.2)):

$$p = \alpha_0 + \beta v + \gamma R - \alpha_F D - \alpha_M M - \alpha_\epsilon\epsilon. \quad (A.8)$$

To simplify notations, let $\hat{\mu}_v \equiv \lambda\hat{k} - \frac{\hat{k}^2}{2}$ and $\hat{\mu}_F \equiv f(\hat{k})$ be the investors' prior mean of profits and emissions as a function of their conjecture $\hat{k}$ (to be solved endogenously). It follows from Equation (A.4) that

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$$\alpha_0 = \frac{\tau_v}{\tau_\Sigma}\hat{\mu}_v - s\frac{\tau_F}{\tau_F + \tau_\xi}\hat{\mu}_F, \quad \beta = \frac{\tau_\eta + \tau_p}{\tau_\Sigma}, \quad \gamma = \frac{\tau_R}{\tau_\Sigma}, \quad \alpha_F = \frac{\tau_\xi}{\tau_F + \tau_\xi}s,$$

$$\alpha_M = \rho \text{var}(v - sF|\mathcal{F}_i), \quad \alpha_\epsilon = \rho \text{var}(v - sF|\mathcal{F}_i) + \frac{\tau_p \Big/ \left(\frac{\beta}{\alpha_\epsilon}\right)}{\tau_\Sigma}.$$

Recall that $\tau_p = (\frac{\beta}{\alpha_\epsilon})^2\tau_\epsilon$ and $X = \frac{\beta}{\alpha_\epsilon}$ is uniquely determined from the cubic function Equation (A.5).

Substituting $R = v + \zeta$ into Equation (A.8) and letting $\alpha_v = \beta + \gamma$ and $\alpha_R = \gamma$, I rewrite the price function as that stated in the lemma:

$$p = \alpha_0 + \alpha_v v + \alpha_R \zeta - \alpha_F D - \alpha_M M - \alpha_\epsilon \epsilon. \tag{A.9}$$

Straightforward algebra verifies

$$\frac{d\alpha_F}{d\tau_\xi} > 0 \text{ and } \frac{d\alpha_v}{d\tau_\xi} > 0.$$

In the second step, I endogenize the investment. The firm takes market conjecture $\hat{k}$ and the price function Equation (A.9) as given and chooses k to maximize the following (recall $D = F + \xi$ and $E[\xi] = 0$):

$$\mathbb{E}[p|\hat{k}, k] = \alpha_0(\hat{k}) + \alpha_v E[v|k] - \alpha_F E[F|k] - \alpha_M M.$$

When choosing investment k, the firm takes the price function (hence, the price coefficients) as given. It follows

$$\frac{dE[p|k,\hat{k}]}{dk} = \alpha_v\frac{dE[v|k]}{dk} - \alpha_F\frac{dE[F|k]}{dk}.$$

The first-order condition characterizing the optimal k^* is $\alpha_v(\tau_\xi)(\lambda - k^*) - \alpha_F(\tau_\xi)f'(k) = 0$, which can be restated as

$$\lambda = k^* + \frac{\alpha_F(\tau_\xi)}{\alpha_v(\tau_\xi)}f'(k^*). \tag{A.10}$$

Having characterized $k^*(\tau_\xi)$, I impose rational expectations $\hat{k} = k^*(\tau_\xi)$. This ensures that the prior beliefs $\mu_v(\hat{k}) = \lambda\hat{k} - \frac{\hat{k}^2}{2}$ and $\mu_F(\hat{k}) = f(\hat{k})$ that investors hold are correct in equilibrium. ■

Proof of Proposition 2

Comparing the first-order condition Equation (A.10) to $\lambda = k^{FB} + sf'(k^{FB})$ in Equation (4), I note that the two conditions will be the same if there exists a τ_ξ^* such that $\frac{\alpha_F(\tau_\xi^*)}{\alpha_v(\tau_\xi^*)} = s$. Using the price coefficients in Lemma 2, I solve τ_ξ^* as

$$\tau_\xi^* = \tau_F\left(\frac{r^2\tau_F^2\tau_\eta^2\tau_\epsilon}{(s^2\tau_v + \tau_F)^2} + \tau_\eta + \tau_R\right)\tau_v^{-1}.$$

where $r = \frac{1}{\rho}$ is the inverse of the investors' risk-aversion ρ. ■

Proof of Proposition 3

Straightforward algebra shows

$$\frac{d\tau_\xi^*}{ds} = -\frac{4sr^2\tau_F^3\tau_\eta^2\tau_\epsilon}{(\tau_F + s^2\tau_v)^3} < 0,$$

which verifies the proposition. ■

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APPENDIX A (continued)

Proof of Lemma 3

The game is solved backward. At $t=2$, the aggregate emissions $\overline{F}=\int_i F(k_i)di$ are known by aggregating the reported emissions from all firms, as in

$$\overline{F}=\int_i D_i di=\int_i [F(k_i)+\xi_i]di=\int_i F(k_i)di. \tag{A.11}$$

Note that $\overline{\lambda}\equiv\overline{\lambda}(\overline{F})$ is determined and known to the investors prior to trading. As discussed in the text, each firm's price function takes the form shown in Equation (A.9), and that the price coefficients are the same as those specified in Lemma 2 (after replacing λ with $\overline{\lambda}$.). This is because noise terms are independent across firms, implying that firm j's reports has no value in updating firm i's profits v_i or emissions F_i. Information about other firms affects firm i's demand function only through their collective influence over $\overline{\lambda}\equiv\overline{\lambda}(\overline{F})$. Since $\overline{\lambda}$ is a known constant at the time of trading (see Equation (A.11)), the price function is characterized as in the proof of Lemma 2.

At $t=1$, firm i takes the price function at $t=1$ (price coefficients) as given and chooses k_i to maximize its expected price. It follows from Equation (A.10) that the first-order condition characterizing firm investment k_i is

$$\overline{\lambda}=k_i+f'(k_i)\frac{\alpha_F(\tau^i_\xi,s)}{\alpha_v(\tau^i_\xi,s)}, \tag{A.12}$$

and the notation $\frac{\alpha_F(\tau^i_\xi,s)}{\alpha_v(\tau^i_\xi,s)}$ emphasizes its dependence on s and firm i's disclosure precision τ^i_ξ.

At $t=0$, the firm chooses τ^i_ϵ to maximize its expected price, knowing that τ^i_ϵ influences the investment k_i it will choose at $t=1$ as in Equation (A.12). Using $M=0$ in the large economy, one can verify that firm i's expected price satisfies $E[p_i]=E[v(k_i)-sF(k_i)]=\overline{\lambda}k_i-\frac{k_i^2}{2}-sf(k_i)$, which is maximized if k_i satisfies $\overline{\lambda}=k_i+sf'(k_i)$. When choosing τ^i_ξ at $t=0$, firm i takes other firms' investment choices and, hence, $\overline{\lambda}=\overline{\lambda}(\int_j F(k_j)dj)$ as given. Recall from Proposition 2 that setting $\tau^i_\xi=\tau^*_\xi$ ensures $\frac{\alpha_F}{\alpha_v}=s$, which, in turn, transforms the firm's first-order condition Equation (A.12) into $\overline{\lambda}=k_i+sf'(k_i)$. As argued above, an investment k_i satisfying $\overline{\lambda}=k_i+sf'(k_i)$ maximizes $E[p_i]$. This proves the optimality of $\tau^i_\xi=\tau^*_\xi$.

It remains to characterize the equilibrium investment k^V and prove the overpollution result. As noted above, firm i takes other firms' investment k_j (hence, $\overline{\lambda}=\overline{\lambda}(\int_j F(k_j)dj)$) as given, and chooses τ^i_ξ at $t=0$ and k_i at $t=1$ so that $\overline{\lambda}=k_i+sf'(k_i)$. In a symmetric equilibrium, I drop the firm-subscript i and obtain $\overline{\lambda}=\overline{\lambda}(f(k))$. The symmetric equilibrium k^V is determined by

$$\overline{\lambda}(f(k^V))=k^V+s\times f'(k^V). \tag{A.13}$$

There exists at most one k^V satisfying Equation (A.13) because its left-hand side is decreasing in k^V and its right-hand side is increasing in k^V (recall $f''(k)\geq 0$). The existence of a solution is guaranteed because the right-hand side of Equation (A.13) is less than its left-hand side at $k=0$, and the opposite holds as $k\rightarrow\infty$.

Compare the condition Equation (A.13) that determines k^V under voluntary disclosure to the following condition used to determine the socially optimal k^S, which is shown in Equation (12):

$$\overline{\lambda}(f(k^S))=k^S+sf'(k^S)+\left|\frac{d\overline{\lambda}}{d\overline{F}}\right|f'(k^S)\,k^S. \tag{A.14}$$

The overpollution claim in the proposition follows by noting that individual firms overlook the externalities associated with the investment, $|\frac{d\overline{\lambda}}{d\overline{F}}|f'(k^S)\,k^S$. ■

Proof of Proposition 4

It is shown in Equation (A.12) that the investment chosen by an individual firm i at $t=1$ satisfies $\lambda=k_i+f'(k_i)\frac{\alpha_F}{\alpha_v}$. The regulator can implement k^S as a symmetric equilibrium via mandating τ^M_ξ if k^S satisfies the firm's first-order condition. That is,

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$$\overline{\lambda}(f(k^S)) = k^S + \frac{\alpha_F(\tau_\xi^M, s)}{\alpha_v(\tau_\xi^M, s)} f'(k^S). \tag{A.15}$$

The price coefficients α_F and α_v (determined at $t=2$) are the same as in the voluntary disclosure regime analyzed at the beginning of Lemma 3, after replacing τ_ξ^V with τ_ξ^M.

Implementing k^S as a symmetric equilibrium requires that the right-hand sides of Equation (A.14) and Equation (A.15) are the same. That is,

$$\frac{\alpha_F(\tau_\xi^M, s)}{\alpha_v(\tau_\xi^M, s)} = s + \left|\frac{d\overline{\lambda}}{d\overline{F}}\right| \times k^S. \tag{A.16}$$

One can verify that $\frac{\alpha_F}{\alpha_v} = 0$ when $\tau_\xi^M = 0$ and that $\frac{\alpha_F}{\alpha_v} = \left(1 + \frac{\tau_v}{\tau_\eta + \tau_p + \tau_R}\right)s$ when $\tau_\xi \to \infty$. It follows that the left-hand side of Equation (A.16) is less than its right-hand side at $\tau_\xi^M = 0$. To ensure a $\tau_\xi^M > 0$ satisfying Equation (A.16), a sufficient condition is to have its left-hand side greater than its right-hand side as $\tau_\xi \to \infty$, which can be stated equivalently as follows (expressing $\frac{d\overline{\lambda}}{d\overline{F}}|_{k=k^S}$ as $\overline{\lambda}'(f(k^S))$):

$$\frac{\tau_v\, s}{\tau_R + \tau_\eta + \tau_p} > \left|\overline{\lambda}'(f(k^S))\right| \times k^S. \tag{A.17}$$

Next, I show $\tau_\xi^M > \tau_\xi^V$. It follows from Equation (A.16) that $\frac{\alpha_F(\tau_\xi^M)}{\alpha_v(\tau_\xi^M)} > s$, and I drop the argument s in $\frac{\alpha_F(\tau_\xi^M, s)}{\alpha_v(\tau_\xi^M, s)}$ for brevity. Recall from Proposition 2 that $\tau_\xi^V = \tau_\xi^*$ is chosen to ensure $\frac{\alpha_F(\tau_\xi^V)}{\alpha_v(\tau_\xi^V)} = s$. Note that $\frac{\alpha_F(\tau_\xi)}{\alpha_v(\tau_\xi)}$ is increasing in the neighborhood of τ_ξ^*. Therefore, for small $\epsilon > 0$, we know $\frac{\alpha_F(\tau_\xi)}{\alpha_v(\tau_\xi)} < s$ for $\tau_\xi = \tau_\xi^V - \epsilon$ and $\frac{\alpha_F(\tau_\xi)}{\alpha_v(\tau_\xi)} > s$ for $\tau_\xi = \tau_\xi^V + \epsilon$. To prove $\tau_\xi^M > \tau_\xi^V$, suppose by contradiction that $\tau_\xi^M < \tau_\xi^V$ (for we know $\tau_\xi^M \neq \tau_\xi^V$). This means $\frac{\alpha_F(\tau_\xi)}{\alpha_v(\tau_\xi)} > s$ holds both at τ_ξ^M, which is less than τ_ξ^V by assumption, and at $\tau_\xi^V + \epsilon$. Because $\frac{\alpha_F(\tau_\xi)}{\alpha_v(\tau_\xi)} < s$ at $\tau_\xi = \tau_\xi^V - \epsilon$ for some arbitrarily small ϵ, it follows from continuity that there are at least two values of $\tau_\xi \in (\tau_\xi^M, \tau_\xi^V + \epsilon)$ satisfying $\frac{\alpha_F(\tau_\xi)}{\alpha_v(\tau_\xi)} = s$. However, this contradicts the fact that there exists a *unique* $\tau_\xi^V = \tau_\xi^*$ satisfying $\frac{\alpha_F(\tau_\xi^V)}{\alpha_v(\tau_\xi^V)} = s$, as shown in Proposition 2.

It remains to verify the claim about stock valuation, $E[p] = E[v(k) - sF(k)] = \overline{\lambda}k - \frac{k^2}{2} - sf(k)$. It is shown before Equation (12) in the text that k^S maximizes $\overline{\lambda}k - \frac{k^2}{2} - sf(k)$. The claim follows by noting that mandating τ_ξ^M induces the firms to choose k^S in equilibrium. ■

Proof of Proposition 5

I prove $\frac{d\tau_\xi^M}{d\tau_R} > 0$ here, and a similar argument applies for $\frac{d\tau_\xi^M}{d\tau_\eta} > 0$. Investigating Equation (A.14) shows that the socially optimal k^S is independent of the quality of the earnings report τ_R. As τ_R increases, it follows from Equation (A.15) that $\frac{\alpha_F}{\alpha_v}$ must hold as a constant because k^S is independent of τ_R. It is easy to verify that an increase in τ_R (i.e., a more precise earnings report) increases the coefficient α_v. Therefore, α_F must also increase to maintain $\frac{\alpha_F}{\alpha_v}$ unchanged. Given $\alpha_F = s\frac{\tau_\xi^M}{\tau_\xi^M + \tau_F}$, we know that α_F is higher if and only if τ_ξ^M increases. This proves $\frac{d\tau_\xi^M}{d\tau_R} > 0$. ■

Proof of Lemma 4

The demand functions of a ESG-conscious investor is $q_i^E = \frac{\mathbb{E}(v - F|\mathcal{F}_i) - p}{\rho\,\mathrm{var}(v - F|\mathcal{F}_i)}$ and that of a profit-only investor is $q_j = \frac{\mathbb{E}(v|\mathcal{F}_j) - p}{\rho\,\mathrm{var}(v|\mathcal{F}_j)}$. (Recall that the notation s is suppressed after redefining $\tilde{F}(k) = s \times F(k)$, although I continue to use F to economize notations.) I guess and verify that the price function is $p = \alpha_0 + \beta v + \gamma R - \alpha_F D - \alpha_M M - \alpha_\epsilon \epsilon$, where $M \geq 0$ is the average supply and ϵ is the supply shock. Observing p is informationally equivalent to observing $q = \frac{p - \alpha_0 - \gamma R + \alpha_F D + \alpha_M M}{\beta} = v - \frac{\alpha_\epsilon}{\beta}\epsilon$, which is a signal of v with a precision $\tau_p = (\frac{\beta}{\alpha_\epsilon})^2 \tau_\epsilon$.

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Applying the market-clearing condition $\omega\int_i q_i^E\, di + (1-\omega)\int_j q_j\, dj = M + \varepsilon$, one can see that the market-clear price satisfies

$$p = \int_i E[v|\mathcal{F}_i]di - \omega\frac{\mathrm{var}(v|\mathcal{F})}{\omega\mathrm{var}(v|\mathcal{F}) + (1-\omega)\mathrm{var}(v-F|\mathcal{F})}E(F|\mathcal{F}_i)$$
$$-\rho\frac{\mathrm{var}(v|\mathcal{F})\mathrm{var}(v-F|\mathcal{F})}{\omega\mathrm{var}(v|\mathcal{F}) + (1-\omega)\mathrm{var}(v-F|\mathcal{F})}(M+\epsilon),$$

where $\mathcal{F}_i = \{\hat{k}, R, D, y_i\}$ is investor i's information set. I drop the subscript in $\mathcal{F}_i$ when expressing $\mathrm{var}(v|\mathcal{F})$ and $\mathrm{var}(v-F|\mathcal{F})$ as their values are the same for all i.

Denote by $\tau_\Sigma = \tau_v + \tau_R + \tau_\eta + \tau_p$. In addition, let $\hat{\mu}_v = \lambda\hat{k} - \frac{\hat{k}^2}{2}$ and $\mu_F = f(\hat{k})$ be the prior means of the firm profit and emissions as a function of the conjectured $\hat{k}$. One can show that $E(v|\mathcal{F}_i) = \frac{\tau_v}{\tau_\Sigma}\hat{\mu}_v + \frac{\tau_\eta}{\tau_\Sigma}y_i + \frac{\tau_R}{\tau_\Sigma}R + \frac{\tau_p}{\tau_\Sigma}(v - \frac{\alpha_\epsilon}{\beta}\epsilon)$ and $E(F|\mathcal{F}_i) = \frac{\tau_F}{\tau_F+\tau_\xi}\hat{\mu}_F + \frac{\tau_\xi}{\tau_F+\tau_\xi}D$. Substituting $y_i = v + \eta_i$ and integrating over i, I obtain the following by comparing coefficients:

$$\alpha_0 = \frac{\tau_v}{\tau_\Sigma}\hat{\mu}_v - \omega\frac{\mathrm{var}(v|\mathcal{F})}{\omega\mathrm{var}(v|\mathcal{F}) + (1-\omega)\mathrm{var}(v-F|\mathcal{F})}\frac{\tau_F}{\tau_F+\tau_\xi}\hat{\mu}_F,$$
$$\beta = \frac{\tau_\eta + \tau_p}{\tau_\Sigma}, \qquad \gamma = \frac{\tau_R}{\tau_\Sigma},$$
$$\alpha_F = \omega\frac{\mathrm{var}(v|\mathcal{F})}{\omega\mathrm{var}(v|\mathcal{F}) + (1-\omega)\mathrm{var}(v-F|\mathcal{F})}\frac{\tau_\xi}{\tau_F+\tau_\xi},$$
$$\alpha_M = \rho\frac{\mathrm{var}(v|\mathcal{F})\mathrm{var}(v-F|\mathcal{F})}{\omega\mathrm{var}(v|\mathcal{F}) + (1-\omega)\mathrm{var}(v-F|\mathcal{F})},$$
$$\alpha_\epsilon = \rho\frac{\mathrm{var}(v|\mathcal{F})\mathrm{var}(v-F|\mathcal{F})}{\omega\mathrm{var}(v|\mathcal{F}) + (1-\omega)\mathrm{var}(v-F|\mathcal{F})} + \frac{\tau_p\Big/\left(\frac{\beta}{\alpha_\epsilon}\right)}{\tau_\Sigma},$$

where $\frac{\mathrm{var}(v|\mathcal{F})}{\omega\mathrm{var}(v|\mathcal{F})+(1-\omega)\mathrm{var}(v-F|\mathcal{F})} = \frac{\tau_F+\tau_\xi}{\tau_F+\tau_\xi+(1-\omega)\tau_\Sigma}$ and $\frac{\mathrm{var}(v|\mathcal{F})\mathrm{var}(v-F|\mathcal{F})}{\omega\mathrm{var}(v|\mathcal{F})+(1-\omega)\mathrm{var}(v-F|\mathcal{F})} = \frac{\tau_F+\tau_\xi+\tau_\Sigma}{\tau_\Sigma[\tau_F+\tau_\xi+(1-\omega)\tau_\Sigma]}$.

The price coefficients are fully characterized once we know the value $\frac{\beta}{\alpha_\epsilon}$ (recall $\tau_p = (\frac{\beta}{\alpha_\epsilon})^2\tau_\epsilon$). Let $X = \frac{\beta}{\alpha_\epsilon}$. Note that $\beta(X)$ and $\alpha_\epsilon(X)$ shown above are functions of X. Tedious algebra shows that (1) there exists a unique $X > 0$ solving $\frac{\beta(X)}{\alpha_\epsilon(X)} = X$, and (2) $\frac{dX}{d\omega} < 0$ (hence, $\frac{d\tau_p}{d\omega} < 0$). Substituting $R = v + \zeta$ and letting $\alpha_v = \beta + \gamma$ and $\alpha_R = \gamma$, I rewrite the price function as $p = \alpha_0 + \alpha_v v + \alpha_R\zeta - \alpha_F D - \alpha_M M - \alpha_\epsilon\epsilon$, as stated in the lemma.

Next, I show that $\frac{dE[p]}{d\omega} < 0$ when the distributions of firm profit and emissions are exogenous. Given the exogenous mean profit μ_v and emissions μ_F, one can show

$$E[p] = \mu_v - \omega\frac{\tau_F+\tau_\xi}{\tau_F+\tau_\xi+(1-\omega)\tau_\Sigma}\mu_F - \rho\frac{\tau_F+\tau_\xi+\tau_\Sigma}{\tau_{\Sigma[\tau_F+\tau_\xi+(1-\omega)\tau_\Sigma]}}M.$$

It is sufficient to show that $\omega\frac{\tau_F+\tau_\xi}{\tau_F+\tau_\xi+(1-\omega)\tau_\Sigma}$ and $\alpha_M = \rho\frac{\tau_F+\tau_\xi+\tau_\Sigma}{\tau_\Sigma[\tau_F+\tau_\xi+(1-\omega)\tau_\Sigma]}$ are increasing in ω for the purpose of proving $\frac{dE[p]}{d\omega} < 0$. Recall $\tau_\Sigma = \tau_v + \tau_R + \tau_\eta + \tau_p$ and $\frac{d\tau_p}{d\omega} < 0$. It follows that $\frac{d\tau_\Sigma}{d\omega} < 0$, from which we conclude $\frac{d}{d\omega}\omega\frac{\tau_F+\tau_\xi}{\tau_F+\tau_\xi+(1-\omega)\tau_\Sigma} > 0$. Further, one can show $\frac{d\alpha_M}{d\omega} = \frac{\partial\alpha_M}{\partial\omega} + \frac{\partial\alpha_M}{\partial\tau_\Sigma}\frac{d\tau_\Sigma}{d\omega} > 0$, where the result uses the fact that $\frac{\partial\alpha_M}{\partial\omega} > 0$, $\frac{\partial\alpha_M}{\partial\tau_\Sigma} = -\frac{(\tau_F+\tau_\xi)^2+(1-\omega)\tau_\Sigma(2\tau_F+2\tau_\xi+\tau_\Sigma)}{\tau_\Sigma^2[\tau_F+\tau_\xi+(1-\omega)\tau_\Sigma]^2} < 0$, and $\frac{d\tau_\Sigma}{d\omega} < 0$. ■

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APPENDIX A (continued)

Proof of Proposition 6

Substituting $\tau_\eta = 0$ (hence, $\tau_p = 0$) into the price coefficients shown in Lemma 4, we obtain $\alpha_F = \omega \frac{\tau_\xi}{\tau_\xi + \tau_F + (1-\omega)(\tau_R + \tau_v)}$ and $\alpha_v = \frac{\tau_R}{\tau_R + \tau_v}$. It is shown in Equation (21) that the optimal τ_ξ^* is chosen to ensure $\frac{\alpha_F}{\alpha_v} = \omega$, from which I obtain $\tau_\xi^* = \frac{\tau_R(\tau_F + (1-\omega)(\tau_R + \tau_v))}{\tau_v}$. Straightforward algebra shows $\frac{d\tau_\xi^*}{d\omega} = -\frac{\tau_R(\tau_R + \tau_v)}{\tau_v} < 0$. ■

Proof of Corollary 2

In this proof, I first characterize the market-clearing price function. Second, I characterize k^{FB}. The closed-form expression of the optimal quality of ESG disclosure τ_ξ^* and its comparative statics are shown in the end.

To characterize the price function, note that a value-only investor j's demand function is still $q_j = \frac{\mathbb{E}(v|\mathcal{F}_j) - p}{\rho \, \text{var}(v|\mathcal{F}_j)}$. The demand of a ESG-conscious investor i, however, is changed to $q_i^E = \frac{\mathbb{E}((1-s)v - sF|\mathcal{F}_i) - (1-s)p}{\rho \, \text{var}((1-s)v - sF|\mathcal{F}_i)}$. I follow similar steps in Lemma 4 to guess and verify the price function $p = \alpha_0 + \beta v + \gamma R - \alpha_F D - \alpha_M M - \alpha_\epsilon \epsilon$. Applying the market-clearing condition $\omega \int_i q_i^E \, di + (1-\omega)\int_j q_j \, dj = M + \varepsilon$, one obtains the price coefficients as:

$$\alpha_0 = \frac{\tau_v}{\tau_\Sigma}\hat{\mu}_v - \omega s \frac{\text{var}(v|\mathcal{F})}{\omega(1-s)\text{var}(v|\mathcal{F}) + (1-\omega)\text{var}[(1-s)v - sF|\mathcal{F}]} \frac{\tau_F}{\tau_F + \tau_\xi}\hat{\mu}_F,$$

$$\beta = \frac{\tau_\eta + \tau_p}{\tau_\Sigma}, \qquad \gamma = \frac{\tau_R}{\tau_\Sigma},$$

$$\alpha_F = \omega s \frac{\text{var}(v|\mathcal{F})}{\omega(1-s)\text{var}(v|\mathcal{F}) + (1-\omega)\text{var}[(1-s)v - sF|\mathcal{F}]} \frac{\tau_\xi}{\tau_F + \tau_\xi},$$

$$\alpha_M = \rho \frac{\text{var}(v|\mathcal{F})\text{var}[(1-s)v - sF|\mathcal{F}]}{\omega(1-s)\text{var}(v|\mathcal{F}) + (1-\omega)\text{var}[(1-s)v - sF|\mathcal{F}]},$$

$$\alpha_\epsilon = \rho \frac{\text{var}(v|\mathcal{F})\text{var}[(1-s)v - sF|\mathcal{F}]}{\omega(1-s)\text{var}(v|\mathcal{F}) + (1-\omega)\text{var}[(1-s)v - sF|\mathcal{F}]} + \frac{\tau_p \Big/ \left(\frac{\beta}{\alpha_\epsilon}\right)}{\tau_\Sigma},$$

where $\tau_\Sigma = \tau_v + \tau_R + \tau_\eta + \tau_p$. These price coefficients are fully characterized once we know the value of $\frac{\beta}{\alpha_\epsilon}$ (recall $\tau_p = (\frac{\beta}{\alpha_\epsilon})^2 \tau_\epsilon$). Let $X = \frac{\beta}{\alpha_\epsilon}$ and note that β and α_ϵ shown above are functions of X. As in Lemma 4, algebra shows that there exists a unique $X > 0$ solving $\frac{\beta}{\alpha_\epsilon} = X$. Substituting $R = v + \zeta$ and letting $\alpha_v = \beta + \gamma$ and $\alpha_R = \gamma$, one can rewrite the price function as

$$p = \alpha_0 + \alpha_v v + \alpha_R \zeta - \alpha_F D - \alpha_M M - \alpha_\epsilon \epsilon.$$

To characterize k^{FB}, one can generalize Equation (18) in the text as follows:

$$\overline{U} \equiv \mathbb{E}[-\exp(-\rho\,[(1-s)v(k) - sF(k)])]^\omega \times \mathbb{E}[-\exp(-\rho\, v(k))]^{1-\omega}. \tag{A.18}$$

Using $\mathbb{E}[-\exp(-\rho v(k))] = -\exp[-\rho(\lambda k - \frac{k^2}{2} - \frac{\rho}{2}\frac{1}{\tau_v})]$ and $\mathbb{E}[-\exp(-\rho[(1-s)v(k) - sF(k)])] = -\exp[-\rho((1-s)(\lambda k - \frac{k^2}{2}) - sf(k) - \frac{\rho}{2}(\frac{(1-s)^2}{\tau_v} + \frac{s^2}{\tau_F}))]$, one can rewrite $\overline{U} = -\exp(-\rho \mathbf{X})$, where $\mathbf{X} = [\omega(1-s) + (1-\omega)](\lambda k - \frac{k^2}{2}) - \omega s f(k) - \frac{\rho}{2}[\omega(\frac{(1-s)^2}{\tau_v} + \frac{s^2}{\tau_F}) + (1-\omega)\frac{1}{\tau_v}]$. The k^{FB} that maximizes $\overline{U}$ is determined by

$$\lambda = k^{FB} + \frac{\omega s}{\omega(1-s) + (1-\omega)} f'(k^{FB}). \tag{A.19}$$

To characterize the optimal τ_ξ^*, we know from Equation (17) that the firm chooses k according to $\lambda = k + \frac{\alpha_F}{\alpha_v}(\tau_\xi, \omega) \times f'(k)$. One can compare this condition to Equation (A.19) above and conclude that τ_ξ^* motivates the firm to choose k^{FB} when $\frac{\alpha_F}{\alpha_v}(\tau_\xi^*, \omega) = \frac{\omega s}{\omega(1-s) + (1-\omega)}$, from which I solve the unique $\tau_\xi^* = \frac{\tau_R(s^2(1-\omega)(\tau_R + \tau_v) + (1-s)\tau_F(1 - s(1-\omega)))}{s(2-s)\tau_R(1-\omega) + \tau_v(1 - s\omega)} > 0$. Algebra verifies $\frac{d\tau_\xi^*}{d\omega} < 0$ if and only if $\tau_F < \frac{s\tau_v}{2-s}$. ■

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APPENDIX A (continued)

Proof of Proposition 7

As argued in the text, the firm's investment decision is determined by the first-order condition $\lambda = k + \frac{\alpha_F}{\alpha_v} f'(k)$. Comparing the firm's first-order condition to that of the social planner in Equation (24), we know that the optimal τ_ξ^* is chosen to ensure $\frac{\alpha_F}{\alpha_v} f'(k) = f'(k)$. One can then solve $\tau_\xi^* = \frac{\tau_R(\tau_F + (1-\omega)(\tau_R + \tau_v))}{\omega\tau_v - (1-\omega)\tau_R}$. It is easy to verify that $\tau_\xi^* > 0$ if and only if $\omega > \frac{\tau_R}{\tau_R + \tau_v}$, and that the optimal τ_ξ^* satisfies $\frac{d\tau_\xi^*}{d\omega} = -\frac{\tau_R(\tau_R + \tau_v)(\tau_F + \tau_v)}{[\omega\tau_v - (1-\omega)\tau_R]^2} < 0$. ■

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