Journal of Financial Economics 163 (2025) 103954

Contents lists available at ScienceDirect

Journal of Financial Economics

journal homepage: www.elsevier.com/locate/finec

Sustainable finance versus environmental policy: Does greenwashing justify a taxonomy for sustainable investments?[☆]

Roman Inderst[a,c], Marcus M. Opp[b,c,d,e,*]

[a] Goethe Universität Frankfurt, Germany
[b] Stockholm School of Economics, Sweden
[c] CEPR, UK
[d] ECGI, Belgium
[e] FTG, USA

ARTICLE INFO

Keywords:
Greenwashing
Sustainability
EU taxonomy
Sustainable Finance Disclosures Regulation
ESG funds
European Green Deal

ABSTRACT

Our paper analyzes whether a planner should design a taxonomy for sustainable investment products when conventional tools for environmental regulation can also be used to address externalities arising from firm production. We first show that the private market provision of ESG funds marketed to retail investors involves greenwashing, so that a mandatory taxonomy is necessary to generate real effects of sustainable finance. However, the introduction of such a taxonomy can only improve welfare, on top of optimally chosen environmental regulation, if financial frictions constrain socially valuable economic activity. Otherwise, environmental policy alone is sufficient to optimally address externalities.

1. Introduction

Next to traditional environmental policy, harnessing private financial investment is increasingly considered important for the ecological transformation of economic activity. However, the impact of sustainable finance do date has been questioned, see e.g., Berk and van Binsbergen (forthcoming). In particular, among policymakers, there is a widespread concern that greenwashing (de Freitas Netto et al., 2020) is one of the key impediments to achieving real effects of sustainable finance.

To ensure that sustainable finance is indeed directed towards activities that have a substantial positive environmental impact, the European Union (EU,2020) created a taxonomy as part of the Sustainable Finance Disclosure Regulation (SFDR), see Appendix D for more details. This taxonomy has two key features. First, it defines firm activities that are considered sustainable, e.g., electricity generation from wind power is an eligible activity, while electricity generation from coal is not eligible. Second, to market a fund as sustainable according to Article 9, each company in a sustainable fund's portfolio must be EU taxonomy-aligned. Funds that are not EU taxonomy-conform must be sold to individual investors as "non-sustainable."

With this background, our research questions are the following: Is such a mandatory taxonomy needed to effectively harness investors' desire to invest sustainably? Additionally, when and why should such a tool be used when environmental policy tools, such as regulatory minimum production standards or emission taxes, are also available?

Our theoretical analysis provides the following high-level insights. Given the prevalence of warm-glow preferences for "owning" funds with a green label, as documented by Bonnefon et al. (2019) and Heeb et al. (2023), the market provision of sustainable investments features a "race to the bottom" in greenwashing.[1] A regulatory framework is necessary to impact firms' investment decisions. However, the mere potential to generate real effects, through such a mandatory taxonomy, is not sufficient to justify government intervention via *financial* regulation: In the absence of *environmental* policy failure, a taxonomy will only lead to welfare improvements if financial constraints constrain

☆ Philipp Schnabl was the editor for this article. We are grateful to an anonymous referee, Bruno Biais, Alexander Guembel, Augustin Landier, Stefano Lovo, Adriano Rampini, Pablo Ruiz-Verdu, Per Strömberg, Jean Tirole, and participants at Stanford, Duke, HEC Paris, Stockholm School of Economics, Universidad Carlos III de Madrid, UCLA, and the Corporate Finance Theory Symposium for their helpful comments and suggestions. This project has received funding from the Marianne and Marcus Wallenberg (MMW) foundation.

* Corresponding author at: Stockholm School of Economics, Sweden.
E-mail addresses: inderst@finance.uni-frankfurt.de (R. Inderst), marcus.opp@hhs.se (M.M. Opp).

[1] This is consistent with widespread concerns about vague (market) standards (Berg et al., 2022) and greenwashing (de Freitas Netto et al., 2020). According to PwC's Asset and Wealth Management Revolution 2022 report, 71% of fund managers themselves believe that greenwashing is a common practice. Indeed, 76% simply plan to relabel existing products so they can be marketed as ESG investment products.

https://doi.org/10.1016/j.jfineco.2024.103954
Received 22 February 2024; Received in revised form 3 October 2024; Accepted 6 October 2024
Available online 23 October 2024

socially valuable economic activity. Otherwise, environmental policy alone is sufficient to rectify inefficiencies caused by externalities.

We derive these results in a parsimonious general equilibrium production framework. Each firm can choose the scale and sustainability of its production, i.e., costly abatement of externalities. Financing from households, either directly or through funds, is limited by outside financing constraints, building on Holmström and Tirole (1997).[2] We extend their model by microfounding firm payoffs in a competitive product market, which allows us to account for consumer surplus in the welfare analysis.

As a benchmark, we consider an economy without sustainable investors to see how far the planner can go purely with environmental regulation: minimum standards, e.g., such as mandatory catalytic converters, and (carbon) taxes. The planner not only cares about firms choosing the appropriate degree of abatement but also accounts for real activity, as determined by aggregate production. In the first-best allocation, firms choose to abate up to the point where the marginal cost of abatement equals the marginal social benefit, and at the optimal aggregate output level, the marginal consumer's reservation price just equals the marginal social cost of production (including the externality). Now, if the planner can only avail herself of environmental policy tools, but no direct subsidies,[3] both over- and underproduction can occur in equilibrium depending on the severity of financial constraints. The optimum environmental policy now trades off real activity against externalities. Environmental policy is optimally less stringent than first-best when financial constraints bind.

We then incorporate investors with sustainability concerns into our model. How to best capture this demand for sustainable investments is the subject of an ongoing debate. If small household investors were affected by externalities like global warming, but have self-interested "homo oeconomicus" preferences, they would treat aggregate externalities as given and behave like "purely profit-motivated investors," which is at odds with the dramatic rise in funds with an ESG label. Instead, studies by Bonnefon et al. (2019) or Heeb et al. (2023) show support for investor preferences that go beyond self interest.[4] In particular, their results suggest that individual investors' "non-pecuniary benefits accrue through stock *ownership* (value alignment), not through the actual *impact* (consequences) of investment decisions."[5]

We build on this empirical literature and assume that a subset of these investors derives additional non-consequentialist warm-glow from owning "ESG funds," which acts as an additional return (see Riedl and Smeets (2017)).[6] To capture the heterogeneity of household preferences, we assume that the intensity of this warm-glow varies across households according to some distribution function. Since the warm-glow effect resulting from a purchase of "moral satisfaction" without any impact, see Kahneman and Knetsch (1992), we model it as a purely decisional utility that does not (directly) enter the social planner's objective, as in Broccardo et al. (2022).

How does the private market respond to such preferences? As is intuitive, the market satisfies the demand for green ESG funds by labeling all firms as green, consistent with the blatant greenwashing observed in practice. A "real" sustainable fund that sets more stringent sustainability requirements cannot compete with funds that offer moral satisfaction at lower (no) return discount. In the market equilibrium, sustainable finance does not generate a greenium for sustainable firms and, hence, yields no impact.

A mandatory taxonomy can prevent such a race to the bottom by imposing a lower bar on sustainability investments of taxonomy-conform firms (which may not be under-cut by private sustainability labels). In equilibrium, a fraction of firms will meet this more stringent sustainability requirement of the taxonomy and, in return, receive a return subsidy (greenium) that just offsets the increased production costs associated with abatement. The share of taxonomy-conforming firms is determined by the fraction of retail investors whose warm glow outweighs the necessary return sacrifice. The regulator now faces the following trade-off. By increasing the sustainability threshold, each abiding firm causes fewer externalities, but also requires a higher financing subsidy to offset the higher production cost to meet the standard. Given a downward sloping supply of sustainable capital, in terms of the accepted return sacrifice, this leads to a smaller share of sustainable firms in equilibrium.

However, does the prevention of greenwashing imply that introducing a taxonomy is always socially desirable if environmental policy tools are optimally chosen? We show that the introduction of a sustainable investment category is not beneficial if firms' internal funds are sufficiently high so that financial constraints do not prohibit aggregate production at the socially efficient scale. Environmental regulation alone is sufficient.[7]

In contrast, with acute financial frictions, stricter environmental regulation in isolation would exacerbate underproduction. By activating a subsidy from sustainably-oriented investors, the planner can mitigate this trade-off between imposing a higher minimum standard (or environmental tax) and, at the same time, inefficiently shrinking the economy. The availability of two tools allows the planner to increase aggregate output while keeping the weighted average social cost constant. As preferences for sustainable investment become stronger, this favors, on the margin, an increase in the sustainability standard. Given the time trend of preferences for sustainability in recent years, our model predicts that optimal sustainability standards should gradually increase over time.

Another potential rationale for a taxonomy is that environmental policy is suboptimally lax. In this case, a taxonomy partially mitigates environmental policy failure by inducing a fraction of firms to produce more sustainably. However, as the taxonomy is a much less effective tool to mitigate environmental externalities, this rationale does not address the more fundamental question of why environmental policy is ineffective.[8] In addition to possessing less effective tools, as pointed out by Tirole (2023) as well as Oehmke and Opp (2022), such mandate shifts of financial regulators have additional drawbacks, such as questions of institutional conflicts and lack of policy coordination.

[2] The relevance of such financial constraints for abatement investments has been empirically documented by Bartram et al. (2022), Xu and Kim (2022), and Lanteri and Rampini (2023).

[3] As is standard on the literature on financial constraints following Holmström and Tirole (1997), we assume that the marginal cost of public funds (taxation distortions) is sufficiently high so that the planner cannot remove financial constraints for all firms in the economy. Relatedly, Hoffmann et al. (2017) analyze the optimal design of subsidized loans to finance abatement activities in an asymmetric information environment.

[4] See Moisson (2020) and Dangl et al. (2023) for how altruistic preferences can be related to different ethical norms.

[5] The specification of non-consequentialist preferences also receives support by a large literature in environmental and resource economics that elicits preferences. For instance, elicited willingness-to-pay frequently fails a so-called "scope test" or "adding-up test": Subjects' willingness-to-pay is relatively insensitive to the actual impact of the respective scenario change, e.g., the number of animals saved, see Boyle et al. (1994) or Desvousges et al. (2012) for prominent studies on these effects and Kahneman (2000) for an explanation.

[6] Our qualitative results are robust to preference specifications for which the strength of the warm-glow is also affected by impact, see Appendix C.

[7] We note that this result even extends to the case in which investors have consequentialist preferences (as long as the warm-glow from impact does not additionally contribute to welfare).

[8] Recently, Allen et al. (2023) have taken a different, positive perspective by modeling society's choice (through voting) over environmental policy, comparing the outcomes when households do or do not have access to sustainable investments. Relatedly, Döttling et al. (2024) analyzes the feedback effects between a "one-person one-vote" political system and a "one-share one-vote" corporate governance regime.

Our paper builds on a rapidly growing literature on the theory of socially responsible investing.[9] This literature consists mainly of two strands: *exclusion* (following the pioneering paper by Heinkel et al. (2001)) and *impact investing*,[10] cf. Oehmke and Opp (forthcoming) for a detailed comparison.[11] Since we aim to model investor demand for sustainable finance products by small retail investors, our model does not feature large activist investors, which are studied in Chowdhry et al. (2018), Oehmke and Opp (forthcoming), Biais and Landier (2022) and Gupta et al. (2022). Instead, our investors are small and non-consequentialist as in Pastor et al. (2021), but the optimal design of a taxonomy allows the regulator to channel the aggregate supply of sustainable finance to achieve impact.[12]

Our paper shares with Piccolo et al. (2022) that it considers the interaction of socially responsible investors and endogenous product market outcomes.[13] The papers differ in their objective. The positive analysis of Piccolo et al. (2022) focuses on the strategic interaction of firms in a setup with market power; this effect is moot in our competitive setting. Instead, our normative paper analyzes the rationale for a taxonomy and its connection to environmental policy. The papers also differ in terms of the mechanism of how sustainable finance generates impact: While investors in Piccolo et al. (2022) influence company decisions via ownership (control rights), our investors induce sustainability investments via a reduction in the cost of capital for taxonomy-conform firms.

None of the literature has addressed the two key questions of our analysis, i.e., whether such subsidized financing is socially beneficial in view of alternative, more direct environmental policy instruments and how to optimally design a sustainable investment classification.[14] The latter issue taps into a large theoretical literature on optimal certification (see Bizzotto and Harstad (2023) for a recent contribution and a detailed survey). This literature, however, typically considers the perspective of a profit-maximizing certifier and the design of labels for products or services when purchasers have limited information about quality.

This paper is organized as follows. In Section 2 we introduce the benchmark economy in which all investors care only about financial returns and, consequently, the social planner can only avail herself of environmental policy instruments. In Section 3 we introduce households with sustainability preferences and provide conditions under which the introduction of a sustainable investment category is optimal (and, if so, which threshold should be optimally chosen). Section 4 concludes. All proofs are relegated to Appendix A.

[9] See e.g., Chowdhry et al. (2018), Davies and Van Wesep (2018), Green and Roth (forthcoming), Landier and Lovo (forthcoming), Oehmke and Opp (forthcoming), Edmans et al. (2022), Pastor et al. (2021), Pedersen et al. (2021), as well as Favilukis et al. (2024).

[10] Laux and Mahieux (2024) analyzes how a firm optimally designs the precision of its (climate risk) measurement and accounting system with an eye on its bargaining perspective vis–a-vis impact investors.

[11] In particular, Oehmke and Opp (forthcoming), Landier and Lovo (forthcoming) as well as Green and Roth (forthcoming) have highlighted how “value aligned” preferences or “narrow” investment mandates typically fail to generate real impact. Apart from the different focus (regulation), our paper extends (Oehmke and Opp, forthcoming) in two ways. First, we incorporate retail investors with empirically relevant warm-glow preferences in a tractable way. Second, firm payoffs are determined in a product market equilibrium rather than exogenously specified, similar to Inderst and Heider (2022).

[12] In contrast to Pastor et al. (2021), preferences are risk-neutral, which ensures tractability, i.e., there is no effect on risk-premia which result from imperfect risk-sharing.

[13] Kaufmann et al. (2024) instead focus exclusively on the product market by providing a framework to analyze competitive equilibria with rational consequentialist consumers.

[14] Biais and Landier (2022), Döttling and Rola-Janicka (2022), and Oehmke and Opp (2022) have analyzed the interaction of environmental regulation with the financial sector when environmental regulation is subject to a commitment problem. There is no commitment problem in our paper.

2. Benchmark economy

We initially analyze a benchmark economy in which all households (investors) are purely profit-motivated. In such an economy, there is no demand for sustainable investing and, hence, there is no scope for a “sustainable investments” taxonomy either.

We first describe the model ingredients and objective functions of *firms*, *households* and the *regulator*. Then, for given environmental regulation, we derive the equilibrium financing and investment decisions by firms, which determines aggregate output and externalities. This first part extends Holmström and Tirole (1997) by microfounding firm payoffs in a competitive product market. We then characterize optimal environmental regulation, which is the first step to answering whether there is additional scope for “sustainable investments” and the taxonomy from a welfare perspective.

2.1. Model primitives

Firms. The economy consists of a unit mass of profit-maximizing firms indexed by i, each endowed with internal funds $A > 0$ (which, thus, also corresponds to aggregate internal funds).[15] Firms compete in the product market: Given individual firm output q_i, each firm reaps a market price of $P(q)$ where $q = \int_0^1 q_i di$ denotes aggregate output and P satisfies the usual conditions, i.e., P is differentiable with $P' < 0$ and $\lim_{q\to\infty} P(q) = 0$. To focus on the effect of socially responsible *investment*, we assume that sustainable production cannot ensure a price premium in the product market.[16]

The production technology choice features a trade-off between profitability and sustainability $\theta_i \leq \theta^{\max}$, which arises, for example, from the costly installation of air filters and θ_i governing their quality. We assume that production generates negative externality of $\rho\left(\theta^{\max} - \theta_i\right)$ per unit of output while investment costs per unit of output are given by $c\left(\theta_i\right)$, where c is a strictly increasing and convex function with $c'(0) = 0$ and $\lim_{\theta\to\theta^{\max}} c'(\theta) = \infty$.[17] In the context of carbon emissions, one can thus interpret $\left(\theta^{\max} - \theta_i\right)$ as the firm's *carbon intensity* and $\rho > 0$ as the social cost per unit of carbon emissions. A firm i is carbon-neutral if its sustainability choice satisfies $\theta_i = \theta^{\max}$. The total cost of production, $c\left(\theta_i\right) q_i$, needs to be financed by a combination of internal funds $A_i \leq A$ and external funds.

External financing is subject to financing frictions adopted from the workhorse model of Holmström and Tirole (1997). Specifically, the sale of output is only successful with probability one if the owner-manager exerts unobservable effort. If she shirks, she obtains a per-unit private benefit $B > 0$, but with probability $\Delta p > 0$ no sale occurs. As is standard in the literature, we assume that the agency rent $\frac{B}{\Delta p}$ is low enough so that shirking is off equilibrium (see exact condition in Appendix-Lemma A.1).

Household investors. External funds are in abundant supply and provided by atomistic, risk-neutral households that seek to maximize their expected net financial payoff. In addition to the investment opportunities offered by firms, households have access to a storage technology that offers a fixed net return r_0 (which is normalized to zero). This is also the return that firms realize on assets that they do not invest productively.

[15] It is straightforward to extend the analysis to the case where firms differ in internal funds, given that each firm is atomistic and that our main characterization pertains to aggregate output.

[16] See Hakenes and Schliephake (2021), Broccardo et al. (2022), and Piccolo et al. (2022) for models that also consider socially responsible *consumption*.

[17] For simplicity, we assume that firms are homogeneous (and, yet, heterogeneous sustainability choices emerge in equilibrium, see Proposition 3). In contrast, Lanteri and Rampini (2023) analyze the implications of firm heterogeneity in terms of financial constraints for the technology adoption of green technologies and the composition of the capital stock.

Regulator. A key objective of our analysis is to investigate the relevance of sustainable finance and its taxonomy in the presence of standard, environmental policy tools. Motivated by its widespread use in practice, our main analysis considers the tool of a minimum sustainability standard θ_m as the main environmental policy tool. In the context of emissions, such regulations impose limits on the emissions intensity, $\theta^{\max} - \theta_m$, for example, by requiring the use of high-quality air filters or catalytic converters. Likewise, it can require investments in protection against health hazards for workers or undue harm on animals. Importantly, we show that all of our results continue to hold if a regulator could, in addition, impose a tax τ per unit of social cost, see Remark 1.

Given production choices θ_i and q_i, welfare, comprises first, gross consumer welfare; second, investment costs; and third, the externality:

$$\Omega = \int_0^q P(q)dq - \int q_i c\left(\theta_i\right) di - \rho \int q_i \left(\theta^{\max} - \theta_i\right) di, \tag{1}$$

which, to simplify expressions, already uses the result that shirking is off equilibrium (see Proof of Appendix- Lemma A.1). The regulator chooses θ_m as to maximize welfare in (1).

We presume that the economic activity is socially valuable, $\Omega > 0$, at least under optimal regulation. It is, thus, necessary that the consumer surplus on the initial unit exceeds the marginal social cost, the sum of the marginal private investment costs $c(\theta)$ and externalities $\theta^{\max} - \theta$ for some θ, i.e.,

$$P(0) > \min_{\theta} \left[c(\theta) + \rho(\theta^{\max} - \theta)\right]. \tag{A1}$$

Timeline. We consider the following logical sequence of events. At $t = 0$ the regulator chooses the minimum production standard θ_m (and, as in our extension, a tax on externalities). At $t = 1$, given this regulatory environment, firms then simultaneously choose their optimal sustainability level θ_i, output q_i, as well as external financing $c\left(\theta_i\right) q_i - A_i$. Households allocate funds to firms and the storage technology. At $t = 2$, managers choose whether to exert effort or not, and output q_i is sold at price $P(q)$.

First-best benchmark. Before analyzing the equilibrium outcome of the just presented economy, it is useful to characterize first-best welfare Ω_{FB}. As firms are homogeneous, first-best welfare can be characterized using two control variables, total output q_{FB} and a uniform standard θ_{FB} across firms. The optimal sustainability level equates, per unit of production, the saved social cost of the externality with the marginal increase in investment cost,

$$c'(\theta_{FB}) = \rho. \tag{2}$$

The optimal aggregate output and market size, in turn, equates marginal consumer surplus with marginal cost of production, comprising the externality:

$$P(q_{FB}) = c(\theta_{FB}) + \rho(\theta^{\max} - \theta_{FB}). \tag{3}$$

2.2. Market equilibrium

We refer to the market equilibrium as the equilibrium behavior of private agents, firms and households, for a given regulatory environment, i.e., θ_m. We endogenize the optimal choice of θ_m in the subsequent section. This market equilibrium is characterized by the following conditions:

Definition 1. Given a minimum standard θ_m, a *Market Equilibrium* is characterized by a co-investment, production and effort strategy for each firm, and an investment strategy for each investor such that:

(a) Each firm i chooses its coinvestment $A_i \leq A$, its technology $\theta_i \geq \theta_m$, its output q_i and its unobservable effort to maximize its net payoff inclusive of private benefits.
(b) Investors decide to allocate their funds to the storage technology and capital provision into each firm to maximize their net payoffs.
(c) Markets for capital clear.

Individual firms' financing and production choices. Since this benchmark economy only features profit-motivated agents, there is, for now, no benefit from exceeding the minimum standard and all firms optimally choose $\theta_i^* = \theta_m$. We now characterize an individual firm's optimal financing contracts yielding coinvestment A_i^* and output q_i^*.

As in Holmström and Tirole (1997), the moral hazard problem limits outside financing capacity and output of each firm. Different from Holmström and Tirole (1997), the optimal choices of each individual firm are affected by the financing and supply decisions of other firms since the product market price is pinned down by the aggregate supply of all firms q. As a result, firms only have an incentive to operate if aggregate supply is sufficiently low so that the product price exceeds the cost of production,

$$P(q) \geq c\left(\theta_m\right). \tag{4}$$

In the absence of prohibitively costly (and suboptimal) environmental regulation, i.e., $c\left(\theta_m\right) < P(0)$, the output quantity q adjusts so that Condition (4) is satisfied in equilibrium (see Proposition 1).

Let D_i denote the promised repayment to household investors, then incentive compatibility of effort requires that the owner's payoff under effort exceed the expected payoff under shirking (inclusive of private benefits),

$$q_i P(q) - D_i \geq (1 - \Delta p)\left[q_i P(q) - D_i\right] + Bq_i. \tag{IC}$$

The investors' participation constraint (IR) requires that outside investors earn at least the required return $r_0 = 0$ on their investment of $c\left(\theta_i\right) q_i - A_i$, where $A_i \leq A$ denotes the insider's coinvestment:

$$D_i \geq c\left(\theta_i\right) q_i - A_i. \tag{IR}$$

In equilibrium, the household investors' (IR) constraint always binds since household capital is in ample supply and investors behave competitively.

When the profitability Condition (4) holds, standard arguments imply that it is (weakly) optimal for the firm to fully co-invest internal funds, $A_i^* = A$. Binding (IR), the absence of shirking, and full coinvestment imply that the firm's gross payoff satisfies:

$$U_i = q_i\left[P(q) - c\left(\theta_m\right)\right] + A. \tag{5}$$

Since individual firms take the market price as given, the objective ((5)) is linear in q_i. Again by condition (4), it is then (weakly) optimal to produce at maximal scale.

In equilibrium, an individual firm's maximal scale is constrained by financial frictions, as we will formally show in Corollary 2 to Proposition 1. Maximal scale is, thus, determined by binding (IR) and (IC) which implies that

$$q_i^* = k(q) A, \tag{6}$$

where the production capacity multiplier $k(q)$ satisfies[18]

$$k(q) = \frac{1}{\frac{B}{\Delta p} - \left[P(q) - c\left(\theta_m\right)\right]} > 0. \tag{7}$$

This expression is an extension of the standard multiplier in Holmström and Tirole (1997) by incorporating product market competition. The production capacity multiplier is a decreasing function of q because larger aggregate output pushes down product prices (and, hence profitability). Using these optimal choices $\theta_i^* = \theta_m$, $A_i^* = A$ and q_i^* (conditional on q), the indirect utility of each firm is given by:

$$U_i^* = \frac{B}{\Delta p} A k(q). \tag{8}$$

[18] Corollary 2 implies that $P(q) - c\left(\theta_m\right) < B/\Delta p$ so that $k(q) > 0$.

We now determine the aggregate output, $q = \int q_i d_i$ that results from the optimal behavior of individual firms.

Aggregate output. While each individual firm's supply is constrained by financial constraints, aggregate economic output, $q^* = \int q_i^* d_i$ is only impacted by financial constraints if firms cannot *jointly* secure sufficient external financing to produce the zero-profit output $\bar{q}$ solving

$$P(\bar{q}) = c\left(\theta_m\right). \tag{9}$$

Proposition 1 intuitively reveals that aggregate production at the frictionless level $\bar{q}$ only occurs in equilibrium if firms' aggregate internal funds A are sufficiently high.

Proposition 1 (*Aggregate Output q^**). *If $P(0) > c\left(\theta_m\right)$ so that environmental regulation is not prohibitively costly, the economy produces $q^* > 0$ which can be characterized as follows:*

1. *If aggregate internal funds A are sufficiently small, $A < \bar{q}B/\Delta p$, financial frictions constrain aggregate output of the economy, $q^* < \bar{q}$, which solves:*
$$q^* = Ak\left(q^*\right). \tag{10}$$
2. *If $A \geq \bar{q}B/\Delta p$, aggregate output is unaffected by financial frictions, $q^* = \bar{q}$.*

The comparative results of aggregate output follow immediately.

Corollary 1. *Output q^* is increasing in aggregate internal funds A (strictly so as long as $A < \bar{q}B/\Delta p$) and strictly decreasing in the minimum standard θ_m.*

Intuitively, larger aggregate internal funds increase aggregate output by mitigating the effects of external financing frictions, leading to larger output. In contrast, a higher minimum standard increases firms' production costs resulting in lower aggregate supply.[19] We now turn to the resulting equilibrium financing capacity and firm rents.

Corollary 2 (*Equilibrium Financing Capacity and Rents*). *For any $A > 0$, the equilibrium capacity multiplier, $k(q^*)$, is finite as $P\left(q^*\right) - c\left(\theta_m\right) < B/\Delta p$. Firms earn scarcity rents in equilibrium, $P\left(q^*\right) > c\left(\theta_m\right) \Leftrightarrow U_i^* > A$, if and only if $A < \bar{q}B/\Delta p$.*

Thus, with endogenous product market competition, the output quantity always adjusts so that the firms' reward, the price $P\left(q^*\right)$, is never so high that firms become financially unconstrained (and (IC) would be slack). This occurs because, in aggregate, the industry exhibits decreasing returns to scale as the inverse demand is downward sloping. When aggregate output is constrained by financial frictions, $A < \bar{q}B/\Delta p$, the scarcity rents imply that all firms lever up to the maximum. Instead, when the economy produces the zero-profit output $\bar{q}$, firms are indifferent between producing and using the storage technology so that $U_i^* = A$.

We finally remark on an additional feature related to the endogenous product price. When firms' internal funds go to zero, $A \to 0$, aggregate output converges to zero only if $P(0) \leq \frac{B}{\Delta p} + c\left(\theta_m\right)$, i.e., only if the incentive constraint binds at the highest product price. Otherwise, when $A \to 0$ aggregate output converges to

$$q_{\min} = P^{-1}\left(\frac{B}{\Delta p} + c\left(\theta_m\right)\right), \tag{11}$$

which is still strictly lower than $\bar{q}$.

[19] The rationale for why equilibrium output strictly decreases with a higher minimum standard is slightly different in the two cases of Proposition 1: When aggregate output is not constrained by financial frictions, this follows immediately from the zero-profit condition for $q^* = \bar{q}$. Otherwise, the higher costs of production reduce the capacity multiplier, k.

2.3. Optimal environmental regulation

We now turn to the planner's optimal choice of the minimum standard. Given the equilibrium characterization, the planner's objective in (1) simplifies to

$$\Omega = \int_0^{q^*(\theta_m)} P(q)dq - q^*\left[c\left(\theta_m\right) + \rho(\theta^{\max} - \theta_m)\right]. \tag{12}$$

The socially optimal choice of the single policy instrument, characterized by the first-order condition $\frac{d\Omega}{d\theta_m} = 0$, aims to balance deviations from the two separate first-order conditions for the technology and quantity in the first-best benchmark, see (2) and (3):

$$\rho - c'\left(\theta_m\right) = \left|\frac{\frac{dq^*}{d\theta_m}}{q^*\left(\theta_m\right)}\right|\left[P\left(q^*\right) - c\left(\theta_m\right) - \rho\left(\theta^{\max} - \theta_m\right)\right], \tag{13}$$

where we have made explicit the dependency of equilibrium output, $q^*\left(\theta_m\right)$, see Corollary 1. The left hand-side of (13) captures the socially optimal technology choice, cf. condition (2). The right-hand side captures condition (3), which is the marginal social surplus of an additional unit of output fixing technology θ_m, scaled by the semi-elasticity of output to environmental standards, $\left|\frac{dq^*}{d\theta_m}/q^*\left(\theta_m\right)\right|$, that results from the feedback effect of the minimum standard on aggregate output. We obtain:

Proposition 2 (*Environmental Regulation*).*If the agency problem is sufficiently strong,*

$$\frac{B}{\Delta p} \geq \rho(\theta^{\max} - \theta_{FB}), \tag{14}$$

there exists a threshold for internal funds A_{FB} such that the optimal standard satisfies $\tilde{\theta}_m > \theta_{FB}$ for $A > A_{FB}$ and $\tilde{\theta}_m < \theta_{FB}$ for $A < A_{FB}$. At $A = A_{FB}$, first-best welfare is achieved, i.e., $\tilde{\theta}_m = \theta_{FB}$ and $q^*\left(\theta_{FB}\right) = q_{FB}$. If $\frac{B}{\Delta p} < \rho(\theta^{\max} - \theta_{FB})$, the optimal standard always satisfies $\tilde{\theta}_m > \theta_{FB}$.

We first consider the case in which the agency constraints are sufficiently strong, so that Condition (14) holds. To see the logic for Proposition 2, set first $\theta_m = \theta_{FB}$. Condition (14) ensures that when internal funds are sufficiently low (precisely, when $A < A_{FB}$), the economy produces output below the socially efficient scale, $q^* < q_{FB}$.[20] Then, the marginal social surplus of an additional unit of output is strictly positive, $P\left(q^*\right) - c\left(\theta_m\right) - \rho\left(\theta^{\max} - \theta_m\right) > 0$.

Now, suppose instead that internal funds are not scarce, so that when $\theta_m = \theta_{FB}$, output expands until $q^* = \bar{q}$. As firms do not take into account the externality, there is overproduction (from a planner perspective), $\bar{q} > q_{FB}$. With q^* being strictly increasing (and continuous) in internal funds, there exists a unique level $A = A_{FB}$ at which $q^* = q_{FB}$. This tension between over- and underproduction is the main force behind the hump-shaped effect of internal funds on welfare, as illustrated in the right panel of Fig. 1.

If the converse of (14) holds, output is always excessively high at $\theta_m = \theta_{FB}$, even as $A \to 0$, and we would find ourselves only at the part where welfare decreases in A. Consequently, it is always optimal to set $\tilde{\theta}_m > \theta_{FB}$.

In the presence of two frictions – financing constraints and production externalities – one would expect one tool to be insufficient to restore first-best. In particular, while the planner can force all firms to choose θ_{FB}, this policy choice does not automatically ensure the socially optimal quantity q_{FB} since output is endogenously supplied by profit-maximizing firms. However, as we have shown, first best welfare Ω_{FB} is achieved when financial constraints are "just right," which stands in stark difference to canonical corporate finance models, where financial constraints reduce total surplus as they prevent firms from exploiting profitable investment opportunities. In the presence of social

[20] If the converse of (14) holds, even as $A \to 0$ the then strictly positive limit $q_{\min}$, as given by (11), strictly exceeds q_{FB} (cf. the proof of Proposition 2).

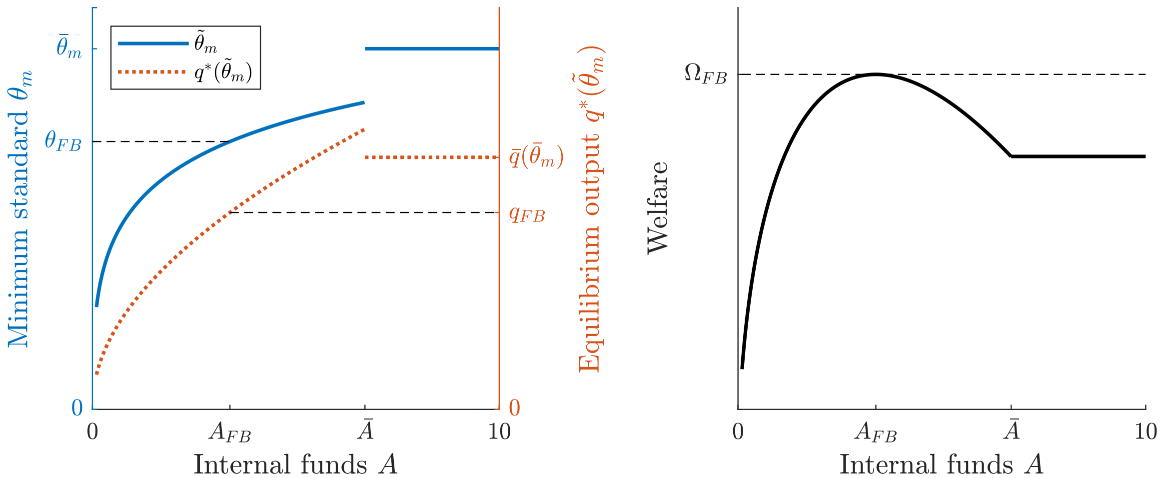

Fig. 1. Optimal minimum standard as a sole policy tool. The graph in the left panel plots the optimal minimum standard $\tilde{\theta}_m$ and the associated equilibrium output $q^*(\tilde{\theta}_m)$ as a function of aggregate internal funds A for the case $\frac{B}{\Delta p} \geq \rho(\theta^{\max} - \theta_{FB})$. Note that the respective units on the y-axis have different scales for $\tilde{\theta}_m$ (left scale) and $q^*(\tilde{\theta}_m)$ (right scale). The right panel plots the resulting welfare under the optimal minimum production standard $\tilde{\theta}_m$. For $A = A_{FB}$, first-best welfare Ω_{FB} is achieved. Financial constraints do not bind for $A \geq \bar{A}$.

externalities, financial constraints are thus no longer unambiguously harmful.

We now turn to the optimal choice of $\tilde{\theta}_m$, which varies with A so as to mitigate over- or underproduction from a social perspective. For $A < A_{FB}$, to avoid "overshrinking" the economy, the environmental standard, solving (13), is optimally chosen to be less stringent $\tilde{\theta}_m < \theta_{FB}$. For $A > A_{FB}$, to counter overproduction from a social perspective, the optimal standard appears to be excessively stringent, $\tilde{\theta}_m > \theta_{FB}$ (see the left panel in Fig. 1). For $A \in (A_{FB}, \bar{A})$, the economy underproduces from a private perspective (as production is still financially profitable) and overproduces from a social perspective. Once $A > \bar{A}$, financial constraints no longer bind (at the optimal choice $\tilde{\theta}_m$), and the optimally policy no longer varies with A. The optimal minimum standard, denoted by $\bar{\theta}_m > \theta_{FB}$ and the realized output $q^* = \bar{q}(\bar{\theta}_m)$ correspond to the optimal policy choices in an economy without financial frictions.[21]

Robustness under (a combined) carbon tax. We now demonstrate the robustness of our main results under broader environmental policies. In particular, we allow the regulator to also impose a tax τ per unit of externality (so that the standard Pigouvian tax level would be $\tau = \rho$). To avoid overburdening the reader with additional notation, we summarize our main point upfront and relegate the formal analysis to Appendix B.

Remark 1 (*Minimum Standard and Carbon Tax*).

Suppose that Condition (14) holds and the planner can use both a minimum standard and a carbon tax. If $A < A_{FB}$, first-best welfare cannot be attained. The optimal carbon tax is zero and the optimal minimum standard and output are characterized by Propositions 1 and 2. If $A > A_{FB}$, first-best welfare can be achieved by setting $\theta_m = \theta_{FB}$ and a positive tax $\tau > 0$.

If $A < A_{FB}$, it is strictly suboptimal to impose a carbon tax because this tax eats into pledgeable income, exacerbates firms financial constraints, and, hence leads to additional reduction in output. Therefore, the planner only uses the minimum standard as characterized by Proposition 2.[22] In contrast, if $A > A_{FB}$, the tax allows the planner to limit overproduction, so that $q^* = q_{FB}$, while at the same time setting the minimum standard to θ_{FB}.

Intuitively, environmental policy tools work well to mitigate production externalities, but not financial frictions. Therefore, even optimal environmental policy fails to restore first-best when financial constraints are sufficiently severe, $A < A_{FB}$. We now analyze if sustainable finance can make a difference and whether a taxonomy is needed.

3. Full model

3.1. Preferences for sustainable investing

Maintaining the assumption that there is ample supply of capital by purely profit-motivated investors, we now incorporate investors with sustainability preferences. These investors with concerns for sustainability are endowed with funds of size K. For ease of exposition, we stipulate that K is sufficiently small, so that profit-motivated investors are needed to ensure that all firms in the economy are able to receive financing.[23]

There is an active debate about how to best capture preferences for ESG investments, both from a normative and positive perspective, in particular regarding the question whether such investors are primarily impact oriented or simply obtain a warm glow from owning "green firms."

Theoretically, if retail investors behaved like the self-interested *homo oeconomicus*, they would understand that the *impact* of their (infinitesimally) small investment on firm decisions and therefore aggregate emissions is zero and there would be no demand for sustainable investment products.[24] Thus, an increased concern about externalities alone, say due to global warming, is not sufficient to explain the large growth of sustainable investment products. Indeed Bonnefon et al. (2019) or Heeb et al. (2023) find micro-level evidence for preferences that depart from pure self-interest. Their results are most

[21] The switch from binding financial constraints to non-binding constraints causes a jump in the policy function exactly at the level of internal funds where the planner is indifferent between causing financial constraints or not. This jump arises because, for $A = \bar{A}$, the objective function has two global maxima. See details in Proof of Proposition 2.

[22] The minimum standard is equivalent to a tax when tax receipts are rebated back to firms in lump-sum fashion. Hence, tax rebates do not change the main result that first-best cannot be achieved for $A < A_{FB}$.

[23] See the proof of Proposition 3 for the exact condition.

[24] See Result 1 in Oehmke and Opp (forthcoming) taking the number of investors to infinity. Considerations for impact would either require size or effective coordination, see Corollaries 6 and 7 in Oehmke and Opp (forthcoming), which is impossible to achieve for retail investors.

consistent with non-consequentialist preferences, in which investors receive a non-pecuniary dividend from owning cleaner firms. (We consider robustness of our results under consequentialist preferences in Appendix C.)

Based on these observations, we consider the polar opposite of homo oeconomicus preferences for investors with sustainability concerns in that households experience a warm-glow boost w per unit of investment when owning firms with a sustainability label. The assumption that households derive their warm glow through the respective classification can be motivated by retail investors' lack of information or excessive complexity associated with a more detailed assessment. Our analysis both considers the case when the sustainability label is provided by the market and when this label is regulated by the taxonomy. The warm glow implies that households are willing to accept a reduction of the financial return by w, consistent with evidence by Riedl and Smeets (2017). We allow for heterogeneity in the strength of the sustainability concerns across households. That is, the warm-glow for household j, w_j, is drawn from the support $[0, \overline{w}]$ with density $f(w)$ and CDF $F(w)$.

As in Broccardo et al., 2022, we view the warm-glow purely as a decisional utility. As the planner's objective remains unaffected compared to our benchmark economy, see (1), our analysis purely focuses on the real effects of sustainable investing and the taxonomy of the sustainability label.[25] We now consider these welfare effects in two settings. First, we consider the setting where the private market, in terms of intermediaries (or firms), provide the label. Second, we consider a setting where the government restricts the use of the sustainability label.

3.2. Market equilibrium

Following the structure of our equilibrium analysis in the benchmark economy, we initially analyze the behavior of firms and households given a minimum production standard θ_m and a "sustainability" standard $\theta_s \geq \theta_m$ that determines the sustainability label for investments. One key outcome variable is the return subsidy Δr, the *greenium*, that is associated with a given sustainability label θ_s. We will endogenize the laissez-faire standard of the ESG label at the very end of this Section. Section 3.3 discusses how a planner would optimally set the standard for sustainable investments (in conjunction with environmental policy).

The presence of sustainability-oriented investors implies the following adjustments to the equilibrium Definition 1. Equilibrium condition 1a) is still valid, but firms now have the non-trivial choice of producing at the minimum standard θ_m or meeting the costlier sustainability standard θ_s to obtain a return subsidy Δr. Investor optimality, equilibrium condition 1(b), now implies that household investor j invests in a "sustainable" fund if and only if $w_j \geq \Delta r$. Finally, the market clearing condition requires that the supply of financing directed to firms with a ESG label, $K(1 - F(\Delta r))$, equals the demand for external financing by firms opting to meet the standard θ_s.

Since investors with sustainability concerns do not have sufficient capital to finance all firms in the economy (cf. the condition in the proof of Proposition 3), the marginal firm in the economy always produces at the minimum standard θ_m and raises financing at the storage rate $r_0 = 0$. Hence, conditional on aggregate output q, the payoffs of firms operating at the minimum standard are as in the benchmark economy, see (8).

Now, if a firm wanted to raise sustainable financing at a subsidized rate $r_0 - \Delta r$, it would optimally choose to just meet the required threshold θ_s.[26] Following similar steps as for the derivation of (8), the entrepreneur's payoff would be

$$U_i(\theta_s) = \frac{B}{\Delta p} A k_s(q), \tag{15}$$

where $k_s(q) := \frac{1-\Delta r}{\frac{B}{\Delta p} - [P(q) - c(\theta_s)(1-\Delta r)]}$ can be interpreted as the outside financing multiplier for firms with a sustainability label which incorporates both the return subsidy Δr and the production cost $c(\theta_s) > c(\theta_m)$.

We now obtain the following useful Lemma regarding aggregate production.

Lemma 1. *Regardless of whether some firms choose to meet the sustainability standard θ_s, aggregate output q^* is identical to the benchmark economy, see characterization in Proposition 1. The equilibrium outside financing multiplier of all firms is $k(q) = \frac{1}{\frac{B}{\Delta p} - [P(q) - c(\theta_m)]}$.*

In the interesting case in which a fraction of firms produces sustainably, the logic for Lemma 1 is as follows.[27] Optimality of firms' choices requires that the payoffs of sustainable firms and unsustainable firms be equalized.[28] Comparing the respective payoffs in (8) and (15), then implies that the outside financing multiplier must be the same for all firms, i.e., firms' optimal choices imply the equilibrium condition

$$k_s(q^*) = k(q^*) \equiv k^*. \tag{16}$$

Now, given that all firms have the same outside financing multiplier as in the benchmark economy, aggregate output is also identical to the one in the benchmark economy.

To determine the share of output that is produced sustainably, ω, we first solve for the equilibrium financing subsidy Δr^* that just outweighs the production cost differential $\Delta c := c(\theta_s) - c(\theta_m) > 0$. Rearranging the equilibrium condition (16) yields

$$\Delta r^* = \frac{\Delta c}{P(q^*) - \frac{B}{\Delta p} + \Delta c}. \tag{17}$$

Given Δr^*, we can now characterize the composition of production.

Proposition 3 (*The Sustainability Subsidy and the Composition of Production*).

Given θ_m and θ_s, total sustainable output is given by:

$$q_s^* = K[1 - F(\Delta r^*)] \frac{k^*}{c(\theta_s) k^* - 1}. \tag{18}$$

The equilibrium share of sustainable output, $\omega^* := \frac{q_s^*}{q^*}$, satisfies

$$\omega^* = \frac{q_s^*}{\min\{\bar{q}, A k^*\}} < 1. \tag{19}$$

Proposition 3 highlights that sustainable output, q_s^*, is the product of the equilibrium supply of sustainable capital, $K[1 - F(\Delta r^*)]$, and a term that reflects leverage as well as the cost of sustainable production. While the distribution of investor preferences F and the sustainability threshold θ_s do not affect aggregate output q^*, they have *compositional* implications for production, i.e., the fraction of firms that produce sustainably versus the ones that produce at the minimum standard. This characterization yields unambiguous comparative statics, which shed more light on the underlying economic forces.

We first analyze the effect of a trend in ESG demand by retail investors.

[25] If instead the warm glow was part of the objective function, a sustainability label would be trivially beneficial, even absent any real effect.

[26] Since exceeding θ_s only results in higher production costs, but entails no benefits, it is optimal to not exceed the threshold.

[27] If no firm produces sustainably, then all firms just raise financing like in the benchmark economy and the result immediately follows.

[28] Producing at threshold θ_s cannot results in lower payoffs since all firms have the option to produce at the minimum standard θ_m. It cannot result in higher payoffs either since all firms would otherwise want to produce sustainably (but there is not enough capital to do so).

Corollary 3. *An increase in the amount of capital held by investors with sustainability concerns K or a First-Order Stochastic Dominance shift in $F(w)$ increase the share of sustainable investment ω^*, while the financing subsidy Δr^* remains unchanged.*

Intuitively, if ceteris paribus there is a greater supply of sustainable capital, this results in a greater share of sustainable investment. Still the financing subsidy Δr^* remains unchanged, as in equilibrium this is pinned down by firms' endogenous decision to become more sustainable and the resulting indifference condition (17).

Moreover, we analyze the effects of the sustainability standard θ_s.

Corollary 4. *An increase in the sustainability standard θ_s decreases the share of sustainable investment ω^* and increases the equilibrium financing subsidy Δr^*. If θ_s is too stringent, so that $\Delta r^* > \bar{w}$, no firm produces sustainably.*

While a higher sustainability standard does not have an effect on aggregate output q^* (see Lemma 1), it increases the cost differential Δc for producing sustainably relative to the minimum standard. This higher cost differential, in turn, requires the capital cost subsidy for sustainable firms to go up, so as to keep sustainable production equally attractive, see (17). The required increase in the subsidy needs to be paid by households and, hence, reduces the attractiveness of the ESG fund for all households. As a result, previously marginal households no longer invest sustainably. This comparative statics highlights a key trade-off that a regulator is facing in our upcoming normative analysis in Section 3.3. While increasing the sustainability cutoff reduces the negative externalities of sustainable firms, it reduces the fraction of firms that choose to produce sustainably.

The laissez-faire standard for sustainable investments. Before analyzing the planner's optimization, we consider as a benchmark, a setting in which competitive intermediaries indexed by j sell funds with a sustainability label to retail investors.[29] Given fund j's cutoff for sustainability θ_s^j, all firms i with $\theta_i \geq \theta_s^j$ are eligible for the sustainability label of fund $j \in \{1, 2, \dots, N\}$.[30] We now determine the resulting laissez-faire sustainability standard θ_s^M that all intermediaries choose.

Proposition 4 (*Greenwashing*). ***In a laissez-faire equilibrium, all intermediaries choose the lowest possible threshold for the sustainability label, i.e., $\forall j$, $\theta_s^j = \theta_s^M = \theta_m$. The resulting greenium for sustainable firms is $\Delta r = 0$.***

The argument for why the market cannot sustain a "real" sustainable fund is immediate, so that we cover it in the main text. If a real sustainable fund j required a standard $\theta_s^j > \theta_m$, it would have to compensate firms for incremental costs $c(\theta_s) - c(\theta_m) > 0$. This, in turn means that fund investors would need to accept a strictly lower return on their investment, i.e., $\Delta r > 0$. However, as long as another fund k offers an investment product with a sustainability label at a lower return discount, warm-glow investors would flock to the latter, undermining the viability of the "real" sustainable fund. This race to the bottom ends when all funds choose the lowest possible sustainability standard for firms, i.e., the regulatory minimum standard (greenwashing).[31] Thus, the lack of a greenium in equilibrium does not necessarily rule out that a significant fraction of investors has preferences for sustainability. We note that this result can even emerge under consequentialist preferences provided that the marginal utility from impact is sufficiently low, see Lemma C.1 in Appendix C.[32]

We now analyze whether and how a regulatory taxonomy can ensure a greenium, which is necessary to create real effects.

3.3. A taxonomy for ESG investments

We stipulate that the planner can set a lower standard $\theta_s > \theta_m$ that any sustainable investment must satisfy, thereby preventing the "race to the bottom," see Proposition 4. This restriction is consistent with actual EU regulation: According to the July 2022 Article 9 guidance by the European Commission, a ESG fund is prohibited from investing in any firm that is not considered sustainable by the EU taxonomy.

We now analyze first when it is optimal to introduce a sustainability classification for investments θ_s. Based on the extended equilibrium characterization in Proposition 3, we can rewrite the planner's objective function (1) as follows:

$$\Omega = \int_0^{q^*} P(q)dq - q^* \left[c\left(\theta_m\right) + \rho(\theta^{\max} - \theta_m)\right] + q_s^*\left(\theta_s\right)\left(\rho(\theta_s - \theta_m) - \left[c\left(\theta_s\right) - c\left(\theta_m\right)\right]\right), \quad (20)$$

where we make the dependence on θ_s explicit and exploit the fact that firms optimally either choose θ_m or θ_s. The first line in (20) captures the known baseline welfare if all investment were non-sustainable (cf. expression (1)). The second line captures the incremental effect of sustainable output with quantity $q_s^*\left(\theta_s\right)$.

As total output q^* does not depend on θ_s, changes in θ_s only affect the social planner's objective through the second term. As a result, the planner's program reduces to that of maximizing the product of $q_s^* v\left(\theta_s\right)$ where $v\left(\theta_s\right)$ captures the incremental benefit per unit of output, trading off the reduction of the externality with the increase in cost,

$$v\left(\theta_s\right) := \rho(\theta_s - \theta_m) - \left[c\left(\theta_s\right) - c\left(\theta_m\right)\right]. \quad (21)$$

When is it optimal to introduce a taxonomy? Note that $v\left(\theta_s\right)$ is maximized for $\theta_s = \theta_{FB}$, see (2), which follows directly from the first-order condition $v'\left(\theta_s\right) = 0$. We then obtain

Proposition 5 (*Optimality of a Taxonomy*).*The introduction of a sustainable investment taxonomy is strictly suboptimal if $\theta_m \geq \theta_{FB}$ and strictly optimal if $\theta_m < \theta_{FB}$.*

We note that Proposition 5 holds irrespective of whether the minimum standard is chosen optimally or results from an environmental policy failure. As one would expect if environmental regulation is sufficiently lax, as e.g., argued by Tirole (2012), a taxonomy increases welfare by mitigating the effects of environmental policy failure. In contrast, if the minimum standard θ_m is already very stringent, $\theta_m \geq \theta_{FB}$, the incremental benefit of introducing an even more stringent classification for sustainable investments is negative, $v\left(\theta_s\right) < 0$, for all $\theta_s > \theta_m$. Hence, the regulator should not introduce a category for sustainable investments. While even in this case the availability of sustainable investment opportunities (and the ensuing warm-glow) would attract investors and thereby lead to subsidized capital costs for sustainable firms, it would induce a fraction of firms to overinvest in sustainability from a welfare perspective.[33]

The first part of Proposition 5 thus qualifies the notion of a general social desirability of an ESG-classification of investment funds. Even

[29] Our analysis, thus, abstracts from company-level ESG ratings, which are theoretically analyzed by Azarmsa and Shapiro (2023). In their model, greenwashing by firms may be detected by a ESG rater.

[30] We note that the interpretation in terms of intermediaries is solely made for expositional reasons. Formally, the results are identical if firms directly seek funding with a self-designated ESG label, i.e., a fund solely consists of one firm.

[31] This logic is not impacted by the market structure for intermediaries. If there were instead a monopolistic supplier of sustainable funds, there would still be zero impact with $\theta_s = \theta_m$, but the fund would itself pocket a fee $\psi > 0$. In particular, the fund would choose its optimal management fee ψ^* as to maximize its revenues $\psi[1-F(\psi)]$ resulting in equilibrium "sustainable capital" of size $K[1 - F(\psi^*)]$.

[32] We thank an anonymous referee and Jean Tirole for suggesting this extension.

[33] Recall that the social planner's objective only accounts for real effects, but not investors' warm-glow perception.

when such investment opportunities meet with positive demand, this could represent "too much of a good thing."

If θ_m is set optimally, we immediately obtain the following result as a Corollary to Propositions 2 and 5.

Corollary 5. *Under optimal environmental regulation, a taxonomy for sustainable investments increases welfare if and only if $A < A_{FB}$.*

That is, the introduction of a taxonomy for sustainable investments can only increase welfare on top of *optimal* environmental regulation if lack of financing is a source of a social inefficiency. Intuitively, if lack of financing is not a concern, the regulator can simply choose stricter environmental regulation for all firms (without having to worry about financial constraints). This intuition for the primacy of environmental regulation extends to the case of consequentialist investor preferences (as long as the planner only cares about real effects), see Appendix C.

Moreover, we can interpret this result in the cross-section of economies.

Corollary 6. *In an economy where environmental policy (θ_m) is optimally chosen, the additional introduction of a sustainable investment taxonomy is more likely to be beneficial if, ceteris paribus, firms' internal funds are more limited (lower A) or the agency problem vis-à -vis external investors is more severe (higher $B/\Delta p$).*

Hence, under optimal environmental policy the introduction of a sustainable investment category is more likely to be socially beneficial when (lack of) financial development or the (mal-)functioning of the legal system sufficiently limit internal funding and raise the costs of external financing. For a developed financial system, as prevailing in the European Union, this would thus seem less likely.

Optimal stringency of the taxonomy. We now characterize the optimal stringency of the sustainability standard when the taxonomy improves welfare as $\theta_m < \theta_{FB}$. This could either be because environmental policy is inefficiently lax due to environmental policy failures or internal funds are sufficiently limited.

Proposition 6 (*Optimal Stringency of Taxonomy*). *Suppose that $\theta_m < \theta_{FB}$, so that it is strictly optimal to introduce a sustainable investment category. Then the optimal threshold, $\hat{\theta}_s$, satisfies*

$$\frac{\partial \ln v\left(\theta_s\right)}{\partial \theta_s} = \left|\frac{\partial \ln q_s^*\left(\theta_s\right)}{\partial \theta_s}\right| > 0, \tag{22}$$

so that $\theta_m < \hat{\theta}_s < \theta_{FB}$.

Similar to the pricing decision of a monopolist, the optimal calibration of $\hat{\theta}_s$ can be expressed in terms of (semi)-elasticities: Ignoring the effect on the supply of sustainable capital $q_s^*\left(\theta_s\right)$, it would be optimal to set $\frac{\partial \ln v(\theta_s)}{\partial \theta_s} = 0$ or equivalently $\hat{\theta}_s = \theta_{FB}$. However, because the planner additionally needs to account for the downward sloping supply of sustainable capital, i.e., $\left|\frac{\partial \ln q_s^*(\theta_s)}{\partial \theta_s}\right| > 0$, see Corollary 4, the optimal choice features $v'(\hat{\theta}_s) > 0$, so that $\hat{\theta}_s < \theta_{FB}$.

Intuitively, investor preferences are a key determinant of the supply elasticity. As investor preferences become more sustainable, in the sense of a monotone hazard rate shift in $F(w)$, the feedback effect on supply becomes dampened so that the regulator optimally increases $\hat{\theta}_s$.

We conclude this section with a brief discussion of the properties of the optimal policy under the joint optimization of θ_m and θ_s. We denote the respective optimizers as $\hat{\theta}_m$ and $\hat{\theta}_s$. Since it is suboptimal to use the second tool of a sustainable investment classification if $A \geq A_{FB}$, by Corollary 5, the planner problem is akin to the one in the benchmark economy (when the planner could only avail herself to the one tool of the minimum standard). That is, the calibration of the optimum minimum standard is characterized by Proposition 2 and the minimum standard is, thus, given by $\hat{\theta}_m = \tilde{\theta}_m$, (see Fig. 2 for $A \geq A_{FB}$). Preferences for sustainable investing do not affect optimal policy.

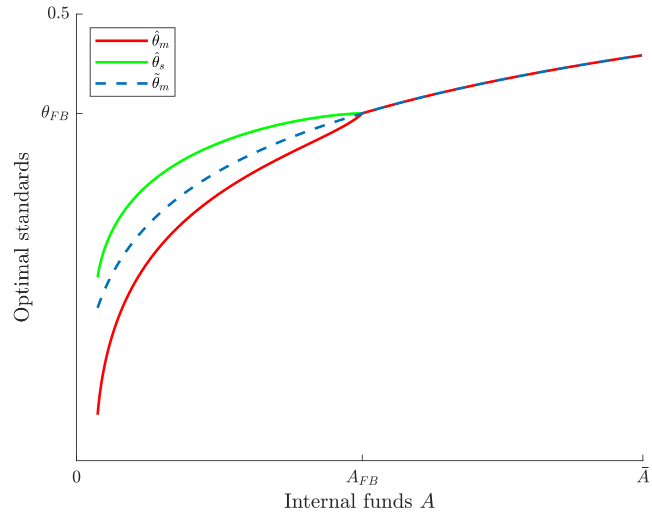

Fig. 2. Jointly optimal policy $(\hat{\theta}_m, \hat{\theta}_s)$. The graph plots the optimal choice $(\hat{\theta}_m, \hat{\theta}_s)$ if the planner can both flexibly a choose a minimum standard and a taxonomy for sustainable investments $\theta_s > \theta_m$. For $A < A_{FB}$, $\hat{\theta}_m < \tilde{\theta}_m < \hat{\theta}_s$. For $A \geq A_{FB}$, we obtain that $\hat{\theta}_m = \tilde{\theta}_m$ and no taxonomy for investments is introduced.

In contrast, if $A < A_{FB}$, it is optimal to introduce the sustainable investments category by Corollary 5. Recall that, under optimal regulation with a minimum standard only, see Proposition 2, the marginal consumer valuation exceeds the marginal social cost of production (including externalities), i.e., $P(q^*) > c\left(\tilde{\theta}_m\right) + \rho\left(\theta^{\max} - \tilde{\theta}_m\right)$. Therefore, *ceteris paribus,* an output expansion would be welfare enhancing. Equipped with the second tool of a taxonomy, it is possible to achieve this by setting the sustainability standard slightly higher than in the benchmark economy, $\theta_s > \tilde{\theta}_m$, and then lower the minimal standard $\theta_m < \tilde{\theta}_m$ until the weighted average social cost, $(1-\omega)\left[c\left(\theta_m\right) + \rho(\theta^{\max} - \theta_m)\right] + \omega\left[c\left(\theta_s\right) + \rho(\theta^{\max} - \theta_s)\right]$ matches the one in the benchmark economy. This perturbation always improves welfare compared to the benchmark economy since it alleviates underproduction in the economy by lowering the minimum standard.

The *optimal* calibration of the respective standards, i.e., $\hat{\theta}_s$ and $\hat{\theta}_m$, see first-order conditions in Proof of Propositions 5 and 6, is illustrated in Fig. 2 for an example specification: the optimal minimum standard is below the one in the benchmark economy $\hat{\theta}_m < \tilde{\theta}_m$ (compare red line for $\hat{\theta}_m$ to blue dotted line for $\tilde{\theta}_m$ for $A < A_{FB}$) and the optimal sustainability standard exceeds the minimum standard of the benchmark economy (compare green line for $\hat{\theta}_s$ to blue dotted line for $\tilde{\theta}_m$).

We finally note that the possibility of setting a carbon tax, as discussed in Appendix B, does not affect the validity of Propositions 5 and 6. Intuitively, when $A > A_{FB}$, first-best welfare can already be achieved, see Remark 1, so that sustainable finance is not needed. When sustainable finance is needed, $A < A_{FB}$, the optimal carbon tax would be zero so that only the minimum standard is used as an environmental policy tool.

4. Concluding remarks

Greenwashing is regularly mentioned as one of the key impediments for impact of sustainable finance. In response, regulators around the world are in the process of developing taxonomies for sustainable (or ESG) investment products. We show that a regulatory standard in the form of a taxonomy is necessary to prevent such a "race to the bottom" and is, hence, instrumental to ensure a greenium and impact of sustainable finance in the presence of empirically documented preferences for sustainability. However, is it beneficial to introduce a classification for sustainable investments when a social planner can optimally choose more direct policy instruments, such as a minimum standard or Pigouvian taxes? The answer is non-trivial as the planner in our model only cares about real effects, but not directly about the warm glow that households experience when investing sustainably.

Our normative paper highlights two frictions that justify a public intervention in the form of taxonomy. First and intuitively, if policy failures render environmental regulation to be too lax, as e.g., argued by Tirole (2012), a taxonomy can help to partially mitigate underinvestment in sustainability. Second, there is a role for harnessing "sustainable capital" even if traditional environmental tools can be optimally chosen, but this requires financial frictions to prevent the economy from running at the socially efficient scale when the socially desirable minimum standard or tax on externalities is set. In this case, the sustainable investment classification adds a valuable second instrument that mitigates the trade-off between achieving higher sustainability for production and generating an inefficient contraction of economic activity.

Our analysis has normative implications for optimal policy across countries. Economies with higher financial development, for which financial constraints are less relevant, should have stricter environmental regulation. Then, there is no role for the introduction of a sustainable investments category unless environmental policy is too lax. In contrast, for economies with poorer financial development, binding financial constraints imply a welfare-enhancing role for sustainable finance even under optimal environmental policy as subsidies are required to finance the transition.

Empirical researchers could calibrate a structural model to gauge whether the two highlighted frictions, financial frictions and environmental policy failure, are sufficiently important in the data to warrant an intervention via financial regulation. An important first step is to determine the welfare-optimal environmental policy, which, e.g., incorporates measures of the social cost of carbon (Rennert et al., 2022). Determining such optimal environmental policy (e.g., the size of the carbon tax) is complex as it needs to account for international leakage, i.e., shifting of production to other jurisdictions. One interesting aspect is that while environmental regulation is limited to apply within a jurisdiction,[34] the taxonomy for investments could be, in principle, extended to firms outside of the jurisdiction (e.g., a European ESG fund could subsidize a Chinese firm). Moreover, while our qualitative model abstracts, for ease of exposition, from firm or industry heterogeneity, such a quantitative exercise should account for cross-sectional differences in the relevance of financial constraints, as e.g., documented by Farre-Mensa et al. (2022). We believe that such a calibration exercise is relevant, both from a research and a policy perspective.

More generally, our paper has analyzed the role of financial regulation for supporting a sustainable transition. We focused on one particular tool, a taxonomy for sustainable investments. Other regulatory initiatives are ongoing, e.g., green monetary policy as studied in Papoutsi et al. (2021), or green capital requirements as studied in Oehmke and Opp (2022). The analysis of which (combination of) tools is most impactful is an interesting question for future empirical and theoretical research. The results of this paper suggest that financial regulation is only part of the optimal policy mix if "finance" is the root of the problem. Put differently, absent frictions in the financial sector, environmental regulation should be at the top of the regulatory pecking order.

CRediT authorship contribution statement

Roman Inderst: Formal analysis, Writing. **Marcus M. Opp:** Formal analysis, Writing.

[34] A Carbon-Border-Adjustment-Tax can mitigate such carbon leakage for imported goods.

Declaration of competing interest

The authors declare the following financial interests/personal relationships which may be considered as potential competing interests: Marcus Matthias Opp reports that financial support was provided by the Marianne and Marcus Wallenberg Foundation (Project number: 2021.0122) and Jan Wallanders och Tom Hedelius stiftelse samt Tore Browaldhs stiftelse (Project number: Fh23-0015). Roman Inderst reports that financial support was provided by the German Research Foundation (DFG) and European Research Council (ERC).

Appendix A. Proofs

Proof of Proposition 1. If $c(\theta_m) > P(0)$, the production cost associated with the environmental minimum standard is so high that profitable production is not even possible at the highest product price $P(0)$. Hence, no firm produces, so that aggregate output satisfies $q^* = 0$.

We now turn to the relevant case when $P(0) > c(\theta_m)$. We first want to show that aggregate output satisfies $q_{\min} < q^* \leq \bar{q}$ where $\bar{q}$ denotes the zero-profit output and $q_{\min}$ is the output that can be produced as internal funds A approach zero, i.e.,

$$q_{\min} = \begin{cases} 0 & \text{if} \quad P(0) \leq \frac{B}{\Delta p} + c(\theta_m) \\ P^{-1}\left(\frac{B}{\Delta p} + c(\theta_m)\right) & \phantom{\text{if}} \quad P(0) > \frac{B}{\Delta p} + c(\theta_m) \end{cases}. \tag{A.1}$$

The lower bound follows from the fact that as long as $P(q) > \frac{B}{\Delta p} + c(\theta_m)$ each individual firm's borrowing constraint would not bind, see (IC) and (IR). The upper bound $\bar{q}$ follows from the fact that for any $q > \bar{q}$ firms would earn a lower return than their outside option $r_0 = 0$.

We now turn to the question whether output $\bar{q}$ is feasible in the presence of financial constraints. Suppose that aggregate output is at $\bar{q}$, then the associated output capacity multiplier in (7) is $k^* = \frac{\Delta p}{B}$. Each individual firm takes this multiplier as given. We now distinguish between two cases.

<u>Case 1)</u> If $A < \bar{q}B/\Delta p$, then even if all firms were to lever up to the maximum (using the candidate multiplier $k^* = \frac{\Delta p}{B}$), aggregate output of $\bar{q}$ would not be feasible. Hence, q^* is the unique solution to

$$q = Ak(q).$$

Uniqueness follows from the fact that $k(q)$ is strictly decreasing and continuous in q and $Ak(q_{\min}) > 0$.

<u>Case 2)</u> If $A \geq \bar{q}B/\Delta p$, it is feasible to produce aggregate output of $\bar{q}$. In this case, at $q^* = \bar{q}$ firms are indifferent between investing and the storage technology. ■

Lemma A.1 (*No Shirking*)**.** *A sufficient condition to rule out shirking in equilibrium is:*

$$\frac{B}{\Delta p} < P(q_{\min}) - \frac{P(q_{\min}) - c(\theta_m)}{\Delta p}, \tag{A.2}$$

where $q_{\min}$ is given by (A.1).

Proof of Lemma A.1. Suppose the entrepreneur shirks in equilibrium, then one only needs to consider the investors' IR constraint:

$$(1 - \Delta p) D_i \geq c(\theta_m) q_i - A_i. \tag{IR*}$$

Binding (IR*) now implies that the face value of debt is set to[35]:

$$D_i = \frac{c(\theta_m) q_i - A}{1 - \Delta p}. \tag{A.3}$$

[35] Because the manager is protected by limited liability, i.e., $D_i \leq P(q)$, there may be an upper bound on the feasible quantity q_i, but this is irrelevant for our argument.

Then, the manager's payoff, including the payoff from the storage technology $\left(A-A_i\right)$, is:

$$
\begin{aligned}
U_i &= (1-\Delta p)\left[q_i P(q)-\frac{c\left(\theta_m\right) q_i-A_i}{1-\Delta p}\right]+B q_i+\left(A-A_i\right) \\
&= q_i\left[(1-\Delta p) P(q)-c\left(\theta_m\right)+B\right]+A .
\end{aligned}
$$

If (A.2) holds, then $(1-\Delta p) P(q)-c\left(\theta_m\right)+B<0$ irrespective of the product price P (since P is highest for $q_{\min}$). As a result, the entrepreneur's utility would be below the payoff received from investing in the storage technology, $U_i<A$, whenever $q_i>0$. Therefore, (A.2) rules out shirking in equilibrium. ■

Proof of Corollary 1. We distinguish based on whether aggregate output is constrained by financial frictions. If output is unconstrained, then $P(q^*)=c\left(\theta_m\right)$, see (9). An increase in A has no effect on q^*. An increase in θ_m and concomitant increase in $c\left(\theta_m\right)$ decreases aggregate output q^* because $P'(q)<0$.

Suppose next that aggregate output is constrained by financial frictions. Then, Proposition 1 implies that q^* is determined from $Ak(q)=q$, where $k(q)=\left(\frac{B}{\Delta p}-\left[P(q)-c\left(\theta_m\right)\right]\right)^{-1}$. Using the implicit function theorem, we obtain that

$$
\frac{\partial q^*}{\partial A}=\frac{k(q)}{1-Ak'(q)}>0, \tag{A.4}
$$

where the sign follows from $k'(q)<0$ (so that the denominator is positive) and $k(q)>0$. Analogously, we obtain

$$
\frac{\partial q^*}{\partial \theta_m}=\frac{A\frac{\partial k(q)}{\partial \theta_m}}{1-Ak'(q)}<0, \tag{A.5}
$$

where the negative sign of the numerator, $\frac{\partial k(q)}{\partial \theta_m}<0$, follows from

$$
\frac{\partial k(q)}{\partial \theta_m}=-\frac{c'\left(\theta_m\right)}{\left(\frac{B}{\Delta p}-\left[P(q)-c\left(\theta_m\right)\right]\right)^2}<0.
$$

■

Proof of Corollary 2. If $P(0) \leq \frac{B}{\Delta p}+c\left(\theta_m\right)$ the result is immediate. Otherwise, the proof of Proposition 1 implies that for any $A>0$, aggregate output satisfies $q^*>q_{\min}$ so that $q^* \in\left(q_{\min}, \bar{q}\right]$ with $P\left(q_{\min}\right)=\frac{B}{\Delta p}+c\left(\theta_m\right)$ and $P(\bar{q})=c\left(\theta_m\right)$. Hence, for any $A>0$, we obtain that $P\left(q^*\right)<P\left(q_{\min}\right)=B/\Delta p+c\left(\theta_m\right)$. Therefore, the capacity multiplier is finite.

We now turn to the rents. If $A \geq \bar{q} B/\Delta p$, equilibrium output satisfies $q^*=\bar{q}$ and $P(q^*)=c\left(\theta_m\right)$. The firm is then indifferent between investing its own funds productively or using the storage technology, so that $U_i^*=A$. This follows from inserting the equilibrium multiplier $k^*=\frac{\Delta p}{B}$ into U_i^* in (8).

If $A<\bar{q} B/\Delta p$, equilibrium output satisfies $q^*<\bar{q}$ so that a firm would strictly prefer to expand output. Strictly positive firm rents, $U_i^*>A$, follow from inserting the equilibrium multiplier $k^*>\frac{\Delta p}{B}$ into U_i^* in (8). ■

Proof of Proposition 2. Recall that first-best requires that all firms choose the sustainability level θ_{FB} and aggregate output be at q_{FB}. The sustainability choice of θ_{FB} can only be ensured by setting the minimum standard to $\theta_m=\theta_{FB}$. If output is unconstrained by financial frictions and $\theta_m=\theta_{FB}$, it is immediate from the then prevailing zero-profit condition, $P(q^*=\bar{q})=c(\theta_{FB})$, that output is socially excessive, $q^*>q_{FB}$. It is thus necessary that aggregate output be constrained by financial frictions to achieve first-best.

We now prove that for some $A \in\left[0, \bar{q}\left(\theta_{FB}\right) \frac{B}{\Delta p}\right]$ first-best can be achieved as long as $\frac{B}{\Delta p} \geq \rho(\theta^{\max}-\theta_{FB})$, i.e., Condition (14) holds. By Proposition 1, where we now set $\theta_m=\theta_{FB}$, output is

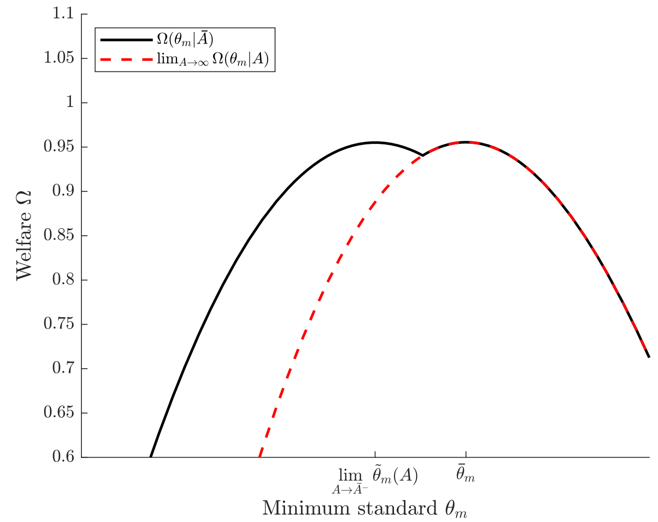

Fig. A.3. Discontinuity of policy function. The black graph plots welfare $\Omega\left(\theta_m \mid A\right)$ as a function of the minimum standard θ_m conditional on internal funds $A=\bar{A}$ for which the planner is indifferent between causing financial constraints or not. The function has two global maxima. The red dashed line plots the welfare function in the absence of financial constraints, i.e., internal funds approaching infinity.

characterized by the fixed point (10), from which q^* is a continuous, strictly increasing function of A over the domain $A \in\left[0, \bar{q}\left(\theta_{FB}\right) \frac{B}{\Delta p}\right]$ with range $\left[q_{\min}\left(\theta_{FB}\right), \bar{q}\left(\theta_{FB}\right)\right]$. Note that we have made explicit the dependency on θ_{FB} also for $q_{\min}$, as defined in (A.1). Given continuity and strict monotonicity as well as $\bar{q}\left(\theta_{FB}\right)>q_{FB}$, it thus suffices that $q_{\min}\left(\theta_{FB}\right)<q_{FB}=P^{-1}\left(c(\theta_{FB})+\rho(\theta^{\max}-\theta_{FB})\right)$. If $q_{\min}=0$, the result is immediate since first-best output q_{FB} is by Assumption (A1) positive. If the minimum output satisfies $q_{\min}=P^{-1}\left(c\left(\theta_{FB}\right)+\frac{B}{\Delta p}\right)$, then $q_{\min}<q_{FB}$ if and only if $\frac{B}{\Delta p}>\rho(\theta^{\max}-\theta_{FB})$, which is condition (14).

Suppose now that, at the optimally chosen minimum standard, aggregate output is constrained by financial frictions. Consider the first-order condition (13) and notably the term

$$
G=P\left(q^*\right)-c\left(\theta_m\right)-\rho\left(\theta^{\max}-\theta_m\right), \tag{A.6}
$$

which is zero at first-best and $A=A_{FB}$. We prove now by contradiction that when $A>A_{FB}$, then $\tilde{\theta}_m>\theta_{FB}$. Assume thus that $A>A_{FB}$ but $\tilde{\theta}_m \leq \theta_{FB}$. Then, from $\rho-c'\left(\tilde{\theta}_m\right) \geq 0$, the first-order condition requires that $G \geq 0$. But compared to $A=A_{FB}$ and θ_{FB}, now $q^*>q_{FB}$ so that $P(q^*)$ is strictly lower, while $c\left(\theta_m\right)+\rho\left(\theta^{\max}-\theta_m\right)$ is weakly higher (and strictly so if $\tilde{\theta}_m<\theta_{FB}$). This together implies $G<0$, a contradiction. The case where $A<A_{FB}$ and now $\tilde{\theta}_m<\theta_{FB}$ is analogous.

If instead, at the optimal standard, aggregate output is not constrained, $q^*=\bar{q}\left(\theta_m\right)$, $G=-\rho\left(\theta^{\max}-\theta_m\right)$ is always negative, so that at the optimum $\tilde{\theta}_m>\theta_{FB}$.

This concludes the proof. We additionally shed light on the discontinuity of the policy function in Fig. 1.

Let $\bar{A}$ denote the value of A for which the planner is indifferent between setting a low value of the minimum standard $\lim_{A\to\bar{A}^-}\tilde{\theta}_m$ (so that financial constraints constrain output $q^*<\bar{q}$) or setting a high value of the minimum standard $\tilde{\theta}_m$ so that aggregate output is not constrained by financial constraints and given by $q^*=\bar{q}\left(\tilde{\theta}_m\right)$. (Recall that $\bar{q}$ is a strictly decreasing function of θ_m). Formally, the objective function $\Omega\left(\theta_m \mid A\right)$ has two global maxima for $A=\bar{A}$ (see Fig. A.3).

Proof of Lemma 1. See main text. ■

Proof of Proposition 3. To provide q_s^* units of sustainable output, each firm demands $c\left(\theta_s\right) A k^*-A$ of capital from outside investors while coinvesting A. Given Δr^*, the total volume of supplied sustainable capital is $K(1-F(\Delta r^*))$. The equalization of demand and supply in equilibrium thus implies that

$$c\left(\theta_s\right)Ak^*-A=K\left(1-F\left(\Delta r^*\right)\right)$$

Solving for A yields the aggregate amount of internal funds provided by all sustainable firms in equilibrium,

$$A_s=\frac{K\left(1-F\left(\Delta r^*\right)\right)}{c\left(\theta_s\right)k^*-1}.$$

Therefore, sustainable output, $q_s^*=A_sk^*$, is given by

$$q_s^*=K\left(1-F\left(\Delta r^*\right)\right)\frac{k^*}{c\left(\theta_s\right)k^*-1}, \tag{A.7}$$

which restates (18). Since aggregate output is given by $q^*=\min\{\bar{q},Ak^*\}$ (by Proposition 1 , respectively Lemma 1) and total sustainable output is given by (18), the ratio is given by (19).

The condition on the short supply of sustainable capital requires that $\omega^*<1$, i.e.,

$$K\left(1-F\left(\Delta r^*\right)\right)\frac{k^*}{c\left(\theta_s\right)k^*-1}<\min\left\{\bar{q},Ak^*\right\},$$

which is always satisfied if the amount of capital owned by investors with sustainability preferences, K, is sufficiently small.

We now adapt Lemma A.1 to account for investors with sustainability preferences. A sufficient condition to rule out shirking in equilibrium is:

$$\frac{B}{\Delta p}<P\left(q_{\min}\right)-\frac{P\left(q_{\min}\right)-\min\left[\left\{c\left(\theta_s\right)(1-\bar{w}),c\left(\theta_m\right)\right\}\right]}{\Delta p}. \tag{A.8}$$

This can be derived by the same steps as in the proof of Lemma A.1, taking into account that a shirking firm can now also become sustainable. To take this into account, we generally denote the firm's interest rate by $r\left(\theta_i\right)$ and its production cost by $c\left(\theta_i\right)$, so that a shirking firm's payoff now reads as follows:

$$U_i=q_i\left[(1-\Delta p)P(q)-c\left(\theta_i\right)\left(1+r\left(\theta_i\right)\right)+B\right]+A_ir\left(\theta_i\right)+A.$$

If (A.8) holds, then $(1-\Delta p)P(q)-c\left(\theta_i\right)q_i(1+r\left(\theta_i\right))+B<0$ holds now also regardless of whether the firm produces unsustainably at cost $c\left(\theta_m\right)$ with $r\left(\theta_m\right)=0$ or sustainably at cost $c\left(\theta_s\right)$ with the highest financing subsidy $\bar{w}$. ∎

Proof of Corollary 3. The invariance of Δr^* follows from (17). Equilibrium output q^* and, hence, the multiplier k^* are also unaffected by $F(w)$ as a result of Proposition 1. A first-order stochastic dominance shift of the distribution $F(w)$ must now decrease $F(\Delta r^*)$ and, hence increases q_s^*. The same holds for an increase in K. ∎

Proof of Corollary 4. We first prove the effect on Δr^*. An increase in θ_s increases Δc. Differentiating (17) implies that $\frac{\partial \Delta r^*}{\partial \Delta c}>0$, because $P(q^*)-\frac{B}{\Delta p}>0$, which follows from (IC). Thus, from (18) q_s^* decreases with Δc (and thus θ_s), so that ω^* in (19) decreases as well. If $\Delta r^*>\bar{w}$, even an investor with the highest warm glow $\bar{w}$ would not invest in sustainable firms, so that no firm would be able to get financing for producing sustainably. ∎

Proof of Proposition 4. See main text. ∎

Proof of Propositions 5 and 6. We first consider the optimal choice of θ_s. The social planner's objective function in (20) reduces to that of maximizing

$$q_s^*\left(\theta_s\right)v\left(\theta_s\right), \tag{A.9}$$

where $v\left(\theta_s\right)$ is given by (21). Proposition 5 follows immediately from the observation that $v'\left(\theta_s\right)$ is strictly positive for all $\theta_s<\theta_{FB}$ and strictly negative for all $\theta_s>\theta_{FB}$.

If $\theta_m<\theta_{FB}$, the first-order condition for θ_s is given by

$$\frac{\partial q_s^*}{\partial\theta_s}v\left(\theta_s\right)+q_s^*\left(\theta_s\right)v'\left(\theta_s\right)=0, \tag{A.10}$$

which can be transformed to obtain (22) in Proposition 6, where $\frac{\partial q_s^*}{\partial\theta_s}<0$ follows from Corollary 4. As a result $v'\left(\hat{\theta}_s\right)>0$ at the optimum so that $\hat{\theta}_s<\theta_{FB}$. Moreover, $\hat{\theta}_s>\theta_m$ so that $v\left(\hat{\theta}_s\right)>0$.

We now characterize the optimal choice of θ_m. Let $C:=(1-\omega)\left[c\left(\theta_m\right)+\rho(\theta^{\max}-\theta_m)\right]+\omega\left[c\left(\theta_s\right)+\rho(\theta^{\max}-\theta_s)\right]$ denote the weighted average social cost of production (including externalities). Then, the first-order condition of (20) with respect to the minimum standard can be stated as:

$$-\frac{dq^*\left(\theta_m\right)}{d\theta_m}\left[P(q^*)-C\right]=q^*(1-\omega)\left[\rho-c'\left(\theta_m\right)\right]+q^*\frac{\partial\omega^*\left(\theta_m\right)}{\partial\theta_m}v\left(\theta_s\right). \tag{A.11}$$

∎

Proof of Corollary 5. As the social planner can now avail herself of both instruments, her program is to choose θ_m and potentially a sustainable investment category with threshold $\theta_s>\theta_m$ so as to maximize Ω in (12). The optimal outcome is denoted by $(\hat{\theta}_m,\hat{\theta}_s)$. We note first that the derivative with respect to θ_s is identical to that in the partial problem of Proposition 5, where we took θ_m as given. It is thus strictly optimal to introduce a sustainable investment category $\hat{\theta}_s>\hat{\theta}_m$ if $\hat{\theta}_m>\theta_{FB}$ and strictly suboptimal otherwise. It thus remains to show that, also in the presence of both potential instruments, $\hat{\theta}_m\geq\theta_{FB}$ ($\hat{\theta}_m<\theta_{FB}$) if $A\geq A_{FB}$ ($A<A_{FB}$). We show this by contradiction.

Suppose that $A<A_{FB}$ and suppose, instead that $\hat{\theta}_m\geq\theta_{FB}$. Then, it would not be optimal to introduce a sustainable investment category with $\hat{\theta}_s>\hat{\theta}_m$, in which case we know however from Proposition 2 that $\hat{\theta}_m=\tilde{\theta}_m<\theta_{FB}$, a contradiction.

For $A=A_{FB}$ the argument is immediate as $\hat{\theta}_m\geq\theta_{FB}$ achieves the first best, while Ω is strictly lower for any choice $\hat{\theta}_m<\theta_{FB}$, irrespective of the choice of θ_s.

Turning finally to $A>A_{FB}$, suppose that $\hat{\theta}_m<\theta_{FB}$, in which case it would be optimal to choose a threshold $\hat{\theta}_m<\hat{\theta}_s<\theta_{FB}$. To show that this is not optimal, it is sufficient to argue that welfare is strictly higher by setting instead $\theta_m=\hat{\theta}_s$, without a sustainable investment category. Denote the thereby realized value by $\widetilde{\Omega}$,

$$\widetilde{\Omega}=\int_0^{q^*(\hat{\theta}_s)}P(q)dq-\rho q^*(\hat{\theta}_s)\left[c\left(\hat{\theta}_s\right)+\rho(\theta^{\max}-\hat{\theta}_s)\right],$$

where we have set $\theta_m=\hat{\theta}_s$. Calculating now the difference $\widetilde{\Omega}-\Omega$, this can be decomposed as follows: first, while quantity q_s^* is produced with standard $\hat{\theta}_s$, quantity $q^*(\hat{\theta}_s)-q_s^*$ is now produced with standard $\theta_m=\hat{\theta}_s$ and no longer with the supposedly optimal minimum standard $\hat{\theta}_m$; second, total output is reduced from $q^*(\hat{\theta}_m)$ to $q^*(\hat{\theta}_s)$. With this decomposition we have $\widetilde{\Omega}-\Omega=\Delta_1+\Delta_2$, where

$$\Delta_1=\left(q^*(\hat{\theta}_s)-q_s^*\right)\left[\rho(\hat{\theta}_s-\hat{\theta}_m)-\left[c\left(\hat{\theta}_s\right)-c\left(\hat{\theta}_m\right)\right]\right],$$

which is strictly positive from $\hat{\theta}_m<\hat{\theta}_s<\theta_{FB}$, and

$$\Delta_2=-\int_{q^*(\hat{\theta}_s)}^{q^*}\left[P(q)-\left[c\left(\hat{\theta}_m\right)+\rho(\theta^{\max}-\hat{\theta}_m)\right]\right]dq,$$

which is strictly positive when, at the lower boundary,

$$P(q^*(\hat{\theta}_s))-\left[c\left(\hat{\theta}_m\right)+\rho(\theta^{\max}-\hat{\theta}_m)\right]<0.$$

This follows by construction, as with $A>A_{FB}$ the marginal social return is negative at least for all $\theta_m\leq\theta_{FB}$, and thus also for $\theta_m=\hat{\theta}_s<\theta_{FB}$ and the corresponding quantity $q^*(\hat{\theta}_s)$. ∎

Proof of Corollary 6. We prove that A_{FB} is strictly increasing in the severity of the agency problem, $\xi=\frac{B}{\Delta p}$. For this recall the definition of A_{FB} from the proof of Proposition 2, which requires that $G\left(\theta_{FB},A_{FB}\right)=0$, where we use the definition of the term G in (A.6) and make explicit the dependency on internal funds, while substituting first-best for the optimally chosen standard. From this we thus have that

$$\frac{dA_{FB}}{d\xi} = -\frac{P'(q^*)\frac{dq^*}{d\xi}}{P'(q^*)\frac{dq^*}{dA}} = -\frac{dq^*/d\xi}{dq^*/dA} > 0,$$

which uses that $\frac{dq^*}{dA} > 0$ and $dq^*/d\xi < 0$ under constrained output (using Eq. (10) in Proposition 1, $q^* = Ak(q^*)$). ■

Appendix B. Pigouvian tax

In this section, we show robustness of our main results to a more general environmental policy. In particular, we allow the regulator to also impose a tax $\tau \geq 0$ per unit of externality (so that the standard Pigouvian tax level would be $\tau = \rho$). For the purpose of this extension only, denote the thus adjusted marginal costs of production, now including taxes on externalities, by $\widetilde{c}(\theta_i) = c(\theta_i) + \tau(\theta^{\max} - \theta_i)$. Hence, the firm now needs to raise now the amount $\widetilde{c}\left(\theta_i\right) q_i - A$, and with this modification the incentive and participation constraints, (IC) and (IR) respectively, remain unchanged, as does the characterization of the firm's payoff U_i.

Ignoring the minimum standard, to maximize U_i the firm would choose θ_i so as to minimize $\widetilde{c}(\theta_i)$, $c'(\theta_i) = \tau$. If the respective solution were above the minimum standard, the latter would be superfluous. On the other hand, any standard that is implemented by a specific choice of the tax τ can be implemented as well by directly imposing this as the minimum standard. By levying (additionally) a tax, the planner extracts some of the firm's funds.

If $A < A_{FB}$, extracting funds from firms is strictly suboptimal, as this leads to additional reduction in output. Therefore, the planner only uses the minimum standard as characterized by Proposition 2.[36]

In contrast, if $A > A_{FB}$, the tax allows the planner to limit over-production. By calibrating the tax accordingly, this allows to achieve first-best output, $q^* = q_{FB}$, while at the same time setting the minimum standard to θ_{FB}.

Proposition 7 (*Minimum Standard and Carbon Tax*). *Suppose now the planner can use both a minimum standard and a carbon tax. If condition holds (14) and $A < A_{FB}$, first-best welfare cannot be attained. The optimal carbon tax is zero and the optimal minimum standard and output are characterized by Propositions 1 and 2. Otherwise, first best can be achieved. If $A > A_{FB}$ holds strictly, achieving first-best requires a positive tax $\tau > 0$ next to the first-best standard $\theta_m = \theta_{FB}$.*

Proof of Proposition 7. If (14) holds and $A \leq A_{FB}$, the characterization follows immediately from the argument in the main text and from Proposition 2.

We now consider the case $A > A_{FB}$. We now characterize the optimal tax $\tau > 0$ which, together with $\theta_m = \theta_{FB}$, ensures the socially optimal output $q^* = q_{FB}$.

For this suppose first that (14) holds. We write out explicitly the (implicit) characterization of q^* when financial constraints bind, but using now costs $\widetilde{c}(\theta_i) = c(\theta_i) + \tau(\theta^{\max} - \theta_i)$. When $\theta_m = \theta_{FB}$ and $q^* = q_{FB}$ is achieved, it thus must hold that

$$q_{FB} = A\frac{1}{\frac{B}{\Delta p} - \left[P\left(q_{FB}\right) - c\left(\theta_{FB}\right) - \tau(\theta^{\max} - \theta_{FB})\right]}. \tag{B.12}$$

Recall that at $A = A_{FB}$ this is satisfied when $\tau = 0$. As the right-hand side of (B.12) is continuous and strictly increasing in A as well as strictly decreasing in τ, there exists a strictly increasing function $\tau(A)$ so that $q^* = q_{FB}$. Define next $A_{CT} = q_{FB}B/\Delta p$, where $\tau(A_{CT}) = \rho$. Observe that there q^* is also obtained from the now modified zero-profit output condition for $\bar{q}$, $P(q_{FB}) = \widetilde{c}(\theta_{FB})$. Consequently, as we leave $\tau = \rho$ unchanged for all $A \geq A_{CT}$ the first best is obtained so that $q^* = \bar{q} = q_{FB}$ (and financial constraints do not bind).

Finally if (14) does not hold, the only difference is that the planner needs to set a positive tax for all levels of A. This tax is still given by (B.12). ■

Incidentally, our results would need to be slightly adjusted when the planner could only use a carbon tax, but not a minimum standard. Intuitively, as the tax reduces firms' financial resources, a carbon tax alone could achieve first best only if financial constraints are less pronounced. Formally, a carbon tax achieves first best if and only if $A \geq A_{CT}$.

Appendix C. Consequentialist preferences and Greenwashing

We now discuss robustness of our results when investor preferences also care about impact $\theta_s - \theta_m$. In particular, we consider preferences of the following form: $w + \eta\left(\theta_s - \theta_m\right)$ for some bounded concave and twice differentiable function η with $\eta(0) = 0$, e.g., $\kappa\left(1 - e^{-(\theta_s - \theta_m)}\right)$ for some constant $\kappa > 0$. We then obtain the following result:

Lemma C.1 (*Robustness of Greenwashing*). *If the marginal utility from impact is sufficiently small, $\eta'\left(\theta_s - \theta_m\right) < \frac{P(q^*) - \frac{B}{\Delta p}}{\left(P(q^*) - \frac{B}{\Delta p} + \Delta c\right)^2} c'\left(\theta_s\right)$ for all θ_s, the market equilibrium features greenwashing.*

Proof of Lemma C.1. A "greenwashing" fund with $\theta_s = \theta_m$ will generate utility w to the investor. Suppose another fund offered an "impact" fund requiring all firms to meet the threshold $\theta_s > \theta_m$. Then, firm indifference would require a financing subsidy of

$$\Delta r^*\left(\theta_s\right) = \frac{\Delta c}{P\left(q^*\right) - \frac{B}{\Delta p} + \Delta c}.$$

Hence, investors in this impact fund would get a net utility of $w - \Delta r^*\left(\theta_s\right) + \eta(\Delta\theta)$. By optimality of investor choices, such a fund is viable in the market if and only if $\eta\left(\theta_s - \theta_m\right) - \Delta r^*\left(\theta_s\right) > 0$ for some $\theta_s > \theta_m$. However, if $\eta'\left(\theta_s - \theta_m\right) < \frac{P(q^*) - \frac{B}{\Delta p}}{\left(P(q^*) - \frac{B}{\Delta p} + \Delta c\right)^2} c'\left(\theta_s\right)$, the term $\eta\left(\theta_s - \theta_m\right) - \Delta r^*\left(\theta_s\right)$ is strictly negative for all $\theta_s > \theta_m$. Hence, greenwashing is the only possible market equilibrium. ■

When Greenwashing arises in equilibrium, see sufficient Condition in Lemma C.1, a taxonomy is needed to ensure impact. Given some taxonomy standard θ_s, the critical threshold investor now obtains a non-pecuniary dividend of

$$w^* = \Delta r^* - \eta(\theta_s - \theta_m).$$

Apart from this different cut-off, all of our analysis holds true: First, the supply of sustainable funds is still given by $K[1 - F(w^*)]$; second, q_s^* is still obtained by applying the derived equity multiplier, so that we now obtain

$$q_s^* = K[1 - F\left(\Delta r^* - \eta(\theta_s - \theta_m)\right)]\frac{k^*}{c\left(\theta_s\right)k^* - 1}.$$

Third, and most importantly, all of our subsequent analysis applies, as this does not depend on the specific characterization of the cutoff w^*. That is, it is still true that introducing a taxonomy is only valuable if either environmental policy is sufficiently lax or financial constraints bind under optimal environmental policy.

[36] The minimum standard is equivalent to a tax when tax receipts are rebated back to firms in lump-sum fashion. Hence, tax rebates do not change the main result that first-best cannot be achieved for $A < A_{FB}$.

Appendix D. Sustainable finance disclosure regulation (SFDR)

The European Union's Sustainable Finance Disclosure Regulation (SFDR) aims at enhancing sustainability-related disclosure. The regulation is part of the European Commissions' Action Plan on Sustainable Finance. It applies to all financial products domiciled in the EU or sold to EU investors. The SFDR came into force in two steps (December 2019 and, with some delay, January 2023).[37]

The SFDR sets out three categories of investment products. Products that meet certain ESG criteria are referred to as Article 8 or Article 9 products. All other products are now referred to as Article 6 products, and it is compulsive to label them as "non-sustainable." Article 8 products are often referred to as "light green," as they promote environmental or social characteristics in the pursuit of other financial objectives. Article 9 products are often referred to as "dark green," as they seek to make a positive impact on society or the environment through sustainable investment. Hence, a non-financial objective is at the core of the latter products.

At the heart of the distinction, as well as of the disclosure requirements, is the concept of taxonomy-aligned investments. A financed economic activity is either taxonomy-aligned or not. Article 9 funds must ensure that all the companies they invest in are EU taxonomy-aligned. Article 8 products must report the fraction of investments that are taxonomy-aligned. For this, funds need to divide the market value of taxonomy-aligned investments by the total market value of all investments. This calculation can rely either on the taxonomy report of invested companies, or on data gathered directly by the fund. The key concept of taxonomy-alignment is explained next:

The undertaken, taxonomy-aligned economic activity must have a substantial positive environmental impact or it must reduce (otherwise incurred) negative impacts. An eligible economic activity is an economic activity that is described in the regulation and satisfies technical screening criteria set out in the taxonomy. The taxonomy has technical screening criteria for over 170 activities (as set out in the Climate Delegated Act and the Environmental Delegated Act) and is evolving. These activities make a substantial contribution to one or more of the acts' climate and environmental objectives (climate protection, adaptation to climate change, sustainable use of water or marine resources, transition to a circular economy, prevention or control of pollution and protection and restoration of biodiversity and ecosystems).

For example, electricity generation from wind power is an eligible activity, while electricity generation from coal is not eligible. Also, manufacturing of batteries can contribute to climate change mitigation, and it must be shown that their production and use results in substantial greenhouse gas emissions reductions.

Eligible economic activities must also not do significant harm to the other climate and environmental objectives and the respective undertakings must demonstrate compliance with minimum standards on human rights, social responsibility, labor rights, and anti-corruption procedures (as set out in the OECD Guidelines for Multinational Enterprises, the UN Guiding Principles on Business and Human Rights, the International Labour Organization's declaration on Fundamental Rights and Principles at Work and its core conventions, as well as the International Bill of Human Rights).

[37] Phase 1 focuses on broad entity-level disclosures around topics such as the entity's policies regarding principal adverse sustainability impacts (PASIs) and related actions. Level 2 focuses on more detailed entity- and product-level disclosures.

References

Allen, Franklin, Barbalau, Adelina, Zeni, Federica, 2023. Reducing carbon using regulatory and financial market tools. Available at SSRN 4357160.

Azarmsa, Ehsan, Shapiro, Joel, 2023. The market for ESG ratings. Working Paper, Oxford University.

Bartram, Söhnke M., Hou, Kewei, Kim, Sehoon, 2022. Real effects of climate policy: Financial constraints and spillovers. J. Financ. Econ. 143 (2), 668–696.

Berg, Florian, Kölbel, Julian F., Rigobon, Roberto, 2022. Aggregate Confusion: The Divergence of ESG Ratings. Rev. Finance 26 (6), 1315–1344.

Berk, Jonathan, van Binsbergen, Jules H., 2021. The impact of impact investing. J. Financ. Econ. (forthcoming).

Biais, Bruno, Landier, Augustin, 2022. Emission caps and investment in green technologies. Working Paper, HEC Paris.

Bizzotto, Jacopo, Harstad, Bård, 2023. The certifier for the long run. Int. J. Ind. Organ. 87, 102920.

Bonnefon, Jean-Francois, Landier, Augustin, Sastry, Parinitha, Thesmar, David, 2019. The moral preferences of investors: Experimental evidence. Working Paper, TSE, MIT and HEC.

Boyle, Kevin J., Desvousges, William H., Johnson, F. Reed, Dunford, Richard W., Hudson, Sara P., 1994. An investigation of part-whole biases in contingent-valuation studies. J. Environ. Econ. Manag. 27 (1), 64–83.

Broccardo, Eleonora, Hart, Oliver, Zingales, Luigi, 2022. Exit versus voice. J. Polit. Econ. 130 (12), 3101–3145.

Chowdhry, Bhagwan, Davies, Shaun William, Waters, Brian, 2018. Investing for impact. Rev. Financ. Stud. 32 (3), 864–904.

Dangl, Thomas, Halling, Michael, Yu, Jin, Zechner, Josef, 2023. Social preferences and corporate investment. Working Paper, WU Vienna.

Davies, Shaun William, Van Wesep, Edward Dickersin, 2018. The unintended consequences of divestment. J. Financ. Econ. 128 (3), 558–575.

de Freitas Netto, Sebastiao Vieira, Sobral, Marcos Felipe Falcao, Ribeiro, Ana Regina Bezerra, Soares, Gleibson Robert da Luz, 2020. Concepts and forms of greenwashing: a systematic review. Environ. Sci. Europe 32 (19).

Desvousges, William, Mathews, Kristy, Train, Kenneth, 2012. Adequate responsiveness to scope in contingent valuation. Ecol. Econom. 84, 121–128.

Döttling, Robin J., Levit, Doron Y., Malenko, Nadya, Rola-Janicka, Magdalena A., 2024. Voting on Public Goods: Citizens vs. Shareholders. NBER Working Papers 32605, National Bureau of Economic Research, Inc.

Döttling, Robin, Rola-Janicka, Magdalena, 2022. Too levered for pigou? A model of environmental and financial regulation. Working Paper, Erasmus University Rotterdam and Tilburg University.

Edmans, Alex, Levit, Doron, Schneemeier, Jan, 2022. Socially responsible divestment. European Corporate Governance Institute–Finance Working Paper.

Farre-Mensa, Joan, Ljungqvist, Alexander, Schroth, Enrique J., 2022. How prevalent are financial constraints in the US?. Swedish House of Finance Research Paper.

Favilukis, Jack, Garlappi, Lorenzo, Uppal, Raman, 2024. How Effective are Portfolio Mandates. Working Paper.

Green, Daniel, Roth, Benjamin, 2021. The allocation of socially responsible capital. J. Finance (forthcoming).

Gupta, Deeksha, Kopytov, Alexandr, Starmans, Jan, 2022. The pace of change: Socially responsible investing in private markets. Available at SSRN 3896511.

Hakenes, Hendrik, Schliephake, Eva, 2021. Responsible investment and responsible consumption. Working Paper, University of Bonn.

Heeb, Florian, Kölbel, Julian F, Paetzold, Falko, Zeisberger, Stefan, 2023. Do investors care about impact? Rev. Financ. Stud. 36 (5), 1737–1787.

Heinkel, Robert, Kraus, Alan, Zechner, Josef, 2001. The effect of green investment on corporate behavior. J. Financ. Quant. Anal. 36 (4), 431–449.

Hoffmann, Florian, Inderst, Roman, Moslener, Ulf, 2017. Taxing externalities under financing constraints. Econ. J. 127 (606), 2478–2503.

Holmström, Bengt, Tirole, Jean, 1997. Financial intermediation, loanable funds, and the real sector. Q. J. Econ. 112 (3), 663–691.

Inderst, Roman, Heider, Florian, 2022. A corporate finance perspective on environmental policy. Working Paper, Goethe University Frankfurt.

Kahneman, Daniel, 2000. Evaluation by moments: Past and future. Choices Values Frames 693–708.

Kahneman, Daniel, Knetsch, Jack L., 1992. Valuing public goods: The purchase of moral satisfaction. J. Environ. Econ. Manag. 22 (1), 57–70.

Kaufmann, Marc, Andre, Peter, Kőszegi, Botond, 2024. Understanding markets with socially responsible consumers*. Q. J. Econ. 139 (3), 1989–2035.

Landier, Augustin, Lovo, Stefano, 2020. Social responsible investing: How to optimize impact? Rev. Financ. Stud. (forthcoming).

Lanteri, Andrea, Rampini, Adriano A., 2023. Financing the adoption of clean technology. Working Paper, Duke University.

Laux, Volker, Mahieux, Lucas, 2024. Exploiting social funds' desire for impact through imprecise financial climate-risk information. Working Paper.

Moisson, Paul-Henri, 2020. Ethics and impact investment. Working Paper, TSE.

Oehmke, Martin, Opp, Marcus, 2022. Green capital requirements. Working Paper, LSE and SSE.

Oehmke, Martin, Opp, Marcus M., 2024. A theory of socially responsible investment. Rev. Econ. Stud. rdae048 (forthcoming).

Papoutsi, Mellina, Piazzesi, Monika, Schneider, Martin, 2021. How unconventional is green monetary policy?. Working Paper, European Central Bank and Stanford University.

Pastor, Lubos, Stambaugh, Robert F., Taylor, Lucian, 2021. Sustainable investing in equilibrium. J. Financ. Econ. 142 (2), 550–571.

Pedersen, Lasse Heje, Fitzgibbons, Shaun, Pomorski, Lukasz, 2021. Responsible investing: The ESG-efficient frontier. J. Financ. Econ. 142 (2), 572–597.

Piccolo, Alessio, Schneemeier, Jan, Bisceglia, Michele, 2022. Externalities of responsible investments. Available at SSRN 4183855.

Rennert, Kevin, Errickson, Frank, Prest, Brian C., Rennels, Lisa, Newell, Richard G., Pizer, William, Kingdon, Cora, Wingenroth, Jordan, Cooke, Roger, Parthum, Bryan, et al., 2022. Comprehensive evidence implies a higher social cost of CO2. Nature 610 (7933), 687–692.

Riedl, Arno, Smeets, Paul, 2017. Why do investors hold socially responsible mutual funds? J. Finance 72 (6), 2505–2550.

Tirole, Jean, 2012. Some political economy of global warming. Econ. Energy Environ. Policy 1 (1), 121–132.

Tirole, Jean, 2023. Socially responsible agencies. Compet. Law Policy Debate 7 (4), 171–177.

Xu, Qiping, Kim, Taehyun, 2022. The limits of limited liability: Evidence from industrial pollution. Rev. Financ. Stud. 35 (2), 576–635.