Counterproductive Sustainable Investing: The Impact Elasticity of Brown and Green Firms *

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October 2024

Abstract

We develop a new measure of impact elasticity: the change in a firm's environmental impact due to a change in its cost of capital. We find that reducing green firms' financing costs leads to minimal impact changes, while increasing brown firms' financing costs causes significant negative impact changes. Thus, sustainable investing strategies that shift capital from brown to green firms contain a counterproductive channel that makes brown firms more brown without making green firms more green. A mistaken focus on *percentage* reductions in emissions rewards already-green firms for trivial reductions in emissions and gives brown firms weak incentives to improve.

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Conflict-of-interest disclosure statement

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I have nothing to disclose

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I have nothing to disclose

A wise man gets more use from his enemies than a fool from his friends. -Baltasar Gracian

I. Introduction

Sustainable investing has exploded in popularity, with $30 trillion in global assets in 2022, expected to grow to $40 trillion by 2030.[1] While a variety of tactics have been employed, the dominant sustainable investing strategy involves making investments in firms that are perceived to be “green” (positive environmental impact) and avoiding investments in firms that are perceived to be “brown” (negative environmental impact).[2] To the extent that sustainable investing changes firm financing conditions, it rewards green firms by lowering their cost of capital and punishes brown firms by raising their cost of capital. The effectiveness of this type of strategy depends critically on how firms alter their behavior in response to changing financing conditions. In this paper, we develop a new measure of “impact elasticity,” defined as the change in the environmental impact of a company due to a change in its cost of capital. Without knowing the impact elasticities of green and brown firms, it is unclear which and how firms should be targeted by sustainable investors.

This paper shows that the dominant sustainable investing strategy of shifting capital from brown to green firms involves an overlooked counterproductive channel: raising the cost of capital for brown firms and lowering it for green firms makes brown firms more brown without making green firms more green. We show empirically that firms that are considered green based on their low greenhouse gas emissions per unit of output have little scope for improvement in their impact. In contrast, brown firms exhibit large negative impact elasticities—they become substantially less brown in response to easier access to capital and more brown if pushed toward financial distress. Furthermore, we show that the dominant sustainable investing strategy has provided weak financial incentives for brown firms to become more green. Due to a mistaken focus on *percentage* changes in emissions, sustainable investors primarily reward green firms for economically trivial reductions in their already low emissions. Brown firms are substantially underweighted by sustainable investors, even if the brown firms substantially reduce emissions or are relatively green within their industries.

[1] See https://www.bloomberg.com/professional/insights/sustainable-finance/esg-aum-set-to-top-40-trillion-by-2030-anchor-capital-markets. We use “sustainable investing” as an umbrella term encompassing strategies aimed at improving firms’ environmental impact on society. Commonly used terms for such investments are green investing, socially responsible investments (SRI), environmental, social and governance (ESG) investing, ethical investing, and corporate social responsibility (CSR) investing, amongst others.

[2] Examples of the dominant investing strategy include screening, where brown firms are excluded, as well as ESG integration, where sustainability metrics are used in portfolio construction leading to an overweight in green firms and underweight in brown firms. Estimates indicate that the majority of capital committed to sustainability-related funds follow screening or integration strategies, rather than impact, engagement, or transition strategies. See Hong and Shore (2023) or https://www.gsi-alliance.org/wp-content/uploads/2023/12/GSIA-Report-2022.pdf.

Recent empirical research suggests that investors with climate-related concerns have already changed the cost of capital for brown and green firms (see, e.g., Chava (2014), van der Beck (2021), Kacperczyk and Peydró (2022), Pástor et al. (2022), Aron-Dine et al. (2023), Green and Vallee (2022), Hsu et al. (2023), Gormsen et al. (2023), and Eskildsen et al. (2024)), though this conclusion remains contentious given the possibility of offsetting flows (Teoh et al. (1999), Berk and van Binsbergen (2021)). We do not take a stance on the extent to which sustainable investing has already altered firms' cost of capital. Instead, we highlight the importance of considering the consequences if the movement succeeds in doing so. Our findings suggest that creating a disparity in the cost of capital between brown and green firms induces counterproductive effects operating through firms' impact elasticities. While there are countervailing forces that could mitigate this effect, it is essential to consider the impact elasticity channel which has been overlooked in popular discussions and academic models.

A simple case study may help illustrate the intuition of our paper. Travelers is an insurance firm in the S&P 500 that looks spectacular on environmental, social, and governance (ESG) metrics. Travelers widely advertises its low greenhouse gas emissions. In 2021, it emitted 33,477 metric tons of carbon, about 1 ton per million dollars of revenue. At the opposite extreme lies Martin Marietta Materials, another S&P 500 firm that supplies heavy building materials. Among ESG rating providers, Martin Marietta is generally considered poor. In 2021, it emitted approximately 5.1 million tons of carbon, corresponding to roughly 1,000 tons per million dollars of revenue. Relative to Travelers, Martin Marietta has 1,000 times as much emissions intensity, measured as emissions scaled by revenue.[3]

The most common sustainable investing strategy dictates that investors should invest in Travelers and avoid Martin Marietta. With that said, if money flows toward Travelers allowing further investments in green projects at subsidized rates, where would it go? If Travelers cut emissions by 100%, it would be equivalent to Martin Marietta cutting its emissions by a mere 0.1%. As an insurance firm, Travelers is also unlikely to develop new green technology that could be adopted by other firms or to manufacture building materials in a manner more environmentally friendly than Martin Marietta currently does. On the other hand, Martin Marietta has the capability of becoming much more green or brown. While the company emits a large amount of carbon, it does so after having made costly investments in new clean production methods to cut its emissions per ton of cement from 0.84 in 2016 to 0.77 in 2019. Conversely, if the market forced Martin Marietta to worry about its short-term survival,

[3]See https://sustainability.travelers.com/iw-documents/sustainability/Travelers_ESGAnalystData2021.pdf and https://mcdn.martinmarietta.com/assets/sustainability/flip/sustainability2021-f/index.html.

the company could double down on its existing brown projects which deliver more front-loaded cash flows. Simply reversing its efficiencies per dollar since 2016 would result in an increase in emissions of approximately one million tons, equal to 30 times Travelers' annual level of emissions.

In our empirical analysis, we show that the intuition of this example is representative of the broader data. We measure firm environmental impact using greenhouse gas emissions. The importance of emissions for sustainable investors is reflected in recent SEC communications concerning the mandatory disclosure of emissions in the holdings of funds that consider environmental factors.[4] Indeed, a recent cover story in *The Economist* argued that emissions should be the sole focus of sustainable investors.[5] We measure firm emissions as raw emissions (scope 1 and scope 2) scaled by firm output. This measure is commonly used by sustainable investors and regulators.[6] It is comparable across firm sizes and captures the trade-off between emissions and output.

We begin by showing that brown firms have much higher levels of emissions than similarly-sized green firms. We divide firms into quintiles by their emissions in the previous year, with quintiles 1 and 5 representing brown and green firms, respectively. The average brown firm has 261 times as much emissions as the average green firm, suggesting that brown firms have much greater scope to meaningfully change their environmental impact. The large scale differences in emissions across brown and green firms also imply that percentage changes in firm emissions can be a misleading metric, as green firms may exhibit large percentage but economically trivial changes in their emissions.

Next, we examine the impact elasticity of green and brown firms. To obtain sufficient statistical power, we consider a broad class of shocks to firms' cost of capital without restricting our attention to changes in financing costs due to sustainable investing. The underlying assumption is that, if the dominant sustainable investing strategy succeeds in altering firms' financing costs, firms would react in a similar fashion as they react to other changes in their financing costs. We explore potential violations of this assumption later in this paper.

Across a variety of tests, we find that brown firms have large negative impact elasticities, while green firms have impact elasticities close to zero. First, brown firms show greater reductions in their

[4]"ESG-focused funds that consider environmental factors... would be required to disclose the carbon footprint and the weighted average carbon intensity of their portfolio." https://www.sec.gov/files/ia-6034-fact-sheet.pdf

[5]The article states, "The environment is an all-encompassing term, including biodiversity, water scarcity and so on. By far the most significant danger is from emissions, particularly those generated by carbon-belching industries. Put simply, the e should stand not for environmental factors, but for emissions alone." https://www.economist.com/leaders/2022/07/21/esg-should-be-boiled-down-to-one-simple-measure-emissions

[6]E.g., the Paris Aligned Benchmarks and ESMA regulations on ESG and sustainable fund names focus on emissions intensity. https://www.esma.europa.eu/sites/default/files/2024-05/ESMA34-472-440_Final_Report_Guidelines_on_funds_names.pdf

emissions after improvements in their financial performance. Stronger past returns ease financial constraints and lower the firm's cost of capital. To show that these patterns are not driven by reverse causality, we examine the relation between firm emissions and the firm's industry return, calculated excluding the focal firm. The intuition is that industry return shocks strongly affect firm financing costs, but individual firm choices of emissions should not affect industry returns. We find that brown firms are much more elastic to industry shocks than green firms. Firm investment choices can take time to fully manifest as changes in emissions, so we also examine longer horizons. We find that changes in brown firm emissions intensity are persistent and larger at longer horizons; they do not appear to be driven by short-term fluctuations in output or stickiness in raw emissions. We also show that brown firms react to financial distress by increasing their emissions, whereas green firms exhibit a much smaller response.

Next, we focus on identifying and quantifying a financial effect operating through the cost of capital, as distinct from potentially correlated productivity shocks. We use three proxies for shocks to the cost of capital to isolate a financial channel. First, we use direct measures of the firm's implied cost of capital (ICC). The change in the ICC represents the portion of past financial returns due to changes in the cost of capital, not changes in expected cash flows. Second, we use the interaction between the firm's ex ante degree of financial distress (measured by interest coverage in the bottom decile) and an industry productivity shock. The intuition is that firms with dangerously high leverage should experience a greater reduction in their cost of capital following an industry-level productivity shock. Third, we use the interaction between whether a firm is an ex ante high dividend payer and a measure of aggregate demand for dividend payments, following techniques introduced in Hartzmark and Solomon (2013, 2019). This interaction derives identification from the fact that firms that offer a high dividend yield experience an additional reduction in their cost of capital thanks to high dividend demand after controlling for macroeconomic effects. Across all three tests, we find that brown firms exhibit large negative impact elasticities, whereas green firm elasticities are close to zero.

Our findings of a negative impact elasticity for brown firms and a close-to-zero one for green firms are consistent with basic corporate finance theory. We consider a stylized model in which a brown firm is initially indifferent between a dark-brown project (e.g., continue high-pollution production or cut corners on pollution abatement) and a light-brown project (e.g., shift to cleaner production). Because the light-brown project entails new production methods, it requires costly investment in new capital and delivers back-loaded cash flows compared to the dark-brown project. Financial distress or an increase in the cost of capital will make short-term cash flows more attractive. Intuitively, an increase in the cost of capital is equivalent to a higher discount rate for future cashflows. Thus, higher cost of capital causes the brown firm to prefer the dark-brown project, leading to a negative impact elasticity.[7] An increase in the cost of capital will similarly cause green firms to prefer short-term cash flows. However, green firms operate in industries (e.g., insurance for Travelers) where they cannot generate substantial environmental externalities regardless of which projects are chosen, leading green firms to have impact elasticities close to zero.

Next, we investigate whether sustainable investors provide incentives for brown firms to become more green. Specifically, brown firms may choose to become more green if sustainable investors reward them by lowering their cost of capital or increasing their share price (e.g., Heinkel et al. (2001) and Davies and Van Wesep (2018)). Although plausible in theory, we show that these incentives have not been provided in practice. Sustainable investment funds do reward firms that improve their impact, consistent with best practices modeled by Oehmke and Opp (2022) and Edmans et al. (2022). However, changes in impact are measured in the wrong units. Sustainable investors appear to suffer from a proportional thinking bias (Tversky and Kahneman (1981), Shue and Townsend (2021)) in which they reward firms with large *percentage* reductions in emissions rather than large *level* reductions in emissions. Influential ESG environmental ratings and governmental regulations similarly reward percentage reductions in emissions rather than level reductions in emissions.[8]

The large scale differences in levels of emissions across firms make this distinction important. A 100% reduction in emissions by a green firm is far less economically meaningful than a 1% reduction by a similarly-sized brown firm. The focus on percentage reductions is mirrored by popular net-zero emissions targets (see Hong et al. (2023)), which require large firm-level percentage reductions in emissions. Perhaps most surprisingly, we find that sustainable investors reward green firms much more than brown firms for the same percentage reduction in emissions. This mistake is consistent with an affect heuristic (e.g., Slovic et al., 2007), in which sustainable investors naively disassociate from brown firms they dislike.[9]

[7]This intuition is similar to the model in Lanteri and Rampini (2023), which shows that financial constraints cause firms to choose dirty over clean technology. Related evidence from Thomas et al. (2022) shows that firms cut pollution abatement efforts to meet earnings targets. Gilje et al. (2020) show that financial distress causes firms in the oil and gas industry to pull forward drilling in existing oil wells at the expense of long-run project returns. Other research has shown that financial constraints and a high cost of capital cause firms to prefer investment in older capital (Eisfeldt and Rampini, 2007; Ma et al., 2022) which may be less environmentally friendly.

[8]For example, the Paris Aligned Benchmarks are based on firm level percentage changes in emissions intensity, see SFPDR Article 8 and 9.

[9]For example, the Carbon Underground 200 list encourages investors to divest from firms that own fossil fuel assets,

In the last section, we evaluate how our impact elasticity channel interacts with different sustainability goals. We preface this section by noting that we consider our paper's main contribution to be the introduction of a counterproductive channel within the dominant sustainable investing strategy based on the negative impact elasticity of brown firms. This channel has been underappreciated: it is not accounted for in existing models of how sustainable investing influences firm behavior and was not widely discussed in the media prior to the release of the working paper of this study.[10] However, the existence of this counterproductive channel does not necessarily imply that the overall impact of the dominant sustainable investing strategy is counterproductive. The net effect of this strategy depends on the strength of potential countervailing forces and investors' specific environmental objectives. Nevertheless, any investor pursuing sustainability goals should take our channel into account.

When assessing the effectiveness of sustainable investing, it is important to recognize that sustainable investors may have varying objectives (Starks, 2023; Pedersen et al., 2021). Setting aside purely pecuniary motives such as maximizing returns adjusted for climate-related risk, environmental objectives can be broadly categorized as: (1) firm-level green transition: switching to greener production to reduce firm-level emissions intensity; (2) de-growth: reducing emissions without concern for reductions in output; and (3) economy-wide green transition: lowering global emissions intensity. Methods to achieve this last goal could include firm-level green transition as well as shrinking brown output while growing green output to replace it.[11]

The counterproductive impact elasticity channel is most straightforward to evaluate in relation to the first two goals. For firm-level green transition, investors need to counteract our channel by providing sufficient incentives for brown firms to become green. As discussed above, existing theoretical work focuses on the promise of a lower future cost of capital as an incentive for brown firms to transition. Our contribution lies in showing that incentive models should also consider the impact elasticity channel, where increasing the cost of capital can directly lead to brown firms becoming more brown. Furthermore, we demonstrate that these incentive effects have been largely absent in practice,

regardless of how the assets are operated. Related evidence from Hartzmark and Sussman (2019), Heeb et al. (2022), Bauer et al. (2021), Baker et al. (2022), and Yang and Yasuda (2023) suggest that sustainable investors are motivated by affect and social signaling, and exhibit willingness-to-pay that is not strongly related to the magnitude of impact.

[10] Industry and media discussions have generally characterized our channel as novel, e.g., https://www.bii.co.uk/en/news-insight/research/counterproductive-sustainable-investing/vbg and https://www.bloomberg.com/opinion/articles/2023-03-22/silicon-valley-bank-ran-out-of-money.

[11] Proponents of the economy-wide transition aim to reduce global emissions without reducing global output, and some even aspire to increase output. As a recent New York Times article summarized, "If there is a dominant paradigm ... it is called green growth—whose adherents populate European governments, the Organization for Economic Cooperation and Development, the World Bank and the White House—the global economy can both continue growing and defuse the threat of a warming planet." https://www.nytimes.com/2021/09/16/opinion/degrowth-cllimate-change.html

as sustainable investors have primarily rewarded already-green firms for large percentage reductions in emissions. However, sustainable investors could enhance their impact by engaging with brown firms (Broccardo et al., 2020) or directing capital toward firms that achieve meaningful reductions in their emissions. Notably, some "transition" investment funds adopt this approach by investing in high-emissions industries and allocating capital to firms within these industries that are credibly reducing emissions.

Regarding the de-growth objective, where investors aim to reduce emissions regardless of output losses, it is theoretically obvious that a sufficiently large increase in the cost of capital will cause any targeted firm or industry to shrink and eventually die, leading to elimination of its emissions. We show that brown firms increase their emissions per unit of output as their cost of capital rises, but it is still the case that raw emissions (unscaled by output) shrinks after sufficiently large increases in the cost of capital. Thus, raising the cost of capital for brown firms while lowering it for green firms is not counterproductive relative to a de-growth goal. However, even a de-growth investor should consider our estimates of the impact elasticity as growth in emissions intensity will affect the pace of raw emissions reductions.

The significant welfare loss associated with de-growth could potentially be avoided through an economy-wide transition that shrinks brown firms and grows green firms to offset the loss in output, thereby reducing global emissions intensity. In practice, many divestment strategies seem to implicitly have such a mechanism in mind. Some academic models, such as Pástor et al. (2021), Berk and van Binsbergen (2021), and Edmans et al. (2022), also contain such a mechanism, conditional on sustainable investors successfully creating a wedge in the cost of capital between green and brown firms. Our findings suggest that a strategy aimed at an economy-wide transition goal, whether in practice or in theory, could be improved by incorporating two important considerations. First, existing models assume that an increase in the cost of capital causes brown output to shrink without corresponding increases in emissions per unit of output. We quantify this opposing force. Second, given that green and brown outputs are generally imperfect substitutes, across- versus within-industry portfolio shares in sustainable strategies matter. Brown firms operate in industries such as energy, transportation, manufacturing, and agriculture, which lack practical alternatives from green industries such as healthcare, finance, and insurance. In the absence of perfect green substitutes for entire brown industries, sustainable investors could contribute to the greening of a brown industry by investing in the firms within that industry that are relatively greener or transitioning toward lower emissions. Importantly, this would not involve underweighting brown industries as a whole or underweighting the greenest subset of firms within brown industries.

In practice, we find that sustainable investors overweight green industries and underweight brown industries. Even the greenest firms within brown industries are underweighted relative to their market capitalization. To illustrate how this could hinder an economy-wide transition goal, consider the high-emissions agriculture industry. If sustainable investors deprive it of capital, less food will be produced. Growth in green industries such as insurance would not fully offset this loss because their products are not perfect substitutes.

While our findings suggest that divesting from entire brown industries in favor of green ones may not be optimal for achieving an economy-wide transition, determining an optimal strategy is a complex problem that is beyond the scope of this paper. Finding the right balance between shrinking brown firms and incentivizing their improvement depends on the substitutability of output across brown and green firms and the elasticities of output and emissions relative to capital costs. Nevertheless, our findings on impact elasticities provide an important component necessary for developing an optimal strategy for an economy-wide transition.

Finally, we acknowledge that the dominant sustainable investing strategy may have long-term consequences beyond those captured in our emissions analysis. For instance, sustainable investors might aim to incentivize future green R&D. While providing long-term incentives for green R&D could be effective, it does not represent the majority of sustainable investing in practice.[12] Research by Cohen et al. (2020) has also pointed out that brown energy firms, which produce the most highly cited green patents, are often excluded from sustainable portfolios.

Our findings align with evidence in Hong et al. (2012) and Xu and Kim (2022) showing that firms do more social and environmental good when they are financially unconstrained. We differ by showing that the magnitude of the relationship between environmental impact and cost of capital varies by whether the firm is brown or green, which has important implications for the effectiveness of the dominant sustainable investing strategy. Our findings also relate to research highlighting issues in the evaluation of sustainability (e.g., Duchin et al. (2022), Gibson Brandon et al. (2021), and Berg et al. (2022)). We show that ESG ratings reflect percentage changes in emissions, favoring green firms with little room for real improvement. Heath et al. (2021) find that sustainable funds buy firms with green

[12]For example, BlackRock and Vanguard categorize financial investments aimed at promoting green innovation as "impact" strategies (see also Barber et al. (2021) for a discussion of targeted impact funds). Although growing in popularity, these strategies are marketed as risky and distinct from mainstream sustainable investing products. Targeted "impact" funds make up only 0.04% of BlackRock's $50 billion and 1.2% of Vanguard's $18 billion in assets in sustainable strategies.

characteristics, but these characteristics do not improve after purchase. We offer a complementary explanation—green firms have limited room for improvement. Our findings suggest that sustainable investing flows and engagement would be more effective if directed toward brown firms.[13]

Finally, while our focus is on sustainable investors aiming to improve firms' environmental impact, our findings also have implications for investors, including those with purely pecuniary motives, who demand compensation for climate transition risk (e.g., Acharya et al. (2023), Ilhan et al. (2023), Jung et al. (2023), Bolton and Kacperczyk (2021), Alekseev et al. (2022)). If investors demand higher expected returns for brown firms because they believe brown firms face higher transition risk, brown firms will be subject to a higher cost of capital. Given their negative impact elasticity, the pricing of transition risk could ironically cause brown firms to become more brown.

II. Framework: Impact Elasticity

We define impact elasticity as the firm's change in environmental impact in response to a change in its cost of capital:

$$\text{impact elasticity} \equiv \frac{\partial \text{ environmental impact}}{\partial \text{ cost of capital}}.$$

Our primary contribution is to document heterogeneity in the impact elasticity as a function of the firm's level of green. We measure firm impact as greenhouse gas emissions per unit of output. Greater emissions implies a more negative firm environmental impact. Therefore, an increase in emissions following a positive shock to a firm's cost of capital translates to a negative impact elasticity.

To obtain sufficient statistical power, we examine a broad class of shocks to firms' cost of capital without restricting our attention to changes in financing costs that are due to sustainable investing. The underlying assumption is that, if the dominant sustainable investing strategy succeeds in altering firm's financing costs, firms would react in a similar fashion as they react to other changes in their financing costs.

Four important considerations apply to our measure of the impact elasticity. First, changes in the cost of capital due to sustainable investing may differ from other shocks to the cost of capital because sustainable investing could incentivize firms to become more green. In other words, firms could be motivated to become green by the inverse of the impact elasticity: the future change in a firm's cost of capital in response to a change in the firm's environmental impact. For example, a

[13]While engagement is less common, there are notable examples, such as Engine No. 1, which successfully engaged with Exxon Mobil to alter its environmental impact (see also Broccardo et al. (2020), Krueger et al. (2020), and Akey and Appel (2019)). Other alternatives to the dominant sustainable investing strategy include regulation and carbon pricing (e.g., Pedersen (2023), Martinsson et al. (2023)).

brown firm may choose to pursue green investment projects because it anticipates that sustainable investors will reward its positive change in impact by lowering its cost of capital in the future. While this incentive channel is promising in theory, we will present empirical evidence that the dominant sustainable investing strategy provided weak financial incentives for brown firms in practice. Instead, sustainable investors and ESG ratings primarily reward firms that are already green for economically trivial but large percentage reductions in their emissions.

Second, we follow standard practice and measure firm environmental impact as a firm's emissions intensity, equal to raw emissions scaled by output. This scaled measure facilitates comparisons across firms of different sizes and matches the sustainable investing practitioner's literature, which often refers to the explicit goal of reducing firm emissions intensity. Such a "transition" goal implicitly recognizes a trade-off between emissions and production. We note that it is theoretically obvious that a sufficiently large increase in the cost of capital will cause any targeted firm or industry to shrink and eventually die, leading to eventual elimination of its emissions.[14] However, for investors who care about both emissions and production, we show that the dominant impact investing strategy contains a counterproductive channel that makes brown firms more brown per unit of production without making green firms meaningfully more green per unit of production.

Third, we measure the impact elasticity as the level change in a firm's emissions intensity for a unit change in its cost of capital. This differs from the standard convention in economics of measuring elasticities in terms of percentage changes. We focus on level changes on purpose, because brown and green firms start with vastly different levels of emissions. As we will show in the next section, a 100% reduction in emissions by a green firm has much less real environment impact than a 1% reduction in emissions by a similarly-sized brown firm.

Fourth, impact elasticity is a measure of firm-level changes in impact in response to firm-level changes in the cost of capital. In theory, sustainable investors could attempt to change the cost of capital at the project level instead of the firm level. This could be implemented through project-specific financing, such as subsidized financing for projects that benefit the environment. It could also be implemented by demanding a firm-level return that is a weighted average of the returns that investors demand for the firm's green and brown projects, where the weights are the sizes of the

[14]Because it is theoretically obvious that a large increase in the cost of capital will reduce or eliminate output, and consequently emissions, we do not focus on the elasticity of raw emissions (unscaled by output) to the cost of capital. Thus, as we will discuss in Section IV.D, the dominant sustainable investing strategy is not counterproductive relative to a "degrowth" objective which seeks to lower emissions irrespective of maintaining output levels, although brown firms' negative impact elasticities will affect the pace of the reductions in unscaled emissions.

various projects. While project-specific green financing exists, the dominant sustainable investing strategy operates at the firm level, through divestment and underweighting of high-polluting firms, raising the cost of capital for all projects (including green ones) conducted by these brown firms. As we will show in the discussion of Table 11, the extent to which sustainable investors underweight brown firms is insensitive to the brown firm's recent reductions in emissions, consistent with non-project-specific financing for brown firms.[15] Thus, the dominant sustainable investing strategy of investing in green firms and divesting away from brown firms is an example of a firm-level shock to the cost of capital, and its effect would depend on the firm-level impact elasticity.

We also note that standard corporate finance theory implies that firms should assess potential investment projects using a project-specific cost of capital that reflects project-specific risk rather than a firm-wide cost of capital. Our firm-level impact elasticity measure can accommodate a project-specific valuation method from the firm's perspective. As shown in the next subsection, we assume that firm-level changes to the cost of capital due to the dominant sustainable investing strategy shifts the firm's project-specific discount rates equally across all projects.

A. Impact elasticities of brown and green firms

While the primary contribution of this paper is empirical, we present a simple stylized model to illustrate one, non-exclusive, reason why brown and green firms might differ in their impact elasticities. The key mechanism of our model is the generally high upfront costs and long payback periods of green projects compared to brown. To motivate these choices, we begin by documenting this view being espoused by market participants and implied by related findings in academic research. A variety of market participants attribute recent declines in green investment to higher interest rates (which feed into higher cost of capital). Similarly, academic research has shown that financial constraints (which likewise feed into higher cost of capital) limit investments in newer greener equipment.

An important recent example concerns Ørsted A/S, the world's largest developer of wind power and a brown firm in the process of transitioning toward cleaner production.[16] In late 2023, Ørsted suddenly canceled two large ongoing wind projects in New Jersey, triggering a write down of $4 billion.[17] Ørsted's head of US operations attributed the decision to unexpected shifts in the cost of

[15] This can be viewed as sustainable investors investing in a manner that violates the law of one price, because they apply a higher cost of capital to all projects pursued by brown firms, even when those projects are green. Empirical evidence of the violation of the law of one price can be seen in Duchin et al. (2022), which shows that brown firms achieve higher total valuation by separating brown and green assets into different firms.

[16] Ørsted is formerly known as DONG, standing for Dansk Olie og Naturgas A/S which means Denmark oil and gas.

[17] https://www.eenews.net/articles/maybe-we-were-too-optimistic-orsted-executive-talks-

capital brought on by the rise in interest rates, noting, "The wind is free ... but interest rates are the fuel of renewables and for offshore wind, because it is so capital intensive." He elaborated, "For every 100 basis points of increase in our weighted average cost of capital [WACC], the offshore wind power prices somewhere between $16 and $20 higher."[18]

The financial press describes a general version of the Ørsted story. Matt Levine, writing for Bloomberg, argues (after discussing findings in an earlier draft of this paper) that "ESG was itself a low-interest-rates phenomenon" due to the long duration of green projects.[19] As he explains it, "When interest rates are zero, discount rates are low, and in some sense what happens in 2050 is as important as what happens tomorrow. And then interest rates went up and now companies just want profits next quarter and care less about what happens in 2050, and so ESG has become a lot less popular."[20]

Government agencies make a similar argument. For example, the International Energy Agency in a report funded by the European Union states that because green energy investments "have relatively high upfront investment costs and lower operating and fuel expenditures over time, ... the WACC can account for 20-50% of the levelised cost of electricity of utility-scale solar PV projects."[21] The article also notes that "the cost of capital for cement, chemicals and steel companies has broadly fallen in recent years, creating an opportunity to finance clean energy investments more affordably."

Even proponents of sustainable investing warn that higher interest rates could slow the green transition. Green Central Banking writes that "higher interest rates will be particularly detrimental for green transition investments, given that those projects typically have high upfront capital costs, even though they generate operational savings in the long term."[22] Positive Money writes that "rising interest rates do not affect all sectors in the same way, and renewable energy projects bear a more significant brunt. This is mainly due to the fact that these projects require large upfront investments, making them more vulnerable to fluctuations in capital costs."[23]

Academic research has likewise argued theoretically that financial constraints, which imply an elevated cost of capital for firms, cause firms to prefer projects with front-loaded cash flows and in-

about-offshore-wind-struggles/

[18] This is not ex-post rationalization, and was discussed and understood ex ante by the management team at Ørsted. For example, in their 2020 annual report, Ørsted listed interest rates as the top business risk. They stated that "funding future wind farms... is exposed to interest rate risks as wind assets are more attractive to buyers when interest rates are low compared to other financial assets with similar risk profiles."

[19] https://www.bloomberg.com/opinion/articles/2024-01-18/coinbase-trades-beanie-babies

[20] https://www.bloomberg.com/opinion/articles/2024-02-14/lyft-had-a-typo

[21] https://www.iea.org/articles/the-cost-of-capital-in-clean-energy-transitions

[22] https://greencentralbanking.com/2023/08/01/dual-interest-rates-green-investment-inflation/

[23] https://positivemoney.org/update/high-interest-rates-green-transition/

vestments in older and less efficient equipment (Bolton et al. (2019); Lanteri and Rampini (2023)). Empirically, Ma et al. (2022) show that young firms buy older equipment compared to mature firms because young firms are financially constrained. Examining a different form of long-lived investment, Ma and Zimmermann (2023) find that higher interest rates cause declines in aggregate R&D and venture capital investment. While the focus of these studies is not on green investment, their results suggest that green investment will react similarly because green investment and green efficiency gains in production are associated with newer and more innovative technology (Avenyo and Tregenna (2022)).

With these motivations in mind, we now turn to our stylized model. Consider a firm evaluating various investment opportunities. Each investment project can be approximated as a perpetuity that generates free cash flow C next year, growing at a rate g. The present value of the investment opportunity is:

$$PV = \frac{C}{r-g}.$$

It is straightforward to show that the value of the investment opportunity decreases in the cost of capital r, and the rate of decrease is greater for higher growth rates g:

$$\frac{\partial PV}{\partial r} < 0 \quad \text{and} \quad \frac{\partial^2 PV}{\partial r \partial g} < 0.$$

The underlying intuition is that an increase in the cost of capital is equivalent to an increase in the discount rate. A higher discount rate implies that cash in the present becomes more attractive relative to cash in the future. An increase in the discount rate makes all investment projects less attractive, but more so for investments with back-loaded cash flows, i.e., projects with higher growth rates.

Suppose that brown firms can choose between two investment opportunities: B or G, with the brown project leading to higher emissions than the green project. B could represent continuing or expanding existing brown production, cutting corners on meeting environmental regulatory standards, or reducing pollution abatement activities. G could represent investing in new pollution abatement technologies, doing more to meet or exceed environmental regulations, investing in new energy efficient and environmentally friendly equipment, or growing the portion of the business that is relatively more green. Because G involves the adoption of new capital, it has a relatively higher upfront cost and relatively more backloaded cash flows compared to B.[24] Thus, we assume $C^B > C^G$ and $g^B < g^G$.

[24] A brown firm can choose a brown project with negative or zero upfront costs by reducing pollution abate-

We allow the projects to differ in risk, corresponding to project-specific costs of capital r^B and r^G.

Suppose that, in the absence of sustainable investing, projects B and G have the same present value, so the firm is indifferent between them:

$$\frac{C^B}{r^B - g^B} = \frac{C^G}{r^G - g^G}.$$

Suppose that there is an increase $\delta > 0$ in the cost of capital for all investments by the brown firm, so the project-specific costs of capital for the brown and green projects are now $r^B + \delta$ and $r^G + \delta$, respectively. The fact that $\frac{\partial^2 PV}{\partial r \partial g} < 0$ implies that the brown project will now be strictly preferred:

$$\frac{C^B}{r^B + \delta - g^B} > \frac{C^G}{r^G + \delta - g^G}.$$

In other words, an increase in the cost of capital will make brown projects appear more attractive relative to green projects, leading to a negative impact elasticity.

In contrast, green firms operate in lines of business where they cannot generate large environmental externalities regardless of which investments are chosen. In our data, green firms are most likely to be in the industries of insurance, healthcare, and financial services. While a change in the cost of capital may lead green firms to prefer investment projects with more or less backloaded cash flows, the project's environmental impact is always negligible, leading to impact elasticities close to zero.

In the simple framework described in this section, we illustrate one *non-exclusive* reason why brown and green firms might differ in their impact elasticities. The framework above shows that the presence of financial constraints is not necessary to generate a negative impact elasticity for brown firms—an increase in the cost of capital directly leads the firm to prefer projects with more front-loaded cash flows. However, financial constraints could be an important channel that amplifies the negative impact elasticities of brown firms. A basic result from corporate finance theory is that financially constrained firms suffer from the debt overhang problem, in which they underinvest in positive NPV projects that require upfront investment. To the extent that raising the cost of capital for brown firms increases their financial constraints, debt overhang would cause brown firms to underinvest in green

ment activities or continuing existing brown projection, respectively. In contrast, transitioning to green production requires new investment that can be associated with long payback periods. For examples of how a brown firm can invest to reduce emissions intensity, see https://www.scientificamerican.com/article/solving-cements-massive-carbon-problem/. For estimates of abatement costs, see https://www.mckinsey.com/capabilities/operations/our-insights/net-zero-or-bust-beating-the-abatement-cost-curve-for-growth. For estimates of cash flows from carbon capture investment, see https://www.clifi.com/research-store/carbon-capture-and-storage-ccs-are-we-there-yetanalyzing-the-target-level-of-eua-prices-to-incentivize-ccs-adoption-in-europe.

projects because green projects tend to require up-front investment in new equipment.[25] For detailed models along these lines, see Lanteri and Rampini (2023), which shows that financially constrained firms choose to adopt dirtier technology than unconstrained firms, as well as Bolton et al. (2019), which shows that financial constraints can lead firms to prefer projects with front-loaded cash flows. Ma et al. (2022) provides direct empirical evidence that young firms buy old equipment because they are financially constrained.

III. Data

Our data sample covers the years 2002 to 2020. Data on greenhouse gas (GHG) emissions comes from S&P Global Trucost. GHG emissions are gas emissions that trap heat in the atmosphere and contribute to the risk of global climate change. The primary greenhouse gases emitted in the U.S. in 2020 are carbon dioxide (79%), methane (11%), nitrous oxide (7%), and fluorinated gases (3%) such as hydrofluorocarbons and perfluorocarbons.[26] We use data on scope 1 and 2 emissions. Scope 1 emissions are direct emissions from equipment that the firm owns. Scope 2 emissions are the indirect emissions associated with the purchase of electricity, steam, and heating, so they occur at a location not controlled by the firm, but are directly tied to firm actions. We present our main results for total scope 1 and scope 2 emissions. We do not study scope 3 emissions (all other indirect emissions that occur in the firm's upstream and downstream activities), because reporting of scope 3 emissions is known to be noisy and incomplete, involves double-counting (the scope 3 emissions of a customer firm could be the scope 1 emissions of a supplier firm), and because sustainable investing strategies primarily screen using scope 1 and 2 emissions.

Trucost coverage of firm emissions are based on firm self-reported disclosures combined with Trucost's proprietary model-based estimates of emissions. While there is likely noise in the model estimates, these are the same data commonly used by sustainable investors for portfolio construction and to measure progress in firm emissions behavior. In supplementary robustness results presented in the Appendix, we present qualitatively similar results using data from the subset of firms that directly self report emissions data. We also supplement Trucost's firm-year-level data with industry-year emissions intensity data generously shared by LaPlue and Erickson (2020), which are based on emissions data collected by the Environmental Protection Agency (EPA).

[25] Financial constraints can lead to underinvestment in positive NPV green projects. If green projects instead have negative NPV under the current cost of capital, a reduction in the firm's cost of capital could shift the project's NPV into the positive range, leading to an increase in green investment. This would also correspond to a negative impact elasticity for brown firms.

[26] See https://www.epa.gov/ghgemissions/overview-greenhouse-gases.

Accounting data on firm financial and real performance, leverage, earnings, and revenue are obtained from the Compustat database. Firm returns come from CRSP and are measured as the logarithm of one plus the fiscal year total return of the firm, adjusted for splits and dividends.[27] Data relating to ESG ratings come from MSCI ESG Ratings (the data was previously known as the Riskmetrics KLD Ratings).

A natural reason for firms to vary in their emissions is differences in size. It is not obvious that a larger firm should be considered less green because it emits more greenhouse gases due to its larger scale, particular for an investor with a green transition goal. Therefore, we follow a convention commonly used by sustainable investment funds, ESG rating companies, and previous studies, and focus on emissions intensity, defined as scope 1 and scope 2 emissions scaled by revenue. Hereafter, we refer to emissions intensity as just "emissions" for brevity, unless otherwise noted. We divide firms into quintiles by their emissions in the previous year, with quintiles 1 and 5 representing brown and green firms, respectively. We classify firms in the middle three quintiles as neutral.

The analysis of the holdings of sustainable investment funds is based on data generously shared by the authors of Cohen et al. (2020). We follow Cohen et al. (2020) and classify funds as sustainable if the fund name contains "ESG" or "green" or if the fund is classified as a sustainable investment fund by either the Forum for Sustainable and Responsible Investment (USSIF) or Charles Schwab. We merge data on sustainable funds with data on monthly holdings by mutual funds from CRSP. For each stock-month, we measure the extent to which it is overweighted by sustainable investment funds relative to the value-weighted market index. For example, if a stock represents 3% of the value of the combined portfolio of all sustainable funds and 2% of the value of the total market portfolio, then we would estimate that sustainable funds overweight the stock by 50%.

Data covering annual firm implied cost of capital (ICC) are generously shared by the authors of Lee et al. (2021). Following the best practices described in Lee et al. (2021), we use the mechanical ICC of Gebhardt et al. (2001) (GLS) as our preferred measure of the ICC. This measure is also similar to those used in previous papers in the ESG literature (e.g., Chava (2014)). As shown in Lee et al. (2021), the estimation of firm-level ICC can be noisy due to the necessity of making assumptions about expected future cash flows and nonunique numerical solutions. To mitigate the problems of noise, we show that our results are robust to using a simple average of four published ICC measures.

Table 1 presents summary statistics of the main variables used in our analysis. The distribution of

[27] The log transformation helps to mitigate the influence of outlier returns. Other adjustments, e.g., winsorising extreme outliers, generally yield similar results.

the variables across the 10th, 50th, and 90th percentile indicate that emissions is right skewed. Total raw emissions (unscaled) in the 90th percentile is nearly 2000 times total raw emissions in the 10th percentile. After scaling by revenue to account for differences in firm size (our preferred measure of emissions), emissions in the 90th percentile is still 155 times as large as in the 10th percentile. The absolute value of annual level changes in emissions is similarly right skewed, with the 90th percentile equal to 442 times the 10th percentile. In contrast, the absolute percentage change in annual emissions is less skewed. However, as we will show, percentage changes in emissions are a poor measure of the true change in firm environmental impact because green firms with low levels of emissions tend to be associated with large percentage changes in their emissions. These summary statistics offer an early indication of our main results: brown firms have the greatest environmental impact and the greatest scope to change their impact.

IV. Results

A. Levels and Changes in firm emissions

We begin our analysis by showing that brown firms have much greater levels of emissions compared to green firms. This suggests that changing the behavior of brown firms is likely to have substantial environmental impact. We also examine year-on-year variability in firm emissions to illustrate why raw changes in emissions intensity is more informative than the more commonly displayed percentage change in emissions intensity.

We divide firms into quintiles based on their level of emissions in each year, with quintile 5 representing firms with the lowest emissions. In subsequent analysis, we refer to firms in quintile 5 as "green," firms in quintile 1 as "brown," and firms in quintiles 2 through 4 as "neutral." In Figure 1 Panel A, which examines the raw level of green house gas emissions (unscaled), the average brown firm releases more than 1,700 times as much emissions as the average green firm. Of course, these differences in emissions across firms could be due to differences in firm size; it would be natural for larger firms to emit more GHG. Therefore, we use emissions scaled by same-year firm revenues as our baseline measure of emissions. In Panel B, we show that, even after scaling by revenues to form quintiles, brown firms release 261 times as much emissions per unit of revenue as green firms in quintile 5. Using both the raw and scaled measures of emissions, neutral firms in quintiles 2 through 4 are associated with emissions levels much closer to that of green firms than of brown firms.

The very large differences in emissions across the five quintiles shown in Figure 1 indicate that any analysis focusing on a firm's annual *percentage* change in emissions is unlikely to be informative. Consider a typical green firm. Even if it doubled or halved its emissions in a single year, its change in behavior would have minimal environmental impact because its baseline level of emissions is several orders of magnitude smaller than the emissions of brown firms of similar size. In contrast, if the average brown firm doubled its emissions, the real environmental impact would be equivalent to the average green firm increasing its emissions by 26,000%.

To illustrate why percentage changes in emissions is a misleading measure, we graph the annual year-on-year variability in firm emissions in Figure 2. In the top left row, we show the annual absolute level change in emissions (scaled by revenue) for brown, neutral, and green firms. We find the average annual variability of emissions by brown firms is 164 times the variability of emissions by green firms. Recall that green firms have an average level of emissions intensity of 5, which means the average annual change in emissions in brown firms is about 35 times the average emissions *level* of green firms. In the top right panel, we weight observations by firm market value as a fraction of market value in each year. We find similar patterns which show that the large gap in variability of emissions between green and brown firms is not driven by small outlier firms.

In the bottom row of Figure 2, we show that differences in variability in emissions across brown and green firms disappear if we measure annual changes in emissions using percentage changes instead of level changes. Green firms have similar or greater percentage variability in their emissions compared to brown firms. We caution that a large percentage change in the emissions of green firms is not economically meaningful, because green firms are associated with levels of emissions several orders of magnitude smaller than the level of emissions for similarly-sized brown firms.

B. Impact elasticity

In this section, we estimate the impact elasticity of green and brown firms by examining how emissions by each type of firm changes following changes to the cost of capital. We begin by using firm and industry financial returns and financial distress measures as proxies for shocks to the cost of capital of firms. Then we present three empirical tests designed to isolate a financial channel, as distinct from shocks to firm productivity.

The dominant sustainable investing strategy seeks to lower the cost of capital for green firms by directing capital toward them and to increase the cost of capital for brown firms by divesting away from them. If green firms react to a lower cost of capital by reducing their emissions (i.e., green firms have a negative impact elasticity), and brown firms react to a higher cost of capital by reducing their emissions (i.e., brown firms have a positive impact elasticity), then we expect that the dominant sustainable investing strategy will cause both brown and green firms to improve their impact on the environment. However, as we will show, the actual impact elasticity of green firms is close to zero and the impact elasticity of brown firms is large and negative. Together, these measures imply that the dominant sustainable investing strategy contains a counterproductive channel that causes brown firms to become more brown without causing green firms to become meaningfully more green.

B.1 Financial returns

We begin by examining the relation between changes in emissions over the next year and a firm's financial performance as measured by its equity returns in the previous year. A positive return in the previous year raises the firm's market valuation and is likely to ease the firm's access to financing, corresponding to a lower cost of capital. Likewise, a negative financial return in the previous year likely corresponds to an increase in the firm's cost of capital. In this and all subsequent analyses, we compare changes in emissions from brown, green, and neutral firms, where these classifications are based on emissions in the previous year. We control for year fixed effects in this and future regressions to account the general time trend of emissions over our sample period. In this analysis and the ones that follow, we deliberately do not control for industry-by-year fixed effects, as our goal is to capture differences in impact elasticities between brown and green firms, including those driven by the fact that brown firms are often concentrated in brown industries. As we will show in Section IV.D, sustainable investors, on average, tend to underweight brown industries, including the greenest firms within those industries.

One limitation of simply looking at the relation between firm emissions and past returns is that any correlation could be driven by reverse causality (e.g., if anticipation of the firm becoming more green causes a change in its share price) or by omitted variables (e.g., if the arrival of an environmentally friendly CEO causes both a shift in green production and share price). To better estimate the causal effect of firm returns on firm emissions, we examine the relation between firm emissions and the firm's industry value-weighted return, calculated excluding the focal firm. The intuition is that the industry return should affect firm-level financial performance, but individual firm choices regarding emissions should not have a strong effect on the industry return calculated excluding the focal firm.

In Table 2, we find that brown firms are significantly more elastic to shocks to firm financial performance than green firms across a variety of specifications. Column 1 shows a large and highly significant negative coefficient on the firm annual return for brown firms indicating that as firm financial performance improves, brown firms reduce their emissions. Symmetrically, the negative coefficient implies that negative performance by brown firms is associated with an increase in emissions. In terms of magnitude, the coefficient of -83.51 implies that a 10% financial return for brown firms is associated with a reduction in emissions of about 8 tons per million dollars of revenue. This *change* in emissions by brown firms due to a modest change in financial returns is greater than the average *level* of emissions for green firms. In contrast, neutral and green firms have close-to-zero and insignificant coefficients on the firm annual return. These results are consistent with brown firms having a large negative impact elasticity and green firms having a close-to-zero impact elasticity.

In Column 2, we find similar patterns using industry returns (calculated excluding the focal firm) instead of firm returns. These results imply that our estimates are unlikely to be due to reverse causality or omitted variables. Rather, exogenous shocks to firm financial performance, as proxied by the industry return, are associated with large declines in emissions by brown firms and small insignificant changes in emissions by green firms. Note that the coefficients for brown firms estimated using industry returns are slightly larger than those using individual firm returns. This may occur because individual firm financial returns are a noisier measure of the true cost of capital change for a firm than the industry average return. This would lead to greater attenuation bias toward zero when using the firm return instead of the industry return.

In all specifications in Table 2, brown firms pollute less following positive financial shocks and pollute more following negative financial shocks. In contrast, green firms have smaller and inconsistently signed changes in emissions. We can reject the hypothesis that brown and green firms have equal elasticities (p-values for a test of equality in coefficients are below 0.01).

The horizon over which cost-of-capital-based green versus brown decisions influence emissions will be somewhat context dependent. For some investments (e.g., a multi-year building project of a new facility with greener technology), the improvement will not manifest as reduced emissions immediately. For other investments (e.g., replacing gas cars with electric or leasing newer, more efficient machines), the influence will occur almost immediately upon investment. In addition, there could be variable cost decisions that impact emissions immediately (e.g., buying more expensive clean energy or turning on scrubbers) which are less likely to occur if a firm has experienced increases in its cost of capital. Thus, while we expect many decisions to influence emissions at the annual horizons we examine, it may take longer than a year for certain investments to fully express itself in the data as changes in firm emissions. Thus, we expect to find similar or larger changes in emissions for brown firms at longer horizons.

Further, a potential concern with the interpretation of our results is that they may be driven by short-term stickiness in raw emissions (unscaled) when firms grow or shrink sales in response to shocks to the cost of capital. For example, suppose that an airline cuts its loyalty program and advertising in response to an increase in its cost of capital, leading to a reduced number of passengers. In the short run, the airline is contractually obligated to operate the same number of flights, so it will operate each flight with fewer passengers and hence have higher emissions intensity (measured as raw emissions scaled by sales). In the long run, however, the airline can reduce the number of routes and sell aircraft, leading to an increase in passengers per flight and a reduction in emissions intensity toward its original levels.

If our results over a one-year horizon are driven by short-term stickiness in raw emissions, our results would not represent the longer-term shift in emissions intensity by firms in response to the shock. If this were the case, we would not find a similar effect over longer periods that allowed for complete responses to the shock. Note that such a concern is relevant even if the cost of capital shock is permanent (as desired by many sustainable investors), because a firm may require time to adjust its production process to the permanent change in its cost of capital.

To explore whether our results are explained by this short-term channel, we examine changes in emissions over a five-year horizon. Table 3 shows regressions where the dependent variable is the change in emissions intensity in year $t+5$ relative to year t, and the change to the cost of capital is represented by financial returns (measured continuously or with an indicator for returns in the lowest decile) in year $t-1$ at the firm or industry level (calculated excluding the focal firm). We find qualitatively similar results to our previous one-year analysis, with larger effect sizes. These longer-horizon results suggest that our findings of a large negative impact elasticity for brown firms are not driven by short-term stickiness or fixed adjustment costs for emissions. The fact that changes in emissions are larger when measured at a five-year horizon than a one-year horizon is consistent with the simple model presented in Section II: an increase (decrease) in the cost of capital causes brown firms to prefer brown (green) investment projects, and the effect of these investment choices on emissions could take several years to fully materialize.

In Appendix Table A1, we repeat the analysis of long-term reactions, with additional control variables for interim firm or industry financial returns in the years between t and $t+4$, interacted with indicators for firm type (brown, neutral, or green), because these interim returns could also impact firm outcomes. We find very similar estimates with these additional controls. This is unsurprising because both firm and industry returns exhibit weak serial correlation in our data.

B.2 Financial distress

A common refrain from sustainable investors is that they wish to punish firms that harm the environment by starving them of capital and pushing them toward financial distress. Before getting to the empirical results, we note that there are reasons ex ante to be skeptical that financial distress would encourage brown firms to become more green. An increase in the firm's cost of capital should cause the firm to prefer investment projects that deliver front-loaded cash flows over those with back-loaded cash flows. In particular, a firm that is in a liquidity crisis or has a high risk of bankruptcy faces a high discount rate, such that the firm will favor investments offering short-term gains. Since transitioning to greener production by brown firms usually entails the adoption of new equipment and technologies that differ from their existing brown investment projects, these new green investments are unlikely to pay off in the very short run and should be less attractive to firms in financial distress. Furthermore, firms near bankruptcy may suffer from the well-known debt overhang problem (Myers, 1977) in which they are unable to raise financing to pursue projects that require upfront investment.

In Table 4, we measure financial distress in four ways. First, we examine an indicator for whether the firm is likely to face challenges in making interest payments on its debt. The low interest coverage indicator is equal to one if firms have positive interest payments and negative earnings, or the firm has an earnings-to-interest ratio that is in the bottom decile within our sample. Second, we measure each firm's Altman Z-score (lower values correspond to greater probability of bankruptcy; see Altman (1983)), and set the low Z-score indicator equal to one if the firm has a Z-score in the bottom decile within our sample. Lastly, we use indicators for whether the firm's financial return is in the bottom decile within our sample. To establish a causal channel, we also examine firm reactions to industry shocks, using indicators for whether the industry return (calculated excluding the focal firm) is in the bottom decile of our sample.

Across all specifications in Table 4, we find that brown firms react to distress by increasing their emissions. In contrast, neutral and green firms exhibit smaller, inconsistently signed, and less significant responses to the proxies of distress. P-value tests of equality show that we can reject the null hypothesis that brown and green firms have equal changes in emissions after experiencing distress. The magnitudes of the coefficients imply that brown firms increase their emissions by approximately 40 to 75 tons per million of revenue after experiencing a distress shock associated with being in the lowest decile of some measure (interest coverage, Z-score, or financial returns) within our sample period. Given that the average level of emissions by green firms is only 5 tons per million in revenue, these results imply that brown firms react to distress by increasing their emissions by at least eight times the level of emissions of the average green firm.

We find that brown firms pollute more per unit of output as they become financially distressed. Thus, pushing brown firms toward bankruptcy can be counterproductive relative to the goal of transitioning brown firms toward being more green. As we discussed in the Introduction, some sustainable investors may pursue alternative goals such as degrowth, where they seek to shrink or kill brown firms, thereby reducing or eliminating their absolute emissions. We discuss this objective in Section IV.D.

B.3 Isolating the financial channel

So far, we have explored the relation between a firm's environmental impact and various proxies for the firm's cost of capital, such as bankruptcy risk and financial returns. A potential concern with the empirical measures above is that they could capture shocks to productivity in addition to the cost of capital. In this section, we present three tests to isolate a financial channel operating through the cost of capital. First, we examine firms' implied cost of capital, a measure that captures the portion of past returns that is due to changes in the cost of capital, as distinct from changes in cash flow expectations. Second, to identify the role of financial constraints, we assess whether firms that are more leveraged react differently to industry productivity shocks. Third, we exploit exogenous variation in a firm's cost of capital induced by changes in investor demand for dividend payments.

In our first test to isolate a cost-of-capital effect, we directly measure the implied cost of capital (ICC) for each firm year. The ICC is defined as the internal rate of return that equates the firm's market value with the present value of expected future cash flows. Thus, the ICC represents the expected return to investors of the firm and the firm's cost of raising capital from the same investors. The change in ICC is designed to be a measure of the portion of past returns that is due to changes in the cost of capital, not changes in expected cash flows.

We use estimates of firm ICCs generously shared by Lee et al. (2021). As our baseline, we follow the recommendations of Lee et al. (2021) and use ICCs estimated following the Gebhardt et al. (2001) (GLS) method where the inputs for future cash flows consist of mechanical forecasts from the cross-sectional forecast model of Hou et al. (2012). Estimates of ICC may be noisy due to non-unique numerical solutions and sensitivity of estimates to the timing of measurement and assumptions regarding the path of future cash flows (for more details, see Lee et al. (2021)). To ensure robustness, we also present results using a composite ICC that is the equal-weighted average for four ICC variants.

In Table 5, we regress the firm's change in emissions intensity on the firm's change in ICC over the previous year, interacted with indicators for whether the firm is brown, neutral, or green. We also control for the direct effects of the firm type indicators (brown, green, or neutral) and fiscal year.

We find that brown firms significantly increase their emissions following an increase in their cost of capital. Once again, neutral and brown firms experience smaller and inconsistently signed changes in their emissions. This is true using the GLS as well as the composite ICC estimates. For example, the coefficient in Column 1 implies that brown firms increase emission by 6.2 tons per million following a one percentage point increase in their ICC. Because an increase in emissions translates to a negative change in environmental impact, these results again imply that brown firms have large negative impact elasticities with respect to their cost of capital, whereas neutral and green firms have smaller impact elasticities closer to zero.

Similarly to our earlier analysis of firm performance, a limitation of looking at the relation between firm emissions and firm ICC is that any measured correlation could be driven by reverse causality (if becoming more green causes the firm to have a lower cost of capital), or by omitted variables bias (e.g., if the arrival of an environmentally friendly CEO causes both a shift in green strategy and cost of capital). To better estimate the causal effect of firm cost of capital on firm emissions, we examine the relation between firm emissions and the firm's industry value-weighted average ICC, calculated excluding the focal firm. The intuition is that industry cost of capital shocks strongly affect firm-level cost of capital, but individual firm choices should not have a strong effect on the industry average cost of capital calculated excluding the focal firm. We find a similar large relation between brown firm emissions intensity with respect to industry ICC, and a smaller and insignificant relation for neutral and green firms. These patterns are robust to using the equal-weighted average of four ICC variants.

In our second test to isolate a cost-of-capital effect, we compare the behavior of firms with different initial leverage following the same industry productivity shock. Firms that are more leveraged are likely more sensitive to productivity shocks because a given level of negative performance increases their probability of bankruptcy and costly financial distress more than for a less constrained firm. Such constrained firms may face additional pressure to increase or maintain cash flows in the short term. For brown firms, this short-termism can translate into dirtier production and higher emissions.

We measure industry productivity shocks for each firm using the value-weighted change in industry return on assets (ROA), calculated excluding the focal firm. In Table 6, we regress the firm's change in emissions on the triple interaction of the change in industry ROA, the firm's leverage in the previous year (measured as a debt-to-value ratio or an indicator for low interest coverage), and indicators for firm type (brown, neutral, or green), controlling for all direct effects and two-way interactions. We find that the relationship between changes in emissions and changes in industry productivity in the previous year is significantly stronger for brown firms with low interest coverage or higher debt-to-value ratios. Levered green firms have smaller reactions in the opposite direction.[28] These results help identify the effect of financial distress as distinct from the general effects of negative performance. For the same negative industry performance shock, highly leveraged brown firms increase emissions more than less leveraged brown firms. This result is consistent with an increase in financial distress that causes brown firms to become more brown.

In our third test to isolate a cost-of-capital effect, we exploit exogenous variation in firm's cost of capital induced by changes in investor demand for dividend payments. Pure dividend demand is behavioral in nature, because rational investors understand that a dividend payment comes with a corresponding drop in value of the firms' equity and therefore does not make them wealthier or poorer (Miller and Modigliani, 1961). Real-world frictions imply that receiving a dividend payout is generally suboptimal for taxable investors. Even so, Hartzmark and Solomon (2019) show that a large class of investors value dividends as distinct from the total return on their equity investments. This behavioral demand influences share prices along a variety of dimensions (e.g., Baker and Wurgler (2004) and Hartzmark and Solomon (2013)).

Importantly for the purposes of this paper, there is large and systematic time variation in the behavioral demand for dividend payments. For example, in low-interest rate environments, investors substitute away from fixed income investments toward dividend-paying stocks based on the misguided perception of dividends as a safe income stream similar to interest collected on bonds. Hartzmark and Solomon (2019) show that in times of high demand for dividend payments, dividend-paying

[28]Green firms, especially leveraged ones, experience a smaller significant increase in emissions following positive productivity shocks. This increase in emissions could be driven in part by green services firms expanding beyond their headquarters or online operations to local physical offices or branches following improvements in productivity, leading to an increase in emissions.

firms experience increased share prices relative to non-dividend-paying firms. Fluctuations in share price due to variation in demand for dividends represent cost of capital shocks driven by misguided investors rather than productivity shocks to affected firms.

In addition, Hartzmark and Solomon (2013) develop a new proxy for dividend payout demand, which has the advantage of being distinct from the general demand to hold the types of firms that pay dividends (e.g., investors may wish to invest in dividend-paying firms because these firms are perceived to be more stable). This proxy builds on the fact that dividend announcement days reveal all the relevant economic information of an upcoming dividend payment, and the pre-announced ex-dividend date is the date when all tax ramifications are resolved. The interim period of approximately one month, after the dividend announcement and before the ex-dividend date, has no fundamental economic content. Yet investors who do not already hold the stock prior to the dividend announcement and want to receive the announced dividend payment (whether due to their own biases or to cater to clients with such biases (e.g., Harris et al. (2015))) must buy the stock in this interim period. Hartzmark and Solomon (2013) document large positive returns in this interim period from price pressure induced by investor demand for dividend payouts. We use aggregate time series variation in this measure as a proxy for variation in shocks to the cost of capital of dividend paying firms driven by behavioral demand for dividend payouts.[29]

We measure dividend demand as the value-weighted interim return across all dividend payment events in each year. We measure dividend demand both continuously and with an indicator for whether dividend demand was above the median during our sample period.[30] Note that we do not claim that dividend demand is uncorrelated with macroeconomic variables that could affect firm emissions. For example, dividend demand is higher during low-interest rate environments, when many investors substitute from bonds toward dividend-paying stocks. Rather, our identifying assumption is that fundamentals such as interest rates that drive dividend demand should have a similar effect on all brown firms, but brown firms that ex ante offer a high dividend yield will experience an additional reduction in their cost of capital thanks to dividend demand.

In Table 7, we examine how emissions from firms with high dividend yields change with demand for dividend payouts. Specifically, we regress changes in firm emissions on aggregate dividend demand in the prior year, an indicator for whether the firm had a high dividend yield (above the median

[29] While price pressure due to trading in the interim period partly reverses subsequent to dividend payment, Hartzmark and Solomon (2019) document that variation in this proxy captures broader variation in demand for dividend paying stocks due to demand for dividend payouts. For our purposes of identifying a cost of capital shock, this aspect is the most relevant.

[30] See Hartzmark and Solomon (2013, 2019) for further information and time series variation in the measure.

of dividend payers) in the prior year, and interactions with our green/brown/neutral firm-type indicators. Because dividend paying firms tend to be larger than non-dividend paying firms, we also control for firm size (measured as the logarithm of firm annual sales) interacted with firm type indicators (green/brown/neutral) and the triple interaction between firm type, firm sales, and aggregate dividend demand. These size controls account for the possibility that larger brown, neutral, or green firms behave differently during periods of high dividend demand.

In Column 1, the coefficient for brown firms on the interaction between the high dividend yield firm indicator and dividend demand is large and highly statistically significant. In Column 2, the coefficient for brown firms on the interaction between the high dividend yield firm indicator and the high dividend demand indicator is -43 and again highly statistically significant. In comparison, the estimated changes in emissions for green high-dividend-yield firms are small and insignificantly different from zero. These results show that increases in the cost of capital induced by variation in dividend demand cause high-dividend-yield brown firms to increase emissions. We do not see similar effects for other brown firms or for high-dividend-yield green firms.

These estimates imply that in the years when dividend demand was high, brown high-dividend-yield firms reduced their emissions by an extra 43 tons per million of revenue compared to brown non-high-dividend-yield firms. By comparison of magnitudes, this is nearly as large as our estimated average increase in emissions when brown firms experience financial distress (40-74 tons per million), which may initially seem like a surprisingly large change due to a dividend demand shock. This direct comparison misses an important component of the magnitude, which is that brown firms with high dividend yields have significantly higher emissions intensity than brown non-dividend paying firms: roughly 1,660 versus 760, respectively. As a result, the 43-ton reduction represents a more modest 2.6% decrease in emissions for these high-dividend firms. This is consistent with the general findings in the paper that a larger impact (as measured by the change in emissions in levels rather than percentages) is achieved for a given cost of capital shock when it is applied to darker brown firms that start with higher emissions intensity.

B.4 Robustness to alternative measures

In this section, we show that our main findings are robust to alternative measures of greenhouse gas emissions and that general investment in long-lived capital exhibit similar patterns.

Firm self-reported emissions In our baseline results, we used data on scope 1 and scope 2 emissions from S&P Trucost, the sustainable investing industry's leading provider of emissions data. Trucost's coverage of firm emissions is based on firms' self-reported disclosures combined with Trucost's proprietary model-based estimates of firms' emissions. Although there is likely to be measurement error in these estimates, these are the same data commonly used by sustainable investors as a screening tool for portfolio choice and as a way to measure progress in firm emissions behavior. In supplementary results in Appendix B, we present qualitatively similar results using data from the subset of firms that self-report annual emissions data. While the reduced sample size leads to slightly noisier estimates, we find qualitatively similar and generally statistically significant effects, consistent with brown firms having a negative impact elasticity and green firms having a close-to-zero impact elasticity.

Industry-level emissions We also supplement Trucost's firm-year-level data with industry-year emissions intensity data. The industry emissions data is generously shared by LaPlue and Erickson (2020) and are based on emissions data collected by the Environmental Protection Agency (EPA) from plant-level reporting. While statistical power declines due to the smaller sample size, these data have the benefit of capturing the total change in industry emissions, *including the effects of entry and exit of firms*. In Appendix Table A2, we find that past industry financial returns are associated with a reduction in industry emissions for brown industries and a close-to-zero change in emissions for green industries. These results are again consistent with our conclusion that brown firms have a negative impact elasticity and green firms have a close-to-zero impact elasticity.

Cost of capital and investment Our analysis so far has shown that greenhouse gas emissions by brown firms increase with their cost of capital. These results are consistent with the negative impact elasticity of brown firms being driven in part by changes in their pollution abatement investments. Given the focus of our paper on greenhouse gas emissions, it would be ideal if we could examine a comprehensive dataset of emissions abatement investments. While data on the emissions of many firms is readily available, unfortunately there is no such unified dataset for investments in the abatement of these emissions. This is partly explained by the absence of standardized technology associated with greenhouse gas abatement across industries. For example, Travelers Insurance cut its emissions by 54% by making investments in more efficient light bulbs, improved building insulation, and electric vehicles.[31] This is fundamentally different from the types of investments discussed by cement manufacturers (e.g., carbon capture, newer and more energy-efficient machines, or adoption of production processes using alternative materials) or cattle firms (e.g., manure separator machines or wearable devices to reduce the methane emissions of cows).

While we cannot broadly measure comparable investments in green house gas emissions, measuring general firm investment in long-lived capital is quite straightforward. Thus, we examine how general capital investment reacts to our cost of capital shocks. We find a robust pattern that firms cut general capital investment following increases in their cost of capital.

Table 8 repeats our previous analysis to examine how general capital expenditures vary with cost of capital shocks. The dependent variable is the change in capital expenditures in the year after the cost of capital shock, where capital expenditures is defined as funds used to acquire, upgrade, and maintain capital assets (i.e., assets with a useful life exceeding one year), scaled by lagged plant, property, and equipment. We find a similar pattern to that implied by examining emissions: firms reduce their capital investments following an increase in their cost of capital.

Of course, general capital investment is not the same as green investment that improves the firm's environmental impact. However, green investment does represent a substantial portion of brown firms' overall capital expenditures and regulators characterize green production as highly dependent on new capital.[32] Green investment focused on decarbonization, clean water, and sustainable infrastructure is estimated to account for 15% of average global capital expenditures over the 2016-2019 period (Goldman Sachs 2022).[33] Given that we find a robust pattern that firms cut general capital investment following increases in their cost of capital, green investment would need to be fundamentally different from other forms of investment to not exhibit a similar response.

C. Incentive effects of the dominant sustainable investing strategy

So far, we have shown that brown firms have large negative impact elasticities and green firms have impact elasticities that are close to zero. This implies that if the dominant sustainable investing strategy succeeds in altering firms' cost of capital, it would have the *direct effect* of making brown firms more brown, without making green firms more green. In this section, we explore the possibility that the dominant sustainable investing strategy could have an additional indirect incentive effect on firm

[31] It also lists more efficient IT equipment and increased use of cloud computing. https://sustainability.travelers.com/drivers-of-sustained-value/eco-efficient-operations#ghg-inventory-goals

[32] https://www.iea.org/articles/the-cost-of-capital-in-clean-energy-transitions

[33] https://www.goldmansachs.com/intelligence/pages/gs-research/green-capex-greenflation-returns-and-opportunity/report.pdf

behavior. Specifically, if sustainable investors reward firms that improve their impact, then brown firms may try to become more green to access a lower cost of capital or higher share price.

In theory, providing financial incentives can be an effective way to motivate brown firms to become more green. However, we show empirically that the dominant sustainable investing strategy in practice has not, on average, provided such incentives.

To study these indirect incentive effects, we examine the extent to which the dominant sustainable investing strategy over the past two decades has rewarded green and brown companies that have improved their environmental impact. Using data on the holdings of sustainable investment funds, we test whether sustainable investors increase their holdings of firms that have lowered their emissions, holding the current level of emissions constant. Using data on ESG ratings released by MSCI, a leading sustainable investment advisory firm, we also test whether firms are rewarded for a decrease in emissions with improvements in their environmental ESG ratings.

Our analysis indicates a lack of meaningful financial incentives for brown firms to become more green. We find that sustainable investment funds indeed overweight firms that have improved their impact over the past several years, consistent with these funds rewarding firms who transition to becoming more green. However, changes in impact are measured in the wrong units. Sustainable investors appear to suffer from a proportional thinking bias (see, e.g., Tversky and Kahneman (1981) and Shue and Townsend (2021)) in which they reward firms with large *percentage* reductions in emissions rather than large *level* reductions in emissions.[34]

Popular ESG environmental ratings similarly reward percentage reductions in emissions rather than level reductions in emissions. For example, the Financial Times recognized firms as climate leaders based on a ranking of percentage reductions in emissions intensity (see Figure 3). Unsurprisingly, the top 10 climate leaders all started with emissions intensity levels below 50 tons per million dollars of revenue. In contrast, the brown firms in our sample have emission intensity levels that average 1,308 tons per million. It is much more environmentally meaningful for a brown firm with high levels of pollution to have a similar high percentage reduction in emissions.

Using data generously shared by Cohen et al. (2020), we classify funds as sustainable if the fund name contains "ESG" or "green" or if the fund is classified as a sustainable investment fund by either the Forum for Sustainable and Responsible Investment (USSIF) or Charles Schwab. To assess whether

[34]The “miles per gallon illusion” describes a related bias in which people undervalue the benefits of replacing the most inefficient automobiles relative to replacing already fuel efficient automobiles with even more fuel efficient ones (Larrick and Soll, 2008).

a firm is favored by sustainable funds, we compare the holdings of two portfolios: the aggregated holdings of all sustainable funds within a year and the holdings of a hypothetical market portfolio that holds all firms in CRSP in proportion to their market value as of the beginning of the year. We measure the extent to which a firm is rewarded by sustainable funds using its "overweight," defined as the difference between the stock's portfolio weight in the aggregate sustainable fund portfolio and the market portfolio, scaled by its weight in the market portfolio.

In Table 9, we regress the firm's overweight in the aggregate sustainable fund portfolio on the firm's current level of emissions as well as the firm's change in emission in the past one or two years. In Columns (1) and (2), we measure the firm's change in emissions in levels. We argue that this is the correct measure of the change in real-world environmental impact of firms. Note that because we measure emissions as raw emissions scaled by revenue, measuring the change in emissions in levels is already adjusted for differences in firm size. In Columns (3) and (4), we measure the firm's change in emissions as the percentage change. This is the incorrect measure of the change in real firm environmental impact. As shown earlier in the bottom row of Figure 2, green firms are associated with large absolute percentage changes. These large percentage changes in emissions by green firms are economically trivial because their level of emissions is several orders of magnitude smaller than the level of emissions of similarly-sized brown firms.

The estimates in Table 9 show that the current level of emissions and percentage changes in emissions are both strong predictors of sustainable fund holdings. Sustainable investment funds reward firms with lower current levels of emissions as well as larger percentage reductions in their emissions. However, the estimated coefficients on the level changes in emissions in Columns (1) and (2) are close to zero and statistically insignificant. In other words, sustainable investment funds, as a whole, fail to reward firms for reducing emissions in the units that actually matter for environmental impact.

In Table 10, we find similar results using the firm's ESG environmental rating as the dependent variable. We find that ESG ratings reward firms with lower current levels of emissions as well as larger percentage reductions in their emissions. However, the estimated coefficients on the level changes in emissions in Columns (1) and (2) are again close to zero and statistically insignificant.

The distinction between percentage and level changes in emissions is important because, holding constant firm size, the average brown firm emits 260 times as much pollution as the average green firm. Comparing a brown and green firm of equal size, an increase in emissions by a brown firm of 1% has the same actual environmental impact as an increase in emissions by a green firm of 260%.

Perhaps most surprisingly, we find that sustainable investors reward green firms more than brown firms for the same percentage reduction in emissions. To incentivize brown firms to improve, sustainable investors should do the opposite and reward brown firms more for the same percentage reduction in emissions. In Table 11, we show that sustainable investors significantly increase their portfolio weights in neutral and green firms in response to percentage reductions in their emissions. However, sustainable investors do not increase their portfolio weights for brown firms that exhibit the same percentage reduction in their emissions. The behavior of sustainable investors stands in contrast to the behavior of the MSCI environmental ratings (see Columns 3 and 4). While environmental ratings reflect changes in emissions measured in the wrong units (percentage instead of level changes), environmental ratings reward percentage reductions in emissions in a similar fashion across brown, neutral, and green firms.

The fact that the aggregate sustainable investing portfolio does not reward reductions in emissions by brown firms is consistent with a behavioral affect heuristic (e.g., Slovic et al., 2007), in which sustainable investors choose to disassociate from or punish brown firms that they dislike, despite the fact that brown firms have the greatest scope to change their environmental impact. The insensitivity of sustainable portfolio weights to improvements in environmental impact by brown firms is also consistent with the widespread use of exclusion lists such as the Carbon Underground 200,[35] which encourages investors to divest from brown firms based on the firms' ownership of potentially polluting assets.

D. Sustainability goals and the impact elasticity channel

Our analysis so far has documented a counterproductive impact elasticity channel within the dominant sustainable investing strategy of directing capital toward green firms and away from brown firms. We show that an increase in the cost of capital for brown firms has the direct effect of making them pollute more per unit of output, and a lower cost of capital for green firms does not lead to meaningful reductions in their emissions. We believe that any investor seeking sustainability goals should take our channel into account. However, the existence of our counterproductive channel does not necessarily imply that the overall impact of the dominant sustainable investing strategy would be counterproductive. Conditional on changing the cost of capital for firms, the net effectiveness of such a strategy depends on the strength of potential countervailing forces and investors' specific environmental objectives. In this last section, we evaluate how our impact elasticity channel interacts with

[35] See https://fossilfreefunds.org/carbon-underground-200.

different sustainability goals.

We begin by differentiating sustainable investors, whom we define as those who directly care about the environmental impact of firms, from investors with purely pecuniary motives, who may trade based on the climate transition risk of financial assets. To the extent that brown firms have higher climate transition risk, the dominant sustainable investing strategy will reduce exposure to such risk in investors' portfolios. However, for investors who seek to reduce exposure to climate risk *and* have positive environmental impact, they should consider the possibility that the pricing of transition risk (through a higher cost of capital for brown firms) could ironically cause brown firms to become more brown.

Turning next to sustainable investors, their environmental objectives can be approximately categorized as: (1) firm-level green transition: encouraging firms to switch to greener production while maintaining the firm's output, i.e., reduce firm-level emissions intensity; (2) de-growth: reducing emissions by shrinking brown firms and industries, without concern for reductions in output; and (3) economy-wide green transition: lowering global emissions intensity while maintaining overall output. A reduction in global emissions intensity can be accomplished through firm-level green transitions and/or shrinking brown firms and growing green firms to replace the loss in brown output.

It is most straightforward to evaluate our counterproductive impact elasticity channel in relation to the first two goals. To achieve a firm transition goal, investors need to counteract the impact elasticity channel by providing sufficient incentives for brown firms to transition. We demonstrate that financial incentives have been weak in practice, because sustainable investors have primarily rewarded already-green firms for large percentage reductions in emissions. However, sustainable investors could strengthen the incentive channel by directing capital toward firms that achieve meaningful reductions in their emissions (measured by absolute rather than percentage changes in emissions). Indeed, some "transition" sustainability investment funds adopt this approach by investing in high-emissions industries and adopting portfolio inclusion rules that reward firms that are credibly moving toward reduced emissions.

Regarding the de-growth objective, where investors aim to reduce emissions regardless of output losses, it is theoretically obvious that a sufficiently large increase in the cost of capital will cause any targeted firm or industry to shrink and eventually die, leading to elimination of its emissions. We show that brown firms increase their emissions per unit of output as their cost of capital rises, but it is still the case that raw firm emissions (unscaled by output) shrinks after sufficiently large increases in the cost of capital. Thus, raising the cost of capital for brown firms while lowering it for green firms is not counterproductive relative to a de-growth goal. However, even a de-growth investor should consider our estimates of the impact elasticity when deciding how to allocate their capital as it will affect the *pace* of global emissions reductions.

In theory, it is possible to avoid the large welfare loss associated with degrowth by pursuing an alternative *economy-wide* transition goal. One strategy to help achieve this goal could be to shrink brown firms but grow green firms to replace the loss in output. The welfare cost of a decrease in output from brown firms disfavored by sustainable investors depends on the extent to which that loss in output can be substituted with growth in output from green firms favored by sustainable investors. As previously discussed, green industries like insurance, healthcare, finance, and legal services provide imperfect substitutes for essential products from brown industries like energy, agriculture, transportation, and building materials. In the absence of perfect green substitutes for entire brown industries, sustainable investors could contribute to a green transition at an industry level by investing in the firms *within* a brown industry that are relatively more green or are transitioning toward becoming more green. Thus, whether the dominant sustainable investing strategy is aligned with an economy-wide green transition goal depends on how sustainable investors adjust their portfolios based on the substitutability of the brown output they are attempting to shrink.

To avoid loss of output from an entire industry, sustainable investment could sort *within* an industry. For example, given the importance of the global food supply, a sustainable investor seeking an economy-wide transition could try to replace brown agricultural output with green agricultural output. To this end, sustainable investors could overweight firms within agriculture that have relatively low emissions or are transitioning toward lower emissions. Importantly, this would not lead to an underweighting of the whole agriculture industry or an underweighting of the greenest agriculture firms. However, the aggregate sustainable portfolio drastically underweights agriculture relative to a value-weighted market portfolio. Agricultural production of livestock in 2020 is weighted at 7% of its market value and agricultural production of crops is weighted at 25% of its market value. Further, it is unlikely that green industries such as insurance, which is weighted at 232% relative to its market cap, would be able to fill in for this loss in agricultural output while maintaining lower emissions intensity.

Extending the intuition of this example to the broader data, Panel A of Figure 4 presents a binscatter plot of the relation between SIC2 industry emissions and the industry's overweight in the aggregate sustainable portfolio. Industries with high emissions are significantly underweighted by sustainable investment funds and industries with low emissions tend to be overweighted. Among industries with low emissions, there exists dispersion in how these industries are weighted in the aggregate sustainable portfolio. This dispersion likely reflects the reality that sustainable investors care about factors beyond emissions, such as the social and governance components of ESG. Nevertheless, the figure shows a clear negative slope in which the aggregate sustainable fund underweights industries with high emissions.

The underweighting of high-emissions industries also reflects influential benchmarks such as the Paris Aligned Benchmarks (PAB). These benchmarks are used to construct sustainable financial products and serve as the basis for much of modern regulation relating to sustainable investing (e.g., recent ESMA ESG labeling guidelines). When discussing the influence of using PAB in the construction of financial products, BNP Paribas state that it can lead to a sectoral "overweight into less polluting activities such as Information Technology, Healthcare and Financials." They continue that PAB considerations typically lead to a lower allocation "in the more carbon-heavy sectors."[36]

Our results showing that sustainable funds underweight brown SIC2 industries may seem at odds with marketing claims that some sustainable funds are sector-adjusted (so that portfolio weights for each sector match the market capitalization of each sector). This apparent contradiction can be explained by the fact that many sustainable funds adjust their portfolio weights using very broad sector definitions, and products produced by firms within a sector are unlikely to be fully substitutable. For example, the influential MSCI sustainable indexes are adjusted using 11 GICS sectors. The GICS sector of consumer staples contains both the agriculture and drug retail industries, which clearly produce imperfect substitutes as products.

In Panel B of Figure 4, we repeat the analysis, this time focusing on the 20% of firms with the lowest emissions intensity in each industry-year. We plot the portfolio overweight of the greenest 20% of firms within each industry-year against the average emissions intensity of their industries. The results are similar to those of Panel A. Among industries with low emissions, there is dispersion in how the greenest firms in these industries are weighted in the aggregate sustainable portfolio, likely reflecting that sustainable investors care about factors beyond emissions. Nevertheless, the figure shows a clear negative slope in which the aggregate sustainable fund underweights the 20% of firms with the lowest emissions intensity within industries with high emissions. Thus, sustainable funds underweight even the greenest firms within brown industries.

[36] https://globalmarkets.cib.bnpparibas/paris-aligned-benchmarks-why-they-matter-on-the-path-to-net-zero/

We acknowledge that the SIC2 industry classification used in our analysis represents a noisy measure of true output substitutability; output produced by different firms within an SIC2 industry may not be perfectly substitutable, and output across pairs of SIC2 industries will vary in their substitutability. Ideally, sustainable investors would use an industry classification that better captures product substitutability from a welfare perspective. Nevertheless, even with our noisy industry categories, we do not expect the greenest firms within brown industries to be substantially underweighted if investors construct their portfolios to grow the types of firms that can realistically substitute for shrinking brown output.

Our analysis in this section is not meant as a critique of all sustainable investing strategies. Indeed, some sustainable investors do "industry-adjust," by investing in relatively green firms and firms that have meaningfully reduced their emissions within a brown industry without underweighting the brown industry as a whole. Such a strategy could potentially be effective in helping critical industries smoothly transition toward lower emissions intensity. However, our results indicate that, on average, sustainable investing funds tend to underweight entire brown industries while overweighting green industries. They also underweight greener firms within brown sectors. This pattern suggests that the dominant investing strategy, as it currently stands, is unlikely to drive a smooth, economy-wide transition.

While divesting from entire brown industries may not be the optimal solution, determining the best strategy for an economy-wide transition is a complex and nuanced challenge. Striking the right balance between reducing the size of brown firms and incentivizing their improvement depends on several factors, including the substitutability of output between brown and green firms, the elasticities of consumer demand for each type of output, and the relationships between output, emissions, and capital costs. Although a comprehensive estimation of these measures is beyond the scope of this paper, our findings on impact elasticities provide an important component necessary for developing an optimal strategy for an economy-wide transition.

V. Conclusion

This paper shows that the dominant sustainable investing strategy of directing capital toward green firms and away from brown firms contains an underappreciated counterproductive channel. We develop a new measure of impact elasticity, defined as a firm's change in environmental impact due to a change in its cost of capital. We show empirically that a reduction in financing costs for firms that are already green leads to small improvements in environmental impact at best. Increasing financing costs for brown firms leads to negative changes in firm impact. We further show that the dominant sustainable investing strategy has provided weak financial incentives for brown firms to become less brown. Due to a mistaken focus on *percentage* reductions in emissions, the sustainable investing movement primarily rewards green firms for economically trivial reductions in their already low levels of emissions. Finally, we show that the dominant sustainable investing strategy has not allocated capital toward relatively green firms within brown industries. Instead, it overweights green services industries that are unlikely candidates to produce output that can easily substitute for shrinking brown output.

Our conclusions are not meant as a negative assessment of all possible sustainable investment strategies. Rather, they highlight potential problems with some of the most popular sustainable investment strategies to date. These strategies go by a variety of names, such as divestment, exclusion, negative screening, and certain forms of ESG integration. Collectively, they lead to an underweighting of brown firms and overweighting of green firms, while offering weak incentives for brown firms to improve. Our analysis suggests that sustainable investment flows and engagement that targets the incentives of green firms would be more effective if targeted at the incentives of brown firms.

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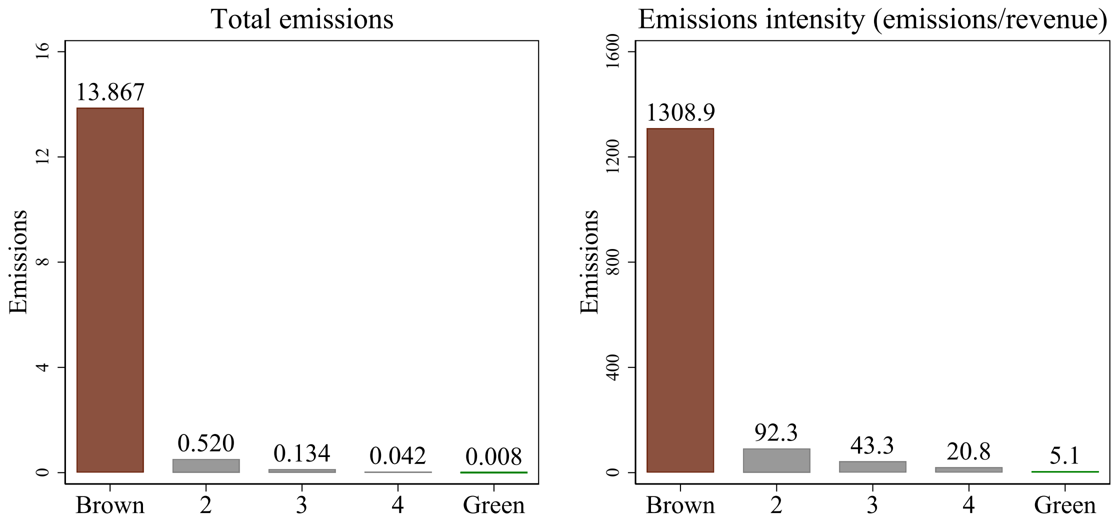
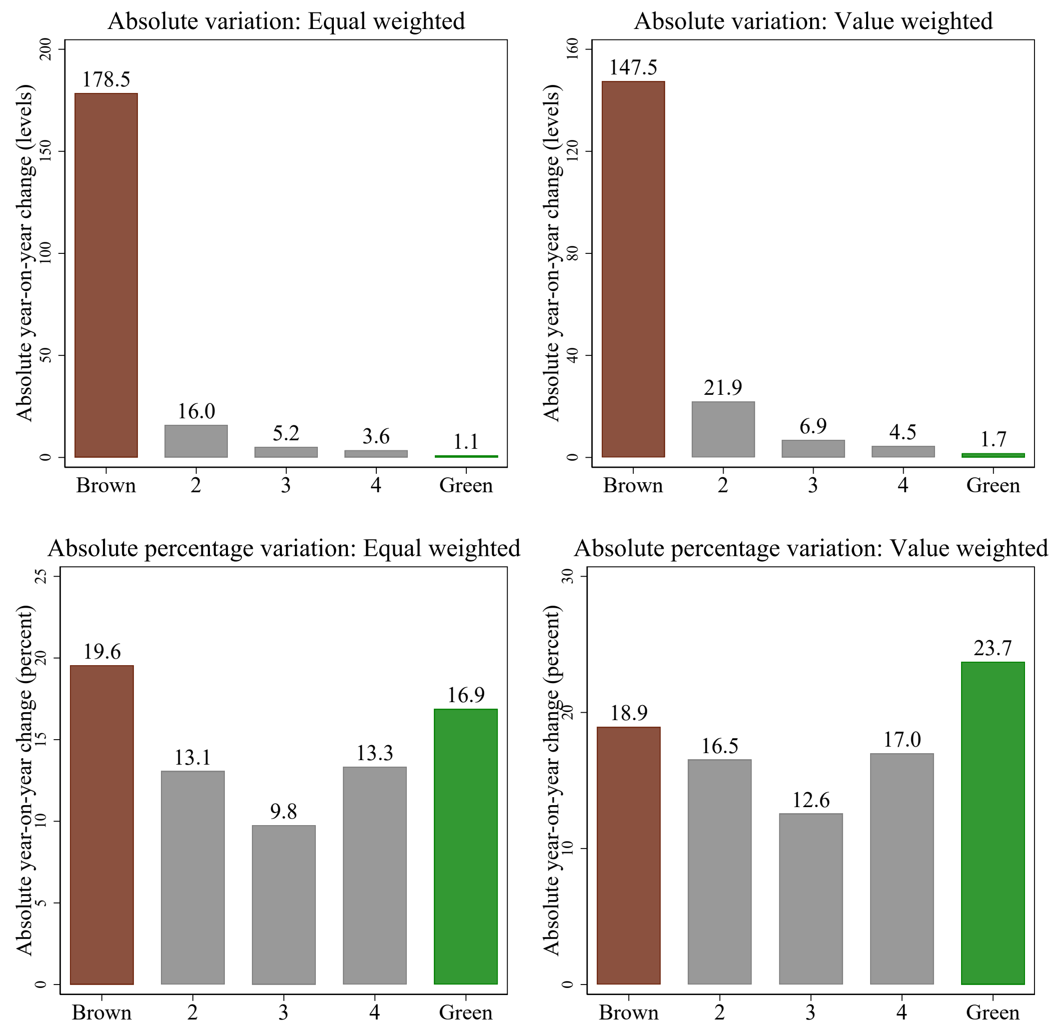
Figure 1: Average emissions of brown and green firms



This figure plots the average emissions of scope 1 and scope 2 greenhouse gases by firms. Firms are sorted into quintiles within each year, with quintile 1 representing brown firms with the highest emissions and quintile 5 representing green firms with the lowest emissions. In the left panel, emissions are measured as million tons of CO_2 equivalents. In the right panel, emissions are measured as tons of CO_2 equivalents emitted per million dollars of revenue (emission intensity).

Figure 2: Absolute level and percentage changes in emissions



This figure plots year-on-year variation in emissions. Variation in emissions for the top two panels is measured as the absolute change in scope 1 and scope 2 emissions intensity from year t to $t+1$, where emissions intensity is measured in tons of CO_2 equivalents emitted per million dollars of revenue. Variation in emissions for the bottom two panels is measured as the absolute percentage change in scope 1 and scope 2 emissions intensity from year t to $t+1$. Absolute changes and absolute percentage changes in emissions are winsorized at the 1% level. In all panels, quintiles are computed within each fiscal year. Observations in panels on the left are equal weighted, while those in panels on the right are weighted by the firm's market capitalization as a fraction of total CRSP market size in the same year.

Figure 3: Focus on percentage reductions in emissions intensity

FINANCIAL TIMES | CLIMATE LEADERS 2022
statista

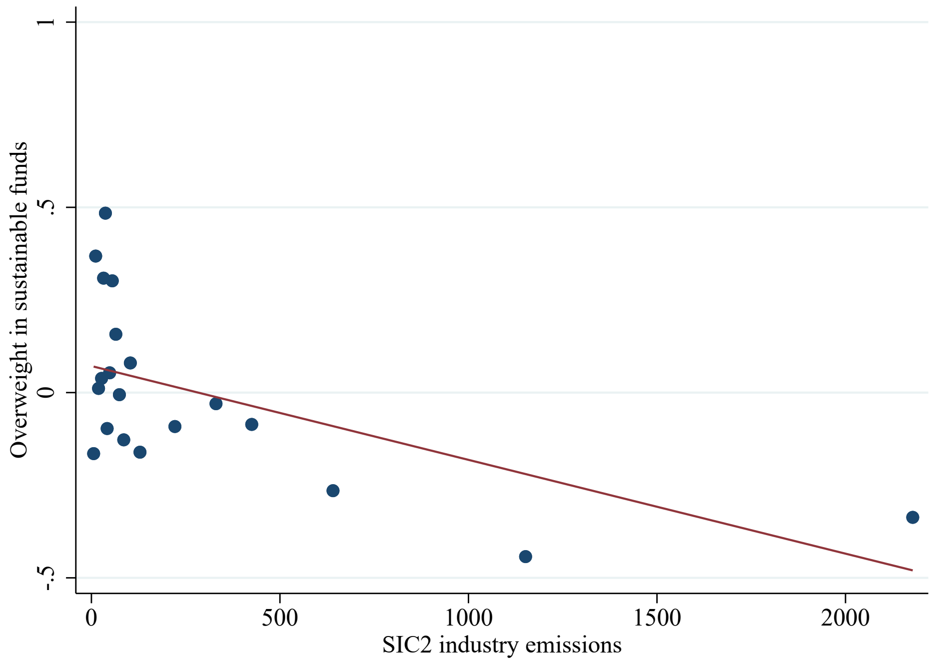
Europe's Climate Leaders 2022

Company	Country	Sector	Reduction of core emissions intensity (Scope 1 and 2) YoY 2015-20 [1]	Core emissions intensity (GHGs in tonnes per €mn revenue) [2]	Core emissions in tonnes (CO2 equivalent) [2]	Total reduction of core emissions 2015-20 [3]	Scope 3 emissions reported? [4]	CDP rating [5]	Participation in Science Based Targets initiative (SBTi) [6]
Logitech International	Switzerland	Technology & Electronics	46.8%	0.4	1,889	88.9%	yes	-	Committed
CAP	Italy	Energy & Utilities	45.2%	14.2	3,365	95.1%	yes	-	-
ICA Gruppen	Sweden	Retail & Ecommerce	42.4%	1.5	19,394	92.1%	yes	Not scored (F)	Targets set, well below 2°C
Rosenberger	Germany	Technology & Electronics	42.3%	0.4	554	89.6%	no	-	-
Vaisala	Finland	Technology & Electronics	41.3%	1.1	431	91.7%	yes	B	-
SEGRO	UK	Property	39.5%	7.2	3,489	86.0%	yes	B	Targets set, 1.5°C
Sopra Steria	France	Consulting & Professional Services	39.4%	1.1	4,842	72.9%	yes	A	Targets set, 1.5°C
Garrigues	Spain	Consulting & Professional Services	37.2%	0.9	329	88.8%	yes	-	-
Akzo Nobel	Netherlands	Chemicals & Materials	36.5%	26.4	225,360	94.1%	yes	Not scored (F)	Targets set, 1.5°C
Intermediate Capital Group	UK	Financial Services	36.4%	0.2	195	80.8%	yes	B	Targets set, 1.5°C

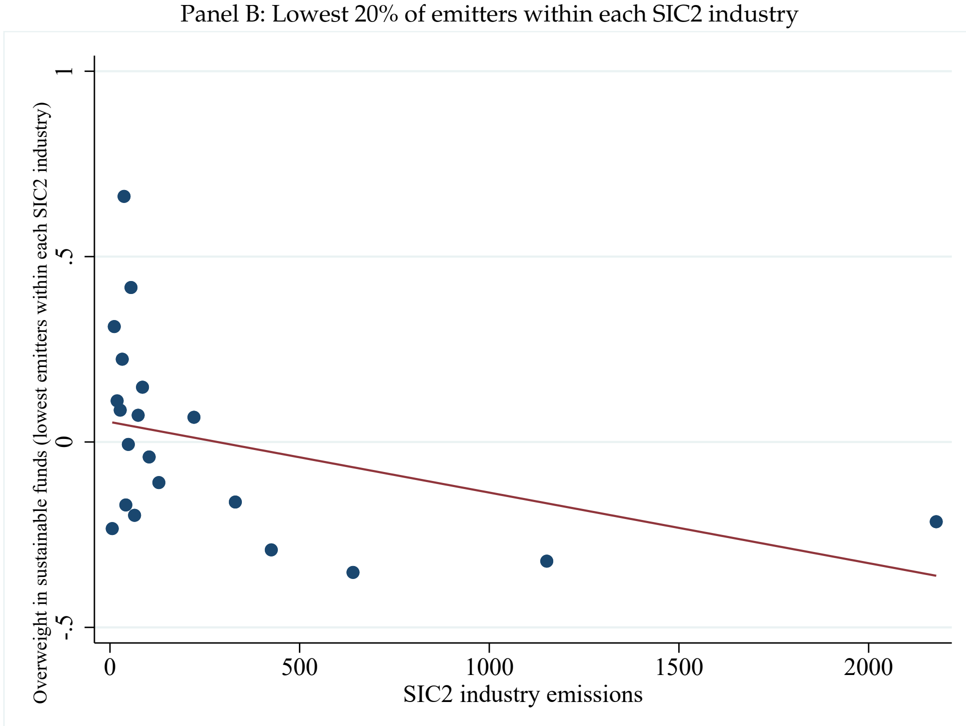
This figure reproduces the Financial Times ranking of the top climate leaders of 2022. Firms are ranked according to their percentage reductions in emissions intensity. The top ten climate leaders all have emissions intensity levels below 27 tons per million euros of revenue, equal to approximately 26 million tons per million dollars of revenue based on the average exchange rate in 2022. This can be contrasted with brown firms in our sample, which have emissions intensity levels averaging 1,308 tons per million dollars of revenue.

Figure 4: Sustainable fund allocations by SIC2 industry

Panel A: Full sample



Panel B: Lowest 20% of emitters within each SIC2 industry



This figure shows the relation between each SIC2 industry's emissions and the extent to which the industry is overweighted in the aggregate sustainable fund portfolio. Panel A uses data on industry emissions in each year based on a value-weighted average of all firms within each SIC2 industry. Panel B uses only the 20% of firms within each industry-year with the lowest emissions to compute overweights in the aggregate sustainable fund portfolio; industry emissions are calculated as the value-weighted average of all firms within each industry. Observations underlying the estimates are at the industry-year level, with the overweight demeaned by year. Estimates are derived from a regression of the industry's overweight in the aggregate sustainable fund portfolio (relative to the weight implied by the industry's market capitalization) on the industry's emissions (measured as raw emissions / revenue). Dots represent a binscatter plot with 20 bins, each representing 5% of the sample.

Table 1: Summary statistics

	Mean	SD	p10	p50	p90
Total emissions	2.9108	14.2872	0.0020	0.0940	3.7344
Emissions intensity (emissions/revenue)	258.3385	733.6663	3.4686	40.9054	534.9951
Absolute changes in emissions	40.9152	136.9312	0.1877	2.1437	82.2685
Absolute percentage changes in emissions	0.1878	0.9823	0.0125	0.0598	0.3220
Changes in emissions	-5.4233	106.6247	-25.0598	-0.5229	11.5415
Annual return	0.1453	0.4603	-0.3499	0.0993	0.6279
Industry annual return	0.1830	0.2195	-0.0647	0.1898	0.4181
ΔICC	-0.0006	0.0265	-0.0274	-0.0013	0.0284
ΔIndustry ICC	-0.0008	0.0126	-0.0136	-0.0016	0.0144
ΔICC composite	0.0035	0.0607	-0.0545	-0.0001	0.0700
ΔIndustry ICC composite	0.0001	0.0302	-0.0306	-0.0032	0.0342

This table presents summary statistics for our main analysis sample, consisting of observations at the firm-year level. Total emissions is measured as million tons of CO_2 equivalents. Emissions intensity is tons of emissions per million dollars of revenue. Hereafter, we refer to emissions intensity as emissions for brevity. Absolute change in emissions is the absolute value of the annual change in the level of emissions. Absolute percentage change in emissions is the absolute value of the annual fractional change in emissions. Annual return is the annual return of the firm, adjusted for splits and dividends. Industry annual return is the annual value-weighted return within each SIC2 industry, calculated excluding the focal firm. ΔICC is the annual change in the firm implied cost of capital estimated using the mechanical GLS method, as described in Lee et al. (2021). ΔIndustry ICC is the annual value-weighted change in industry ICC, calculated excluding the focal firm. ΔICC composite is the annual change in the firm implied cost of capital estimated using the composite method, as described in Lee et al. (2021). ΔIndustry ICC composite is the annual value-weighted change in industry ICC composite, calculated excluding the focal firm. Returns and ICCs are measured as logarithms of one plus the quantity to reduce the influence of outlier observations.

Table 2: Emissions and financial performance

	Changes in emissions	
	(1)	(2)
Brown × Annual return	-83.51***	
	(9.186)	
Neutral × Annual return	1.717	
	(1.102)	
Green × Annual return	0.277	
	(1.453)	
Brown × Industry annual return		-133.1***
		(19.41)
Neutral × Industry annual return		-8.773*
		(4.846)
Green × Industry annual return		-9.688*
		(5.702)
p-value: Brown × X = Green × X	0.000	0.000
Type FE	Yes	Yes
Year FE	Yes	Yes
N	23654	24277
R^2	0.0459	0.0378

This table shows changes in firms' emissions following changes in firm or industry financial performance. The dependent variable is the change in scope 1 and scope 2 greenhouse gas emissions from year t to $t+1$, where emissions is measured in tons of CO_2 equivalents emitted per million dollars of revenue. We regress the dependent variable on the interactions between firm- or industry-level returns in the previous year and indicators for whether the firm is brown, neutral, or green. All other variables are as defined in Table 1. All columns include year fixed effects and indicators for whether the firm is brown, neutral, or green. Below each regression, we report the p-value for the test of whether the coefficient for the interaction term containing the indicator for brown firms is equal to the coefficient for the interaction term containing the indicator for green firms. *, **, and *** indicate significance at the 10%, 5%, and 1% levels, respectively. Standard errors are in parentheses and are clustered at the firm level.

Table 3: Long run changes in emissions and financial performance

	Changes in emissions			
	(1)	(2)	(3)	(4)
Brown × Annual return	-212.5***			
	(33.52)			
Neutral × Annual return	-13.24***			
	(5.087)			
Green × Annual return	-10.25**			
	(4.583)			
Brown × Industry annual return		-300.8***		
		(71.09)		
Neutral × Industry annual return		-68.31***		
		(17.62)		
Green × Industry annual return		-50.50***		
		(18.87)		
Brown × Low annual return			239.2***	
			(42.98)	
Neutral × Low annual return			19.55***	
			(7.112)	
Green × Low annual return			10.44*	
			(6.271)	
Brown × Low industry annual return				122.7***
				(33.84)
Neutral × Low industry annual return				41.99***
				(10.17)
Green × Low industry annual return				16.95*
				(10.17)
p-value: Brown × X = Green × X	0.000	0.000	0.000	0.000
Type FE	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes
N	12201	12433	12201	12433
R^2	0.0843	0.0785	0.0812	0.0750

This table shows long run changes in firms' emissions following changes in firm or industry financial performance. The dependent variable is the 5-year change in scope 1 and scope 2 greenhouse gas emissions from year t to $t+5$, where emissions is measured in tons of CO_2 equivalents emitted per million dollars of revenue. We regress the dependent variable on the interactions between measures of firm or industry returns in the previous year and indicators for whether the firm is brown (quintile 1 in terms of emissions in year t), neutral (quintiles 2-4), or green (quintile 5). Low annual return (low industry annual return) indicator is equal to one if the firm has an annual return (industry annual return) in the bottom decile within our sample. All other variables are as defined in Table 1. All columns include year fixed effects and indicators for whether the firm is brown, neutral, or green. Below each regression, we report the p-value for the test of whether the coefficient for the interaction term containing the indicator for brown firms is equal to the coefficient for the interaction term containing the indicator for green firms. *, **, and *** indicate significance at the 10%, 5%, and 1% levels, respectively. Standard errors are in parentheses and are clustered at the firm level.

Table 4: Emissions and financial distress

	Changes in emissions			
	(1)	(2)	(3)	(4)
Brown × Low interest coverage	40.73***			
	(14.22)			
Neutral × Low interest coverage	-4.964***			
	(0.926)			
Green × Low interest coverage	-5.412***			
	(1.400)			
Brown × Low Z-score		44.59***		
		(11.85)		
Neutral × Low Z-score		-4.111***		
		(0.965)		
Green × Low Z-score		0.282		
		(2.363)		
Brown × Low annual return			73.68***	
			(9.694)	
Neutral × Low annual return			-3.193**	
			(1.270)	
Green × Low annual return			-3.627**	
			(1.802)	
Brown × Low industry annual return				54.79***
				(10.17)
Neutral × Low industry annual return				3.113
				(2.785)
Green × Low industry annual return				1.378
				(2.932)
p-value: Brown × X = Green × X	0.001	0.000	0.000	0.000
Type FE	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes
N	19747	19080	23654	24277
R^2	0.0289	0.0297	0.0360	0.0325

This table shows changes in firms' emissions following financial distress. The dependent variable is the change in scope 1 and scope 2 greenhouse gas emissions from year t to $t+1$, where emissions is measured in tons of CO_2 equivalents emitted per million dollars of revenue. We regress the dependent variable on the interactions between indicators for financial distress in the previous year and indicators for whether the firm is brown (quintile 1 in terms of emissions in year t), neutral (quintiles 2-4), or green (quintile 5). The low interest coverage indicator is equal to one if the firm has positive interest payments and negative earnings, or the firm has an earnings to interest ratio that is in the bottom decile within our sample. The low Z-score indicator is equal to one if the firm has an Altman Z-score in the bottom decile within our sample. Low annual return (low industry annual return) indicator is equal to one if the firm has an annual return (industry annual return) in the bottom decile within our sample. All columns include year fixed effects and indicators for whether the firm is brown, neutral, or green. Below each regression, we report the p-value for the test of whether the coefficient for the interaction term containing the indicator for brown firms is equal to the coefficient for the interaction term containing the indicator for green firms. *, **, and *** indicate significance at the 10%, 5%, and 1% levels, respectively. Standard errors are in parentheses and are clustered at the firm level.

Table 5: Emissions and implied cost of capital (ICC)

	Changes in emissions			
	(1)	(2)	(3)	(4)
Brown × ΔICC	619.4***			
	(149.6)			
Neutral × ΔICC	-25.10			
	(20.90)			
Green × ΔICC	4.207			
	(19.20)			
Brown × ΔIndustry ICC		521.1*		
		(284.0)		
Neutral × ΔIndustry ICC		-210.8***		
		(80.24)		
Green × ΔIndustry ICC		-72.61		
		(70.97)		
Brown × ΔICC composite			402.5***	
			(105.3)	
Neutral × ΔICC composite			-6.994	
			(14.28)	
Green × ΔICC composite			-4.821	
			(15.50)	
Brown × ΔIndustry ICC composite				504.3***
				(133.5)
Neutral × ΔIndustry ICC composite				-30.99
				(26.90)
Green × ΔIndustry ICC composite				36.26
				(31.23)
p-value: Brown × X = Green × X	0.000	0.037	0.000	0.001
Type FE	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes
N	16283	24173	7078	22747
R^2	0.0329	0.0265	0.0340	0.0282

This table shows changes in firms' emissions following changes in firm or industry implied cost of capital (ICC). Measures of the ICC are as defined in Table 1. The dependent variable is the change in scope 1 and scope 2 greenhouse gas emissions intensity from year t to $t+1$, where emissions intensity is measured in tons of CO_2 equivalents emitted per million dollars of revenue. All columns include year fixed effects and indicators for whether the firm is brown, neutral, or green. Below each regression, we report the p-value for the test of whether the coefficient for the interaction term containing the indicator for brown firms is equal to the coefficient for the interaction term containing the indicator for green firms. *, **, and *** indicate significance at the 10%, 5%, and 1% levels, respectively. Standard errors are in parentheses and are clustered at the firm level.

Table 6: Interaction between leverage and real productivity shocks

	Changes in emissions	
	(1)	(2)
Brown × Low interest coverage × ΔIndustry ROA	-580.9*	
	(299.5)	
Neutral × Low interest coverage × ΔIndustry ROA	8.113	
	(41.08)	
Green × Low interest coverage × ΔIndustry ROA	188.6**	
	(87.36)	
Brown × Firm leverage × ΔIndustry ROA		-907.3*
		(498.5)
Neutral × Firm leverage × ΔIndustry ROA		-72.55
		(93.76)
Green × Firm leverage × ΔIndustry ROA		342.3***
		(111.6)
p-value: Brown × X × Z = Green × X × Z	0.014	0.014
Type × ΔIndustry ROA	Yes	Yes
Type × Low interest rate	Yes	Yes
Type × Firm Leverage	No	No
Type FE	Yes	Yes
Year FE	Yes	Yes
N	19677	24182
R^2	0.0300	0.0282

This table shows the interaction between leverage and real productivity shocks. The dependent variable is the change in scope 1 and scope 2 greenhouse gas emissions from year t to $t+1$, where emissions is measured in tons of CO_2 equivalents emitted per million dollars of revenue. We regress the dependent variable on the interactions between firm leverage (as measured by an indicator for low interest coverage or the firm's debt-to-market value ratio), the change in industry ROA, and indicators for whether the firm is brown (quintile 1 in terms of emissions in year t), neutral (quintiles 2-4), or green (quintile 5). The low interest coverage indicator is equal to one if the firm has positive interest payments and negative earnings, or the firm has an earnings to interest ratio that is in the bottom decile within our sample. All other variables are as defined in Table 1. All columns include year fixed effects, indicators for whether the firm is brown, neutral, or green, the interactions between firm type and firm leverage (or indicator for low interest coverage), the interactions between firm type and the change in industry ROA. Below each regression, we report the p-value for the test of whether the coefficient for the interaction term containing the indicator for brown firms is equal to the coefficient for the interaction term containing the indicator for green firms. *, **, and *** indicate significance at the 10%, 5%, and 1% levels, respectively. Standard errors are in parentheses and are clustered at the firm level.

Table 7: Dividend demand shocks to the cost of capital

	Changes in emissions	
	(1)	(2)
Brown × High dividend yield firm × Dividend demand	-68.08**	
	(34.29)	
Neutral × High dividend yield firm × Dividend demand	0.385	
	(3.334)	
Green × High dividend yield firm × Dividend demand	-2.079	
	(2.191)	
Brown × High dividend yield firm × High dividend demand		-42.96**
		(18.00)
Neutral × High dividend yield firm × High dividend demand		-0.217
		(1.804)
Green × High dividend yield firm × High dividend demand		-0.447
		(1.020)
p-value: Brown × X × Z = Green × X × Z	0.055	0.019
Type × Dividend demand	Yes	No
Type × High dividend demand	No	Yes
Type FE	Yes	Yes
Firm size interaction controls	Yes	Yes
Year FE	Yes	Yes
N	17113	17113
R^2	0.0395	0.0399

This table shows the relationship between emissions and dividend demand shocks. The dependent variable is the change in scope 1 and scope 2 greenhouse gas emissions from year t to $t+1$, where emissions is measured in tons of CO_2 equivalents emitted per million dollars of revenue. Dividend demand is an annual variable equal to the value-weighted interim return (in %) between the dividend announcement day and the ex-dividend day across all dividend payment events in the previous year. The high dividend demand indicator represents whether the interim return was above the median over our sample period. High dividend yield firm is an indicator for whether the firm had a dividend yield above the median of dividend payers in the prior year. All columns control for the direct effects and interactions of (High) dividend demand and indicators for whether the firm is brown, neutral, or green, year fixed effects. All columns also control for firm size (measured as the logarithm of firm annual sales) interacted with firm type indicators (green/brown/neutral) and the triple interaction between firm type, firm sales, and aggregate dividend demand. For each regression, we report the p-value for the test of whether the coefficient for the interaction term containing the indicator for brown firms is equal to the coefficient for the interaction term containing the indicator for green firms. *, **, and *** indicate significance at the 10%, 5%, and 1% levels, respectively. Standard errors are in parentheses and are clustered at the firm level.

Table 8: Capital expenditures and cost of capital

	Changes in capital expenditures		
	(1)	(2)	(3)
ΔICC	-0.549***		
	(0.0548)		
Low interest coverage × ΔIndustry ROA		1.411***	
		(0.273)	
High dividend yield firm × High dividend demand			0.0232**
			(0.0107)
Direct effects of interaction terms	Yes	Yes	Yes
Year FE	Yes	Yes	Yes
N	73730	99194	96197
R^2	0.0111	0.0125	0.0111

This table explores the relation between capital expenditures and changes to the firm's cost of capital. We measure capital expenditures using the Compustat variable capx scaled by ppent (property, plant, and equipment). The dependent variable is the change in capital expenditures in the next year. We regress the dependent variable on three proxies for changes to the firm's cost of capital in the previous year: (1) the change in the firm's implied cost of capital, (2) the interaction between an indicator for whether the firm's interest coverage is in the bottom decile within our sample and the change in the firm's SIC2 industry return on assets (ROA), and (3) the interaction between an indicator for whether the firm had a dividend yield above the median of dividend payers in the prior year and an indicator for high aggregate dividend demand. All columns include year fixed effects and control for the direct effects of each variable in interaction terms. The sample includes all Compustat observations for which we have data on the cost of capital measures in each column. *, **, and *** indicate significance at the 10%, 5%, and 1% levels, respectively. Standard errors are in parentheses and clustered at the firm level.

Table 9: Portfolio holdings of sustainable funds and changes in emissions

	Overweight in aggregated sustainable funds			
	(1)	(2)	(3)	(4)
Emissions	-0.00729***	-0.00809***	-0.00703***	-0.00769***
	(0.00238)	(0.00253)	(0.00234)	(0.00249)
$\Delta_{t,t-1}$ Emissions (changes in levels)	-0.00178			
	(0.00571)			
$\Delta_{t,t-2}$ Emissions (changes in levels)		0.000585		
		(0.00466)		
$\Delta_{t,t-1}$ Emissions (changes in percents)			-0.0968**	
			(0.0382)	
$\Delta_{t,t-2}$ Emissions (changes in percents)				-0.0549*
				(0.0282)
Year FE	Yes	Yes	Yes	Yes
N	24308	21082	24308	21082
R^2	0.0107	0.0113	0.0108	0.0114

This table shows the relation between the holdings of sustainable funds and firm emissions levels and changes. The dependent variable measures the extent to which a firm is overweighted in the aggregate sustainable portfolio relative to the stock's weight in a value-weighted market portfolio (overweight is calculated as $\frac{w_{SF}-w_{mkt}}{w_{mkt}}$, where w_{SF} is the stock's weight in the aggregate sustainable portfolio and w_{mkt} is the stock's weight in a value-weighted market portfolio). All columns control for the level of emissions. Columns (1) and (2) control for the one- and two-year change in the level of emissions, respectively. Columns (3) and (4) control for the one- and two-year percentage change in emissions, respectively. All columns include year fixed effects. *, **, and *** indicate significance at the 10%, 5%, and 1% levels, respectively. Standard errors are in parentheses and are clustered at the firm level.

Table 10: Environmental ESG ratings and changes in emissions

	Environmental score			
	(1)	(2)	(3)	(4)
Emissions	-0.0190***	-0.0198***	-0.0189***	-0.0196***
	(0.00346)	(0.00361)	(0.00348)	(0.00363)
$\Delta_{t,t-1}$ Emissions (changes in levels)	-0.00503			
	(0.00756)			
$\Delta_{t,t-2}$ Emissions (changes in levels)		0.00181		
		(0.00766)		
$\Delta_{t,t-1}$ Emissions (changes in percents)			-0.128***	
			(0.0353)	
$\Delta_{t,t-2}$ Emissions (changes in percents)				-0.0892***
				(0.0257)
Year FE	Yes	Yes	Yes	Yes
N	9867	8552	9867	8552
R^2	0.156	0.167	0.156	0.169

This table shows the relation between ESG environmental ratings and changes in emissions as measured in terms of level or percentage changes. The dependent variable is the MSCI ESG environmental score. All columns control for the level of emissions. Columns (1) and (2) control for the one- and two-year changes in the level of emissions, respectively. Columns (3) and (4) control for the one- and two-year percentage changes in emissions, respectively. All columns include year fixed effects. *, **, and *** indicate significance at the 10%, 5%, and 1% levels, respectively. Standard errors are in parentheses and are clustered at the firm level.

Table 11: Portfolio holdings of sustainable funds and changes in emissions by firm type

	Overweight in aggregated sustainable funds		Environmental score	
	(1)	(2)	(3)	(4)
Emissions	-0.00626**	-0.00605**	-0.0163***	-0.0157***
	(0.00308)	(0.00304)	(0.00443)	(0.00462)
Brown × $\Delta_{t,t-1}$Emissions (change in percents)	-0.0131		-0.136*	
	(0.0752)		(0.0706)	
Neutral × $\Delta_{t,t-1}$Emissions (change in percents)	-0.138***		-0.120**	
	(0.0494)		(0.0549)	
Green × $\Delta_{t,t-1}$Emissions (change in percents)	-0.200***		-0.138**	
	(0.0588)		(0.0598)	
Brown × $\Delta_{t,t-2}$Emissions (change in percents)		0.00887		-0.0836
		(0.0480)		(0.0531)
Neutral × $\Delta_{t,t-2}$Emissions (change in percents)		-0.0819**		-0.0707*
		(0.0381)		(0.0362)
Green × $\Delta_{t,t-2}$Emissions (change in percents)		-0.168**		-0.151***
		(0.0720)		(0.0490)
p-value: Brown × X = Green × X	0.052	0.048	0.985	0.346
Year FE	Yes	Yes	Yes	Yes
Type FE	Yes	Yes	Yes	Yes
N	24308	21082	9867	8552
R^2	0.0110	0.0119	0.159	0.173

This table shows how sustainable investing reacts to percentage changes in firm emissions depending on whether the firm is brown, neutral, or green. The dependent variable in columns (1) and (2) is the stock's overweight in the aggregate sustainable portfolio as defined in Table 9. The dependent variable in columns (3) and (4) is the stock's MSCI KLD environmental rating as defined in Table 10. All columns include year fixed effects and indicators for whether the firm is brown, neutral, or green. Below each regression, we report the p-value for the test of whether the coefficient for the interaction term containing the indicator for brown firms is equal to the coefficient for the interaction term containing the indicator for green firms. *, **, and *** indicate significance at the 10%, 5%, and 1% levels, respectively. Standard errors are in parentheses and are clustered at the firm level.

Online Appendix for

Counterproductive Sustainable Investing

Samuel M. Hartzmark   Kelly Shue

Appendix A

Table A1: Long run changes in emissions, controlling for interim returns

	5-year Changes in emissions			
	(1)	(2)	(3)	(4)
Brown × Annual return	-209.4***			
	(36.27)			
Neutral × Annual return	-10.50*			
	(5.788)			
Green × Annual return	-7.677			
	(5.207)			
Brown × Industry annual return		-272.0***		
		(72.68)		
Neutral × Industry annual return		-48.64***		
		(17.40)		
Green × Industry annual return		-32.88*		
		(19.78)		
Brown × Low annual return			232.3***	
			(38.47)	
Neutral × Low annual return			15.00**	
			(7.113)	
Green × Low annual return			7.329	
			(6.074)	
Brown × Low industry annual return				90.60***
				(32.83)
Neutral × Low industry annual return				22.08**
				(9.086)
Green × Low industry annual return				-1.225
				(9.682)
p-value: Brown × X = Green × X	0.000	0.000	0.000	0.002
Interim return FE	Yes	Yes	Yes	Yes
Type FE	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes
N	11837	12202	11837	12202
R^2	0.0966	0.0891	0.0840	0.0897

This table repeats the analysis in Table 3 with the addition of control variables for the intersection between firm type (brown, neutral or green) and the firm or industry annual returns in the interim period, years t to $t+4$.

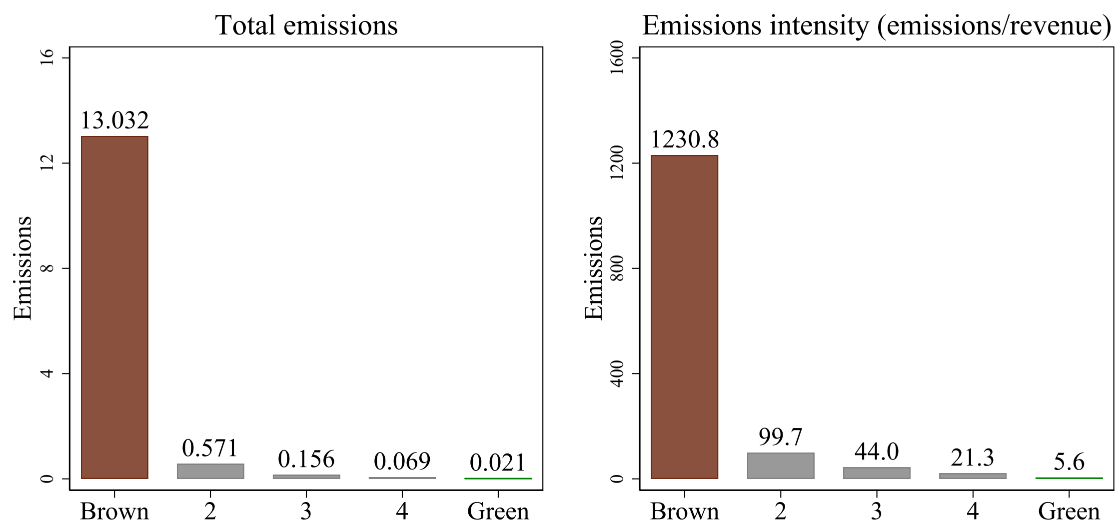
Table A2: Industry-level emissions, financial performance, and implied cost of capital (ICC)

	Changes in emissions			
	(1)	(2)	(3)	(4)
Brown × Industry annual return	-133.1***			
	(19.41)			
Neutral × Industry annual return	-8.773*			
	(4.846)			
Green × Industry annual return	-9.688*			
	(5.702)			
Brown × Low industry annual return		54.79***		
		(10.17)		
Neutral × Low industry annual return		3.113		
		(2.785)		
Green × Low industry annual return		1.378		
		(2.932)		
Brown × ΔIndustry ICC			1473.9***	
			(365.8)	
Neutral × ΔIndustry ICC			-228.2	
			(147.5)	
Green × ΔIndustry ICC			-108.0	
			(111.7)	
Brown × ΔIndustry ICC composite				1098.2***
				(225.5)
Neutral × ΔIndustry ICC composite				-71.37
				(46.59)
Green × ΔIndustry ICC composite				-17.54
				(43.21)
p-value: Brown × X = Green × X	0.000	0.000	0.000	0.000
Type FE	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes
N	24277	24277	24160	22735
R^2	0.0378	0.0325	0.0643	0.0672

This table presents the relation between SIC2 industry-level changes in emissions intensity, and the industry's financial performance in the previous year. Emissions intensity is measured in tons of emissions per million dollars of gross output. Industry annual return and industry implied cost of capital are calculated as the average of the firm annual return and ICC, respectively, weighted by the firm's market capitalization as a fraction of total CRSP market size in the same year. The regressions are weighted by the gross output of the industry as a fraction of total gross output in each year. Below each regression, we report the p-value for the test of whether the coefficient for the interaction term containing the indicator for brown firms is equal to the coefficient for the interaction term containing the indicator for green firms. *, **, and *** indicate significance at the 10%, 5%, and 1% levels, respectively. Standard errors are in parentheses and are clustered at year.

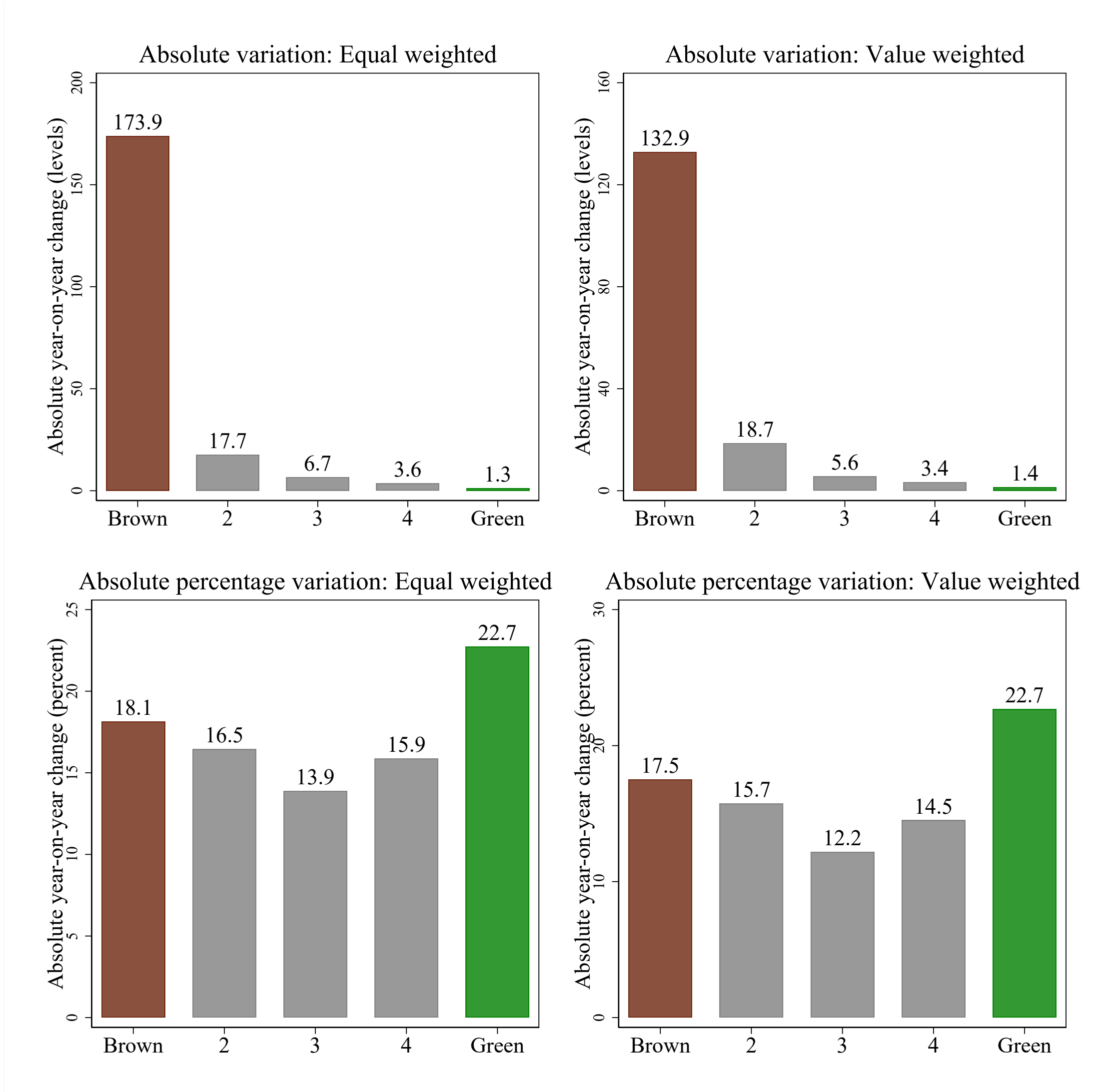
Appendix B: Result using non-estimated emission data

Figure B1: Average emissions by quintile: without estimated data



This figure replicates Figure 1 using the subsample of firm-year observations without Trucost model-estimated emissions data.

Figure B2: Absolute level and percentage change in emissions: without estimated data



This figure replicates Figure 2 using the subsample of firm-year observations without Trucost model-estimated emissions data.

Table B1: Emissions and financial performance: without estimated data

	Changes in emissions	
	(1)	(2)
Brown × Annual return	-109.3***	
	(14.52)	
Neutral × Annual return	-0.346	
	(3.185)	
Green × Annual return	2.071	
	(3.547)	
Brown × Industry annual return		-199.0***
		(29.36)
Neutral × Industry annual return		-6.187
		(11.76)
Green × Industry annual return		-7.152
		(11.09)
p-value: Brown × X = Green × X	0.000	0.000
Type FE	Yes	Yes
Year FE	Yes	Yes
N	7363	7512
R^2	0.0622	0.0553

This table replicates Table 2 using the subsample of firm-year observations without Trucost model-estimated emissions data.

Table B2: Long run changes in emissions and financial performance: without estimated data

	Changes in emissions			
	(1)	(2)	(3)	(4)
Brown × Annual return	-209.6***			
	(47.14)			
Neutral × Annual return	-23.02**			
	(9.093)			
Green × Annual return	-18.88*			
	(9.710)			
Brown × Industry annual return		-333.0***		
		(85.38)		
Neutral × Industry annual return		-70.21**		
		(33.66)		
Green × Industry annual return		-55.09*		
		(31.12)		
Brown × Low annual return			175.8***	
			(47.91)	
Neutral × Low annual return			18.75*	
			(10.70)	
Green × Low annual return			13.82	
			(11.34)	
Brown × Low industry annual return				115.0***
				(41.43)
Neutral × Low industry annual return				26.96
				(17.43)
Green × Low industry annual return				1.361
				(16.16)
p-value: Brown × X = Green × X	0.000	0.000	0.001	0.003
Type FE	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes
N	4222	4289	4222	4289
R^2	0.0914	0.0852	0.0833	0.0783

This table replicates Table 3 using the subsample of firm-year observations without Trucost model-estimated emissions data.

Table B3: Emissions and financial distress: without estimated data

	Changes in emissions			
	(1)	(2)	(3)	(4)
Brown × Low interest coverage	14.19			
	(23.40)			
Neutral × Low interest coverage	-6.885*			
	(3.564)			
Green × Low interest coverage	-3.248			
	(6.000)			
Brown × Low Z-score		39.26*		
		(21.58)		
Neutral × Low Z-score		0.152		
		(3.393)		
Green × Low Z-score		18.36		
		(19.49)		
Brown × Low annual return			84.65***	
			(15.41)	
Neutral × Low annual return			-1.120	
			(3.491)	
Green × Low annual return			-5.293	
			(3.952)	
Brown × Low industry annual return				74.39***
				(16.29)
Neutral × Low industry annual return				-5.433
				(6.500)
Green × Low industry annual return				-5.323
				(5.638)
p-value: Brown × X = Green × X	0.467	0.471	0.000	0.000
Type FE	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes
N	6736	6299	7363	7512
R^2	0.0329	0.0355	0.0448	0.0431

This table replicates Table 4 using the subsample of firm-year observations without Trucost model-estimated emissions data.

Table B4: Emissions and implied cost of capital (ICC): without estimated data

	Changes in emissions			
	(1)	(2)	(3)	(4)
Brown × ΔICC	1175.4***			
	(251.9)			
Neutral × ΔICC	-30.78			
	(44.97)			
Green × ΔICC	-63.87			
	(48.23)			
Brown × ΔIndustry ICC		1941.9***		
		(405.5)		
Neutral × ΔIndustry ICC		-214.8		
		(161.2)		
Green × ΔIndustry ICC		-80.20		
		(127.3)		
Brown × ΔICC composite			615.8***	
			(204.7)	
Neutral × ΔICC composite			-77.17*	
			(39.80)	
Green × ΔICC composite			-57.58	
			(39.98)	
Brown × ΔIndustry ICC composite				1176.6***
				(189.7)
Neutral × ΔIndustry ICC composite				-62.01
				(54.63)
Green × ΔIndustry ICC composite				2.489
				(54.60)
p-value: Brown × X = Green × X	0.000	0.000	0.001	0.000
Type FE	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes
N	4695	7484	1769	7083
R^2	0.0535	0.0445	0.0447	0.0481

This table replicates Table 5 using the subsample of firm-year observations without Trucost model-estimated emissions data.

Table B5: Interaction between leverage and real productivity shocks: without estimated data

	Changes in emissions	
	(1)	(2)
Brown × Low interest coverage × ΔIndustry ROA	-1207.6**	
	(556.1)	
Neutral × Low interest coverage × ΔIndustry ROA	58.19	
	(127.6)	
Green × Low interest coverage × ΔIndustry ROA	395.0*	
	(229.2)	
Brown × Firm leverage × ΔIndustry ROA		-2238.9**
		(889.9)
Neutral × Firm leverage × ΔIndustry ROA		-208.2
		(199.4)
Green × Firm leverage × ΔIndustry ROA		565.6***
		(215.6)
p-value: Brown × X × Z = Green × X × Z	0.008	0.002
Type × ΔIndustry ROA	Yes	Yes
Type × Low interest rate	Yes	Yes
Type × Firm Leverage	No	No
Type FE	Yes	Yes
Year FE	Yes	Yes
N	6728	7485
R^2	0.0380	0.0387

This table replicates Table 6 using the subsample of firm-year observations without Trucost model-estimated emissions data.

Table B6: Dividend demand shocks to the cost of capital: without estimated data

	Changes in emissions	
	(1)	(2)
Brown × High dividend yield firm × Dividend demand	-96.01*	
	(49.89)	
Neutral × High dividend yield firm × Dividend demand	7.870*	
	(4.405)	
Green × High dividend yield firm × Dividend demand	-7.763	
	(5.030)	
Brown × High dividend yield firm × High dividend demand		-50.23*
		(26.84)
Neutral × High dividend yield firm × High dividend demand		4.820**
		(2.299)
Green × High dividend yield firm × High dividend demand		-1.332
		(2.631)
p-value: Brown × X × Z = Green × X × Z	0.077	0.068
Type × Dividend demand	No	No
Type × High dividend demand	Yes	Yes
Type FE	Yes	Yes
Year FE	Yes	Yes
N	4430	4430
R^2	0.0396	0.0397

This table replicates Table 7 using the subsample of firm-year observations without Trucost model-estimated emissions data.