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COUNTERPRODUCTIVE SUSTAINABLE INVESTING: THE IMPACT ELASTICITY OF BROWN AND GREEN FIRMS

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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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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 (Pástor et al., 2021). 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 when their cost of capital increases. 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.

Recent empirical research suggests that investors with climate-related concerns have already changed the cost of capital for brown and green firms (see, for example, Chava (2014), van der Beck (2021), Kacperczyk and Peydró (2022), Pástor et al. (2022), Aron-Dine et al. (2023), Green and Vallee (2022),

[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.

[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.

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 offset 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 intensity from 950 in 2019 to 840 in 2021. Conversely, if the market increased Martin Marietta's discount rate, pushing it to care more about short-term profits, the company could double down on its existing brown projects which deliver more front-loaded cash flows. Simply reversing its efficiencies per dollar since 2019 would result in an increase in emissions intensity of 110, more than 100 times Travelers' annual level of emissions

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

per dollar.

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 257 times as much emissions intensity 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, we proxy for changes in a firm's cost of capital using past financial returns, and show that brown firms reduce their emissions after improvements in their financial performance, whereas green firms do not respond meaningfully. Firm investment

[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

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.

Next, we focus on identifying and quantifying a financial effect operating through the cost of capital, as distinct from potentially correlated productivity shocks. We present three tests to isolate a financial channel. First, we use the firm's implied cost of capital (ICC), defined as the internal rate of return that equates the firm's market value with the present value of expected future cash flows. Changes in ICC capture the portion of past financial returns due to changes in the cost of capital, not changes in expected cash flows. Because ICCs are measured with noise, we show robustness across several ICC measures, as well as measures of the cost of debt and the weighted average cost of capital (WACC). Second, we proxy for shocks to the cost of capital using the interaction between whether a firm is an ex ante high dividend payer and a measure of aggregate demand for dividend payments, following Hartzmark and Solomon (2013, 2019). This interaction identifies a financial effect because firms with higher dividend yields experience an additional reduction in their cost of capital when dividend demand is high, after controlling for macroeconomic conditions. Finally, we exploit variation in the share of long-term debt maturing in a given year, which largely reflects the accumulation of debt issuance decisions made years in advance. Firms that needed to roll over a larger share of long-term debt during the Credit Crisis of 2007 therefore faced a plausibly exogenous increase in their cost of capital (Almeida et al., 2012). Across all three tests, we find that brown firms exhibit large negative impact elasticities, whereas green firms' 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 present 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. 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. 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 en-

vironmental externalities regardless of which projects are chosen, leading green firms to have impact elasticities close to zero.

Consistent with our stylized model, we show that shocks to the cost of capital affect real investment choices. We examine several forms of investment that could plausibly influence emissions and broader environmental outcomes. First, we examine innovation investment using data on both green patents and total patents. Second, we examine toxic-chemical abatement investments as reported to the Environmental Protection Agency (EPA). Finally, we analyze overall capital investment. While not inherently green, capital investment is associated with lower energy intensity and reduced emissions because newer vintages of capital tend to be more efficient (Díaz and Puch, 2019; Steinbuks and Neuhoff, 2014; Alam, 2022). Capital investment is also readily observable, and it is reasonable to expect that green investment and investment more broadly respond similarly to cost of capital shocks. Across patenting activity, abatement investments, and general capital expenditures, we find that real investment declines when the cost of capital rises. These findings suggest that real investment is an important channel linking financing conditions to emissions outcomes.

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.[7]

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

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

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.[8]

In the last section, we provide a simple quantitative framework to assess how the impact elasticity channel interacts with changes in output in determining total emissions. We preface this discussion by emphasizing that our paper's main contribution is the introduction of a counterproductive impact elasticity channel, which has been underappreciated in both academic models and public discourse prior to our working paper.[9] Given heterogeneity in sustainable investor goals and heterogeneity in parameter values in different settings, characterizing an optimal sustainable investing strategy is beyond the scope of this paper. However, we can show that, under plausible assumptions, the impact elasticity channel, whereby brown firms increase emissions per unit of output, can outweigh offsetting changes in output and raise total emissions. We also outline conditions under which competing forces dominate. Even when sustainable investing reduces overall emissions, the impact elasticity channel remains relevant because it affects the magnitude of those reductions and should be considered by investors pursuing any sustainability goal.

A key insight from our framework is that a within–brown-industry sustainable investing strategy, in which investors shift capital from relatively brown firms to relatively green firms within the same brown industry, is likely to be more effective at reducing global emissions levels and emissions intensity than an across-industry strategy, in which capital is shifted from brown industries to green industries. The within-industry approach has two main advantages. First, reductions in output from the relatively brown firm are likely to be larger because product substitutability between relatively brown and relatively green firms is higher within an industry. Second, relatively green firms within brown industries typically have greater scope to reduce emissions when their cost of capital declines.

However, when we examine the data, we find that sustainable investors primarily pursue an across-industry strategy. On average, sustainable investors overweight green industries and underweight brown industries, and even the greenest firms within brown industries are underweighted relative to their market capitalization. This pattern holds both for sustainable investor portfolio holdings

[8]For example, the Carbon Underground 200 list encourages investors to divest from firms that own fossil fuel assets, 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 related to the magnitude of impact.

[9]Industry and media discussions have generally characterized our channel as novel, for example, 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.

and for popular sustainability indices used as benchmarks. Our findings therefore suggest that sustainable investing could increase its effectiveness by shifting toward a within-brown-industry strategy.

Finally, we acknowledge that the dominant sustainable investing strategy may have uncertain consequences for green R&D. Our analysis of patents implies that driving a wedge in the cost of capital for brown and green firms would lower innovation by brown firms and increase innovation by green firms. Since brown firms conduct a substantial share of green R&D (consistent with evidence on energy firms by Cohen et al. (2020)), and green firms cluster in industries such as healthcare and financial services that are unlikely candidates for meaningful green R&D, we do not find strong evidence that sustainable investing would increase net green innovation.

Our findings relate to evidence in Hong et al. (2012) and Xu and Kim (2022) showing firms do less social and environmental good when financially distressed. While these papers do not study emissions directly, their results imply that firms may increase emissions when near bankruptcy. We differ from this literature by identifying a broader cost-of-capital channel that does not rely on distress.

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 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.[10]

Finally, our findings 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 perceive greater transition risk, brown firms will face a higher cost of capital. Given their negative impact elasticity, the pricing of transition risk could ironically cause brown firms to become more brown.

[10]Engine No. 1 is an example of a successful engagement strategy with Exxon Mobil to alter its environmental impact (see also Broccardo et al. (2020), Krueger et al. (2020), and Akey and Appel (2019)). "Transition" investment funds target brown firms by investing in high-emissions industries and allocating capital to firms within these industries that are credibly reducing emissions. Other alternatives to the dominant sustainable investing strategy include regulation and carbon pricing (e.g., Pedersen (2023), Martinsson et al. (2023)).

I. 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. For example, a 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.[11] However, for investors who care

[11] We discuss how raw emissions (unscaled by output) respond to changes in the cost of capital in Section VII.

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.[12] While project-specific green financing exists, the dominant sustainable investing strategy operates at the firm level, 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 X, 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.[13] 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.

Table X about here

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.

[12] 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 various projects.

[13] 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.

A. *Impact elasticities of brown and green firms*

While the primary contribution of this paper is empirical, we present a 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, the Internet Appendix documents a variety of market participants attributing recent declines in green investment to higher interest rates (which feed into higher cost of capital). For example, 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.[14] 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."[15] The Internet Appendix provides examples from green energy executives, sustainable investing proponents and government agencies each expressing a similar sentiment.

With these motivations in mind, we now turn to our stylized model. Consider a firm evaluating various investment opportunities. Each 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, that is, projects with higher growth rates.

[14] https://www.bloomberg.com/opinion/articles/2024-01-18/coinbase-trades-beanie-babies
[15] https://www.bloomberg.com/opinion/articles/2024-02-14/lyft-had-a-typo

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.[16] Thus, we assume $C^B > C^G$ and $g^B < g^G$. 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, the two projects have the same present value, so the firm is indifferent between project B and G :

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

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.

[16] A brown firm can choose a brown project with negative or zero upfront costs by reducing pollution abatement activities or continuing existing brown production, 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.

This framework demonstrates that neither financial distress (bankruptcy risk) nor financial constraints (expensive external capital) are necessary to generate a negative impact elasticity for brown firms. A higher cost of capital naturally leads firms to discount future cash flows more heavily, thereby favoring projects with front-loaded returns. For example, an increase in the risk-free rate or in the risk premium for climate transition risk will raise the discount rate even for unconstrained brown firms, shifting preferences toward brown projects. Consistent with this, our empirical analysis shows that negative impact elasticities apply to brown firms that are far from financial distress.

While not necessary for our mechanism, financial distress is an important channel through which firms can experience a high shadow cost of capital. For example, Myers (1977) develops a debt overhang model in which a distressed, highly leveraged firm cannot easily attract new capital for positive-NPV projects because the gains primarily accrue to existing creditors. As a result, the firm undertakes new projects only if they offer unusually high returns, effectively raising its hurdle rate or "shadow cost of capital." Similarly, Lanteri and Rampini (2023) and Bolton et al. (2019) show how financing constraints distort investment toward shorter-term projects. Empirically, Gilje et al. (2020) find that distressed oil and gas firms pull forward drilling, while Ma et al. (2022) show that constrained firms purchase older, less efficient equipment. Our framework generalizes this literature on financial distress and constraints. To the extent that sustainable investors raise the cost of capital for brown firms, they may trigger financial distress or exacerbate existing constraints. However, such constraints are not required for our mechanism: an increase in the cost of capital can directly lead brown firms to prefer brown projects.

II. Data

Our data covers the years 2002 to 2020. Data on greenhouse gas (GHG) emissions comes from S&P Global Trucost. 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. We present our main results for total scope 1 and scope 2 emissions. We do not study scope 3 emissions (other indirect emissions that occur in the firm's upstream and downstream activities), because reporting of scope 3 emissions is 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 emissions is based on firm self-reported disclosures combined with proprietary model-based estimates. 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.

Accounting data on firm financial and real performance, leverage, earnings, and revenue are 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.[17] Data relating to ESG ratings come from MSCI ESG 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.[18] It is an actual (as opposed

[17] The log transformation helps to mitigate the influence of outlier returns.

[18] This is a "mechanical" measure in that it does not utilize analyst forecasts, but instead uses model-based estimates. GLS is based on a residual income model with earnings forecasts from Hou et al. (2012) and does not require an assumption

to warranted) measure, meaning it is intended to capture a firm's realized ICC rather than the ICC implied by its characteristics. We choose this measure because Lee et al. (2021) finds its performance is superior in the cross-section relative to other mechanical measures as well as compared to analyst-based measures. 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 non-unique numerical solutions. To mitigate the problems of noise, we show that our results are robust to using a composite ICC measure equal to simple average of four published mechanical ICC measures.

Data on firms' cost of debt was generously provided by the authors of Eskildsen et al. (2024). In analyses using only changes in the cost of debt to proxy for changes in the cost of capital, we restrict the sample to firms with non-zero debt. We compute each firm's weighted average cost of capital (WACC) using the implied cost of equity (the composite ICC), the cost of debt, and market-value weights. Specifically, equity and debt weights are given by $E_{i,t}/(E_{i,t} + D_{i,t})$ and $(1 - \tau_t) * D_{i,t}/(E_{i,t} + D_{i,t})$, where $E_{i,t}$ and $D_{i,t}$ denote the market value of equity and book value of debt, respectively, and τ_t is the statutory corporate tax rate (τ_t is 21% beginning in 2018 and 35% prior to 2018). This construction yields a measure of the marginal WACC, which is the relevant cost of capital for evaluating incremental investment projects. Note that coverage for the composite ICC, as well as for the cost of debt and WACC measures (which use the composite ICC as an input), is more limited than for our baseline sample, resulting in a smaller sample size in regressions using these variables.

We also examine multiple data sources to measure investment. Capital expenditures are from Compustat. For patent data, we follow the same steps as described in Cohen et al. (2020) and Liu and Ma (2025). Specifically, the data comes from the USPTO Patent Assignment Dataset and the classification of green patents is done following the guidelines developed by the OECD. Data on toxic chemical abatement expenditures comes from the Environmental Protection Agency's Toxic Release Inventory (TRI) program and the data was graciously shared by the authors of Duchin et al. (2022).

Table I about here

Table I Panel A presents summary statistics of the main variables in our analysis. The distribution of the variables across the 10th, 50th, and 90th percentiles indicate that emissions are 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 154 times as large as in the 10th percentile. The

of market efficiency (Lee, 2001).

absolute value of annual level changes in emissions is similarly right skewed, with the 90th percentile equal to 438 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.

In Table I Panel B, we compare green, neutral, and brown firms by age, sales, assets, leverage, return on assets, and market-to-book ratios, reporting the 25th, 50th, and 75th percentiles for each category. Note that we do not claim that firms are randomly assigned to be brown, green, or neutral. Differences in emissions naturally reflect fundamental differences across firms, such as industry, business strategies, and many other factors. Our primary goal is to estimate how changes in the cost of capital affect emissions for brown and green firms. Identifying the full set of underlying reasons for *why* brown and green firms differ in their impact elasticities is beyond the scope of our paper, although we will present evidence on investment choices as one important channel. We also control for the firm characteristics summarized in Panel B in all regressions throughout our analysis.

III. 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 are 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 greenhouse 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. 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 257 times as much emissions per

Figure 1 abou
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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. To illustrate why percentage change 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 162 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 32 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.

Figure 2 abou
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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.

IV. Impact elasticity

In this section, we estimate the impact elasticity of green and brown firms by examining how emissions by each type of firm change following changes to the cost of capital. We begin by using firm and industry financial returns 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.

A. 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. Under standard asset pricing theory, a decrease in the firm's cost of capital corresponds to a discount rate shock and produces positive financial returns. Conversely, an increase in the cost of capital should produce negative

returns. 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 for the general time trend of emissions over our sample period. 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 VII.C, 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 an omitted firm-time variable (e.g., if the arrival of an environmentally friendly CEO causes both a shift in green production and share price). To show that these channels are not driving our results, 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 II, we find that brown firms are significantly more elastic to shocks to firm financial performance than green firms. Column 1 shows a large and highly significant negative coefficient on the firm annual return for brown firms. This indicates that as firm financial performance improves, brown firms reduce their emissions and that negative performance by brown firms is associated with an increase in emissions. 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.

Table II about here

In column 2, we find similar patterns using industry returns (calculated excluding the focal firm) instead of firm returns. The coefficients for brown firms estimated using industry returns are slightly larger than those using individual firm returns. This may occur because individual firm returns are a noisier measure of the true cost of capital change for a firm than the industry 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 II, 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 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 experiences 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 for certain investments to fully express in the data as changes in emissions. Thus, we expect 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 measured emissions intensity. 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 III shows regressions where the dependent variable is the change in emissions intensity in year $t+5$ relative to year t. We find qualitatively similar results to

Table III abou
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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 in Section I: 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.[19]

B. Isolating the financial channel

So far, we have explored the relation between a firm's emissions and financial returns as a proxy for changes in the cost of capital. A potential concern is that financial returns may also reflect shocks to productivity, since returns contain both discount rate news (cost of capital) and cash flow news (expected productivity). 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, we exploit exogenous variation in a firm's cost of capital induced by changes in investor demand for dividend payments. Third, we exploit the idea that firms that needed to roll over a larger share of long-term debt during the Credit Crisis of 2007 faced a plausibly exogenous increase in their cost of capital.

B.1. Implied cost of capital

In our first test to isolate a cost-of-capital effect, we directly measure the implied cost of capital (ICC). The ICC is defined as the internal rate of return that equates the firm's market value with the present value of expected cash flows. Thus, it 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 past returns that is due to changes in the cost of capital, not changes in expected cash flows.

In the first two columns of Table IV, 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), fiscal year, and firm controls as described in Table I Panel B.

Table IV abou
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[19] In even-numbered columns of Table III, we repeat the analysis controlling for interim 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. This is unsurprising because both firm and industry returns exhibit weak serial correlation in our data.

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 emissions. This is true using the GLS as well as the composite ICC estimates. 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. These results again imply that brown firms have large negative impact elasticities, whereas neutral and green firms have smaller impact elasticities closer to zero.

Our ICC measures capture a firm's implied cost of *equity* capital. The firm's overall cost of capital is a weighted average of its implied cost of equity and cost of debt, that is, a WACC. In Table IV columns 3 and 4, we examine how changes in the cost of debt and WACC affect emissions in the next year. We find approximately similar estimates as in the analysis using ICC proxies for the cost of equity: an increase in the cost of capital of one percentage point corresponds to an approximate 4 to 5 tons per million increase in emissions by brown firms and a close to zero change for neutral and green firms.

As in our earlier analysis of firm performance, a limitation of looking at the relation between firm emissions and implied cost of capital is that the relation could be driven by reverse causality or by omitted variables bias. To better estimate the effect of firm cost of capital on firm emissions, we examine the relation between firm emissions and the firm's industry value-weighted WACC, 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. This also allows us to expand our sample to firms for which we have missing data on cost of debt or composite ICC measures. We find similar estimates of the impact elasticity for green and brown firms using the industry WACC.

B.2. Dividend demand

In our second 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 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.

Following Hartzmark and Solomon (2013), we measure interim returns on a characteristic-adjusted basis: the return that occurs between the dividend announcement and the ex-date after subtracting the return of a portfolio matched on size, book-to-market, and momentum. 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.[20] 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

[20]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.

the median during our sample period.[21]

We do not claim that dividend demand is uncorrelated with macroeconomic variables that could affect firm emissions. Rather, our identifying assumption is that fundamentals 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. Internet Appendix Table IA.I shows a "first stage" regression demonstrating that firms with higher dividend yields indeed experience higher returns and lower implied cost of capital and WACC when aggregate dividend demand is high.

In Table V, 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 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.

Table V about here

In column 1, the coefficient for brown firms on the interaction between the high dividend yield firm indicator and dividend demand is negative 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 decreases in the cost of capital induced by variation in dividend demand cause high-dividend-yield brown firms to decrease 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 43 tons per million of revenue more than brown non-high-dividend-yield firms. This is approximately as large as the estimated average change in emissions by brown firms when their cost of capital falls by 6 percentage points. This may initially seem like a surprisingly large change due to a dividend demand shock (our first stage estimates imply that dividend

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

demand variation lowers cost of capital by approximately 2%). This direct comparison misses 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.3. Debt rollover and the Credit Crisis

Our third test exploits a firm's need to rollover long-term debt during the Credit Crisis of 2007 as an exogenous shock to its cost of capital. The fraction of a firm's long-term debt that matures in a given year creates plausibly exogenous variation in refinancing needs, since maturity schedules reflect debt issuance decisions made years in advance. When a large share of long-term debt matures at once, sometimes referred to as a "maturity wall," firms must refinance under whatever credit conditions prevail at that time. Under normal credit conditions, financing costs are largely independent of the maturity wall because rollover risk is minimal. However, when credit markets weaken, such as during the Credit Crisis, firms facing a maturity wall experience an increase in their cost of capital (He and Xiong, 2012). This variation during the Credit Crisis is used by Almeida et al. (2012) to establish a causal effect of credit supply on firm investment and by Carvalho (2015); Benmelech et al. (2011); Duval et al. (2020) to estimate the effects of increases in financing costs on various types of firm activity.

Following these papers, we proxy for firm's debt rollover needs using the fraction of long term debt scheduled to mature in each fiscal year, which we call LT debt share due.[22] We regress the change in firm emissions in the next year on the interaction between LT debt share due and an indicator for whether the year is 2007, the year of the Credit Crisis. We also examine a dummy variable indicating whether LT debt share is high.[23] We control for the firm's total leverage and long-term leverage in all specifications. We exclude financial firms because their capital structures and debt maturities may be regulated. Our empirical specification tests whether firms with greater LT debt share due during the Credit Crisis experienced differential changes in emissions, controlling for the average relation between emissions, leverage, and the fraction of long-term debt maturing in a given year.

Table VI shows that firms with more long-term debt maturing during the Credit Crisis increased

Table VI abou

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[22] Measured as dd1/(dd1+dltt) using Compustat data.

[23] Above 20%, which corresponds to the 80th percentile among firms with long-term debt in our sample.

their emissions significantly in the following year. This holds using the continuous measure of LT debt share in column 1 and the high-share indicator in column 3. The coefficient in column 3 implies that firms in the top quintile of long term debt maturing experienced an extra 30 tons per million increase in emissions in the year after the Credit Crisis. Columns 2 and 4 expand the analysis by firm type: brown, neutral, or green. We find that the average increase in emissions is driven almost entirely by brown firms. Column 4 shows that brown firms with a high share of long-term debt maturing during the Credit Crisis increased their emissions by approximately 100 tons per million.

Reassuringly, in non-crisis years we find a near-zero relationship between emissions and the share of long-term debt maturing, with estimates that are small and inconsistently signed. This is expected because rollover risk should be low in normal years (He and Xiong, 2012) regardless of LT debt share due. Consistent with this interpretation, Internet Appendix Figure IA.5 shows that the relationship between same-year long-term debt share due and subsequent changes in emissions intensity is close to zero for brown firms in the five years before and after the Credit Crisis, while the crisis-year coefficient is large and positive. [24]

Taken together, the three tests point to a common conclusion. Across various implied cost of capital measures, dividend-demand shocks, and crisis-induced rollover shocks, increases in the cost of capital lead brown firms to increase emissions, while neutral and green firms show little response. These results support the view that our estimated impact elasticities are driven by a financial channel operating through the cost of capital rather than by correlated changes to fundamental productivity.

C. Robustness and heterogeneity

In this section, we explore heterogeneity in our main findings (summarized for convenience in Internet Appendix Table IA.III and robustness to alternative measures and specifications.

C.1. Variation by financial distress

While financial distress is one channel through which firms experience a high shadow cost of capital, our framework in Section I predicts that even brown firms far from financial distress would increase emissions following an increase in their cost of capital. In this subsection, we show empirical results consistent with this channel. Internet Appendix Table IA.IV repeats our baseline analysis but restricts the sample to firms that have zero debt or have interest coverage of ten or higher (this coverage ratio

[24] In supplementary analysis, Internet Appendix Table IA.II reports descriptive statistics showing that the dividend-demand and debt-rollover shocks have meaningful support among both brown and green firms.

is typically associated with firms rated A to AA). We find estimates of impact elasticity that are very similar within this sample of firms that are far from financial distress.

Internet Appendix Table IA.V examines the full sample but allows for heterogeneous responses to changes in the cost of capital depending on whether the firm is close to financial distress. We proxy for distress using a low interest coverage indicator, equal to one if the firm has positive interest payments and negative earnings or if its interest coverage ratio lies in the bottom decile of our sample. The triple interaction terms suggest that distressed firms exhibit a somewhat stronger reaction to changes in ICC and WACC, although the triple interaction using returns is close to zero. With that said, we do not find a statistically different response across distressed and non-distressed firms. Thus, while we do not rule out that distressed brown firms may have a larger emissions response to cost of capital shocks, our main results are not driven by financial distress alone.

C.2. Potential non-linearities

Internet Appendix Figure IA.4 plots the nonparametric local polynomial relationship between changes in emissions in year $t+1$ and the firm's annual return (top panel) and change in implied cost of capital (bottom panel) in year t. The local-linear polynomials are estimated using an Epanechnikov kernel and the optimal rule-of-thumb bandwidth. The variables are residualized for year fixed effects and firm controls as defined in Table I.

The figure shows that, while the relation is not perfectly linear, emissions of brown firms decline with firm returns and increase with the implied cost of capital. The change in emissions for green firms is well approximated by a horizontal line, consistent with an impact elasticity close to zero. Altogether, although we do not rule out potential nonlinearities, a linear specification appears to offer a reasonable approximation of the main patterns in the data.

C.3. Alternative specifications and sample periods

In Internet Appendix Table IA.VI, we re-estimate our baseline regressions with the inclusion of firm fixed effects and standard errors clustered at the industry level. We find that the estimates remain similar in magnitude to our baseline results and statistically significant after adding firm fixed effects and clustering standard errors at the industry level. The Internet Appendix reports analogous specifications with firm fixed effects for all regressions examining firm behavior, with similar results.

One may wonder if green and brown firms differ in their impact elasticities because green firms

on average have substantially better access to capital than brown firms due to the actions of sustainable investors during our sample. Sustainable investing only became popular in the later part of our sample, roughly 2016 to 2018 in the US. In Internet Appendix Table IA.VII we re-run our analysis using data from 2010 and prior (well before sustainable investing became popular) and find similar results.

C.4. Firm self-reported emissions

In our baseline results, we used data on 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 Internet Appendix Table IA.VIII, we present qualitatively similar results using data from the subset of firms that self-report annual emissions data.

V. Cost of capital and real 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.

This section examines several forms of real investment that could influence emissions and broader environmental outcomes. First, we study patent activity as a proxy for investment in innovative technologies. Second, for the subset of firms (almost all of which are brown) that are required by the Environmental Protection Agency (EPA) to report investments in toxic chemical abatement, we analyze how these abatement investments respond to cost of capital shocks. Finally, we examine how firms adjust investment in long-lived capital more generally in response to changes in the cost of capital. Note that these tests are designed to document an investment response to financing conditions, not a differential investment response by firm type. Such investment changes are more likely to mat-

ter for emissions among brown firms, which have larger environmentally relevant production and abatement margins.

Across all three contexts, we regress future changes in real investment on changes in the firm's cost of capital in year t. To better isolate a financial channel, we follow the convention of our earlier empirical tests in Section IV.B and proxy for shocks to the cost of capital using the change in the composite implied cost of capital, the change in the WACC, and 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. In regressions using variation in dividend demand, we control for the direct effects of the variables included in the interaction terms, as well as firm size 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 firms behave differently during periods of high dividend demand.[25]

We begin by examining how investments in innovation respond to changes in the cost of capital. We measure innovation using patent data from the USPTO Patent Assignment Dataset and study both green patents and total patents. Green patents are those with explicit environmental objectives following the methodology in Cohen et al. (2020); Liu and Ma (2025). We find that brown firms conduct more green R&D than green firms, consistent with findings in Cohen et al. (2020) for energy firms (which are often classified as brown by sustainable investors). The average annual number of green patents per million in sales is .0000926 and .0000142 for brown and green firms, respectively.[26]

We also analyze patents not explicitly classified as green, since they may reflect newer or more efficient production methods that reduce emissions.[27] Because patent filing and approval occur with a lag after initial innovation investments, we study patenting activity two years after the cost of capital shock. To facilitate comparisons across firms of different sizes, we scale the number of patents by sales, since larger firms may naturally invest more in innovation. Our dependent variable is the change in firm patenting activity, measured as the number of new patents (total or green) in year $t+2$ minus new patents in year t, scaled by sales in year t. We exclude firms that never filed a patent; such firms

[25] For these tests of real investment, we do not use variation from the interaction between the fraction of long-term debt maturing and the Credit Crisis. Because data on real investment are more limited, such as the smaller EPA sample or noisier patenting measures, we do not observe sufficient variation corresponding to a one-year shock like the Credit Crisis to obtain meaningful estimates.

[26] Green patents also account for a larger share of total patenting at brown firms: green patents represent 17% of total annual patents for brown firms, compared with 1.3% for green firms.

[27] Examining all patenting offers a more comprehensive dataset, and ex-ante it is plausible that green patenting and other patenting respond similarly to cost of capital shocks. Thus, it is reassuring to find similar patterns in the full patenting sample.

may engage in innovation but rely on non-patented forms of knowledge protection.

In Table VII Panel A, columns 1–2 and 5–6 show that increases in the composite ICC and WACC are associated with significant declines in total patenting activity and green patenting activity, respectively. A one percentage point increase in the cost of capital corresponds to a 4% decline in patents per million in sales relative to the mean patenting level in the regression sample, and a 2% decline in green patents relative to the mean. Using variation in dividend demand to proxy for cheaper access to financing, we find in columns 3 and 6 that a decrease in the cost of capital leads to a significant increase in total patenting, although the change in green patenting is not statistically significant. Overall, these tests suggest that higher cost of capital reduces both general innovation and green innovation.

Table VII about here

In our next setting, we examine how chemical abatement investments respond to changes in the cost of capital. The EPA operates the Toxic Release Inventory (TRI) program, which tracks hazardous chemical releases and related abatement activity (see Duchin et al. (2022) for a detailed discussion). Firms are required to participate once they exceed a minimum level of chemical emissions, and have at least 10 employees at an establishment. As a result, firms covered in the TRI data are predominantly brown firms. As part of this program, firms report the adoption of new pollution abatement measures. This data is noteworthy in that it provides direct annual measures of abatement adoption across a wide range of abatement types related to toxic chemicals, covering a long period (1990 to 2020), a large number of firms, and a highly granular set of facility-by-chemical observations. A limitation is that the data report counts of new abatement measures rather than investment amounts, and the abatement activities pertain to toxic chemicals rather than greenhouse gas emissions. Even so, we view this dataset as a useful proxy for a firm's broader pollution abatement efforts.

We aggregate this granular data to the firm-year level by weighting facility–chemical observations by their toxicity. The EPA measures each chemical's toxicity using the RSEI score, which reflects the product of the chemical's toxicity weight, the estimated dose, and the potentially exposed population. Our dependent variable is the total number of new toxic chemical abatement measures adopted in the following year by each firm, averaged across all facility–chemical observations and weighted by the corresponding RSEI scores. In addition to this measure of new abatement activity, we also examine an indicator for whether the firm adopted any new chemical abatement measure in the next year.

In Table VII Panel B, columns 1–2 and 5–6 show that increases in ICC and WACC are associated with significant decreases in both total new chemical abatement and the likelihood of adopting any new abatement measure. A one percentage point increase in the cost of capital corresponds to a 1% de-

cline in the probability of adopting any new abatement (relative to the sample mean). Using variation in dividend demand, which proxies for cheaper access to financing, columns 3 and 6 indicate that a decrease in the cost of capital leads to a significant increase in total new abatement and a significantly higher probability of adopting at least one new abatement measure. Taken together, these tests show that increases in the cost of capital reduce toxic chemical abatement investments.

Finally, we examine how general investments in long-lived capital 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 (that is, assets with a useful life exceeding one year), scaled by lagged plant, property, and equipment. Table VII Panel C shows a similar pattern to that of patenting and toxic chemicals abatement: 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 directly improves a firm's environmental impact. However, existing research shows that increases in capital investment are associated with lower energy intensity and reduced emissions because newer vintages of capital, even if not explicitly categorized as green, tend to be more energy efficient and less polluting than older capital (Díaz and Puch, 2019; Steinbuks and Neuhoff, 2014; Alam, 2022).

In addition, prior work indicates that green investment represents a substantial share of brown firms' overall capital expenditures, and regulators often describe green production as highly dependent on new capital.[28] Green investment focused on decarbonization, clean water, and sustainable infrastructure is estimated to account for roughly 15% of global capital expenditures over the 2016 to 2019 period (Goldman Sachs 2022).[29] Given that we observe that firms reduce general capital investment following increases in their cost of capital, green investment would need to be fundamentally different from other forms of capital investment in order not to respond similarly.

Taken together, our analyses of real investment show that increases in the cost of capital lead firms to reduce investment across multiple dimensions, including general innovation, green patenting, pollution abatement, and overall capital formation. These changes in real investment represent an important channel through which the cost of capital can affect firm emissions. However, we caution that real investment is unlikely to be the only channel, which is why we study emissions data directly in our main analysis. Cost of capital may also influence ongoing business strategy and operating de-

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

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

cisions that affect emissions. For example, firms might scale back on existing abatement measures or regulatory compliance, or adjust variable-cost decisions such as purchasing cleaner energy or usage of pollution-control equipment, such as scrubbers.[30] These choices would not be reflected in our investment data. We therefore interpret our findings on investment as supporting evidence that highlights one important mechanism through which firms alter their emissions in response to the cost of capital.

VI. 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 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 has not, on average, provided such incentives.

To study these indirect incentive effects, we examine the extent to which sustainable investors have rewarded companies that improved their environmental impact. Using data on the holdings of sustainable investment funds, we test whether they increase their holdings of firms that lowered their emissions, holding the current level of emissions constant. Using data on ESG ratings 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 incentives for brown firms to become more green. Sustainable investment funds indeed overweight firms that improved their impact, 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, for example, 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.[31]

[30] Related evidence from Thomas et al. (2022) shows that firms adjust pollution abatement efforts at a high frequency to meet earnings targets.

[31] 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

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 Internet Appendix Figure IA.1). 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 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 VIII, 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 in Figure 2, green firms are associated with large 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 that of similarly-sized brown firms.

Table VIII about here

The estimates in Table VIII 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

and Soll, 2008).

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 IX, 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.

Table IX abou here

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. In Table X, 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. This 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 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,[32] which encourages divestment from brown firms based on the firms' ownership of potentially polluting assets.

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

VII. Total emission impact and implications for sustainability goals and practices

We have documented a counterproductive impact elasticity channel: a higher cost of capital causes brown firms to pollute more per unit of output, while a lower cost of capital for green firms yields limited emissions reductions. We believe that any investor seeking sustainability goals should take our channel into account. However, the existence of our counterproductive channel does not imply that the overall impact of the dominant sustainable investing strategy would be counterproductive.

In this final section, we show that the net effectiveness of the dominant strategy depends on the strength of countervailing forces and investors' environmental objectives. We first present a framework that illustrates how the impact elasticity channel interacts with output responses to determine the strategy's overall influence on global emissions. Using this framework we provide a back of the envelope calculation to give plausible ranges of the overall impact of sustainable investing. We then describe how various sustainability goals map into our framework. Finally, we empirically examine investing practices, focusing on across-industry allocations that may affect the strategy's effectiveness.

A. Framework to understand change in total emissions

This section provides a simple quantitative framework to assess how the impact elasticity channel interacts with changes in output in determining global emissions. We also clarify how product substitutability governs the elasticity of output with respect to the cost of capital and, ultimately, the effectiveness of sustainable investing strategies.

Consider a world with two representative firms indexed by $i \in \{B, G\}$, representing a brown firm and a green firm. Let S_i denote the sales of firm i, which we use as a proxy for output.[33] We assume the two firms are initially equal in size, denoted by S (so that $S_B = S_G = S$). This symmetry ensures that if sustainable investors create a wedge between the costs of capital faced by brown and green firms, the induced changes in financing costs and output are symmetric in magnitude. Let E_i denote the level of emissions for firm i, and let emissions intensity be defined as $e_i = E_i/S_i$, with $e_B > e_G$. World emissions level is $E_W = e_B S_B + e_G S_G$, and world emissions intensity is $e_W = \frac{E_B+E_G}{S_B+S_G}$.

To model the cost-of-capital wedge created by sustainable investors, we write the cost of capital r_i for firm i as the combination of a firm-specific baseline rate $\bar{r}_i$ (the rate absent sustainable investing) and an incremental wedge δ. Specifically, we define the cost of capital for B as $r_B = \bar{r}_B + \delta$ and for G as

[33] Ideally, we would observe physical output rather than sales, but we are constrained to study sales because of data limitations. This distinction is muted in our framework because firms charge approximately constant markups over marginal cost. As a result, changes in sales largely reflect changes in quantities up to a proportional price adjustment.

$r_G = \bar{r}_G - \delta$. We model outcomes for firm i as functions of these rates, denoted $e_i(r_i)$ and $S_i(r_i)$. This representation allows us to solve for a simultaneous increase in the cost of capital for B and decrease for G as δ rises, while allowing for potential heterogeneity in their baseline costs of capital.

By the chain rule, $dr_B/d\delta = 1$ and $dr_G/d\delta = -1$. To keep the notation tractable, let $\frac{de_i}{dr}$ denote elasticities evaluated at baseline rates $\bar{r}_i$, so we can express the wedge sensitivities as $\frac{de_B}{d\delta} = \frac{de_B}{dr}$ and $\frac{de_G}{d\delta} = -\frac{de_G}{dr}$. Similarly, assuming the two firms share a common output elasticity with respect to the cost of capital, denoted $\frac{d\ln S}{dr}$, the response of output to the wedge is: $\frac{d\ln S_B}{d\delta} = \frac{d\ln S}{dr}$ and $\frac{d\ln S_G}{d\delta} = -\frac{d\ln S}{dr}$.

Differentiating world emissions with respect to δ and evaluating at $\delta = 0$ yields

$$\left.\frac{dE_W}{d\delta}\right|_{\delta=0} = S\left[\left(\frac{de_B}{dr} - \frac{de_G}{dr}\right) + \frac{d\ln S}{dr}(e_B - e_G)\right].$$

The first term in parentheses represents the net impact elasticity effect. Assuming $\frac{de}{dr} \geq 0$, as implied by our empirical estimates, this term captures the increase in brown emissions intensity (due to higher rates) and the reduction in green emissions intensity (due to lower rates). The second term captures the change in emissions due to changes in output. Since the output elasticity $\frac{d\ln S}{dr}$ is negative, this term reduces emissions, with the magnitude scaled by the difference in intensities $(e_B - e_G)$. Note that this derivation is local and applies to small increases in the cost-of-capital wedge. For sufficiently large increases in δ, brown firms eventually exit, as we will discuss in the next subsection.

A similar decomposition applies to world emissions intensity. Differentiating e_W with respect to δ and substituting the cost-of-capital derivatives yields

$$\left.\frac{de_W}{d\delta}\right|_{\delta=0} = \frac{1}{2}\left[\left(\frac{de_B}{dr} - \frac{de_G}{dr}\right) + \frac{d\ln S}{dr}(e_B - e_G)\right].$$

These results imply that both world emissions levels and world emissions intensity decline if

$$\frac{d\ln S}{dr} < -\frac{1}{e_B - e_G}\left(\frac{de_B}{dr} - \frac{de_G}{dr}\right).$$

This condition highlights that the effectiveness of the dominant sustainable investing strategy depends on the net sensitivity of emissions intensities versus output. If the green firm cannot become "greener" (so $\frac{de_G}{dr} \approx 0$), world emissions will decline only if the brown firm's output contracts enough (captured by a sufficiently negative $\frac{d\ln S}{dr}$) to offset its rising emissions intensity.

Next, we provide back-of-the-envelope estimates of plausible ranges of magnitudes for the overall

emissions impact. Because sustainable investing is context specific, we aim only to provide rough magnitudes. However, the framework can be applied generally using scenario-specific parameters.

Our estimates in Table IV imply a large impact elasticity for brown firms of roughly 400 to 600 tons per million dollars of sales for a unit increase in the cost of capital, and a close-to-zero elasticity for green firms. For this calculation, we assume $\frac{de_B}{dr} = 500$ and $\frac{de_G}{dr} = 0$. We estimate the elasticity of output with respect to the cost of capital by regressing changes in log sales on changes in firms' weighted average cost of capital, yielding $\frac{d \ln S}{dr} = -0.4$.

We consider a stylized world with one brown and one green firm, each with $35 billion in annual sales (the approximate size of a S&P 500 firm) and use the average emissions intensity of $e_B = 1{,}309$ for brown firms and $e_G = 5$ for green firms. We consider a one percentage point shock to the cost of capital (so elasticity estimates are divided by 100), implying the change in world emissions levels is $35{,}000(500 + (-0.4) \cdot (1{,}309 - 5))/100 = -7{,}560$ tons.

This calculation shows that a one-percentage-point increase in the cost of capital for B and decrease for G reduces global emissions by approximately 7,560 tons and reduces emissions intensity by 0.11 tons per million dollars of sales. Although total emissions decline, the magnitude is modest. Absent the increase in brown firm emissions intensity induced by the impact elasticity channel (that is, if $\frac{de_B}{d\delta} = 0$), total emissions would instead fall by 182,560 tons. Thus, even when total emissions contract, the impact elasticity channel substantially slows the pace of emissions reductions.

However, this estimate likely represents an upper bound on the emissions reduction, as it relies on an output elasticity that may be too high to characterize industry-level changes. Our measured output elasticity is identified from idiosyncratic, firm-level variation in the cost of capital, in a setting in which consumers can easily substitute away from the affected firm toward other firms producing similar products. Interpreting our simple model as a world in which B and G represent firms in brown and green industries, the industry-wide output elasticity is likely to be smaller. If we consider a smaller, and plausibly more relevant, industry-wide output elasticity of $\frac{d \ln S}{dr} = -0.2$, global emissions would increase: $35{,}000(500 + (-0.2) \cdot (1{,}309 - 5))/100 = 83{,}720$ tons. Under this calibration, the contraction in brown output is insufficient to offset the increase in emissions intensity, and sustainable investing that raises the cost of capital for brown firms would increase global emissions.

The key parameter in these expressions is the elasticity of output with respect to the cost of capital, which depends on the substitutability of brown and green products. Consider a simple CES demand system where brown and green products enter a consumption aggregator with elasticity of

substitution $\sigma > 1$. An increase in the cost of capital raises marginal costs and prices; the resulting revenue change reflects both price pass-through and substitution. Under monopolistic competition with Cobb–Douglas production, the (negative) revenue elasticity increases in absolute value with σ.[34]

When consumers can easily substitute away from brown products (high σ), increases in the cost of capital lead to large reductions in brown output, amplifying emissions reductions. When substitution is limited—as is likely across broad industries such as manufacturing versus healthcare—output responses are smaller, and the impact elasticity channel is relatively more important.

This distinction has direct implications for sustainable investing strategies. Targeting relatively brown and green firms *within* an industry is likely to generate larger output responses because substitutability is high. By contrast, strategies that classify entire industries as brown or green rely on substitution across fundamentally different products, where substitution may be more limited. As a result, strategies involving divestment from entire brown industries are more likely to operate through the impact elasticity channel, raising emissions intensity at brown firms while generating only modest output reductions. In this sense, tilting capital allocation *within* industries is more likely to reduce global emissions than reallocating capital *across* industries.

A within-brown-industry strategy would also benefit from the fact that $\frac{de_G}{dr}$ will not be close to zero, as a relatively green firm within a brown industry can still meaningfully reduce its emissions. Assuming sustainable investors create a one percentage point shift in the cost of capital for B and G (relatively brown and green firms within a brown industry), that the two firms have the same impact elasticity of 500, and that G has 10% lower emissions intensity than B, we estimate the total change in emissions as: $35{,}000(500 - 500 + (-0.4) \cdot (1{,}309 - 0.9 \cdot 1309))/100 = -18{,}326$ tons, demonstrating that a within-brown-industry sustainable investing strategy can effectively lower total emissions. A full summary of our calculations across various scenarios is presented in Internet Appendix Table

[34] To see how substitutability maps into the output (sales) elasticity, consider a CES demand system in which brown and green products enter a consumption aggregator with elasticity of substitution $\sigma > 1$. Final demand implies $q_i = Q\left(\frac{p_i}{P}\right)^{-\sigma}$ where $i \in \{B, G\}$, and the price index is $P = \left(p_B^{1-\sigma} + p_G^{1-\sigma}\right)^{\frac{1}{1-\sigma}}$. We assume firms utilize Cobb–Douglas production technology $Y = AK^{\alpha}L^{1-\alpha}$, where $\alpha \in (0,1)$ represents the capital share of production. Under this technology, marginal cost is proportional to r_i^{α}. Under monopolistic competition firms charge a constant markup, implying $p_i \propto r_i^{\alpha}$. Let $S_i \equiv p_i q_i$ denote firm i's sales (revenue). Then $S_i = Q\, p_i^{1-\sigma} P^{\sigma-1}$, so differentiating with respect to $\ln r$ yields

$$\frac{d\ln S_i}{d\ln r} = \alpha(1 - s_i)(1 - \sigma), \qquad s_i \equiv \frac{p_i^{1-\sigma}}{p_B^{1-\sigma} + p_G^{1-\sigma}}.$$

Note that the main text uses the semi-elasticity $\frac{d\ln S}{dr}$ to match our empirical regression specification. The two are related by $\frac{d\ln S_i}{dr} = \frac{1}{r}\frac{d\ln S_i}{d\ln r}$. Since $r > 0$, a higher σ implies a stronger sales response (larger negative magnitude) for both the log-log elasticity derived here and the semi-elasticity used in the text.

IA.IX.

Finally, we note that reductions in world emissions intensity do not necessarily imply welfare improvements when brown and green outputs are imperfect substitutes. With symmetric CES preferences, even if green output expands one-for-one with the contraction in brown output so that total output is unchanged, aggregate welfare generally declines because the resulting reallocation moves consumption away from the utility-maximizing mix when the elasticity of substitution is finite.

Taken together, this framework shows how the impact elasticity channel interacts with output responses to determine the overall effects of the dominant sustainable investing strategy on emissions. Changes in the cost of capital can have very different environmental consequences depending on output responses, which in turn depend on product substitutability. Our back-of-the-envelope calculations illustrate plausible ranges of outcomes, highlighting the importance of accounting for the impact elasticity channel even when other forces offset it.

B. Sustainability goals

While the framework above illustrates how sustainable investing can influence emissions, evaluating a strategy's success requires specifying the investor's objective (Starks, 2023; Pedersen et al., 2021). In this section, we describe common sustainability goals and how each maps into the framework.

We begin by differentiating sustainable investors, whom we define as those who 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 that the pricing of transition risk (through increasing the costs of capital for brown firms by δ) 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 reduce firm-level emissions intensity, a metric that values the firm's output while seeking a reduction in emissions; (2) economy-wide green transition: lowering global emissions intensity; and (3) de-growth: reducing emissions by shrinking brown firms and industries, without concern for reductions in output.

To achieve a firm-level transition goal, investors need to counteract the impact elasticity channel by providing sufficient incentives for brown firms to transition. We demonstrate that finan-

cial 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. 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.

An economy-wide green transition investor seeks to reduce global emissions intensity e_W while maintaining total output.[35] Our framework shows that introducing a small symmetric wedge in the costs of capital for brown and green firms can induce green firms to expand and offset the contraction in brown output, leaving aggregate output unchanged. Whether this strategy actually reduces global emissions intensity depends on whether the contraction in brown output is large enough to offset its rising emissions intensity, a trade-off governed by product substitutability. Substitutability also matters for economy-wide transition investors who care about consumption utility rather than output alone. With symmetric CES tastes for green and brown goods and finite elasticity of substitution, a reallocation that shifts the consumption mix away from equal quantities lowers the CES consumption index and therefore reduces welfare even if aggregate output is unchanged. Accordingly, emissions per unit of consumption utility can rise even when emissions per unit of output fall.

A de-growth investor seeks to decrease global emissions without the constraint of maintaining output. Our framework shows that the impact elasticity channel introduces a key complication: as the cost of capital rises, brown firms increase emissions per unit of output. Consequently, raising the cost of capital for brown firms may be counterproductive even for a degrowth investor if the decline in output does not offset the increase in emissions intensity. That said, it is theoretically obvious that a sufficiently large increase in the cost of capital will eventually cause any targeted firm or industry to exit, reducing emissions to zero. Thus, raising the cost of capital for brown firms is not counterproductive relative to a de-growth goal, provided the increase is large enough to force exit, or more generally, that the contraction in output offsets the increase in emissions per unit of output. Nevertheless, even de-growth investors should account for our estimated impact elasticities, as the "browning" of firms along the path to exit can substantially slow the pace of global emissions reductions.

[35] 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

C. *Sustainable strategies in practice: industry allocations*

Our framework suggests that a "within-brown-industry" strategy, which reallocates capital from relatively brown to relatively green firms within the same industry, has greater potential to reduce aggregate emissions than an across-industry strategy, where capital is shifted from entire brown industries to green industries. The across-industry approach has two main disadvantages. First, reductions in brown output are likely to be muted because substitutability across industries is lower than substitutability within industries (output from brown industries such as energy, agriculture, manufacturing, and transportation is imperfectly substitutable with output from green industries such as technology, finance, and healthcare). Second, because firms in green industries already have near-zero emissions, they have limited scope for further emissions reductions compared to relatively green firms within brown industries. In this section, we examine the data and show that sustainable investors primarily pursue an across-industry strategy.

Panel A of Figure 3 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.

Figure 3 abou
here

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. For example, the influential MSCI sustainable indexes are adjusted using only 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 3, 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. This evidence is inconsistent with a within-industry sorting strategy in which sustainable investors overweight relatively green firms and underweight relatively brown firms within a brown industry.

In supplementary analysis presented in Internet Appendix Section IA.C, we show that popular sustainability benchmark indices likewise overweight green industries, and do not meaningfully overweight relatively green firms within brown industries. Altogether, our results indicate that sustainable funds and indices tend to underweight entire brown industries while overweighting green industries. They also underweight relatively green firms within brown industries, which runs counter to a within-industry sorting strategy that would overweight relatively green firms within brown industries. This across-industry approach can limit the effectiveness of sustainable investing strategies aimed at achieving an economy-wide transition.

VIII. 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 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, sustainable investors primarily pursue an across-industry approach, which may be less effective at achieving an economy-wide transition.

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 in-

vestment 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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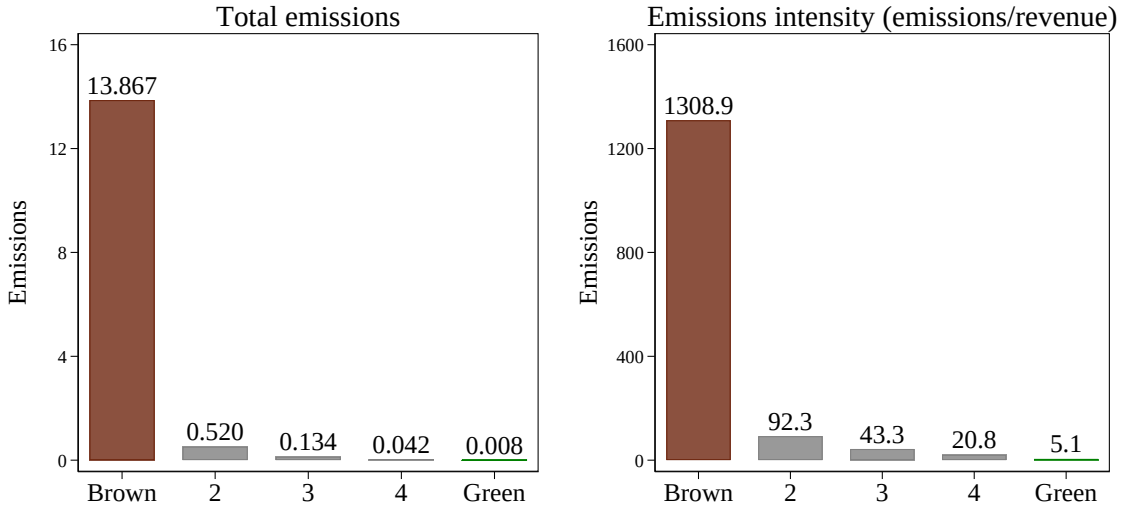
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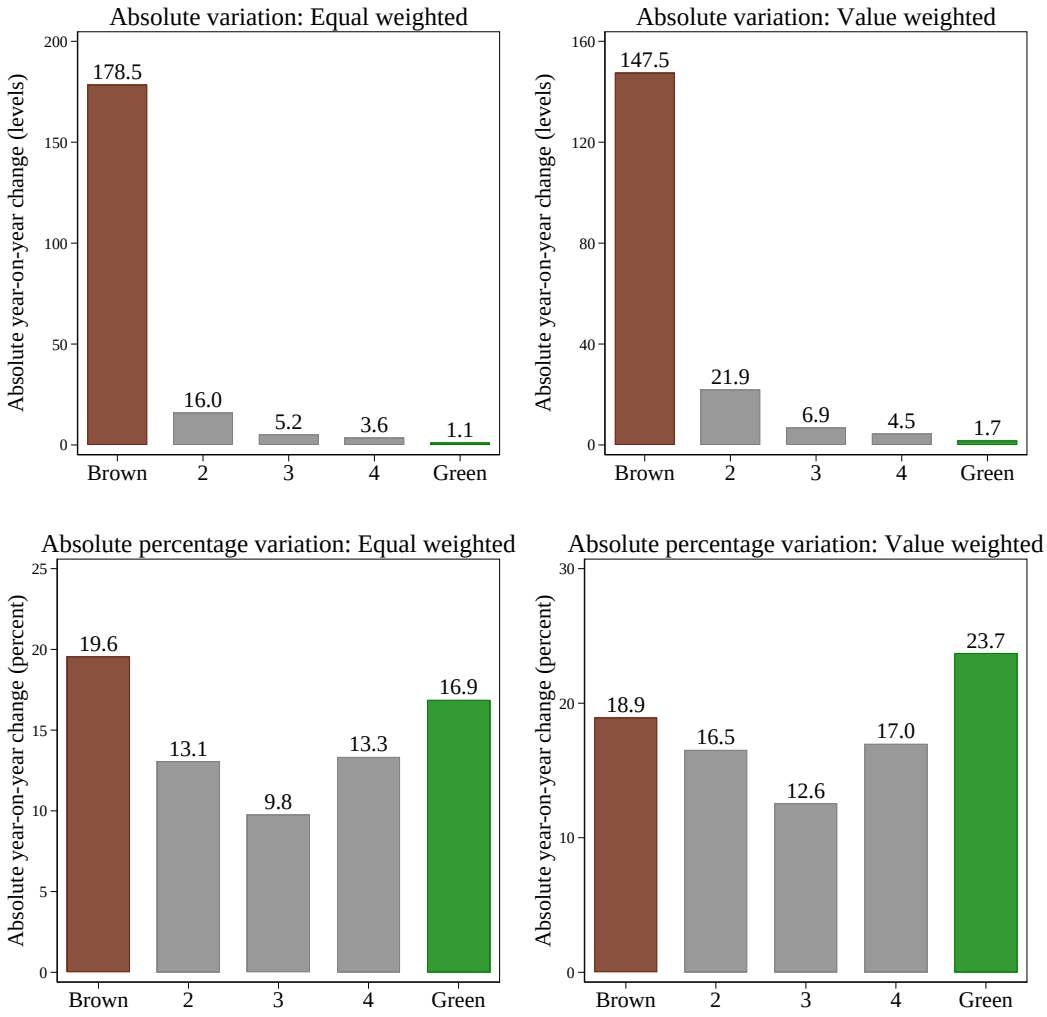
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Figure 1. Average emissions of brown and green firms



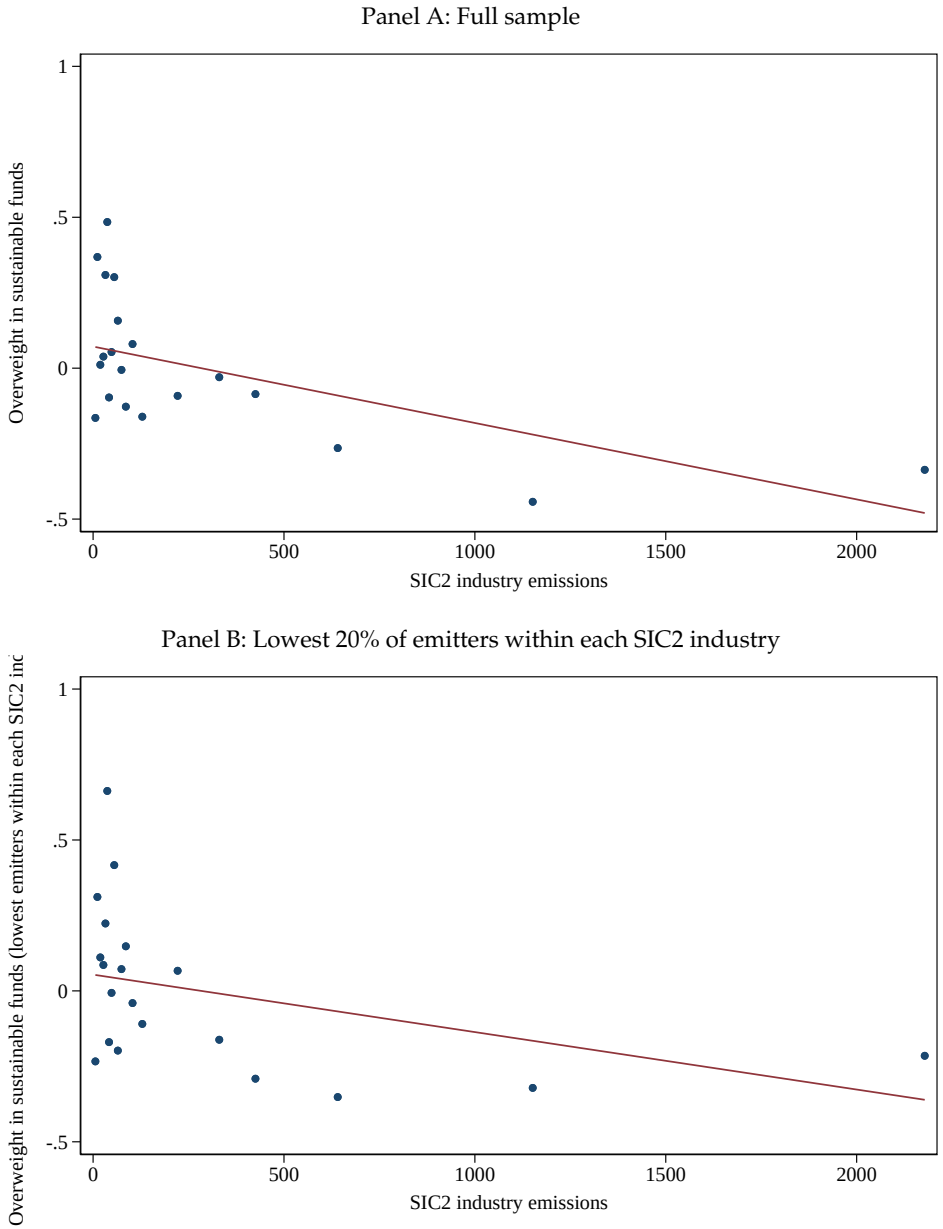
This figure plots the average emissions of scope 1 and scope 2 greenhouse gases by firms. Firms are sorted into quintiles within each year, with quintile 1 representing brown firms with the highest emissions and quintile 5 representing green firms with the lowest emissions. In the left panel, emissions 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. Sustainable fund allocations by 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 I. Summary statistics

Panel A: Full sample

	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	0.1450	0.4588	-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
ΔICC composite	0.0035	0.0607	-0.0545	-0.0001	0.0700
ΔCost of debt	-0.0024	0.0243	-0.0170	-0.0016	0.0125
ΔFirm WACC	0.0030	0.0605	-0.0502	-0.0006	0.0643
ΔIndustry WACC	-0.0004	0.0267	-0.0286	-0.0036	0.0289

Panel B: Variation by brown, neutral, and green

	Brown			Neutral			Green		
	p25	p50	p75	p25	p50	p75	p25	p50	p75
Log Age	2.3979	2.8332	3.1781	2.1972	2.7726	3.1355	2.1972	2.7726	3.0910
Log Sales	7.0288	8.1757	9.3053	6.4136	7.6921	8.8785	6.2380	7.6999	9.2504
Log Assets	7.7897	8.9302	10.1030	6.8805	8.0555	9.1947	8.0333	9.3493	10.7903
Leverage to book	0.2054	0.3090	0.4145	0.1102	0.2568	0.4153	0.0461	0.1150	0.2421
ROA	0.0504	0.0825	0.1318	0.0417	0.0919	0.1419	0.0104	0.0184	0.0778
Market to book	0.8272	1.0600	1.4524	1.0187	1.4768	2.3539	0.4161	0.9705	1.9364

This table presents summary statistics for our main analysis sample, consisting of observations at the firm-year level. Panel A shows summary statistics for the full sample. 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. Returns are measured as logarithms of one plus the raw return to reduce the influence of outlier observations. 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). 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). ΔCost of debt is the annual change in the cost of debt financing among firms with non-zero debt. ΔFirm WACC is the annual change in the firm weighted average cost of capital (WACC). ΔIndustry WACC is the annual value-weighted change in firm WACC within each SIC2 industry excluding the focal firm. Panel B shows the 25th, 50th, and 75th percentiles of each firm characteristic across firms classified as green, neutral, or brown. Firm characteristics are from the Compustat database and winsorized at the 1% level. Log age is the logarithm of firm age in years. Log sales and log assets are the logarithm of annual sales and assets. Leverage to book is debt scaled by assets (Compustat variables (dlc+dltt)/at), and return on assets is operating cash flow scaled by lagged assets (Compustat variables (ib+dp)/L.at). Market to book is market value of assets scaled by book value of assets (Compustat variables (me+dlc+dltt+pstkl+txditc)/at).

Table II. Emissions and financial performance

	Changes in emissions			
	(1)	(2)	(3)	(4)
Brown × Annual return	-83.51***	-83.44***		
	(9.186)	(9.249)		
Neutral × Annual return	1.717	1.843		
	(1.102)	(1.206)		
Green × Annual return	0.277	0.274		
	(1.453)	(1.551)		
Brown × Industry annual return			-133.1***	-132.6***
			(19.41)	(19.45)
Neutral × Industry annual return			-8.773*	-8.718*
			(4.846)	(4.934)
Green × Industry annual return			-9.688*	-10.39*
			(5.702)	(5.833)
p-value: Brown × X = Green × X	0.000	0.000	0.000	0.000
Firm controls	No	Yes	No	Yes
Type FE	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes
N	23654	23654	24277	24277
R^2	0.0459	0.0469	0.0378	0.0388

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 I. All columns include year fixed effects and indicators for whether the firm is brown, neutral, or green. Firm controls include the logarithm of firm age, sales, and assets, book leverage ratio, return on assets, and market to book. 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 III. Long run changes in emissions and financial performance

	Changes in emissions			
	(1)	(2)	(3)	(4)
Brown × Annual return	-225.3***	-228.4***		
	(34.97)	(37.63)		
Neutral × Annual return	-18.29***	-15.63**		
	(5.920)	(6.390)		
Green × Annual return	-14.46**	-14.23**		
	(5.807)	(6.300)		
Brown × Industry annual return			-325.3***	-321.8***
			(69.15)	(72.27)
Neutral × Industry annual return			-74.36***	-69.91***
			(17.58)	(17.69)
Green × Industry annual return			-59.57***	-59.55***
			(18.95)	(19.72)
p-value: Brown × X = Green × X	0.000	0.000	0.000	0.000
Firm controls	Yes	Yes	Yes	Yes
Interim return × type FE	No	Yes	No	Yes
Type FE	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes
N	11837	11837	12005	12005
R^2	0.0902	0.0997	0.0810	0.0909

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). All columns include year fixed effects and indicators for whether the firm is brown, neutral, or green. Columns 2 and 4 include controls for interim returns in the years between t and $t+4$, interacted with indicators for firm type (brown, neutral, or green). All other variables are as defined in Tables I and II. 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 IV. Emissions and implied cost of capital (ICC)

	Changes in emissions				
	(1)	(2)	(3)	(4)	(5)
Brown × ΔICC	623.8***				
	(149.0)				
Neutral × ΔICC	-32.41				
	(21.56)				
Green × ΔICC	3.861				
	(19.98)				
Brown × ΔICC composite		401.8***			
		(104.2)			
Neutral × ΔICC composite		-11.16			
		(15.13)			
Green × ΔICC composite		-3.678			
		(16.49)			
Brown × ΔCost of debt			461.2**		
			(227.5)		
Neutral × ΔCost of debt			-34.15		
			(49.71)		
Green × ΔCost of debt			-58.84		
			(83.92)		
Brown × ΔWACC				394.3***	
				(101.1)	
Neutral × ΔWACC				-13.02	
				(14.67)	
Green × ΔWACC				-1.739	
				(16.85)	
Brown × ΔIndustry WACC					494.5***
					(148.2)
Neutral × ΔIndustry WACC					-50.69*
					(30.68)
Green × ΔIndustry WACC					29.31
					(38.96)
p-value: Brown × X = Green × X	0.000	0.000	0.035	0.000	0.002
Firm Controls	Yes	Yes	Yes	Yes	Yes
Type FE	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes
N	16283	7078	7744	7078	22747
R^2	0.0345	0.0363	0.0344	0.0360	0.0283

This table shows changes in firms' emissions following changes in firm or industry implied cost of capital (ICC) and weighted average cost of capital (WACC). Measures of the ICC and WACC are as defined in Table I. 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 V. Dividend demand shocks to the cost of capital

	Changes in emissions	
	(1)	(2)
Brown × High dividend yield firm × Dividend demand	-67.84**	
	(34.26)	
Neutral × High dividend yield firm × Dividend demand	-0.255	
	(3.391)	
Green × High dividend yield firm × Dividend demand	-2.171	
	(2.338)	
Brown × High dividend yield firm × High dividend demand		-42.73**
		(17.98)
Neutral × High dividend yield firm × High dividend demand		-0.538
		(1.836)
Green × High dividend yield firm × High dividend demand		-0.503
		(1.144)
p-value: Brown × X × Z = Green × X × Z	0.056	0.019
Type × Dividend demand	Yes	No
Type × High dividend demand	No	Yes
Type × High dividend yield	Yes	Yes
Type FE	Yes	Yes
Firm size interaction controls	Yes	Yes
Firm Controls	Yes	Yes
Year FE	Yes	Yes
N	17113	17113
R^2	0.0403	0.0406

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 VI. Long-term debt maturity and the Credit Crisis

	Changes in emissions			
	(1)	(2)	(3)	(4)
LT debt share due	0.940	2.956		
	(5.565)	(4.681)		
LT debt share due × Financial Crisis	65.27***			
	(21.24)			
LT leverage	0.262	-4.129	15.99	10.83
	(22.17)	(22.76)	(22.76)	(22.97)
Brown × LT debt share due × Financial Crisis		237.3*		
		(123.0)		
Neutral × LT debt share due × Financial Crisis		9.048		
		(11.77)		
Green × LT debt share due × Financial Crisis		-5.046		
		(6.167)		
High LT debt share due			5.839**	3.123
			(2.935)	(2.800)
High LT debt share due × Financial Crisis			36.32***	
			(11.60)	
Brown × High LT debt share due × Financial Crisis				98.60*
				(57.19)
Neutral × High LT debt share due × Financial Crisis				1.838
				(3.942)
Green × High LT debt share due × Financial Crisis				-5.304
				(3.938)
p-value: Brown × X × Z = Green × X × Z		0.050		0.070
Two-way interactions	No	Yes	No	Yes
Type FE	No	Yes	No	Yes
Firm controls	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes
N	16881	16881	16881	16881
R^2	0.0202	0.0375	0.0206	0.0376

This table examines the relation between emissions and shocks to cost of capital as proxied by whether the firm has a large share of long term debt that is due during the Credit Crisis of 2007. Financial firms, defined as firms with SIC codes 6000–6999, are excluded. 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. LT debt share due is the share of long term debt that is due in year t. High LT debt share due is an indicator for whether the share of long term debt that is due in year t exceeds 0.2, which represents the 80th percentile in our sample. Credit Crisis is an indicator for whether year t is equal to 2007, the year of the Credit Crisis. Columns 1 and 3 examine the change in emissions when firms have to roll over more long-term debt during the Credit Crisis. In columns 2 and 4, we separately examine the change in emissions for brown, neutral, and green firms, and we report the p-value for the test of whether the coefficient for the triple interaction term containing the indicator for brown firms is equal to the coefficient for the triple 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 VII. Firm real investment

Panel A: Patents

	Changes in patents			Changes in green patents		
	(1)	(2)	(3)	(4)	(5)	(6)
ΔICC Composite	-0.00566***			-0.000205**		
	(0.00199)			(0.0000915)		
ΔWACC		-0.00623***			-0.000198**	
		(0.00223)			(0.0000981)	
High dividend yield × Dividend demand			0.00212***			0.00000658
			(0.000595)			(0.0000321)
Firm Controls	Yes	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes	Yes
N	5159	5159	12728	5159	5159	12728
R^2	0.0268	0.0273	0.0723	0.0147	0.0146	0.0259

Panel B: Abatement activities

	Total abatement			Any abatement		
	(1)	(2)	(3)	(4)	(5)	(6)
ΔICC Composite	-0.149**			-0.105**		
	(0.0657)			(0.0478)		
ΔWACC		-0.152**			-0.106**	
		(0.0696)			(0.0538)	
High dividend yield × Dividend demand			0.0696***			0.0394**
			(0.0256)			(0.0169)
Firm Controls	Yes	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes	Yes
N	3983	3983	9927	3983	3983	9927
R^2	0.0318	0.0318	0.0320	0.0418	0.0417	0.0371

Table VII. Firm real investment (continued)

Panel C: Capital expenditures

	Changes in capital expenditures		
	(1)	(2)	(3)
ΔICC Composite	-0.216***		
	(0.0325)		
ΔWACC		-0.176***	
		(0.0409)	
High dividend yield × Dividend demand			0.0193*
			(0.0107)
Firm Controls	Yes	Yes	Yes
Year FE	Yes	Yes	Yes
N	38711	24001	97333
R^2	0.0139	0.0152	0.0224

This table explores the relation between real investment and changes to the firm's cost of capital. In Panel A, the dependent variable is the change in the firm's patenting activity, measured as the number of new patents in year $t+2$ minus new patents in year t, scaled by sales in year t. Columns 1-3 examine all new patents, while columns 4-6 examine green patents, that is, those categorized as green following the definition in Cohen et al. (2020). The sample is restricted to firms that have at least one patent during our sample period. In Panel B columns 1-3, the dependent variable is the total number of new toxic chemicals abatement measures adopted in the next year by each firm as reported to the EPA, averaged across all firm facility-chemical level observations in each year and weighted by the Risk-Screening Environmental Indicator (RSEI) score of each facility's chemical release. A RSEI Score is calculated as chemical toxicity weight multiplied by the estimated dose, multiplied by the potentially exposed population. In columns 4-6, the dependent variable is an indicator for whether the firm adopted any new chemical abatement measure in the next year. The sample is restricted to firms covered by the EPA TRI abatement data. In Panel C, the dependent variable is the change in capital expenditures in the next year, where capital expenditure is measured as the Compustat variable capx scaled by ppent (property, plant, and equipment). In all panels, 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 ICC composite, (2) the change in the firm's WACC (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 firm controls, year fixed effects, and controls for the direct effects of each variable in interaction terms. *, **, and *** indicate significance at the 10%, 5%, and 1% levels, respectively. Standard errors are in parentheses and clustered at the firm level.

Table VIII. 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 IX. 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 X. 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 $\times$ $\Delta_{t,t-1}$ Emissions (change in percents)	-0.0131		-0.136*	
	(0.0752)		(0.0706)	
Neutral $\times$ $\Delta_{t,t-1}$ Emissions (change in percents)	-0.138***		-0.120**	
	(0.0494)		(0.0549)	
Green $\times$ $\Delta_{t,t-1}$ Emissions (change in percents)	-0.200***		-0.138**	
	(0.0588)		(0.0598)	
Brown $\times$ $\Delta_{t,t-2}$ Emissions (change in percents)		0.00887		-0.0836
		(0.0480)		(0.0531)
Neutral $\times$ $\Delta_{t,t-2}$ Emissions (change in percents)		-0.0819**		-0.0707*
		(0.0381)		(0.0362)
Green $\times$ $\Delta_{t,t-2}$ Emissions (change in percents)		-0.168**		-0.151***
		(0.0720)		(0.0490)
p-value: Brown $\times$ X = Green $\times$ 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 VIII. The dependent variable in columns 3 and 4 is the stock's MSCI KLD environmental rating as defined in Table IX. 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.