Sustainable Short Selling

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ABSTRACT

This study examines the effect of short selling on firm carbon emissions. We distinguish between active short sellers, motivated by financial gain, and passive short sellers, who primarily focus on hedging. Our findings indicate that active short selling of environmentally unfriendly ("brown") firms leads to reduced carbon emissions. Instrumental variable and triple difference-in-differences tests offer evidence of a causal link between active short selling and carbon reduction. Our evidence supports a sustainability discipline mechanism, whereby active short sellers encourage green innovation and enhance climate disclosure. We rule out alternative explanations, including increased costs of capital and operational downsizing. In contrast, passive short sellers (hedgers) have no impact on emissions. These results highlight the role of financially motivated active short sellers in driving environmental improvements and facilitating firms' transitions toward a greener economy.

Keywords: Climate finance; Carbon emission; Short selling; Green innovation

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"There are two ways to do ESG. You can own companies and vote to make a bad company into a better company or you can own less of the bad guys and short them."

Clifford S. Asness

AQR Capital Management LLC

1. Introduction

As the global economy transitions toward a low-carbon future, financial markets are playing an increasingly significant role in driving reductions in emissions. Existing studies highlight two primary mechanisms that can reduce corporate carbon emissions: active shareholder engagement through channels such as activism (Azar et al., 2021; Akey and Appel, 2019; Chu and Zhao, 2019), and divestment from carbon-intensive ("brown") firms (Rohleder et al., 2022; Choi et al., 2024; Gantchev et al., 2022). However, this literature almost exclusively focuses on the long side of capital markets, while the "short side" remains largely unexplored. Short sellers have traditionally been examined for their roles in market efficiency, price discovery, and corporate behavior, yet their potential influence on environmental outcomes remains understudied. This paper fills this gap by investigating whether short selling can serve as a sustainability-enhancing disciplinary force, particularly for high-emission brown firms.

Short selling is not a homogeneous activity and can arise from two distinct motivations: information driven trading and hedging. To separate these motives, we follow Jiao et al. (2016) and jointly consider changes in short interest and hedge fund ownership. Prior studies show that hedge funds are among the most sophisticated and influential short sellers in equity markets, and that their short-side activity reflects informed and value-relevant trading (Jiao et al., 2016; Qian et al., 2024; Ma, 2019; Appel and Fos, 2024). This joint consideration of changes in short interest and hedge fund ownership allows us to distinguish short positions that reflect informed negative beliefs about firm fundamentals from positions that reflect portfolio hedging needs. We classify active short selling as cases where short interest increases while hedge fund ownership decreases, which indicates speculative trading based on negative private or public information about the firm. In contrast, passive short selling is defined as an increase in both short interest and hedge fund ownership, indicating that hedge funds build long–short arbitrage portfolios to hedge systematic

risk. This distinction is important because only active short sellers have incentives to monitor corporate behavior and potentially exert disciplinary pressure. In contrast, passive short sellers arise mechanically from hedging and arbitrage strategies and are unlikely to impose the same level of informational scrutiny or managerial incentives.[1]

We begin by examining whether short sellers incorporate sustainability in their trading decisions. According to Pástor et al. (2022), increased demand for green stocks raises their prices, potentially leading to lower expected returns. If short sellers perceive green firms as overvalued, they may target them for short selling. Conversely, Diamond and Verrecchia (1987) suggest that short sellers exploit informational advantages by trading before negative information becomes public. If brown firms face greater negative information, short sellers may focus on them; however, if green firms face more downside news such as greenwashing allegations, they may also become short selling targets. Thus, whether short sellers preferentially target green or brown firms is ultimately an empirical question. Our results show that short sellers do consider firms' environmental performance: higher emission intensity is positively related with greater aggregate short selling, and the relationship is particularly strong for active short sellers. In contrast, passive short intensity shows no association with emission intensity. This pattern provides initial evidence that the carbon–shorting relation is driven primarily by informed, profit-driven active short sellers rather than hedging-motivated passive short positions.

Having established that short sellers incorporate firm sustainability in their short selling strategies and short sell more brown firms, we next investigate what motivates them to do so. Since short sellers are rational, profit-seeking arbitrageurs who prioritize financial gains over nonpecuniary or ethical considerations, we focus on the financial motivation and whether they benefit from shorting environmentally underperforming firms. Prior research suggests that short selling stocks with high ESG ratings involves greater synchronization risk, short squeeze risk, and reputational risks (Cao et al., 2024), which may increase the cost of short selling and lower the probability of earning positive returns.[2] This raises the key question of whether shorting environmentally detrimental,

[1] We further measure the intensive margin of active and passive short selling to capture the heterogeneity in short interest levels. *Active short intensity* is defined as short interest conditional on a stock being actively shorted, and *Passive short intensity* is defined as short interest conditional on a stock being passively shorted. See Section 2 for more details.

[2] Cao et al. (2024) identify several heightened risks associated with shorting stocks that have high ESG scores. First, there is an increased synchronization risk, as investors holding long positions are less inclined to sell overvalued stocks that demonstrate superior ESG performance. Second, stocks with high ESG scores are prone to short squeeze risks,

high-emission firms provides superior financial outcomes for short sellers.

We first look at the individual stock level and compare the returns of brown and green firms in the year they are subjected to either active or passive short selling.[3] Our results show that brown firms experience significantly lower returns when exposed to active short selling, whereas passive short selling shows no such effect. For green firms, neither active nor passive short selling is associated with lower returns. The decrease in stock price benefits short sellers, as lower stock returns indicate higher potential profits for them. This finding is consistent with the interpretation that passive short selling is driven primarily by hedging purposes, rather than financial gains. We then assess the financial returns at the institutional level by evaluating the performance of hedge funds engaged in shorting brown stocks. Our results indicate that hedge funds, as major short sellers, actively shorting brown stocks tend to outperform other hedge funds. Taken together, our findings lend support to the hypothesis that financial gains motivate arbitrageurs who actively short sell environmentally detrimental firms.

Many investors have publicly committed to short selling brown firms including hedge fund giants such as AQR and Man Group.[4] The managed funds association argued that short selling can lead to more capital allocation to carbon neutral investments and can work to pressure companies to reduce their greenhouse gas emissions.[5] In fact, short selling may be more effective than shareholder engagement in promoting environmental goals, as it allows investors to avoid the conflicts associated with holding long positions in companies with poor ESG performance. Shareholders often face a dilemma: while they wish to influence a company by owning its shares, they may hesitate to support measures that could decrease profits—even if such measures are essential for reducing emissions. In contrast, short sellers can push for meaningful environmental progress without the conflict of maintaining a financial stake in companies that may need to sacrifice profits to improve sustainability.[6] Therefore, it is important to understand whether the short selling effort has any

which are exacerbated by sentiment-driven positive price adjustments during periods of increased public attention to ESG issues. Third, short sellers face potential reputational risks when they publicly disclose substantial positions in high ESG stocks, as such actions may tarnish their public image.

[3]We sort firms into quintiles according to their carbon emission intensity. Brown firms are defined as the firms in the lowest quintile while green firms are defined as the firms in the highest quintile.

[4]Man Group posted a whitepaper in 2020: "What does responsible investing need to do to become fully mature? Go short." See https://www.man.com/maninstitute/big-green-short. CEO of AQR Cliff Asness wrote a paper "Shorting counts". See https://www.aqr.com/Insights/Perspectives/Shorting-Counts.

[5]See https://www.mfaalts.org/industry-research/the-use-of-short-selling-to-achieve-esg-goals/ for more details.

[6]James Jampel, founder of the $700 million hedge fund HITE Asset Management, believes that shorting can play a powerful role in helping the economy reduce carbon emissions. He argues that "there's this inherent conflict within

significant and sustainable impact on the carbon emission of shorted firms. We thus fill the gap in the literature and provide empirical evidence on whether short selling has an impact on firm carbon policies.

To assess whether short selling activities are associated with subsequent reduction in carbon emissions, we compare changes in emission intensity from brown and green firms over one, two, and three years. We find that brown firms reduce their carbon emissions when subjected to active shorting. The significant negative trend increases from one year to three years. This suggests that the reduction in carbon emissions is not merely a short-term effect due to temporary fluctuations in emission trends but reflects a longer-term shift in their environmental impact. In contrast, passive short sellers have no impact on emissions. These results underline the asymmetric impact of active versus passive shorting on the emissions of brown firms. Interestingly, institutional divestment appears to have no impact on carbon reduction. This supports findings from prior studies (Berk and Van Binsbergen, 2025; Atta-Darkua et al., 2023) that divestment strategies have a minimal impact on firms' environmental performance.

To address issues of potential endogeneity and spurious correlation, we adopt a twofold approach. First, we implement an instrumental-variable (IV) approach using non-ESG news as the instrument. We exclude ESG-related negative news because firms that already face such public scrutiny may begin improving their environmental performance, which could directly affect carbon-emission outcomes and violate the exclusion condition. Non-ESG news satisfies the relevance condition because it strongly predicts active short selling intensity. It also satisfies the exclusion restriction because the construction of IV explicitly removes all ESG-related negative news—the primary channel through which firms face pressure to change their environmental practices. Thus, conditional on control variables in the regression, non-ESG news influences carbon reduction outcomes only through the channel of active short selling behavior. The second stage regression results show that the fitted value of active short intensity leads to reduction in carbon intensity for brown firms, and this provides the first causal evidence that active short sellers reduce firm-level carbon emissions.

Second, we examine the effects of active short selling using a staggered difference-in-difference-

the investors who care about ESG, because they want to be able to change the company by owning it. But if you own it, you don't want to decrease its profits, even if that is what might be necessary to decrease emissions." See https://www.institutionalinvestor.com

in-difference (DDD) framework. We adopt the stacked regression approach recommended by Baker et al. (2022). Specifically, for each active short-selling event, we assign a clean control group to the treated firms. The clean control group includes both (1) firms that have not yet experienced any active short-selling event and (2) firms that never experience such an event within the sample period. The treated group consists of firms experiencing the active short-selling event. If a firm experiences more than one active short-selling activity during the sample, it is included in the treated group only for its first event. We then construct an event-specific identifier and stack the corresponding event-level datasets. The results support a causal interpretation of the relationship between active short intensity and carbon reduction.

Finally, we explore potential mechanisms through which active short selling contributes to carbon reduction in brown firms. Specifically, we explore two potential channels: the cost of capital channel and the sustainability discipline channel. The intuition behind the cost of capital channel is that when firms face active shorting, both divestment pressure on the long side and a high level of short interest on the short side can depress stock prices and increase the cost of capital. A significant increase in capital costs may force any targeted firm to reduce operations, potentially leading to its decline and the eventual elimination of its emissions (Gormsen et al., 2024; Choi et al., 2024). If brown firms are downsizing in response to the increased cost of capital from active short selling, we should observe two patterns: (1) an increase in the cost of capital following active shorting, and (2) a decline in operational activities such as revenue or capital expenditures.

To examine whether active short selling raises the cost of capital for brown firms, we use the implied cost of capital from Lee et al. (2021) and find no evidence that active short sellers raise the cost of capital for brown firms. We further examine financial performance through equity returns, where a negative return may signal a higher cost of capital, and find no return differences in the years that follow active short selling.

In addition, we examine whether active short selling affects firm operations and whether brown firms reduce their operational activities after being actively shorted. We measure operations using revenue and capital expenditures in the years that follow an active short selling event. If emission reductions occur through operational downsizing, active short selling should lead to lower sales and lower capital expenditures. However, we do not observe a consistent pattern of declines in either measure within the three years after active short selling. Taken together, the results do not

support the view that higher cost of capital or operational downsizing explains reductions in carbon emissions.

Lastly, we test the disciplining channel. Prior research shows that short sellers act as an "invisible hand" in financial markets and can discipline corporate policies across several dimensions, including earnings management, financial misconduct, and innovation (Massa et al., 2015; Hirshleifer et al., 2011; He et al., 2023). We therefore propose that short sellers can also improve environmental performance through a similar disciplinary mechanism. The intuition is that active short sellers can discipline brown firms by uncovering and publicizing environmental risks, weak transition plans, or regulatory exposure, thereby attracting greater scrutiny from investors, analysts, and the media. This pressure can depress valuations and create potential managerial consequences, prompting managers to enhance environmental practices to protect compensation, reputation, and job security. As a result, brown firms may pursue cleaner technologies, strengthen climate disclosure, or advance emission-reduction efforts. We assess this disciplinary channel through its effects on green innovation and climate-related disclosure.

We examine whether brown firms boost their green innovations following active short selling. We document a significant positive correlation between active short selling and the issuance of green patents by brown firms in the subsequent year. This effect is not observed after passive short selling. Our findings align with the findings by Choi et al. (2024), who find that carbon-intensive public firms are likely to decrease their carbon emissions by enhancing their green patenting activities in response to market pressures.

To further test the disciplining channel, we examine whether active short sellers can pressure firms to increase climate-related disclosure. Corporate disclosure is one of the most direct tools managers use to shape market perceptions. Prior research shows that the threat of short selling can lead to strategic disclosure responses that improve firm's information environment (Chen et al., 2020). They show that the threat of short selling induces managers to enhance disclosure by issuing more long-run good-news forecasts to deter future short selling. Consistent with their findings, we provide evidence that brown firms increase climate-related disclosure after exposure to active short-selling pressure. Overall, these results support a sustainability discipline channel, in which active short sellers induce brown firms to increase green innovation and climate-related disclosure over time.

This paper contributes to several strands of the literature. First, we contribute to the current literature on sustainable investing. There is a growing body of literature exploring how institutional investors influence firm environmental performance, but the majority of existing research has focused on the long-term side. To the best of our knowledge, we are the first to link short-selling behavior to carbon-emission reduction. While shareholder activism and divestment are essential channels for investors to influence firms' carbon policies, previous researchers have yielded mixed evidence regarding the effectiveness of these approaches. For example, engagement (Azar et al., 2021) and shareholder activism (Akey and Appel, 2019; Chu and Zhao, 2019) influence corporate environmental behaviors and result in lower carbon emissions and toxic chemical emissions.[7] Empirical evidence also shows that divestment from brown firms is associated with increased price pressure and thus contributes to the reduction of these firms' carbon emissions (Rohleder et al., 2022; Choi et al., 2024; Gantchev et al., 2022). In contrast, others argue that divestment strategies have had little impact (Berk and Van Binsbergen, 2025; Atta-Darkua et al., 2023) and the increase in financing costs for brown firms can even lead to an increase in their emission (Hartzmark and Shue, 2022). We provide evidence on how active short selling is associated with firm environmental performance and their potential role in driving carbon emission reductions in the economy.

Second, this paper relates to the literature on the real effects of short selling. The economic impact of short sellers has been intensively debated by academics, practitioners, and policymakers over the past few decades. Previous studies have examined the effects of short selling activities on corporate decisions, financial reporting decisions, and external auditing (Grullon et al., 2015; De Jong et al., 2011; Li and Zhang, 2015; Hope et al., 2017).[8] For example, He et al. (2023) posit that short sellers play a disciplining role to help improve the inherent quality and fundamental nature of corporate innovation. Massa et al. (2015) show that short sellers function as an external governance mechanism to discipline managers and reduce earnings management. In this paper, we complement the above literature by documenting a sustainability-based disciplinary effect associated with active short sellers; primarily, their behavior is leading to the improvement of corporate green innovation,

[7] Dyck et al. (2019) find that institutional ownership drives the environmental and social (E&S) performance of firms worldwide. However, U.S. investors, as a whole, do not actively contribute to driving environmental and social (E&S) improvements in U.S. firms.

[8] Jiang et al. (2022) review research on how short-selling affects corporate behavior and financial reporting. The evidence indicates that the threat of short-selling significantly impacts the efficiency and creativity of corporate innovation, the motivations behind managerial empire building, the structure of executive compensation, and the quality of financial reporting.

climate-related disclosure and the reduction of carbon emissions.

Third, our paper contributes to a growing literature that combines information on both long and short sides (Chen et al., 2019; Jiao et al., 2016), and links it to firm environmental performance. Current studies investigating the relationship between short selling and firm environmental performance primarily use aggregate short interest and do not focus on the potential long term effects of short seller behaviour on green innovations and carbon emissions (Hong et al., 2022; Jain et al., 2016; Cao et al., 2024).[9] By analyzing both short selling activity and hedge fund holdings, we can differentiate between short selling driven by financial gain and that motivated by hedging. Notably, short selling for hedging purposes does not correlate with improvements in firm environmental performance, whereas active short selling is associated with better carbon performance. Our approach offers significant advantages over merely analyzing aggregate short interest, providing a more comprehensive perspective on how different motivations behind short selling impact firm carbon emissions.

A key caveat of our study is that we do not suggest short sellers intentionally seek to influence firms to reduce their carbon emissions through their actions. Short sellers typically focus on short-term gains, aiming for immediate trading profits, rather than having a genuine interest in a firm's environmental innovations or carbon policies, unless these factors immediately affect the firm's market value. Therefore, the effects observed in this study may represent unintended positive outcomes arising from the actions of active short sellers, who enhance price discovery and accelerate the incorporation of negative ESG news into firms' stock prices. Unlike earlier research that centered on "voice" as the main form of discipline, our study points to "short selling" as a potential governance strategy. We reveal an "invisible hand" of short selling driven by external market forces, rather than actions taken internally by shareholders of the company or actions taken externally by activist investors.

The structure of the paper is as follows: Section 2 outlines the data sources and methodology used in the analysis. Section 3 presents the empirical tests, including key results and robustness checks. Finally, Section 4 concludes with a summary of findings and implications.

[9]Our paper differs from Hong et al. (2022) and Jain et al. (2016) in several important ways. While Hong et al. (2022) and Jain et al. (2016) focus on Corporate Social Responsibility (CSR) as a whole, we specifically examine environmental aspects. Additionally, whereas their analysis centers on firms with high CSR, we provide a broader perspective by studying both "green" and "brown" firms. This allows us to show that short sellers do not simply avoid firms with high ESG ratings but actively target brown firms and not neutral or green firms.

2. Data and methodology

2.1. Short selling data

Short selling activity is driven by two primary motivations: hedging and information-driven trading. To distinguish between these trading motivations, we follow Jiao et al. (2016) and jointly consider short selling and hedge fund holdings. An "active short selling" is defined by an increase in short interest concurrent with a decrease in hedge fund ownership, indicating speculative activity based on negative information. In contrast, a "passive short selling" occurs when both short interest and hedge fund ownership increase simultaneously, suggesting that hedge funds take both long and short positions to build arbitrage portfolios primarily for hedging purposes.

We obtained short interest from the Compustat Short Interest file, which reports fortnightly short interest for stocks listed on the NYSE, AMEX, and NASDAQ.[10] For each stock in our sample, we calculate monthly short interest (SI) as the ratio of shares sold short at the end of the month to total shares outstanding.[11] We then compute the annual average of monthly short interest to obtain the annual short interest in year t. The change in short interest, $\Delta SI_{i,t}$, is defined as the difference in annual short interest between year $t-1$ and year t. We use hedge fund quarterly holdings data from Form 13F filings to measure hedge fund ownership. For each stock, we compute the annual average of hedge fund quarterly holdings, denoted as $HFOwn_{i,t}$ for stock i in year t. The change in hedge fund ownership, $\Delta HFOwn_{i,t}$, is defined as the difference in annual hedge fund ownership between year $t-1$ and year t.[12] We define two binary variables to capture different types of short selling. The variable $Active_Short_{i,t}$ equals one when hedge fund ownership decreases from year $t-1$ to year t while short interest increases during the same period, and zero otherwise. We define $Passive_Short_{i,t}$ as one when both hedge fund ownership and short interest increase concurrently. The formal definitions are given below, where $I\{.\}$ is an indicator function:

$$Active_Short_{i,t} = I\{\Delta HFOwn_{i,t} < 0\} \times I\{\Delta SI_{i,t} > 0\}$$
$$Passive_Short_{i,t} = I\{\Delta HFOwn_{i,t} > 0\} \times I\{\Delta SI_{i,t} > 0\}$$

[10] The data have been used in several previous studies(Asquith et al., 2005; Jiao et al., 2016; Jain et al., 2016; Lee et al., 2022; Hanson and Sunderam, 2014).

[11] The use of the short interest in the middle of a month leads to very similar results.

[12] We measure hedge fund ownership and short interest at the annual level because our main dependent variable, carbon emission intensity, is available only at annual frequency.

We further measure the intensive margin of active and passive short selling to capture the heterogeneity in short interest levels. *Active short intensity* is defined as short interest conditional on a stock being actively shorted, and *Passive short intensity* is defined as short interest conditional on a stock being passively shorted. The formal definitions are as follows:

$$Active_Short_Intensity_{i,t} = SI_{i,t} \mid Active_Short_{i,t} = 1$$
$$Passive_Short_Intensity_{i,t} = SI_{i,t} \mid Passive_Short_{i,t} = 1$$

2.2. Sustainability data

Our firm-level carbon emissions data are obtained from S&P Global Trucost.[13] Trucost classifies emissions into three scopes consistent with the GHG Protocol Corporate Standard. Scope 1 emissions originate directly from sources owned or controlled by the firm, such as combustion equipment, boilers, furnaces, and vehicles. Scope 2 emissions represent indirect emissions from purchased electricity, steam, heat, or cooling. Scope 3 emissions include all other indirect emissions (not covered by Scope 2) that occur across the firm's value chain, including both upstream and downstream activities.[14] We use data on Scope 1 and Scope 2 emissions, consistent with Hartzmark and Shue (2022), and exclude Scope 3 emissions because their disclosure is often noisy, incomplete, and subject to double counting, as a customer firm's Scope 3 emissions may overlap with a supplier firm's Scope 1 emissions.

We focus on emission intensity rather than total emissions, defined as Scope 1 and Scope 2 emissions scaled by revenue. Emission intensity reflects the efficiency of the production process, where a lower value indicates that a firm produces the same output with fewer emissions. This measure is widely used by sustainable investors, ESG rating agencies, and prior research (Rohleder et al., 2022; Hartzmark and Shue, 2022; Bolton and Kacperczyk, 2021).[15] To measure changes in emissions, we follow Hartzmark and Shue (2022) and use the change in a firm's emission intensity in levels rather than in percentage terms. Hartzmark and Shue (2022) argue that this is the appropriate measure of changes in firms' real environmental impact. Percentage changes can be

[13]Trucost's emissions data are based on firms' self-reported disclosures supplemented by proprietary model-based estimates. Although some estimation noise may exist, these data are widely used by sustainable investors for portfolio construction and in academic research (Choi et al., 2023; Hartzmark and Shue, 2022).

[14]See `https://ghgprotocol.org/sites/default/files/standards_supporting/FAQ.pdf`.

[15]See https://assets.bbhub.io/company/sites/60/2020/10/FINAL-TCFD-Annex-Amended-121517.pdf

misleading because green firms often show large percentage reductions despite having very low baseline emissions. These large percentage changes in emissions by green firms are economically trivial because their level of emissions is several orders of magnitude smaller than the level of emissions of similarly-sized brown firms.

We measure a firm's carbon-related disclosure as the percentage of climate- or emission-related terms in its 10-K filing, calculated as the ratio of the number of such term occurrences to the total word count. The identification of carbon-related terms follows the methodology of Kim et al. (2023). We obtain firm-level data on total news coverage and ESG-related negative news from Refinitiv. Total news coverage is measured as the total number of news buzzwords linked to each firm in a given month. ESG-related negative news captures the monthly volume of media reports concerning a firm's involvement in activities that violate recognized environmental, social, or governance standards, scaled from 1 to 100. We average the monthly data to construct annual measures. We also obtain patent data from the USPTO's Bulk Data Storage System. For each patent, we collect the patent number, assignee, application date, issuance date, International Patent Classification (IPC) code and Cooperative Patent Classification (CPC) code. We identify green patent if its CPC code contains the Y02/Y04S tag.[16] We restrict our sample to patents that are filed or issued to public firms only.

2.3. Other data and sample summary

We obtain firm-level accounting variables, including book value per share, total debt, capital expenditures, revenue, earnings, and total assets, from Compustat. Firm return data are sourced from CRSP. The cost of capital is the firm's implied cost of capital (ICC) estimated using the mechanical GLS method of Lee et al. (2021).[17] All variables are winsorized at the 1st and 99th percentiles. Our final sample comprises 20,181 firm-year observations with 821 unique firms for the fiscal years 2015 to 2023.

Table 1 Panel A presents summary statistics for the main variables used in the analysis. On average, short interest is 3.6% with a standard deviation of 4.4%, indicating substantial cross-

[16] Green patents refer to inventions and innovations associated with environmental management, water conservation, biodiversity protection, climate change mitigation, and greenhouse gas management.

[17] This measure is also used in previous papers (Hartzmark and Shue, 2022; Chava, 2014). We thank Charles Wang for providing the ICC data.

sectional variation across firms. Overall, 19.3% of firm-year observations are classified as actively shorted, while 28.9% are passively shorted, suggesting that a larger proportion of firms are shorted primarily for hedging purposes. Firms file an average of 4.1 green patents per year and disclose 0.012% of carbon-related terms in their 10-K filings. The average implied cost of capital across firms is 7.4%.[18] Panel B presents the correlation matrix. Active short intensity shows a positive correlation with carbon emission intensity (0.011), suggesting that active short sellers tend to target firms with higher carbon emissions. In contrast, passive short intensity has a negative correlation (–0.347), indicating that the two types of short sellers respond differently to firms' carbon profiles; thus, it is important to distinguish between them in the analysis. Institutional divestment is positively related to active short intensity (0.213) but negatively to passive short intensity (–0.466), suggesting that active short sellers often move with institutional divestors, while passive shorts may act in the opposite direction.

3. Empirical Results

3.1. Do short sellers incorporate sustainability in their trading decisions?

This section examines the factors that determine short-selling behaviors, with a particular focus on whether short sellers' actions are influenced by firms' sustainability characteristics—that is, whether they target stocks with stronger or weaker environmental performance. According to Pástor et al. (2022), increased demand for green stocks raises their prices, potentially leading to lower expected returns. If short sellers perceive green firms as overvalued, they may target them for short selling. Conversely, Diamond and Verrecchia (1987) suggest that short sellers exploit informational advantages by trading before negative information becomes public. If brown firms face more negative information, short sellers may focus on them; however, if green firms face negative news, such as allegations of greenwashing, short sellers might target them instead.

We start our analysis by sorting firms into quintiles each year according to their carbon emission intensity. We then compute the average short interests for firms within each quintile and plot the

[18]Panel A in Appendix table A1 reports industry-level averages of carbon emissions and emission intensity based on the Fama–French 12 industry classification. Emission intensity varies substantially across industries. Utilities exhibit by far the highest emission intensity (1,732.6) and total emissions (8,665.4 thousand tons), followed by Oil, Gas, and Coal Extraction and Chemicals and Allied Products. In contrast, service-oriented and financial sectors, such as Finance and Telephone and Television Transmission, show the lowest emission intensity.

time series trends in Figure 1. Throughout the sample period, firms with higher carbon emission intensity exhibit consistently higher short interest compared to low-emission firms. A noticeable kink appears around 2021, when short interest for both high- and low-emission firms declines sharply. This drop coincides with the strong stock market performance in 2021, which reduced investors' incentives to take short positions and led to a temporary decline in overall short-selling activity.[19] After 2021, short interest partially rebounds for both groups, though the gap between high- and low-emission firms persists. This pattern suggests an initial evidence that emission intensity remains an important factor in short sellers' targeting behavior.[20]

We next test this relation using regression analysis with additional control variables. Specifically, we run the following regression:

$$Short\ Selling_{i,t} = \alpha + \beta_1 Carbon\ Emission_{i,t} + \beta_2 Control_{i,t} + \epsilon_{i,t} \tag{1}$$

where $Short\ Selling_{i,t}$ represents three measures of short-selling activity. Columns (1) and (2) report the aggregate short-selling behavior, measured as the average short interest for firm i in year t. Columns (3) and (4) focus on active short-selling behavior, where active short intensity is defined as short interest conditional on the stock being actively shorted. Columns (5) and (6) capture passive short-selling behavior, where passive short intensity is defined as short interest conditional on the stock being passively shorted. $Carbon\ Emission_{i,t}$ is the carbon emission intensity of firm i in year t. $Control_{i,t}$ includes control variables such as firm size, book-to-market ratio, stock return, return on assets (ROA), leverage, and news coverage. The book-to-market ratio is calculated as the ratio of a firm's book value to its market capitalization. Return is the firm's annual stock return. Log asset is the natural logarithm of firm total assets. ROA is defined as the ratio of net income to total assets. Leverage is measured as the ratio of average total assets to average shareholders' equity. News coverage is measured as the logarithm of the total number of news buzzwords associated with each firm, obtained from Refinitiv. We control for firm and year fixed effects in the regression.

[19] In 2021, major U.S. indexes such as the S&P 500 (+26.9%), Nasdaq (+21.4%), and Dow Jones (+18.7%) all posted substantial gains.

[20] One concern is that carbon emissions largely reflect industry-specific effects, since some sectors naturally generate more emissions than others. Thus, the observed pattern may capture industry differences rather than true firm-level variation in environmental performance. To address this issue, we replot the average short interest by firms' carbon emission intensity within Fama–French 48 industries (Appendix Figure A1). The results remain consistent, supporting the view that short sellers increasingly consider environmental criteria in their investment decisions.

The results are tabulated in Table 2. Columns (1) and (2) examine aggregate short interest. The coefficients on emission intensity are positive and statistically significant, indicating that firms with higher carbon emissions attract greater short-selling activity overall. This discovery confirms the observations in Figure 1, indicating that short sellers are concerned with a firm's environmental performance; firms with poorer environmental practices tend to attract more short selling activity. Columns (3) and (4) focus on active short intensity. The positive and significant coefficients imply that active short sellers are particularly prone to short high-emission firms. In contrast, columns (5) and (6) show that passive short intensity is unrelated to emission intensity. This pattern highlights that the carbon–shorting relationship is mainly driven by informed, discretionary active short sellers rather than hedging activities.

The control variables also provide additional insights. Firms with lower returns, smaller size, higher leverage, and lower ROA tend to have higher short interest. Active short intensity is also positively related to news coverage, indicating that active short sellers respond to public information and media signals when forming trading strategies. Interestingly, passive short intensity is not associated with any of the control variables , suggesting that passive shorting is largely mechanical and insensitive to firm fundamentals or information signals. This lack of association arises because passive short positions typically result from hedging rather than active information gathering. Hence, passive shorting reflects structural or liquidity motives rather than informed trading.[21]

3.2. Motivation of short-selling behavior

Having established that short sellers respond to firms' environmental performance, we next examine what motivates them to short high-emission firms. Short sellers are typically rational and profit-driven arbitrageurs who focus on financial performance rather than nonpecuniary preferences or ethical considerations.[22] Therefore, our analysis focuses on the financial incentives underlying their behavior. Prior research suggests that shorting firms with high ESG ratings entails higher synchronization risk, short squeeze risk, and reputational concerns (Cao et al., 2024), all of which increase the costs of such positions and reduce their expected profitability. This raises the question

[21] Our findings are related with those of Cao et al. (2024), who document that firms with lower ESG performance experience greater short-selling demand, particularly among overpriced stocks. We extend their evidence by showing that firms with higher carbon emissions attract more short-selling activity, and that this effect is driven primarily by active short sellers, rather than passive or mechanical short positions.

[22] Hedge funds account for most short-selling activity and are primarily profit-driven rather than ESG-motivated.

of whether shorting environmentally detrimental firms with high emissions offers superior financial returns.

We analyze the stock returns of firms following short-selling activity, distinguishing between firms with different emission levels and between active and passive short positions. To classify firms as "green" or "brown," we follow prior studies (Hartzmark and Shue, 2022; Choi et al., 2024) and sort firms into emission quintiles, where quintile 1 represents firms with the lowest emission intensity and quintile 5 represents those with the highest emission intensity. In subsequent analysis, we refer to firms in quintiles 1 as "green" and firms in quintiles 5 as "brown".[23]We compare the returns from brown and green firms in the year they are subjected to either active or passive short selling, controlling for other firm characteristics. We estimate the following regression:

$$\begin{aligned} \textit{Return}_{i,t} = \alpha + \beta_1 \, \textit{Type}_i \times \textit{Active Short Intensity}_{i,t} + \beta_2 \, \textit{Type}_i \times \textit{Passive Short Intensity}_{i,t} \\ + \beta_3 \, \textit{Active Short Intensity}_{i,t} + \beta_4 \, \textit{Passive Short Intensity}_{i,t} + \beta_5 \, \textit{Control}_{i,t} + \epsilon_{i,t} \end{aligned} \quad (2)$$

Where $\textit{Type}_i$ represents brown firms in Column (1) and green firms in Column (2). The dependent variable is firm's annual stock return in the year being shorted. Active short intensity is defined as short interest conditional on the stock being actively shorted, while passive short intensity is defined as short interest conditional on the stock being passively shorted. $\textit{Control}_{i,t}$ includes control variables such as firm size, book-to-market ratio, stock return, return on assets (ROA), leverage, and news coverage. We control for firm and year fixed effects, and $\textit{Type}_i$ is absorbed by the firm fixed effects.

In column (1) of Table 3 Panel A, we observe a negative and statistically significant coefficient on the interaction term between brown and active short intensity, indicating that brown firms experience significantly lower returns when they are actively shorted. This finding is consistent with a financially driven trading motive that active short sellers identify and profit from overvalued or poorly performing brown firms. Conversely, the coefficient on brown and passive short intensity is insignificant, implying that passive short selling is primarily driven by hedging considerations rather than profit-seeking motives. Column (2) shows slight positive but statistically insignificant coefficients for all interaction terms for green firms, suggesting that short selling of green firms,

[23]As a robustness check, we also classify firms into tertiles, and the results remain consistent.

whether active or passive, is not associated with substantial price decreases. This is likely because short-selling green firms creates higher costs and risks: many investors are unwilling to sell green stocks even when overvalued, and the risk of short squeezes is greater(Cao et al., 2024). Overall, our analysis reveals that shorting environmentally detrimental (brown) firms is associated with profitable returns, particularly when the short selling is active rather than passive.

Thus far, we have explored short sellers' financial motivations by analyzing the returns of stocks being shorted. An alternative approach is to examine returns at the institutional level of hedge funds. Given that hedge funds are prominent players in short selling stocks, we evaluate the performance of hedge funds engaged in shorting brown stocks. If short selling environmentally detrimental firms does indeed lead to higher returns, we would expect to observe better performance among funds that actively short brown firms. However, since hedge funds' short positions are not publicly disclosed, we must filter out which hedge funds short sell brown stocks through the following algorithm.

First, we estimate the green beta for each hedge fund by assessing its return exposure to a green factor developed by Pástor et al. (2022). A larger green beta suggests that a fund is greener due to greater exposure to green assets (Kuang et al., 2023). We sort funds into quintiles based on their green beta, defining those in the highest quintile as green funds. Next, we separate these green funds into two categories: those that are green by investing in green stocks and those that are green by shorting brown stocks. This second category is in line our brown*active short sellers. To filter out the latter category, we calculate the weighted average carbon risk score of each fund using its 13F holdings and classify these scores into quintiles. Funds that rank in the highest quintile for both green beta and holding-level carbon emission are identified as primarily shorting brown stocks to maintain their high green beta classification. This method enables us to identify hedge funds that are environmentally friendly due to their short-selling activities.

We then analyze the performance of these funds by regressing hedge fund returns on a dummy variable that equals 1 for brown short-selling hedge funds and 0 otherwise, while controlling for fund characteristics. The results, detailed in Panel B in the Table 3, show significant positive coefficients for the brown short-selling hedge fund dummy in both the excess return (columns 1 and 2) and the seven-factor alpha (columns 3 and 4).[24] This significant positive association indicates that hedge

[24]Fund excess return is defined as fund return mimus risk free rate. Fund alpha is calculated as the intercept of

funds engaged in shorting brown stocks tend to outperform other funds (such as those focused on investing in green stocks or shorting greenwashing stocks). These findings lend support to the hypothesis that financial gains motivate arbitrageurs who actively short sell environmentally detrimental firms.

3.3. Short selling and carbon emission

Having demonstrated that arbitrageurs frequently short sell brown stocks and gain from these transactions, an important follow-up question arises: is short selling brown firms associated with their carbon policies, such as carbon emissions? Much of the existing research on how financial institutions influence firms' carbon strategies primarily examines "long" investment actions, including engagement or divestment. For instance, Azar et al. (2021) discovered a negative relationship between ownership by the Big Three (BlackRock, Vanguard, and State Street Global Advisors) and subsequent carbon emissions among MSCI index constituents. Similarly, Choi et al. (2023) argue that divestment by financial institutions leads public firms to implement climate-friendly policies and reduce their carbon footprints. Despite this, there is a noticeable lack of empirical evidence regarding the relationship between short selling and firms' carbon policies. However, studies have documented the tangible effects of short selling on various aspects of corporate governance, such as earnings management (Massa et al., 2015), payout strategies (Chen et al., 2019), and corporate innovation (He et al., 2023). This gap in the literature makes the potential influence of short sellers on firm carbon policies an intriguing and open area for investigation.

In this section, we study how short selling relates to subsequent changes in firms' carbon emissions, focusing in particular on whether brown firms that are actively shorted reduce their emissions. We estimate the following regression model:

$$\begin{aligned}\Delta Emission\ Intensity_{i,t} = \alpha + \beta_1 Brown_i \times Active\ Short\ Intensity_{i,t} + \\ \beta_2 Brown_i \times Passive\ Short\ Intensity_{i,t} + \beta_3\, Active\ Short\ Intensity_{i,t} \\ + \beta_4\, Passive\ Short\ Intensity_{i,t} + \beta_5\, Control_{i,t} + \epsilon_{i,t} \qquad (3)\end{aligned}$$

The dependent variable measures a firm's reduction in carbon emissions intensity over one-, two-

regression of fund excess return on seven factors from Fung and Hsieh (2004) seven-factor model.

, and three-year horizons. The main variable of interest is the interaction term between $Brown_i$ and $Active\ Short\ Intensity_{i,t}$, which captures the effect of active short selling on emission changes among brown firms. For comparison, we also include the interaction term between $Brown_i$ and $Passive\ Short\ Intensity_{i,t}$. Control variables include firm size, book-to-market ratio, stock return, return on assets (ROA) and leverage. To further ensure that the effect of active short selling is not driven by institutional divestment, we control for institutional divestment, represented as a dummy variable that equals one if the firm experiences divestment by institutional investors other than hedge funds in that year.[25] We control for firm and year fixed effects, and $Brown_i$ is absorbed by the firm fixed effects.

Table 4 reports the regression results. The interaction term between brown firms and active short intensity is positive but statistically insignificant in the one-year horizon, consistent with the idea that emission reductions cannot occur immediately after short-selling pressure, as firms require time to adjust their production processes. The effect becomes significantly negative in the two- and three-year horizons, with the magnitude of the coefficients increasing over time. This pattern indicates that the impact of active short selling on emission reduction materializes gradually and strengthens in the longer term. The results suggest that the observed decline in carbon emissions is not merely a short-term response to temporary fluctuations in emission trends, but rather reflects a more persistent, structural improvement in firms' environmental performance. Specifically, a one–standard–deviation increase in active short intensity for brown firms is associated with a reduction of 38.53 (1.882×20.474) tons of carbon emissions per million dollars of revenue three years after being actively shorted. This decline represents approximately 27% of the average firm's carbon emission intensity, indicating the economically meaningful impact of active short selling on firms' long-term environmental performance. In contrast, the interaction between brown firms and passive short intensity remains insignificant across all horizons, implying that only informed, active short sellers play a meaningful role in driving long-term environmental changes. These results underline the asymmetric impact of active versus passive shorting on the emissions of brown firms. Interestingly, institutional divestment shows no impact on carbon reduction. This supports findings from prior studies (Berk and Van Binsbergen, 2025; Atta-Darkua et al., 2023) that divestment

[25]Institutional ownership is calculated using 13F institutional holdings data, with hedge fund holdings excluded, as hedge fund divestment is already reflected in active short-selling activity.

strategies have little effect on firms' environmental performance.

As a comparison, Appendix Table A2 reports the results for green firms. In contrast to brown firms, the interaction between green firms and active short intensity is positive and statistically significant over the two- and three-year horizons (2.529 and 5.788, respectively), suggesting a slight increase rather than a reduction in carbon emission intensity following active short selling. As we will discuss later in the paper, this pattern implies that active short sellers do not exert the same disciplinary effect on already environmentally friendly firms, whose emissions are less subject to improvement pressure. Our findings reinforce the interpretation that the emission reductions are primarily driven by brown firms, for which active short sellers' monitoring and sustainability discipline play a more meaningful role in inducing long-term environmental improvements.

3.4. Causality issues

In this section, we address potential endogeneity concerns using a twofold approach. First, we implement an instrumental variable (IV) specification to mitigate bias arising from reverse causality or omitted variables. Second, we employ a staggered difference-in-difference-in-difference (DDD) framework to further isolate the causal effect of short-selling behavior on firms' carbon emissions.

3.4.1. An instrumental variable approach

We begin with an instrumental variable specification. We use non-ESG news as an instrumental variable for active short selling. A valid instrument must satisfy two requirements: relevance (it must be correlated with active short-selling behavior) and the exclusion restriction (it must be unrelated to carbon emission and affect carbon-emission reductions only through active short selling). Non-ESG news is constructed as the portion of total news coverage unrelated to ESG-related negative events. We remove ESG-related negative news because firms that have already received such ESG criticisms may have begun improving their environmental performance, which could directly impact carbon-emission outcomes. To isolate the non-ESG component of news, we regress total news coverage on ESG-related negative news and use the residual as our measure of non-ESG news.

Non-ESG news satisfies the relevance condition because active short sellers respond strongly to general news, while passive short sellers do not, a pattern documented in Table 2. In addition,

the first stage results in Table 5 show that non-ESG news strongly predicts active short selling intensity and F-tests confirm the relevance conditions. It also satisfies the exclusion restriction because the construction of IV explicitly removes all ESG-related negative news—the primary channel through which firms face pressure to change their environmental practices. By taking out news items that refer to ESG concerns, we eliminate reputational or regulatory pressures that could directly influence carbon-reduction decisions. The remaining variation reflects general corporate news unrelated to sustainability, which does not focus on environmental issues or motivate firms to adjust carbon emission performance. Therefore, conditional on control variables in the regression, non-ESG news influences carbon reduction outcomes only through the channel of active short selling behavior, which supports the exclusion restriction. We perform a two-stage IV regression as follows:

$$\begin{aligned}\text{The 1st stage: } \textit{Active Short Intensity}_{i,t} &= \alpha + \beta_1\big(\textit{Brown}_i \times \textit{Non-ESG News}_{i,t}\big) \\ &\quad + \beta_2\, \textit{Non-ESG News}_{i,t} + \beta_3\, \textit{Controls}_{i,t} + \epsilon_{i,t} \qquad (4)\end{aligned}$$

$$\begin{aligned}\textit{Brown}_i \times \textit{Active Short Intensity}_{i,t} &= \alpha + \beta_1\big(\textit{Brown}_i \times \textit{Non-ESG News}_{i,t}\big) \\ &\quad + \beta_2\, \textit{Non-ESG News}_{i,t} + \beta_3\, \textit{Controls}_{i,t} + \epsilon_{i,t} \qquad (5)\end{aligned}$$

$$\begin{aligned}\text{The 2nd stage: } \Delta\textit{Emission Intensity}_{i,t} &= \alpha + \beta_1\left(\textit{Brown}_i \times \widehat{\textit{Active Short Intensity}}_{i,t}\right) \\ &\quad + \beta_2\, \widehat{\textit{Active Short Intensity}}_{i,t} + \beta_3\, \textit{Controls}_{i,t} + \epsilon_{i,t} \qquad (6)\end{aligned}$$

Columns (1) and (2) in Table 5 report the first-stage 2SLS results, where the endogenous variables, $\textit{Active Short Intensity}_{i,t}$ and $\textit{Brown}_i \times \textit{Active Short Intensity}_{i,t}$, are instrumented by the two instruments $\textit{Non-ESG News}_{i,t}$ and $\textit{Brown}_i \times \textit{Non-ESG News}_{i,t}$. The coefficients on the two corresponding instrumental variables are both significantly positive, indicating high correlations between our IVs and the endogenous variables. The t-statistics are always above 3, translating into an F-test of 140.2 in column (1) and 11.3 in column (2), both of which are above the threshold of weak exogeneity provided by Staiger and Stock (1994). Columns (3) to (5) report second-stage results using the two instrumented variables as regressors. Consistent with the OLS regression estimates in Table 4, the coefficient on the main variable of interest is significantly negative in all regressions. These instrumental variable regressions thus offer the first evidence that active short selling has a causal effect on carbon emission reductions.

3.4.2. Staggered difference-in-difference-in-difference (DDD) method

Next, we examine the effects of active short selling using a staggered difference-in-difference-in-difference (DDD) framework. Our main question of interest is whether active short selling has heterogeneous effects on brown firms. Recent work by Goodman-Bacon (2021) and Baker et al. (2022) highlights that staggered difference-in-differences estimators can be biased and may produce estimates that differ in magnitude or even in sign from the true average treatment effects. The primary source of this bias is that the estimator partly relies on comparisons between later-treated and earlier-treated observations, where the earlier-treated firms serve as controls. When treatment effects vary over time, already treated observations act as improper controls, potentially distorting the estimated effects for later-treated units.

To mitigate this concern, we adopt the stacked regression approach recommended by Baker et al. (2022). Specifically, for each active short-selling event, we assign a clean control group to the treated firms (i.e., firms that experience an active short sale). The clean control group includes both (1) firms that have not yet experienced any active short-selling event and (2) firms that never experience such an event within the sample period. The treated group consists of firms experiencing the active short-selling event. If a firm experiences more than one active short-selling activities during the sample, it is included in the treated group only for its first event. We then construct an event-specific identifier and stack the corresponding event-level datasets. The regression model is specified as follows:

$$\Delta Emission\ Intensity_{i,t} = \alpha + \beta_1 Post_{i,t} \times Treat_i \times Brown_i + \beta_2 Post_{i,t} \times Treat_i + \beta_3 Controls_{i,t} + \epsilon_{i,t} \tag{7}$$

where the main explanatory variable is the interaction term $Post_{i,t} \times Treat_i \times Brown_i$. $Post_{i,t}$ equals one for years at and after the first active short selling event, and zero otherwise. $Treat_i$ equals one for firms experiencing at least one active short selling, and zero otherwise. $Brown_i$ equals one for firms in the highest quintile of emission intensity, and zero otherwise. The outcome variable of interest, $\Delta Emission\ Intensity_{i,t}$, corresponds to firm's reduction in carbon emission intensity over one-, two-, and three-year horizons. We Control variables include firm size, book-to-market ratio, stock return, return on assets (ROA) and leverage. We estimate the DDD regression with

firm-cohort and year-cohort fixed effects. [26]

The staggered DDD design exploits two sources of variation: (1) differences between treated and control firms in changes in carbon emissions following active short selling, and (2) cross-sectional variation in firms' environmental profiles, distinguishing between green and brown firms. Within the staggered DDD framework, $Post_{i,t} \times Treat_i$ picks up the difference-in-differences (DID) effect between the control group and the treated group because of the active short selling activity. The interaction term, $Post_{i,t} \times Treat_i \times Brown_i$, estimates the third difference: that is, whether the active short selling has different effects on firms with different levels of environmental performance.

Table 6 present the regression results. Columns (1)–(3) use event windows of 1, 2, and 3 years before and after the event, while column (4) includes the full sample period. The interaction term $Treat \times Post \times Brown$ is insignificant using the one-year window around the event in column (1). This suggest there is no immediate effect on emission reduction and is consistent with the idea that firms need time to adjust production processes and adopt emission-abatement measures after active short selling. In wider windows (columns (2)-(4)), the coefficient on $Treat \times Post \times Brown$ becomes large and significantly negative, indicating that brown firms substantially reduce emission intensity over time following active short selling. The results are also economically significant. Column (3), for instance, shows that after being actively short-sold, brown firms reduce their carbon emission intensity by 41.4 tons of carbon emissions per million dollars of revenue more than other firms over the 3-year event window. Given that the sample mean of emission intensity is 141.7 tons of carbon emissions per million dollars of revenue, this reduction corresponds to about a 29% decrease relative to the average level.

It is worth noting that, despite the negative and significant coefficient on the interaction term, the coefficients on $Treat \times Post$ are often positive. While positive signs for the stand-alone coefficients may seem counterintuitive, this pattern does not necessarily imply environmental deterioration for other non-brown firms (green firms). Since green firms generally have lower initial baseline emissions and less room for improvement, even small operational fluctuations or scale expansions can translate into higher emission intensity. Taken together, these results highlight a heterogeneous treatment effect: active short selling appears to exert disciplinary pressure on brown firms to reduce

[26] Note that we do not separately include $Treat_i$, $Brown_i$, or their interaction term $Treat_i \times Brown_i$ in the regression, as these components are absorbed by the firm-cohort fixed effects. Similarly, $Post_{i,t}$ is not included separately because it is absorbed by the year-cohort fixed effects.

emissions, while its impact on greener firms is less favorable.

3.5. Underlying mechanism

In this section, we aim to delve deeper into the possible economic mechanisms through which active short selling contributes to carbon reduction in brown firms. Specifically, we explore two potential channels: cost of capital channel and and sustainability discipline channel.

3.5.1. Cost of capital channel

We begin by examining whether active short selling raises the cost of capital for brown firms. When firms are actively shorted, divestment pressure from long investors combined with elevated short interest can depress equity valuations and thereby increase their cost of capital (Gormsen et al., 2024; Choi et al., 2024). Although still debated, a growing literature shows that a higher cost of capital can induce firms to reduce carbon emissions.[27] This channel operates similarly to a carbon tax by discouraging carbon-intensive investment and reallocating capital toward greener technologies both across and within firms (Chittaro et al., 2025; Pedersen, 2023). Moreover, a sufficiently large increase in the cost of capital can force targeted firms or industries to scale back operations, leading to lower emissions through reduced production (Choi et al., 2024).[28]

If brown firms are downsizing in response to the increased cost of capital from active short selling, we should observe two patterns: (1) an increase in the cost of capital following active shorting, and (2) a decline in operational activities such as revenue or capital expenditures. We next test these two implications.

We first examine whether active short selling raises the cost of capital for brown firms. Following Hartzmark and Shue (2022), we measure the cost of capital using the implied cost of capital based on the mechanical GLS method of Lee et al. (2021). We estimate the same specification as Equation (3) but replace the dependent variable with the implied cost of capital. Table 7 shows that the coefficient on the key interaction, *Brown* $\times$ *Active Short Intensity*, is statistically and economically

[27] Hartzmark and Shue (2022)find that an increase in brown firms' cost of capital has significant counterproductive effects, ultimately making brown firms even more brown.

[28] This operational reduction could naturally lead to a decrease in carbon emissions if it results in the curtailment or cessation of high-pollution projects. However, it does not necessarily indicate a shift towards cleaner production methods. Instead, these firms may simply reduce the scale of their operations while continuing to engage in environmentally harmful practices.

insignificant. This result indicates that active short selling does not alter the cost of capital for brown firms.

As an alternative measure, we look at firms' financial performance through equity returns. A negative financial return likely corresponds to an increase in the firm's cost of capital. Likewise, A positive return raises the firm's market valuation and is likely to ease the firm's access to financing, corresponding to a lower cost of capital. Appendix Table A3 reports that brown firms do not experience lower returns one, two, or three years after active short selling. These results again point to no change in their cost of capital. Recall that Panel A of Table 3 shows that brown firms have lower returns in the year they are actively shorted. However, we find no evidence of return changes in the years that follow. This pattern suggests that active short selling creates only a temporary, short-run impact on financial performance, while the cost of capital is a longer-horizon outcome. Because active short sellers operate as short-term arbitrageurs, any return effect they create appears to reverse quickly rather than persist into the future.

We next examine whether active short selling affects firm operations and whether brown firms reduce their operational activities after being actively shorted. We measure operations using revenue and capital expenditures in the years that follow an active short selling event. If emission reductions occur through operational downsizing, active short selling should lead to lower sales and lower capital expenditures. Table 8 presents the results. Columns 1–3 report capital expenditures, and columns 4–6 report sales. We do not observe a consistent pattern of declines in either measure within the three years after active short selling. Capital expenditures fall in first 2 years but become insignificant and economically small in year 3. For sales, brown firms show a temporary decline one year after active short selling but actually experience higher sales in year 3. This inconsistent pattern suggests that these firms are not shrinking or cutting back their carbon-intensive operations.

Taken together, the results do not support the view that higher cost of capital or operational downsizing explains reductions in carbon emissions. Instead, we find no significant change in the cost of capital or in operating activity for brown firms in the years after active short selling.

3.5.2. Discipline channel

Short selling may also influence corporate behavior through a disciplinary channel. Prior research shows that short sellers act as an "invisible hand" in financial markets and can discipline corporate policies across several dimensions, including earnings management, financial misconduct, and innovation (Massa et al., 2015; Hirshleifer et al., 2011; He et al., 2023). We therefore propose that short sellers can also improve environmental performance through a similar disciplinary mechanism.

The intuition is that active short sellers can discipline brown firms to reduce emissions by uncovering and publicizing environmental risks, weaknesses in transition plans, or exposure to future regulatory and litigation costs, which increases scrutiny from investors, analysts, media, and other stakeholders. Their research and trading activities send a negative market signal that can depress valuation and highlight long-horizon environmental risks. The subsequent decline in stock prices can trigger rapid negative market reactions and potential disciplinary consequences for managers, including lower bonus payouts and even CEO or executive turnover. Because managers are highly sensitive to compensation, reputation, and job security, they may respond by adopting cleaner technologies, strengthening climate-related disclosure, or accelerating emission-reduction plans to restore credibility and limit further negative scrutiny. We examine the potential disciplining role of short sellers through their impact on green innovation and climate-related disclosure.

We begin by examining whether active short selling disciplines brown firms to reduce carbon emissions by improving their green innovation. Cohen et al. (2020) show that brown energy firms often produce some of the most highly cited green patents, and Hege et al. (2023) suggest that emission reductions can occur through supply chain networks, with climate-related innovations embedded in suppliers' products helping downstream firms lower emissions. Motivated by this evidence, we test whether brown firms increase their green innovation output after active short selling. We estimate the same specification as Equation (3) but replace the dependent variable with the number of green patents a firm applies for within one, two, and three years after the short-selling event. Table 9 reports the results. We find a significant positive association between active short selling and subsequent green patenting by brown firms in the following year, while no comparable effect is observed when firms are subject to passive short selling. These results align

with the findings by Choi et al. (2024), who find that carbon-intensive public firms are likely to decrease their carbon emissions and enhance their green patenting activities in response to market pressures.[29]

Additionally, active short sellers can pressure firms to increase climate-related disclosure through a disciplinary mechanism. Corporate disclosure is one of the most direct tools managers use to shape market perceptions. Prior research shows that the threat of short selling can lead to strategic disclosure responses that improve firm's information environment (Chen et al., 2020). They find that short selling threat induce managers to enhance disclosures through more long-run good news forecasts to discourage future short selling activities. In our setting, if active short selling disciplines managers, we would expect managers respond by expanding the scope, credibility, and transparency of climate-related disclosure, such as detailed emissions reporting, transition targets, and risk assessments, to restore confidence, reduce informational asymmetry, and discourage continued short-selling pressure.

The results in Table 10 shows that brown firms increase climate-related disclosure after exposure to active short-selling pressure. The interaction term between *Brown* and *Active Short Intensity* is insignificant in the first year, becomes positive and marginally significant in the second year, and turns stronger and statistically significant in the third year. This suggests that disclosure adjustments require time to materialize through internal processes and formal reporting channels. In contrast, passive short-selling pressure shows weaker and less consistent effects.

To summarize, the results support a sustainability discipline channel, in which active short sellers induce brown firms to increase green innovation and climate-related disclosure over time. We observe these changes after active short selling, while no similar pattern appears after passive short selling.

3.6. Robustness tests

In this subsection, we report the results of several robustness tests for our baseline analysis of Equation (3). First, to address the concern that the relation between active short selling and emission reduction could be driven by industry-level time varying characteristics, we perform the

[29]Our findings differ from those of Choi et al. (2024) in that they additionally report that brown firms undergo operational downsizing under financial pressure, as indicated by reductions in sales, total assets, and capital expenditures.

baseline tests by controlling for both firm and industry*year fixed effects. The results in Panel A of the Appendix show that the coefficient on *Brown* × *Active short intensity* remains significantly positive in columns (2) and (3). This pattern is consistent with the main results in Table 4, indicating that the effect of active short selling on emission reduction appears gradually and strengthens over a longer horizon.

Second, to ensure our findings are not sensitive to how we define brown firms, we re-estimate the baseline models using an alternative definition that classifies brown firms as those in the top tertile of emission intensity. As shown in Appendix Panel B, the results remain robust.

Third, instead of relying on active short intensity to capture active shorting behavior, we adopt a binary indicator approach. Active short is coded as one when hedge fund ownership decreases while short interest increases from year $t-1$ to year t, and zero otherwise. Passive short is coded as one when both hedge fund ownership and short interest increase from $t-1$ to t, and zero otherwise. The results in Appendix Panel C are consistent with our baseline findings. The coefficient magnitudes become larger because the binary indicators capture whether a firm is actively shorted or not, rather than the intensity level of shorting, making the estimated effect reflect the presence of active shorting behavior rather than variation in its scale.

4. Conclusion

Effectively addressing the global carbon footprint requires collaboration among scientists, governments, corporations, financial institutions, and the public. While significant research has explored institutional investors' long-side activities, such as shareholder engagement and divestment, the role of short sellers in mitigating carbon risks remains underexplored. This paper examines short sellers' behavior and its potential impact on sustainability. We aim to address three key questions: (1) Do short sellers consider a firm's environmental performance when making decisions? (2) What drives the short selling of "brown firms"? (3) Does short selling encourage firms to reduce carbon emissions?

We distinguish between passive short sellers, primarily motivated by hedging, and active short sellers, who are engaged market participants and short-term speculators seeking quick profits from declining stock prices. We find that short sellers consider firms' sustainability, as higher emission

intensity is associated with greater aggregate short selling, but only for active short selling, while passive short selling shows no relation. We further show that active shorting of "brown" firms is primarily profit-motivated at both the firm and institution levels: brown firms earn lower returns when actively shorted, and hedge funds shorting these firms achieve higher returns and alphas. These results suggest that the primary motivation for active short sellers targeting brown firms is to capitalize on trading profits.

Our findings indicate that active short selling of brown firms is linked to reduced carbon emissions, while passive short sellers have minimal impact. Instrumental variable tests and a triple difference framework support a causal interpretation that active short selling helps reduce emissions. We explore two potential mechanisms: cost of capital channel and sustainability discpline channel. The evidence strongly supports the latter, showing that actively shorted brown firms increase green patents and climate related disclosure. There is no significant evidence of increase in cost of capital or operational downsizing in these firms following active short selling. Our paper provides new insights into a surprising and unintended real effect in which active short sellers encourage firms to reduce carbon emissions.

Overall, this study contributes to the growing field of sustainable investing by highlighting how short sellers can influence firms' environmental practices and support a transition toward a more sustainable global economy. These findings provide valuable insights for practitioners and policymakers, offering a deeper understanding of short selling's implications for sustainability goals. By aligning market practices with global carbon reduction objectives, informed decision-making can foster a more sustainable financial ecosystem.

REFERENCES

Akey, Pat, and Ian Appel, 2019, Environmental externalities of activism, *Available at SSRN 3508808* .

Appel, Ian, and Vyacheslav Fos, 2024, Short campaigns by hedge funds, *The Review of Financial Studies* 37, 1460–1493.

Asquith, Paul, Parag A Pathak, and Jay R Ritter, 2005, Short interest, institutional ownership, and stock returns, *Journal of Financial Economics* 78, 243–276.

Atta-Darkua, Vaska, Simon Glossner, Philipp Krueger, and Pedro Matos, 2023, Decarbonizing institutional investor portfolios: helping to green the planet or just greening your portfolio?, *Available at SSRN 4212568* .

Azar, José, Miguel Duro, Igor Kadach, and Gaizka Ormazabal, 2021, The big three and corporate carbon emissions around the world, *Journal of Financial Economics* 142, 674–696.

Baker, Andrew C, David F Larcker, and Charles CY Wang, 2022, How much should we trust staggered difference-in-differences estimates?, *Journal of Financial Economics* 144, 370–395.

Berk, Jonathan B, and Jules H Van Binsbergen, 2025, The impact of impact investing, *Journal of Financial Economics* 164, 103972.

Bolton, Patrick, and Marcin Kacperczyk, 2021, Do investors care about carbon risk?, *Journal of financial economics* 142, 517–549.

Cao, Jie, R David McLean, Xintong Zhan, and Weiming Elaine Zhang, 2024, Social responsibility ratings and limited arbitrage, *Available at SSRN 4942679* .

Chava, Sudheer, 2014, Environmental externalities and cost of capital, *Management science* 60, 2223–2247.

Chen, Xia, Qiang Cheng, Ting Luo, and Heng Yue, 2020, Short sellers and long-run management forecasts, *Contemporary Accounting Research* 37, 802–828.

Chen, Yong, Zhi Da, and Dayong Huang, 2019, Arbitrage trading: The long and the short of it, *The Review of Financial Studies* 32, 1608–1646.

Chittaro, Lautaro, Monika Piazzesi, Marcelo J Sena, and Martin Schneider, 2025, Asset returns as carbon taxes, Technical report, National Bureau of Economic Research.

Choi, Darwin, Zhenyu Gao, Wenxi Jiang, and Hulai Zhang, 2023, Carbon stock devaluation, *Available at SSRN 3589952* .

Choi, Darwin, Zhenyu Gao, Wenxi Jiang, and Hulai Zhang, 2024, Carbon firm devaluation and green actions, Technical report, Working paper, The Chinese University of Hong Kong.

Chu, Yongqiang, and Daxuan Zhao, 2019, Green hedge fund activists, *Available at SSRN 3499373* .

Cohen, Lauren, Umit G Gurun, and Quoc H Nguyen, 2020, The esg-innovation disconnect: Evidence from green patenting, Technical report, National Bureau of Economic Research.

De Jong, Abe, Marie Dutordoir, and Patrick Verwijmeren, 2011, Why do convertible issuers simultaneously repurchase stock? an arbitrage-based explanation, *Journal of Financial Economics* 100, 113–129.

Diamond, Douglas W, and Robert E Verrecchia, 1987, Constraints on short-selling and asset price adjustment to private information, *Journal of Financial Economics* 18, 277–311.

Dyck, Alexander, Karl V Lins, Lukas Roth, and Hannes F Wagner, 2019, Do institutional investors drive corporate social responsibility? international evidence, *Journal of Financial Economics* 131, 693–714.

Fung, William, and David A Hsieh, 2004, Hedge fund benchmarks: A risk-based approach, *Financial Analysts Journal* 60, 65–80.

Gantchev, Nickolay, Mariassunta Giannetti, and Rachel Li, 2022, Does money talk? divestitures and corporate environmental and social policies, *Review of Finance* 26, 1469–1508.

Goodman-Bacon, Andrew, 2021, Difference-in-differences with variation in treatment timing, *Journal of econometrics* 225, 254–277.

Gormsen, Niels Joachim, Kilian Huber, and Sangmin Oh, 2024, Climate capitalists, Technical report, National Bureau of Economic Research.

Grullon, Gustavo, Sébastien Michenaud, and James P Weston, 2015, The real effects of short-selling constraints, *The Review of Financial Studies* 28, 1737–1767.

Hanson, Samuel G, and Adi Sunderam, 2014, The growth and limits of arbitrage: Evidence from short interest, *The Review of Financial Studies* 27, 1238–1286.

Hartzmark, Samuel M, and Kelly Shue, 2022, Counterproductive sustainable investing: The impact elasticity of brown and green firms, *Available at SSRN 4359282* .

He, Jie, Xiao Ren, and Xuan Tian, 2023, Do short sellers affect corporate innovation? evidence from a policy experiment, *The Review of Corporate Finance Studies* cfad007.

Hege, Ulrich, Kai Li, and Yifei Zhang, 2023, Climate innovation and carbon emissions: Evidence from supply chain networks, *Available at SSRN 4557447* .

Hirshleifer, David, Siew Hong Teoh, and Jeff Jiewei Yu, 2011, Short arbitrage, return asymmetry, and the accrual anomaly, *The Review of Financial Studies* 24, 2429–2461.

Hong, Yongtao, Wei Wei, and Alex Young, 2022, The effect of short selling on corporate social responsibility: Evidence from a quasi-experiment, *Journal of Corporate Accounting & Finance* 33, 79–87.

Hope, Ole-Kristian, Danqi Hu, and Wuyang Zhao, 2017, Third-party consequences of short-selling threats: The case of auditor behavior, *Journal of Accounting and Economics* 63, 479–498.

Jain, Archana, Pankaj K Jain, and Zabihollah Rezaee, 2016, Value-relevance of corporate social responsibility: Evidence from short selling, *Journal of Management Accounting Research* 28, 29–52.

Jiang, Haiyan, Ahsan Habib, and Mostafa Monzur Hasan, 2022, Short selling: A review of the literature and implications for future research, *European Accounting Review* 31, 1–31.

Jiao, Yawen, Massimo Massa, and Hong Zhang, 2016, Short selling meets hedge fund 13f: An anatomy of informed demand, *Journal of Financial Economics* 122, 544–567.

Kim, Jeong-Bon, Chong Wang, and Feng Wu, 2023, The real effects of risk disclosures: evidence from climate change reporting in 10-ks, *Review of Accounting Studies* 28, 2271–2318.

Kuang, Huan, Bing Liang, Tianyi Qu, and Mila Getmansky Sherman, 2023, Are the hedges of funds green?, *Available at SSRN 4773780* .

Lee, Charles MC, Eric C So, and Charles CY Wang, 2021, Evaluating firm-level expected-return proxies: implications for estimating treatment effects, *The Review of Financial Studies* 34, 1907–1951.

Lee, Sam Sunghan, Zhejia Ling, and Zabihollah Rezaee, 2022, Sec comment letter disclosures and short sellers' front-running, *The Accounting Review, Forthcoming* .

Li, Yinghua, and Liandong Zhang, 2015, Short selling pressure, stock price behavior, and management forecast precision: Evidence from a natural experiment, *Journal of Accounting Research* 53, 79–117.

Ma, Lei Matthew, 2019, Short selling risk and hedge fund performance, in *Short Selling Risk and Hedge Fund Performance: Ma, Matthew* ([Sl]: SSRN).

Massa, Massimo, Bohui Zhang, and Hong Zhang, 2015, The invisible hand of short selling: Does short selling discipline earnings management?, *The Review of Financial Studies* 28, 1701–1736.

Pástor, L'uboš, Robert F Stambaugh, and Lucian A Taylor, 2022, Dissecting green returns, *Journal of Financial Economics* 146, 403–424.

Pedersen, Lasse Heje, 2023, Carbon pricing versus green finance, *Available at SSRN 4382360* .

Qian, Jialin, Zhen Shi, and Baozhong Yang, 2024, Short-selling hedge funds, *Available at SSRN 4764190* .

Rohleder, Martin, Marco Wilkens, and Jonas Zink, 2022, The effects of mutual fund decarbonization on stock prices and carbon emissions, *Journal of Banking & Finance* 134, 106352.

Staiger, Douglas O, and James H Stock, 1994, Instrumental variables regression with weak instruments.

Figure 1. Short Interest and Carbon Emission

This figure plots the average annual short interest from 2015 to 2023, sorted by firms' carbon emission intensity. Carbon emission intensity are measured as tons of CO_2 equivalents (scope 1 and scope 2) emitted per million dollars of revenue. Each year, firms are sorted into quintiles based on their carbon emission intensity. Firms in the lowest quintile are defined as low emission intensity firms. Firms in the highest quintile are defined as high emission intensity firms. Annual short interest is computed as the average of monthly short interest, where monthly short interest equals the ratio of shares sold short at month-end to total shares outstanding.

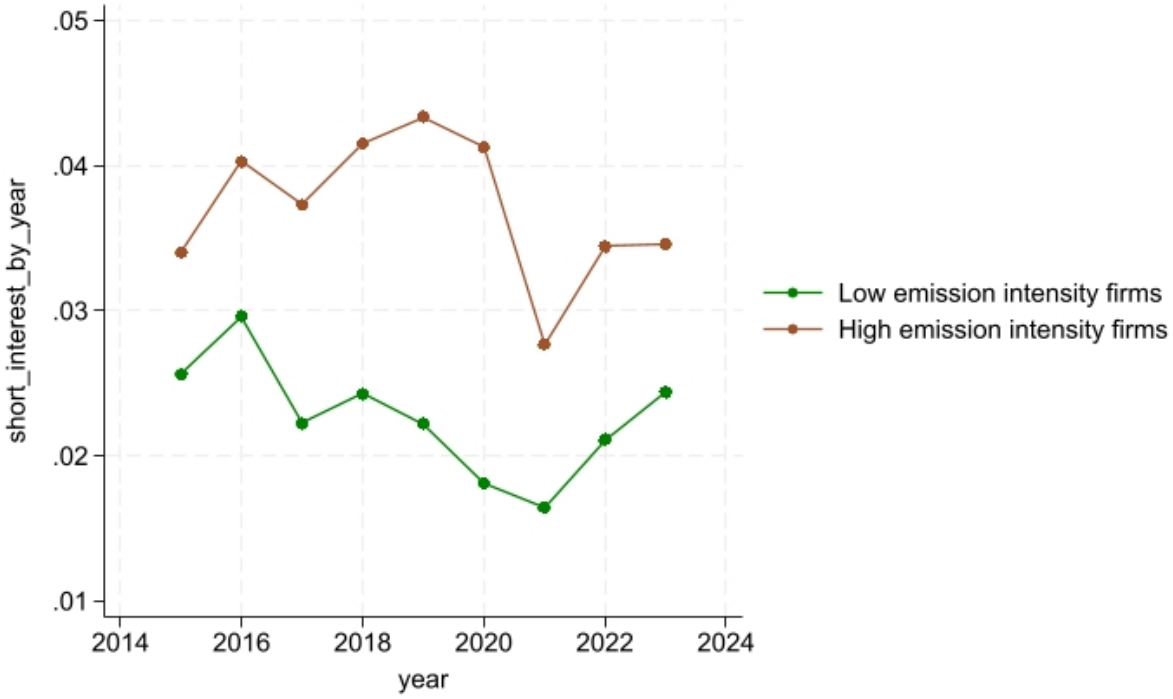


Table 1: Summary Statistics

This table reports the descriptive statistics of firm characteristics. Short interest is calculated as the ratio between the number of shares sold short at the end of the month and the total number of shares outstanding, reported in percentage form. Carbon emission is the total emissions measured as million tons of CO_2 equivalents (scope 1 and scope 2) from S&P Global Trucost. Carbon emissions intensity is tons of emissions per million dollars of revenue. Active short is assigned a value of one when there is a decrease in hedge fund ownership and an increase in short interest from year $t-1$ to year t, and zero otherwise. Passive short is assigned a value of one when there is an increase in hedge fund ownership and an increase in short interest from year $t-1$ to year t, and zero otherwise. Active short intensity is defined as short interest conditional on the stock being actively shorted. Passive short intensity is defined as short interest conditional on the stock being passively shorted. Green patents is the number of green patents a firm applies per year. Carbon disclosure is measured as the percentage of carbon-related words relative to the total number of words in a firm's 10-K filing. Cost of capital is the firm's implied cost of capital estimated using the mechanical GLS method of Lee et al. (2021). Institutional divestment is a dummy variable that equals one if the firm experiences divestment by institutional investors other than hedge funds in that year. Log asset is the logarithm of firm's total assets. Return is the annual return of the firm, adjusted for splits and dividends. Book to market ratio is the ratio of company's book value to its market capitalization. ROA is the ratio of company's net income by its total assets. Leverage is the ratio of company's average total assets to its average shareholders' equity. Capex is the firm's annual capital expenditure, measured in thousands of dollars. Revenue is the firm's total annual sales, measured in millions of dollars.

Panel A: Firm Characteristics

Variables	Mean	Min	Max	Median	SD
Short interest (%)	3.619	0.000	19.439	1.847	4.376
Carbon emission	0.823	0.000	29.700	0.329	3.545
Carbon emission intensity	141.653	0.887	3,192.358	32.365	436.698
Active short intensity (%)	0.647	0.000	9.414	0.000	1.882
Passive short intensity (%)	1.249	0.000	14.381	0.000	3.003
Active short	0.193	0.000	1.000	0.000	0.395
Passive short	0.289	0.000	1.000	0.000	0.453
Green patent	4.085	0.000	131.000	0.000	17.428
Carbon disclosure (%)	0.012	0.000	0.380	0.003	0.023
Cost of capital (%)	7.424	-53.471	47.797	6.953	4.057
Institutional divestment	0.324	0.000	1.000	0.000	0.468
Log asset	7.868	0.587	12.510	7.813	1.840
Return	0.158	-0.902	11.903	0.048	0.844
Book to market ratio	0.491	-7.760	5.514	0.206	0.822
ROA	-0.015	-16.152	0.424	0.022	0.266
Leverage	0.300	0.000	4.110	0.269	0.262
Capex (in thousand)	0.287	0.000	5.202	0.209	0.812
Revenue	5,287.975	0.000	73,723.000	1,091.553	12,386.140

Panel B: Correlation Matrix

	Carbon emission intensity	Active short intensity	Passive short intensity	Institutional divest-ment	Log asset	Return	Book to market ratio	ROA	Leverage
Carbon emission intensity	1								
Active short intensity	0.011	1							
Passive short intensity	-0.347	-0.199	1						
Institutional divestment	-0.049	0.213	-0.466	1					
Log asset	0.417	-0.345	-0.333	0.706	1				
Return	-0.434	-0.241	-0.140	-0.077	-0.252	1			
Book to market ratio	0.286	0.232	0.173	0.066	0.338	-0.283	1		
ROA	-0.003	0.251	0.002	0.196	0.282	-0.476	-0.003	1	
Leverage	0.160	-0.265	-0.272	0.456	0.521	-0.163	0.760	0.405	1

Table 2: Determinants of Short Selling Behavior

This table investigates the relationship between short selling, carbon emission intensity and other firm characteristics. The dependent variable in columns (1)–(2) is the firm's short interest, in columns (3)–(4) is the active short intensity, and in columns (5)–(6) is the passive short intensity. Short interest is measured as the annual average of monthly short interest, where monthly short interest is defined as the ratio of shares sold short at the end of the month to the total number of shares outstanding. Active short intensity is defined as short interest conditional on the stock being actively shorted. Passive short intensity is defined as short interest conditional on the stock being passively shorted. All dependent variables are measured in percentage. Emission intensity is the adjusted carbon emission intensity, defined as tons of carbon emissions per million dollars of revenue, divided by 1,000. Book to market ratio is the ratio of company's book value to its market capitalization. Return is firm's stock return. Log asset is the logarithm of firm's total assets. ROA is the ratio of company's net income to its total assets. Leverage is the ratio of company's average total assets to its average shareholders' equity. News coverage is measured as the logarithm of the total number of news buzzwords associated with each firm, obtained from Refinitiv. All regressions include firm fixed effects and year fixed effects. The t-statistics in the brackets are calculated from robust clustered standard errors by the firm. ***, **, and * denote significance at the 0.01, 0.05, and 0.10 levels.

	Short interest		Active short intensity		Passive short intensity	
VARIABLES	(1)	(2)	(3)	(4)	(5)	(6)
Emission intensity	0.549**	0.446*	0.317*	0.206*	-0.107	-0.107
	(2.03)	(1.67)	(1.66)	(1.74)	(-0.57)	(-0.57)
Book to market		0.014		0.008		0.047
		(0.14)		(0.16)		(0.81)
Return		-0.210***		-0.058***		-0.036
		(-4.96)		(-2.66)		(-1.05)
Log assets		1.066***		0.343***		0.141
		(6.92)		(6.46)		(1.49)
ROA		-0.945***		-0.330***		-0.100
		(-3.00)		(-2.69)		(-0.74)
Leverage		1.973***		0.510***		-0.285
		(4.69)		(3.23)		(-1.09)
News coverage		2.001		1.675**		-0.015
		(1.45)		(2.16)		(-0.01)
Year FE	YES	YES	YES	YES	YES	YES
Firm FE	YES	YES	YES	YES	YES	YES
Observations	20,181	19,810	20,181	19,810	20,181	19,810
R-squared	0.621	0.637	0.190	0.191	0.255	0.260

Table 3: Motivation of Short Selling

Panel A reports firms' stock returns in the year when they are actively or passively shorted. The dependent variable is firm's annual stock return in the year being shorted. We divide firms into quintiles based on their level of emission intensity in each year. Brown firms are defined as the firms in the highest quintile. Green firms are defined as the firms in the lowest quintile. Active short intensity is defined as short interest conditional on the stock being actively shorted. Passive short intensity is defined as short interest conditional on the stock being passively shorted. Book to market ratio is the ratio of company's book value to its market capitalization. Return is firm's stock return. Log asset is the logarithm of firm's total assets. ROA is the ratio of company's net income to its total assets. Leverage is the ratio of company's average total assets to its average shareholders' equity. News coverage is measured as the logarithm of the total number of news buzzwords associated with each firm, obtained from Refinitiv. Panel B reports the regression results examining the effect of active short sellers on hedge fund performance. Active short seller equals one if a hedge fund is identified as a green fund that short sells brown stocks, and zero otherwise. The dependent variables in column (1) and (2) are funds monthly excess return (%) and that of column (3) and (4) are Fung and Hsieh (2004) seven-factor alpha (%). The regression includes the following control variables: the natural logarithm of fund size, fund age, fund lock-up period (in months), management fee (%), incentive fee (%), a dummy variable for a fund with a high-water mark and a dummy variable for a fund with leverage. The t-statistics are in parentheses. Standard errors are clustered by fund and month. ***, **, and * indicate significance at the 1%, 5%, and 10% levels, respectively.

Panel A. Short Selling and Stock Return

	Return	
VARIABLES	(1)	(2)
Brown*active short intensity	-0.014**	
	(-2.11)	
Brown*passive short intensity	0.005	
	(0.76)	
Green*active short intensity		0.034
		(1.36)
Green*passive short intensity		0.028
		(1.05)
Active short intensity	-0.010**	-0.018*
	(-2.03)	(-1.87)
Passive short intensity	-0.006*	-0.019
	(-1.87)	(-1.13)
Book to market	-0.165***	0.090
	(-3.64)	(0.44)
Log assets	-0.253***	0.066
	(-6.23)	(0.18)
ROA	0.559***	0.499
	(3.58)	(1.39)
Leverage	-0.207**	-0.501**
	(-2.01)	(-2.39)
News coverage	-0.823**	-6.149
	(-2.44)	(-0.99)
Year FE	YES	YES
Firm FE	YES	YES
Observations	19,810	19,810
R-squared	0.215	0.250

Panel B. Short Seller's Performance

	Excess return		Alpha	
VARIABLES	(1)	(2)	(3)	(4)
Short sellers (Active short sellers of brown firms)	0.193**	0.199**	0.232***	0.160**
	(2.52)	(2.29)	(3.70)	(2.43)
Size		0.016**		0.039***
		(2.09)		(5.36)
Fund age		-0.007***		-0.014***
		(-3.21)		(-6.95)
Lock Up Period		0.004*		0.001
		(1.93)		(0.81)
Management Fee		0.034		0.184***
		(0.92)		(5.60)
Incentive Fee		-0.003		0.004
		(-0.99)		(1.40)
High Water Mark		0.098*		0.068
		(1.67)		(1.33)
Leveraged		-0.028		0.006
		(-0.88)		(0.21)
Year month FE	YES	YES	YES	YES
Investment style FE	YES	YES	YES	YES
Observations	125,876	78,512	108,150	68,396
R-squared	0.2478	0.2381	0.0422	0.0455

Table 4: Impact on Carbon Emission

This table shows the relationship between changes in firms' emission intensity and short selling activities. The dependent variable is the 1-year, 2-year and 3-year change in carbon emission intensity, measured as tons of emissions per million dollars of revenue. Brown is a dummy variable equal to one for firms in the highest quintile of emission intensity within each year, and zero otherwise. Active short intensity is defined as short interest conditional on the stock being actively shorted. Passive short intensity is defined as short interest conditional on the stock being passively shorted. Book to market ratio is the ratio of company's book value to its market capitalization. Return is firm's stock return. Log asset is the logarithm of firm's total assets. ROA is the ratio of company's net income to its total assets. Leverage is the ratio of company's average total assets to its average shareholders' equity. Institutional divestment is a dummy variable that equals one if the firm experiences divestment by institutional investors other than hedge funds in that year. All regressions include firm fixed effects and time fixed effects. The t-statistics in the brackets are calculated from robust clustered standard errors by the firm. ***, **, and * denote significance at the 0.01, 0.05, and 0.10 levels.

VARIABLES	Δ Emission Intensity		
	1 year	2 years	3 years
	(1)	(2)	(3)
Brown*Active short intensity	1.008	-12.597***	-20.474***
	(0.35)	(-3.07)	(-4.50)
Brown*Passive short intensity	-0.344	2.541	-2.349
	(-0.17)	(0.77)	(-0.78)
Active short intensity	-0.114	0.193	0.043
	(-0.41)	(0.41)	(0.06)
Passive short intensity	0.256	0.004	-0.217
	(1.13)	(0.01)	(-0.52)
Book to market	-0.488	-4.182	-12.622
	(-0.16)	(-0.55)	(-1.53)
Return	-0.013	-0.131	3.484
	(-0.01)	(-0.05)	(0.98)
Log assets	5.517	17.036**	20.167
	(1.21)	(2.04)	(1.51)
ROA	-10.398	-5.553	-27.921
	(-0.45)	(-0.11)	(-0.38)
Leverage	-14.713*	-12.707	11.028
	(-1.66)	(-0.66)	(0.38)
Institutional divestment	1.875	0.174	-4.590
	(0.67)	(0.05)	(-0.91)
Year FE	YES	YES	YES
Firm FE	YES	YES	YES
Observations	17,659	15,556	13,543
R-squared	0.086	0.169	0.276

Table 5: Causality: Instrument variable

This table reports the results of Two-Stage Least Squares (2SLS) regressions that examine whether active short selling facilitate firm carbon reduction. Column (1) and (2) show the first stage regression. The dependent variable in column (1) is the interaction term between *Brown* and *Active short intensity*, and in column (2) is *Active short intensity*. *Active short intensity* is defined as short interest conditional on the stock being actively shorted. *Brown* is a dummy variable equal to one for firms in the highest quintile of emission intensity within each year, and zero otherwise. The two instruments are *Brown×Non-ESG news* and *Non-ESG news*, where *Non-ESG news* is defined as news coverage excluding ESG-related negative news and is measured as the residual from regressing total news coverage on ESG-related negative news. Columns (3) to (5) show the results of second stage 2SLS regressions. The dependent variable is the 1-year, 2-year and 3-year change in carbon emission intensity, measured as tons of emissions per million dollars of revenue. *Book to market ratio* is the ratio of company's book value to its market capitalization. *Return* is firm's stock return. *Log asset* is the logarithm of firm's total assets. *ROA* is the ratio of company's net income to its total assets. *Leverage* is the ratio of company's average total assets to its average shareholders' equity. *Institutional divestment* is a dummy variable that equals one if the firm experiences divestment by institutional investors other than hedge funds in that year. All regressions include firm fixed effects and time fixed effects. The t-statistics in the brackets are calculated from robust clustered standard errors by the firm. ***, **, and * denote significance at the 0.01, 0.05, and 0.10 levels.

	First Stage		Second Stage		
			Δ Emission Intensity		
	Brown×active short intensity	Active short intensity	1 year	2 years	3 years
VARIABLES	(1)	(2)	(3)	(4)	(5)
Brown× Non-ESG news	1.732***	0.140			
	(11.84)	(0.90)			
Non-ESG news	-0.080	0.542***			
	(-0.72)	(3.36)			
Brown×Active short intensity (IV)			-53.806***	-89.759***	-105.701***
			(-5.19)	(-3.91)	(-3.13)
Active short intensity (IV)			54.665**	81.610*	86.212
			(2.14)	(1.73)	(0.92)
Book to market	-0.000	-0.000	-0.315	-2.700	-15.512
	(-1.06)	(-0.43)	(-0.11)	(-0.35)	(-1.48)
Return	-0.000	-0.000	-0.526	-0.513	4.180
	(-1.51)	(-0.91)	(-0.32)	(-0.18)	(1.15)
Log assets	0.096***	0.361***	-7.063	-8.253	-15.719
	(3.36)	(7.03)	(-0.73)	(-0.40)	(-0.38)
ROA	-0.104*	-0.322***	18.927	6.086	-13.720
	(-1.85)	(-2.91)	(1.55)	(0.12)	(-0.21)
Leverage	0.246**	0.539***	-28.477*	-45.356	-27.480
	(2.48)	(3.57)	(-1.81)	(-1.22)	(-0.40)
Institutional divestment	0.042	0.112***	-1.392	-7.783	-13.502
	(1.34)	(2.63)	(-0.43)	(-1.33)	(-1.11)
Year FE	YES	YES	YES	YES	YES
Firm FE	YES	YES	YES	YES	YES
Observations	19,810	19,810	16,781	13,931	11,216
R-squared	0.229	0.191	0.089	0.192	0.332

Table 6: Causality: Staggered Difference-in-Difference-in-Difference (DDD)

This table reports the results of staggered triple Difference-in-Difference (DiD) regressions that explain change in carbon emission intensity after being actively shorted. We use stacked regression as suggested by Baker et al. (2022) and construct an event-specific identifier and stack together the event-specific data sets. The dependent variable is the change in carbon emission intensity, which is measured as tons of emissions per million dollars of revenue. Columns (1)–(3) use event windows of 1, 2, and 3 years before and after the event, while column (4) includes the full sample period. *Treat* is a dummy variable that equals one if the firm is ever being actively shorted. *Post* is an indicator equal to one after the firm's first time being actively shorted. *Brown* firms are defined as those in the highest quintile of emission intensity within each year. Book to market ratio is the ratio of company's book value to its market capitalization. Return is firm's stock return. Log asset is the logarithm of firm's total assets. ROA is the ratio of company's net income to its total assets. Leverage is the ratio of company's average total assets to its average shareholders' equity. Institutional divestment is a dummy variable that equals one if the firm experiences divestment by institutional investors other than hedge funds in that year. All regressions include firm-cohort fixed effects and year-cohort fixed effects. The t-statistics in the brackets are calculated from robust clustered standard errors by the firm. ***, **, and * denote significance at the 0.01, 0.05, and 0.10 levels.

	Δ Emission Intensity			
VARIABLES	(-1,1)	(-2,2)	(-3,3)	All sample
	(1)	(2)	(3)	(4)
*Treat*Post*Brown*	3.726	-31.991**	-41.428***	-39.617***
	(0.18)	(-2.24)	(-3.57)	(-3.83)
*Treat*Post*	5.293***	11.639***	12.787***	12.493***
	(3.09)	(4.31)	(4.71)	(4.31)
Book to market	5.525	7.844	7.915*	5.684
	(1.13)	(1.62)	(1.72)	(1.46)
Return	2.397	0.487	0.137	0.689
	(0.99)	(0.32)	(0.10)	(0.52)
Log assets	10.277	7.341	10.807	12.153
	(0.56)	(0.71)	(1.31)	(1.50)
ROA	-9.506	-21.188**	-22.462***	-16.429**
	(-1.23)	(-2.51)	(-2.61)	(-2.53)
Leverage	6.575	17.024	15.909	18.559
	(0.33)	(1.08)	(1.01)	(1.22)
Institutional divestment	0.302	0.516	0.820	4.678
	(0.05)	(0.10)	(0.15)	(0.85)
Observations	8,352	22,553	31,757	46,872
R-squared	0.465	0.316	0.219	0.163
Firm-cohort FE	YES	YES	YES	YES
Year-cohort FE	YES	YES	YES	YES

Table 7: Short Selling and Cost of Capital

This table shows the relationship between firm's cost of capital and short selling activities. The dependent variable, cost of capital, is the firm's implied cost of capital estimated using the mechanical GLS method of Lee et al. (2021) in 1-year, 2-year and 3-year following the short-selling activity. Brown is a dummy variable equal to one for firms in the highest quintile of emission intensity within each year, and zero otherwise. Active short intensity is defined as short interest conditional on the stock being actively shorted. Passive short intensity is defined as short interest conditional on the stock being passively shorted. Book to market ratio is the ratio of company's book value to its market capitalization. Return is firm's stock return. Log asset is the logarithm of firm's total assets. ROA is the ratio of company's net income to its total assets. Leverage is the ratio of company's average total assets to its average shareholders' equity. Institutional divestment is a dummy variable that equals one if the firm experiences divestment by institutional investors other than hedge funds in that year. All regressions include firm fixed effects and time fixed effects. The t-statistics in the brackets are calculated from robust clustered standard errors by the firm. ***, **, and * denote significance at the 0.01, 0.05, and 0.10 levels.

	Cost of capital		
	1 year	2 years	3 years
VARIABLES	(1)	(2)	(3)
Brown*Active short intensity	0.009	-0.034	-0.037
	(0.22)	(-0.96)	(-0.96)
Brown*Passive short intensity	0.027	0.015	-0.037
	(1.24)	(0.57)	(-1.29)
Active short intensity	-0.014	0.009	0.021*
	(-1.11)	(0.70)	(1.91)
Passive short intensity	-0.033***	-0.016	0.019**
	(-3.53)	(-1.61)	(2.02)
Book to market	1.986***	-0.794***	-0.359**
	(7.44)	(-3.97)	(-2.15)
Return	-0.198***	-0.061	-0.021
	(-3.82)	(-1.30)	(-0.35)
Log assets	0.233*	0.316**	0.234*
	(1.69)	(2.43)	(1.69)
ROA	8.566***	0.577	-0.051
	(8.67)	(1.21)	(-0.61)
Leverage	0.564	0.131	0.361
	(1.20)	(0.28)	(0.65)
Institutional divestment	0.208***	0.075	0.080
	(3.19)	(1.14)	(1.01)
Year FE	YES	YES	YES
Firm FE	YES	YES	YES
Observations	14,533	14,010	13,458
R-squared	0.695	0.662	0.664

Table 8: Short Selling and Firm Operation

This table shows the relationship between firm operation and short selling activities. The dependent variable in columns (1)–(3) is the firm's capital expenditure (in thousand) in the one-, two-, and three-year periods following the short-selling activity, while the dependent variable in columns (4)–(6) is the firm's sales (log of total revenue) over the same periods. Brown is a dummy variable equal to one for firms in the highest quintile of emission intensity within each year, and zero otherwise. Active short intensity is defined as short interest conditional on the stock being actively shorted. Passive short intensity is defined as short interest conditional on the stock being passively shorted. Book to market ratio is the ratio of company's book value to its market capitalization. Return is firm's stock return. Log asset is the logarithm of firm's total assets. ROA is the ratio of company's net income to its total assets. Leverage is the ratio of company's average total assets to its average shareholders' equity. Institutional divestment is a dummy variable that equals one if the firm experiences divestment by institutional investors other than hedge funds in that year. All regressions include firm fixed effects and time fixed effects. The t-statistics in the brackets are calculated from robust clustered standard errors by the firm. ***, **, and * denote significance at the 0.01, 0.05, and 0.10 levels.

	Capex			Sales		
	1 year	2 years	3 years	1 year	2 years	3 years
VARIABLES	(1)	(2)	(3)	(4)	(5)	(6)
Brown*Active short intensity	-0.008	-0.007*	0.009	-0.018***	-0.003	0.009*
	(-1.46)	(-1.69)	(1.54)	(-4.47)	(-0.65)	(1.86)
Brown*Passive short intensity	-0.001	-0.003	0.004	-0.003	-0.001	0.001
	(-0.38)	(-1.50)	(1.54)	(-1.39)	(-1.62)	(1.14)
Active short intensity	-0.000	-0.001	-0.000	0.003	0.004	-0.001
	(-0.59)	(-0.75)	(-1.29)	(1.26)	(1.59)	(-0.55)
Passive short intensity	-0.001	0.001*	-0.000	-0.000	0.004**	0.000
	(-1.61)	(1.69)	(-0.41)	(-1.29)	(2.45)	(0.16)
Book to market	-0.014**	-0.021***	-0.020***	-0.084***	-0.067***	-0.057***
	(-2.57)	(-3.48)	(-2.76)	(-5.95)	(-5.02)	(-4.98)
Return	0.002	0.005	0.005**	0.019**	0.015	0.011
	(0.88)	(1.50)	(2.02)	(2.01)	(1.50)	(1.14)
Log assets	0.061***	0.037***	0.021**	0.577***	0.423***	0.319***
	(6.29)	(4.02)	(1.99)	(25.66)	(19.24)	(13.28)
ROA	0.022*	-0.013	-0.019*	0.028	-0.037	-0.034
	(1.66)	(-1.33)	(-1.79)	(1.14)	(-0.64)	(-0.66)
Leverage	-0.078***	-0.050***	-0.033*	0.244***	0.085	0.010
	(-4.11)	(-2.76)	(-1.72)	(2.94)	(1.31)	(0.14)
Institutional divestment	-0.000	0.004	-0.002	-0.048	-0.043	-0.034**
	(-0.09)	(0.80)	(-0.94)	(-0.68)	(-0.68)	(-2.26)
Year FE	YES	YES	YES	YES	YES	YES
Firm FE	YES	YES	YES	YES	YES	YES
Observations	19,290	18,521	17,765	19,290	18,521	17,765
R-squared	0.941	0.942	0.941	0.968	0.968	0.967

Table 9: Short Selling and Green Innovation

This table shows the relationship between green innovation and short selling activities. The dependent variable is the number of green patents apply in 1-year, 2-year and 3-year following the short selling activity. Brown is a dummy variable equal to one for firms in the highest quintile of emission intensity within each year, and zero otherwise. Active short intensity is defined as short interest conditional on the stock being actively shorted. Passive short intensity is defined as short interest conditional on the stock being passively shorted. Book to market ratio is the ratio of company's book value to its market capitalization. Return is firm's stock return. Log asset is the logarithm of firm's total assets. ROA is the ratio of company's net income to its total assets. Leverage is the ratio of company's average total assets to its average shareholders' equity. Institutional divestment is a dummy variable that equals one if the firm experiences divestment by institutional investors other than hedge funds in that year. All regressions include firm fixed effects and time fixed effects. The t-statistics in the brackets are calculated from robust clustered standard errors by the firm. ***, **, and * denote significance at the 0.01, 0.05, and 0.10 levels.

	# Green patents		
	1 year	2 years	3 years
VARIABLES	(1)	(2)	(3)
Brown*Active short intensity	0.039*	0.081***	0.038**
	(1.93)	(2.93)	(2.15)
Brown*Passive short intensity	0.013	0.006	0.020
	(0.93)	(0.39)	(0.91)
Active short intensity	-0.019	-0.008	0.006
	(-1.36)	(-0.60)	(0.39)
Passive short intensity	-0.012	-0.006	0.004
	(-1.04)	(-0.78)	(0.44)
Book to market	0.015	0.153**	0.146*
	(0.25)	(2.30)	(1.71)
Return	-0.015	-0.033	0.003
	(-0.22)	(-0.49)	(0.15)
Log assets	0.619***	0.668***	0.547***
	(2.87)	(3.22)	(2.63)
ROA	-0.371	-0.332	-0.343*
	(-1.38)	(-1.32)	(-1.90)
Leverage	0.380	0.247	-0.275
	(0.75)	(0.50)	(-0.49)
Institutional divestment	0.302*	0.133	-0.269
	(1.88)	(0.78)	(-1.35)
Year FE	YES	YES	YES
Firm FE	YES	YES	YES
Observations	19,349	18,580	17,827
R-squared	0.645	0.645	0.646

Table 10: Short Selling and Climate Disclosure

This table shows the relationship between climate disclosure and short selling activities. The dependent variable is firm's climate disclosure, measured as the percentage of carbon-related words relative to the total number of words in a firm's 10-K filing. Brown is a dummy variable equal to one for firms in the highest quintile of emission intensity within each year, and zero otherwise. Active short intensity is defined as short interest conditional on the stock being actively shorted. Passive short intensity is defined as short interest conditional on the stock being passively shorted. Book to market ratio is the ratio of company's book value to its market capitalization. Return is firm's stock return. Log asset is the logarithm of firm's total assets. ROA is the ratio of company's net income to its total assets. Leverage is the ratio of company's average total assets to its average shareholders' equity. Institutional divestment is a dummy variable that equals one if the firm experiences divestment by institutional investors other than hedge funds in that year. All regressions include firm fixed effects and time fixed effects. The t-statistics in the brackets are calculated from robust clustered standard errors by the firm. ***, **, and * denote significance at the 0.01, 0.05, and 0.10 levels.

	Climate disclosure		
	1 year	2 years	3 years
VARIABLES	(1)	(2)	(3)
Brown*Active short intensity	0.001	0.031*	0.052**
	(0.05)	(1.95)	(2.03)
Brown*Passive short intensity	0.004	0.013	0.028**
	(0.36)	(1.17)	(2.30)
Active short intensity	-0.001	-0.005	-0.004
	(-0.32)	(-1.20)	(-0.92)
Passive short intensity	0.002	-0.002	-0.004
	(0.87)	(-0.71)	(-1.24)
Book to market	-0.027	0.053	0.041
	(-0.65)	(1.01)	(1.00)
Return	0.043***	0.018*	-0.000
	(3.02)	(1.89)	(-0.03)
Log assets	-0.279***	-0.299***	-0.284***
	(-5.77)	(-6.10)	(-5.71)
ROA	0.200**	0.051	0.009
	(2.50)	(0.75)	(0.13)
Leverage	-0.283***	-0.219***	-0.127
	(-3.01)	(-2.13)	(-1.19)
Institutional divestment	-0.034	-0.003	0.021
	(-1.32)	(-0.12)	(0.78)
Year FE	YES	YES	YES
Firm FE	YES	YES	YES
Observations	17,435	16,784	16,122
R-squared	0.872	0.875	0.875

Appendix

Figure A1. Short Interest and Carbon Emission within Industry

This figure plots the average annual short interest from 2015 to 2023, sorted by firms' carbon emission intensity within Fama–French 48 industries. Carbon emission intensity are measured as tons of CO_2 equivalents (scope 1 and scope 2) emitted per million dollars of revenue. Each year, firms are sorted into quintiles based on their carbon emission intensity within each industry. Firms in the lowest quintile are defined as low emission intensity firms. Firms in the highest quintile are defined as high emission intensity firms. Annual short interest is computed as the average of monthly short interest, where monthly short interest equals the ratio of shares sold short at month-end to total shares outstanding.

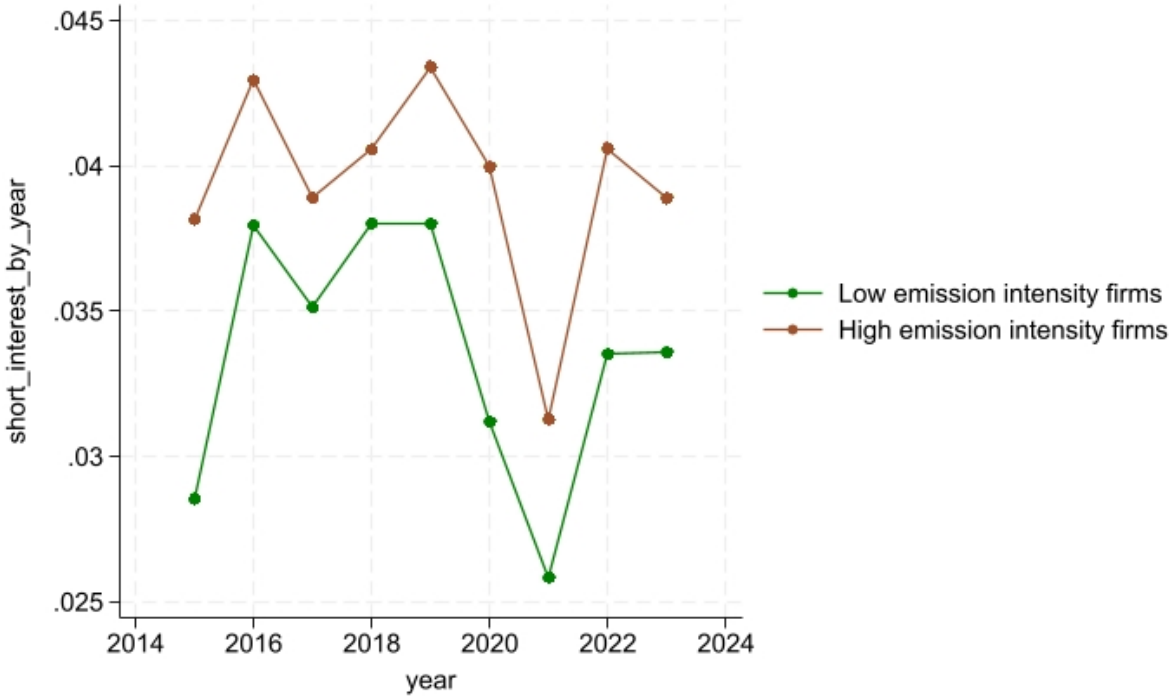


Table A1: Additional Summary Statistics

Panel A presents the average carbon emissions (in thousand) and carbon emission intensity of firms by industry. The industry is classified according to Fama-French 12 industries code based on firms' four-digit SIC code. Panel B reports the Pearson correlations among different variables. Short interest is calculated as the ratio between the number of shares sold short at the end of the month and the total number of shares outstanding, reported in percentage form. Carbon emission is the total emissions measured as million tons of CO_2 equivalents (scope 1 and scope 2) from S&P Global Trucost. Carbon emissions intensity is tons of emissions per million dollars of revenue. Active short intensity is defined as short interest conditional on the stock being actively shorted. Passive short intensity is defined as short interest conditional on the stock being passively shorted. Institutional divestment is a dummy variable that equals one if the firm experiences divestment by institutional investors other than hedge funds in that year. Log asset is the logarithm of firm's total assets. Return is the annual return of the firm, adjusted for splits and dividends. Book to market ratio is the ratio of company's book value to its market capitalization. ROA is the ratio of company's net income by its total assets. Leverage is the ratio of company's average total assets to its average shareholders' equity.

Emissions by Fama–French Industry

Fama–French 12 industry code	**Emission Intensity**	**Emission (in thousand)**
Utilities	1,732.560	8,665.449
Oil, Gas, and Coal Extraction and Products	588.214	3,744.294
Chemicals and Allied Products	415.194	2,402.987
Other – Mines, Constr., BldMt., Trans., Hotels, Bus Serv., Entertainment	231.450	1,281.246
Manufacturing	188.376	874.633
Consumer NonDurables	126.496	726.173
Wholesale, Retail, and Some Services	66.743	672.775
Business Equipment – Computers, Software, and Electronic Equipment	51.322	150.640
Consumer Durables	43.520	353.734
Healthcare, Medical Equipment, and Drugs	39.441	73.410
Finance	26.385	48.861
Telephone and Television Transmission	20.874	552.481

Table A2: Impact on Carbon Emission for Green Firms

This table shows the relationship between changes in green firms' emission intensity and short selling activities. The dependent variable is the 1-year, 2-year and 3-year change in carbon emission intensity, measured as tons of emissions per million dollars of revenue. Green is a dummy variable equal to one for firms in the lowest quintile of emission intensity within each year, and zero otherwise. Active short intensity is defined as short interest conditional on the stock being actively shorted. Passive short intensity is defined as short interest conditional on the stock being passively shorted. Book to market ratio is the ratio of company's book value to its market capitalization. Return is firm's stock return. Log asset is the logarithm of firm's total assets. ROA is the ratio of company's net income to its total assets. Leverage is the ratio of company's average total assets to its average shareholders' equity. Institutional divestment is a dummy variable that equals one if the firm experiences divestment by institutional investors other than hedge funds in that year. All regressions include firm fixed effects and time fixed effects. The t-statistics in the brackets are calculated from robust clustered standard errors by the firm. ***, **, and * denote significance at the 0.01, 0.05, and 0.10 levels.

	Δ Emission Intensity		
	1 year	2 years	3 years
VARIABLES	(1)	(2)	(3)
Green*Active short intensity	-0.304	2.529**	5.788***
	(-0.44)	(2.37)	(4.31)
Green*Passive short intensity	-0.382	-1.566**	-0.079
	(-0.90)	(-2.25)	(-0.12)
Active short intensity	0.110	-2.578**	-4.760***
	(0.15)	(-2.44)	(-3.75)
Passive short intensity	0.229	0.566	-0.612
	(0.51)	(0.78)	(-0.84)
Book to market	-0.469	-4.978	-14.462*
	(-0.15)	(-0.65)	(-1.69)
Return	-0.018	0.074	3.843
	(-0.01)	(0.03)	(1.08)
Log assets	5.483	16.993**	20.477
	(1.20)	(2.04)	(1.53)
ROA	-10.474	-4.173	-25.683
	(-0.46)	(-0.08)	(-0.35)
Leverage	-14.729*	-13.192	8.503
	(-1.65)	(-0.68)	(0.29)
Institutional divestment	1.862	0.244	-4.160
	(0.67)	(0.07)	(-0.82)
Year FE	YES	YES	YES
Firm FE	YES	YES	YES
Observations	17,659	15,556	13,543
R-squared	0.086	0.166	0.271

Table A3: Short Selling and Financial Performance

This table shows the relationship between firm's financial performance and short selling activities. The dependent variable firm's stock return in 1-year, 2-year and 3-year following the short-selling activity. Brown is a dummy variable equal to one for firms in the highest quintile of emission intensity within each year, and zero otherwise. Active short intensity is defined as short interest conditional on the stock being actively shorted. Passive short intensity is defined as short interest conditional on the stock being passively shorted. Book to market ratio is the ratio of company's book value to its market capitalization. Return is firm's stock return. Log asset is the logarithm of firm's total assets. ROA is the ratio of company's net income to its total assets. Leverage is the ratio of company's average total assets to its average shareholders' equity. Institutional divestment is a dummy variable that equals one if the firm experiences divestment by institutional investors other than hedge funds in that year. All regressions include firm fixed effects and time fixed effects. The t-statistics in the brackets are calculated from robust clustered standard errors by the firm. ***, **, and * denote significance at the 0.01, 0.05, and 0.10 levels.

	Return		
	1 year	2 years	3 years
VARIABLES	(1)	(2)	(3)
Brown*Active short intensity	0.002	0.012	0.017
	(0.27)	(1.51)	(1.52)
Brown*Passive short intensity	-0.012*	0.018	0.003
	(-1.81)	(1.57)	(0.43)
Active short intensity	0.013***	-0.004	0.000
	(3.00)	(-1.36)	(0.03)
Passive short intensity	0.001	-0.001	-0.004
	(0.40)	(-0.25)	(-1.45)
Book to market	0.131	0.268***	0.073***
	(1.60)	(5.56)	(2.25)
Log assets	-0.458***	-0.242***	-0.073***
	(-13.56)	(-8.79)	(-2.94)
ROA	-0.413***	-0.093	-0.038
	(-3.20)	(-1.14)	(-0.58)
Leverage	0.682***	0.601***	0.075
	(5.93)	(5.55)	(0.92)
ESG negative news	-0.075**	-0.021	0.008
	(-2.42)	(-0.68)	(0.25)
Non ESG news	-0.968***	0.450	0.519
	(-2.59)	(1.53)	(1.46)
Year FE	YES	YES	YES
Firm FE	YES	YES	YES
Observations	19,800	19,245	18,551
R-squared	0.238	0.218	0.199

Table A4: Robustness

This table presents a series of robustness checks examine the relationship between changes in firms' emission intensity on short selling activities. Panel A reports the regression results using alternative fixed effects, including firm fixed effects and year-by-industry fixed effects. Panel B presents the regression results using an alternative definition of brown firms, where Brown is a dummy variable equal to one for firms in the highest tertile of emission intensity within each year and zero otherwise. Panel C reports the regression results using binary indicators for active and passive short selling. Active short is assigned a value of one when there is a decrease in hedge fund ownership and an increase in short interest from year $t-1$ to year t, and zero otherwise. Passive short is assigned a value of one when there is an increase in hedge fund ownership and an increase in short interest from year $t-1$ to year t, and zero otherwise. The dependent variable in all regressions is the 1-year, 2-year and 3-year change in carbon emission intensity, measured as tons of emissions per million dollars of revenue. Active short intensity is defined as short interest conditional on the stock being actively shorted. Passive short intensity is defined as short interest conditional on the stock being passively shorted. All regressions include control variables of Book to market ratio, return, log asset, ROA, leverage and institutional divestment, firm fixed effects and time fixed effects. The t-statistics in the brackets are calculated from robust clustered standard errors by the firm. ***, **, and * denote significance at the 0.01, 0.05, and 0.10 levels.

Panel A: Using different fixed effects

VARIABLES	Δ Emission Intensity		
	1 year	2 years	3 years
	(1)	(2)	(3)
Brown*Active short intensity	0.066	-11.655***	-15.072***
	(0.02)	(-2.92)	(-3.46)
Brown*Passive short intensity	-1.762	-0.161	-3.739
	(-0.87)	(-0.05)	(-1.19)
Controls	YES	YES	YES
Year*Industry FE	YES	YES	YES
Firm FE	YES	YES	YES
Observations	17,585	15,489	13,485
R-squared	0.147	0.245	0.344

Panel B: Different definition of brown firms

VARIABLES	Δ Emission Intensity		
	1 year	2 years	3 years
	(1)	(2)	(3)
Brown*Active short intensity	1.121	-6.617**	-11.279***
	(0.66)	(-2.56)	(-3.83)
Brown*Passive short intensity	-0.261	1.364	-1.088
	(-0.24)	(0.77)	(-0.61)
Controls	YES	YES	YES
Year FE	YES	YES	YES
Firm FE	YES	YES	YES
Observations	17,659	15,556	13,543
R-squared	0.086	0.167	0.273

[Continued]

Panel C: Use dummy for active and passive short

VARIABLES	Δ Emission Intensity		
	1 year	2 years	3 years
	(1)	(2)	(3)
Brown*Active short (dummy)	-7.439	-62.152***	-109.265***
	(-0.54)	(-2.90)	(-4.32)
Brown*Passive short (dummy)	6.113	11.784	-10.460
	(0.55)	(1.18)	(-0.64)
Controls	YES	YES	YES
Year FE	YES	YES	YES
Firm FE	YES	YES	YES
Observations	17,659	15,556	13,543
R-squared	0.086	0.169	0.276