# Sustainable Short Selling

Bing Liang, Loriana Pelizzon, Tianyi Qu, and Mila Getmansky Sherman*

**ABSTRACT**

This study examines the relationship between short interest and firm environmental performance, revealing that short interest is negatively associated with environmental metrics, especially after firms experience negative ESG news. We distinguish between passive short sellers, primarily hedging-focused, and active short sellers, driven by financial gains. Our findings indicate that active short selling of environmentally unfriendly ("brown") firms correlates with reduced carbon emissions, achieved through increased green patents and investments in cleaner production processes rather than operational downsizing. In contrast, passive short sellers have minimal impact on emissions. These results highlight the potential of active short sellers, motivated solely by financial returns, to drive environmental improvements and support firms' transitions toward greener economic practices.

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

JEL classification: G20, G23, G41, Q54

*Bing Liang is at the Isenberg School of Management, University of Massachusetts at Amherst; email: bliang@isenberg.umass.edu. Loriana Pelizzon is at Financial Research SAFE, Goethe University, Ca' Foscari University of Venice, CEPR.; email: Pelizzon@safe-frankfurt.de. Tianyi Qu is at the Hankamer School of Business, Baylor University; e-mail: tianyi_qu@baylor.edu. Mila Getmansky Sherman is at the Isenberg School of Management, University of Massachusetts Amherst; e-mail: msherman@isenberg.umass.edu. We thank Marie Briere, Max Croce, Lina Han, Marcin Kacperczyk, Anya Mkrtchyan, Nikunj Kapadia, Hossein Kazemi, Wenting Ma, Roberto Rigobon, Marti Subrahmanyam, and seminar participants at CREDIT Conference, University of Massachusetts Amherst for their insightful comments. All errors remain ours.

*"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 advances toward sustainability, financial institutions play a critical role in addressing climate change by redirecting capital from environmentally harmful activities to eco-friendly initiatives. Professional asset managers increasingly incorporate sustainability considerations into their investment strategies, though research has predominantly focused on the "long side." Studies highlight two key methods for reducing corporate carbon emissions: active shareholder engagement, 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). Surprisingly, little attention has been given to the "short side." Traditionally, short sellers are studied for their roles in market efficiency, price discovery, and corporate behavior, but their impact on firms' environmental performance remains underexplored. This study addresses this gap by examining the relationship between short sellers and sustainability, focusing on their potential role in reducing corporate carbon emissions and the motivations driving their behavior.

We begin by examining whether short sellers' behavior is influenced by firm sustainability, specifically investigating whether short sellers target stocks with more or less favorable environmental metrics. 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. This study seeks to empirically determine whether short sellers are more likely to short-sell green or brown firms.

To determine whether short sellers consider firm sustainability, we focus specifically on environmental scores (E scores) rather than the broader ESG (Environmental, Social, Governance) framework or individual Social and Governance components, reflecting the growing global emphasis on climate-related issues. Investors and policymakers increasingly agree that environmental concerns, particularly carbon emissions, are the most pressing aspects of sustainable investing. We test the association between short interest and firms' environmental metrics while controlling for firm characteristics. To account for baseline variations in short interest across firms and industries, we measure abnormal short interest (ASI) as the difference between a firm's current short interest and its average short interest over the past 12 months. Our findings show that greater ASI is associated with lower firm-level E scores. This relationship is both statistically and economically significant: a one-unit decrease in environmental score corresponds to a 3.1% increase in short interest and a 0.6% increase in ASI.

Next, we investigate how short sellers respond to environmental news, with a particular focus on their reactions to negative environmental news. Prior research indicates that short sellers are not only well-informed but also possess superior insights into firms (Engelberg et al., 2012). They actively trade on firm-specific information and are adept at identifying unfavorable information about firms (Deshmukh et al., 2015; Akbas et al., 2017). Additionally, they can distinguish between positive and negative signals, adjusting their trading strategies accordingly (Blau et al., 2013). We define negative environmental news as the aggregate of media reports highlighting a company's practices that violate principled environmental standards. Our analysis shows that short sellers increase their positions during the month of a negative news release and maintain these positions in subsequent months. This behavior aligns with the findings of Hong et al. (2022), which suggest that short selling facilitates the incorporation of adverse news into stock prices.[1]

Having established that short sellers directly incorporate firm sustainability in their short selling strategies, we next investigate whether they derive benefits from shorting environmentally underperforming firms and explore the financial motivations for such activities. Previous research highlights that financial motivations play an important role in investors' push for greater environmental commitments (Dyck et al., 2019). Short selling stocks with high ESG ratings involves greater syn-

[1]Hong et al. (2022) examines the relationship between short selling and corporate social responsibility (CSR). They find that CSR can have an insurance effect on a firm's reputation by generating moral capital or goodwill that protects firms during negative events.

chronization risk, short squeeze risk, and reputational risks (Cao et al., 2024), which could heighten the costs for short sellers and diminish the likelihood of achieving profitable outcomes from such strategies.[2] We explore short sellers' financial motivations by analyzing the returns of stocks being shorted. We differentiate between "active" and "passive" short sales since arbitragers have a variety of purposes for short selling. Some investors engage in short selling to capitalize on perceived overpricing or corporate misconduct, while others use it as part of broader strategies for hedging or providing liquidity. Following the methodology of Jiao et al. (2016), we define an "active short sale" as characterized by a rise in short interest coupled with a decline in hedge fund ownership, reflecting speculative actions based on negative perceptions. Conversely, a "passive short sale" is measured by simultaneous increases in short interest and hedge fund ownership, indicating hedge funds employing mixed long and short strategies primarily for hedging purposes.

We then compare the returns from brown and green firms in the year they are subjected to either active or passive short selling.[3] We find that brown firms experience significantly lower returns when subjected to active short selling, whereas no such effect is observed for passive short selling. 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 also 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 actively shorting brown stocks tend to outperform other hedge funds (such as those focused on investing in green stocks or shorting greenwashing stocks). We find that active short selling of brown and not green firms is associated with superior hedge fund performance. Contrary to Pástor et al. (2022), we do not find overpricing (and therefore lower expected return) of green stocks; instead, actively short selling brown firms allows hedge funds to accumulate profits. Our findings lend support to the hypothesis that financial gains motivate arbitrageurs who actively short sell environmentally detrimental firms.

[2]Cao et al. (2024) identify several heightened risks associated with shorting stocks that have high environmental, social, and governance (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, 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 tertiles according to their carbon emissions. Brown firms are defined as the firms in the lowest tertile while green firms are defined as the firms in the highest tertile.

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 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 changes in carbon emissions, we compare changes in emissions from brown and green firms over one, two, and three years, with a particular focus on the changes in emissions of brown firms that undergo active short selling. We find that brown firms reduce their carbon emissions significantly more than green firms 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, brown firms continue to emit more following a passive short strategy. These results underline the asymmetric impact of active versus passive shorting on the emissions of brown firms.

[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 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/article/2bstm0rrcqbkfd4hxyww0/portfolio/when-it-comes-to-achieving-esg-goals-is-short-selling-more-effective-than-shareholder-activism.

One potential concern with interpreting our results is that the reduction in emissions may be driven by hedge funds divesting their "long" positions in brown firms rather than actively shorting those firms. This is plausible because active short selling encompasses both a reduction in long positions and an increase in short positions. However, if the results were solely driven by hedge fund divestments from the long side, we would expect to observe a similar reduction in emissions for brown firms across divestment activities, independent of short selling. To disentangle between these two channels, we investigate the relationship between changes in hedge fund ownership and changes in emissions over several years, controlling for the level of short interest. We find no significant effect on the coefficient of hedge fund ownership for brown and green firms. Additionally, the coefficient on short interest is also insignificant. These findings suggest that hedge fund divestment from brown firms alone does not correlate with reductions in carbon emissions in subsequent years. This supports the notion that an active short-selling strategy, combining both an increase in shorts and a decrease in long positions simultaneously, is what leads to a decrease in carbon emissions from brown firms.

Finally, we explore potential mechanisms firms can use to reduce carbon emissions. Firms can reduce carbon emissions through two main channels: operational downsizing and improvements in production processes. The intuition behind the first 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 or industry to reduce operations, potentially leading to its decline and the eventual elimination of its emissions. Improving the production process is an alternative pathway for brown firms to reduce emissions. Firms can enhance their production line either through green innovation or through investment in production technology. Green innovation can drive long-term carbon emission reductions; however, a more immediate strategy is to invest in production technology and upgrade to greener, more sustainable production processes.

To test whether brown firms downsize operations in response to being actively shorted, we explore the impact of active short selling on firm operations by looking at changes in sales and earnings in the following years. If brown firms are downsizing in response to financial pressures from short selling, we would expect to see a decrease in operational activities such as sales and earnings before interest and taxes (EBIT). This 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. Contrary to this hypothesis, we observe a slight increase in sales and no significant change in earnings for brown firms. Therefore, our analysis does not support the hypothesis that operational downsizing drives reductions in carbon emissions.

We then examine the alternative channel that firms shift to cleaner production methods and reduce their emissions. We begin by examining whether brown firms enhance their green innovation and issuing more green patents following active short selling.[7] Cohen et al. (2020) highlight that brown energy firms often produce the most highly cited green patents. Nonetheless, the actual impact of these patents on reducing carbon emissions remains a debated issue in existing literature. Bolton and Kacperczyk (2023) find little evidence that green innovation leads to significant carbon emission reductions in the innovating firms or others within the same sector. In contrast, Hege et al. (2023) find that climate innovations aid customer firms in lowering their carbon emissions, with the primary impact driven by innovations incorporated into the supplier's products. 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 in green firms and we do not find evidence in 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.

We next test the second approach for improvement in the production process by comparing the capital expenditures (CapEx) of brown and green firms following active and passive short selling. Since shifting to greener production often involves brown firms adopting new technologies and equipment different from their existing investments, it typically requires significant capital investment. Companies making these transitions might see their capital expenditures rise as they invest in new technologies and infrastructure. Therefore, we hypothesize that brown firms experiencing active short selling are associated with an increase in capital expenditures. Consistent with this

[7]He et al. (2023) document that short sellers help with improving firm technology innovation through discipline mechanism.

prediction, we find that capital expenditures for brown firms increase following active short selling but not after passive short selling. This finding supports our hypothesis that active short selling is associated with higher capital expenditures in brown firms. Overall, our findings indicate that downsizing operations is not a driver of carbon reduction. Instead, brown firms reduce emissions by enhancing their production processes. Specifically, they boost green innovation by issuing more green patents and increase capital expenditures to invest in production technology.

This paper contributes to several strands of the literature. First, we contribute to the current literature on sustainable investing. There is a growing literature exploring how institutional investors drive firm environmental performance, but the majority of existing research has focused on the long side. 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 results in lower carbon emissions and toxic chemical emissions.[8] Empirical evidence also shows that divestment from brown firms is associated with increased price pressure and thus contribute 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, 2021; Edmans and Kacperczyk, 2022; 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 short sellers' behavior is associated with carbon risk 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 policy makers 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).[9] For example, He et al. (2023) posit

[8] 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.

[9] 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.

that short sellers play a disciplining role to help to 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 providing new insights into a surprising and unintended real effect of short sellers; primarily, their behavior is associated with the improvement of corporate green innovation and reduction of carbon emission.

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).[10] 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 purposes. 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 "exit" as a potential governance strategy (Broccardo et al., 2022; Zink, 2024). We reveal an "invisible hand" of short selling driven

[10]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.

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.

# 2. Data and methodology

## 2.1. Short selling data

A commonly used proxy for short selling activity is the short interest data. We obtained short interest from the Compustat Short Interest file, which reports fortnightly short interest for stocks listed on the NYSE, AMEX, and NASDAQ.[11] For each stock in our sample, we compute its monthly short interest ($SI$) as the ratio between the number of shares sold short at the end of the month and the total number of shares outstanding. The use of the short interest in the middle of a month leads to very similar results. Since some firms and industries tend to have large short interest in general, we control for a given firm's normal level of short interest and define abnormal short interest ($ASI$) as short interest in the current month minus the average short interest in the past 12 months. Because our ESG and carbon emission data are available at annual frequency, we take the average of 12 monthly $SI$ and $ASI$ to calculate yearly $SI$ and $ASI$.

Short selling 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 sale" 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 sale" occurs when both short interest and hedge fund ownership increase simultaneously, reflective of hedge funds employing long and short positions to construct arbitrage portfolios, primarily for hedging. To integrate information from both the long and short sides of trading, we compile hedge fund quarterly holdings data from Form 13F filings to calculate hedge fund ownership for each stock, denoted as $HFOwn_{i,t}$ for stock $i$ in year

[11] 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).

$t$. We introduce a binary variable, $Active_Short_{i,t}$, assigned a value of one when there is a decrease in hedge fund ownership from year $t-1$ to year $t$ coupled with an increase in short interest during the same period, and zero otherwise; thus, $Active_Short_{i,t} = I\{\Delta HFOwn_{i,t} < 0\} \times I\{\Delta SI_{i,t} > 0\}$. We identify passive short through a concurrent rise in both hedge fund ownership and short interest, labeled $Passive_Short_{i,t} = I\{\Delta HFOwn_{i,t} > 0\} \times I\{\Delta SI_{i,t} > 0\}$.

## 2.2. Sustainability data

We assess firm ESG performance using data from Refinitiv, previously known as Thomson Reuters ASSET4. Refinitiv's ESG ratings evaluate a company's ESG performance, commitment, and effectiveness across ten key areas: environmental resource management, emissions control, innovation in environmental products, workforce relations, human rights practices, community engagement, product responsibility, management quality, shareholder relations, and CSR strategy implementation. These ratings compile over 400 ESG metrics for each company, sourced from a variety of materials including annual reports, corporate websites, NGO websites, stock exchange disclosures, CSR reports, and reputable news outlets. ESG ratings are reported as percentile scores between 0 and 100, where a higher score indicates a firm has a better ESG rating. It is important to note that the Refinitiv ESG rating is an industry-adjusted score. For these calculations, Refinitiv compares firms' ratings to those of similar companies within the Refinitiv Business Classification industry. For the purpose of this analysis, we are specifically focusing on the environmental (E) pillar.

We complement the ESG data with Refinitiv carbon emission database that measures both Scope 1 and Scope 2 $CO_2$ emissions of firms. Scope 1 emissions are those that come directly from sources owned or controlled by the company, such as emissions from combustion, boilers, furnaces, vehicles, etc. Scope 2 emissions, on the other hand, refer to indirect emissions associated with the purchase of electricity, steam, heat, or cooling.

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.[12] We restrict our sample to patents that are filed or

[12]Green patents refer to inventions and innovations associated with environmental management, water conservation,

issued to public firms only.

### 2.3. Other data and sample summary

We obtain firm's return, number of shares outstanding, book value per share, total debt, earnings before interest and taxes, common equity, capital expenditure, sale, and total assets from Compustat. Our final sample comprises 18,967 firm-years with 3,509 unique firms for the fiscal years 2012 to 2020.

Panel A of Table 1 displays summary statistics for key variables in our study. On average, short interest stands at 4.5%, with a standard deviation of 5.4%, indicating significant cross-sectional variability in short interest across different stocks. The abnormal short interest is 0.1% after adjusting for firm's normal level of short interest. The data show an average of 5.7 green patents issued per firm annually, while the total number of patents issued per firm is 69.7 per year. In general, 17.7% of the firm-year observations are actively shorted, while 41.2% are passively shorted. Panel B reports carbon emissions by industry, the average figure in our dataset is 5.7 million tons in Scope 1 and Scope 2 emissions, with the Utilities sector leading in emissions at 24.5 million tons. This is closely followed by the oil, gas, coal extraction, and products and manufacturing sectors. We report the Pearson correlations among short-selling related variables, environmental score, hedge fund ownership, and other variables in Panel C. The correlation between the environmental score (ESG score) and short interest is negative, at -0.188 (-0.177), suggesting that short sellers often target firms with poorer environmental performance. Additionally, we note a negative, albeit weak, correlation between short interest and hedge fund ownership.

## 3. Empirical Results

### 3.1. Is short seller behavior related to sustainability?

#### *3.1.1. Short interest and environmental score*

This section examines the relationship between firm-level environmental performance and short selling activities. We start our analysis by sorting stocks into tertiles each year according to their

biodiversity protection, climate change mitigation, and greenhouse gas management.

environmental scores (E scores). We then compute the average short interests for firms within each tertile and depict the time series trends in Figure 1. Our findings reveal that firms with the lowest environmental scores (tertile 1) consistently exhibit the highest short interest throughout our sample period. Notably, there was an acceleration in short selling activity following the 2015 Paris Agreement, with a peak observed in 2020. Conversely, firms with the highest environmental scores (tertile 3) demonstrate the lowest short interest. This pattern suggests an emerging trend where short sellers are increasingly targeting firms with poorer environmental performance, indicating a growing consideration of environmental criteria in their investment decisions.

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

$$Short\ Interest_{i,t} = \alpha + \beta_1 E_Score_{i,t} + \beta_2 Control_{i,t} + \epsilon_{i,t} \tag{1}$$

where $Short\ Interest_{i,t}$ is the average short interest for firm $i$ in year $t$. We also use the $Abnormal\ Short\ Interest_{i,t}$ as the dependent variable to control for a given firm's normal level of short interest. $E_Score_{i,t}$ is the Environmental scores (E in ESG score) for firm $i$ in year $t$. $Control_{i,t}$ are control variables including size, book-to-market ratio, return, and return on assets. We control for industry and year fixed effects in the regression.

The results are tabulated in Table 2. In Columns (1) and (3), the coefficients on $E_Score_{i,t}$ are statistically negative, which suggests that lower environmental performance is associated with higher short selling activities. After controlling for a set of firm characteristics, we find that a one-point increase in environmental scores is associated with a 0.031% decrease in short interests (SI) and a 0.64% decrease in abnormal short interests (ASI). 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. The control variables also yield interesting insights. Higher short interest is associated with firms that are smaller in size, have a lower book-to-market ratio, and exhibit lower return on assets (ROA). In this paper, we specifically focus on environmental scores rather than the broader ESG framework or individual Social (S) and Governance (G) scores because of the increasing global emphasis on climate-related issues. There is a growing consensus among investors and policymakers that

environmental concerns, particularly carbon emissions, are the most urgent aspects of sustainable investing. However, we also examine how short sellers respond to a firm's overall ESG score and results are consistent: firms with lower ESG scores attract more short interest.[13]

### *3.1.2. Short interest and negative environmental news*

Over the past decade, there has been a marked increase in environmental awareness, significantly influencing various financial industry stakeholders, including short sellers. Prior research has shown that short sellers are not only well-informed but also possess superior information about firms (Engelberg et al., 2012). They trade on firm-specific information and are able to discover unfavorable information about firms (Deshmukh et al., 2015; Akbas et al., 2017). Moreover, they can differentiate between positive and negative signals and adjust their trading strategies accordingly (Blau et al., 2013). In this section, we explore how short sellers respond to environmental news, focusing particularly on their reactions to negative environmental news.

We collect monthly data on firm-level negative ESG news from Refinitiv. This data consists of an aggregate of media reports about a company's practices in violation of principled environmental, social, and governance behaviors. An increased count of negative ESG news articles suggests that the firm is linked to more environmental, social, and governance violations during that month. We then run the following regression:

$$Short\ Interest_{i,t+n} = \alpha + \beta_1 ESG\ Negative\ News_{i,t} + \beta_2 Control_{i,t} + \epsilon_{i,t} \tag{2}$$

where $Short\ Interest_{i,t+n}$ is either the monthly short interest ($SI$) or abnormal short interest ($ASI$) in the month $t+n$ ($n = 0, 1, 3$). $Control_{i,t}$ are control variables including size, book-to-market ratio, return, and return on assets. To differentiate the impact of ESG-specific negative news from other general news on short-selling behavior, we include a control variable for other news coverage that measures total news coverage excluding ESG negative news.[14] We control for industry and

[13] Our findings align with those of Cao et al. (2024), who observed that higher ESG performance correlates with reduced short selling demand among overpriced stocks. We extend their results to a broader, unconditional scenario, demonstrating that this relationship also holds for stocks that are not considered overpriced.

[14] The Refinitiv data provides total news coverage (total buzz words) for each firm. To isolate ESG negative news and measure other news coverage, we regress total news coverage on ESG negative news and use the resulting residuals as a proxy for other news coverage. This ensures that other news coverage is orthogonal to and independent of ESG negative news.

year fixed effects in the regression.

We report the results in Table 3. The coefficients are significantly positive in all settings, indicating a positive relationship between the negative environmental news and short interest. This finding is consistent with Diamond and Verrecchia (1987) that short selling can facilitate the incorporation of bad news into stock prices. We also find a positive association between other news coverage and short interest. Although we cannot distinguish whether this coverage is positive or negative, the positive correlation may indicate that increased other general media attention often signals potential concerns or risks related to firm operations, financial performance, or market stability. Notably, the analysis reveals that short sellers increase their positions within the month of the negative news release ($n = 0$) and continue to respond in subsequent months. Due to the lack of precise timing of the news release and the lack of the daily frequency of short interest data, it remains inconclusive whether short sellers are capable of predicting and front running the negative news. Collectively, these findings imply that arbitrageurs escalate their short selling activities both in reaction to and subsequent to negative environmental news.

### 3.2. Short seller's financial return

Having established that short sellers are influenced by firms' environmental performance, we next investigate whether they derive benefits from shorting environmentally underperforming firms and explore the financial motivations for such activities. Previous research highlights that shorting stocks with high environmental, social, and governance (ESG) ratings involves greater synchronization, short squeeze risks and reputational risks (Cao et al., 2024), which could heighten the costs for short sellers and diminish the likelihood of achieving profitable outcomes from such strategies. This raises the question of whether short selling environmentally detrimental firms can yield profitable returns.

To investigate the effects of short selling on firms with different environmental impacts, we analyze the stock returns of firms classified as "brown" and "green" after being shorted. We divide firms into tertiles based on their level of emissions each year, with tertile 1 representing firms with the lowest emissions and tertile 3 representing those with the highest emissions. In subsequent analysis, we refer to firms in tertile 1 as "green" and firms in tertile 3 as "brown". Additionally, we differentiate between "active" and "passive" short sales, following the methodology of Jiao et al.

(2016). An "active short sale" is characterized by a rise in short interest coupled with a decline in hedge fund ownership, reflecting speculative actions based on negative perceptions. Conversely, a "passive short sale" is marked by simultaneous increases in short interest and hedge fund ownership, indicating hedge funds employing mixed long and short strategies primarily for hedging purposes. 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. Additionally, we adjust for industry and year fixed effects to control for variations across industries and the general time trend of returns throughout our sample period.

The first two columns in Table 4 tabulate results for active shorts and the last two columns tabulate results for passive shorts. In Table 4, columns 1 and 2, we observe that brown firms exhibit significantly lower returns when they are actively shorted. Conversely, the coefficients for green firms are insignificant, suggesting that actively shorting green firms is not associated with substantial price decreases, likely due to higher synchronization risks and the possibility of short squeezes (Cao et al., 2024). Columns 3 and 4 present close-to-zero and statistically insignificant coefficients for both brown and green firms, indicating that passive short selling has a negligible impact on the financial returns of these firms. This finding is consistent with the interpretation that passive short selling is driven primarily by hedging objectives, rather than financial gains. Firms that are larger, have a higher book-to-market ratio, and higher leverage tend to exhibit lower returns. Negative ESG news is associated with lower returns as well. This result aligns with Derrien et al. (2022) that negative ESG news have negative consequences on firms' future profit and are thus are reflected in the stock returns. Additionally, other news coverage is associated with lower returns, though this effect is only weakly significant because it encompasses both positive and negative news. Overall, our analysis reveals that short selling environmentally detrimental firms is associated with profitable returns, particularly when the short selling is active rather than passive. Contrary to Pástor et al. (2022), we do not find overpricing (and therefore lower expected return) of green stocks; instead, actively short selling brown firms allows hedge funds to achieve superior performance.

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. 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. 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 risk are identified as primarily shorting brown stocks to maintain their high green beta classification. This method allows us to isolate hedge funds that are green 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 Table A1 in the Appendix, 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). This significant positive association indicates that hedge 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: does short selling brown firms is 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, includ-

ing 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 investigate the relationship between short selling activities and subsequent changes in carbon emissions over one, two, and three years. We compare changes in emissions from brown and green firms, where these classifications are based on emissions in the previous year. Additionally, we distinguish between "active" and "passive" short sales, with a particular focus on the changes in emissions of brown firms that undergo active short selling. In the regression, we control for firm-specific characteristics and the previous year's change in emissions in order to capture any trend effect. 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 there is a decrease in institutional ownership and zero otherwise.[15] We account for differences across industries and temporal trends in emissions by incorporating fixed effects for both year and industry throughout our sample period.

Table 5 reports the regression results. We find that brown firms significantly reduce their carbon emissions more than green firms when subjected to active shorting. The significant negative coefficients reported in columns 1 to 3 for brown firms highlight this trend, with an increasing magnitude of coefficients 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. Specifically, the coefficient of -0.408 in column 1 indicates that brown firms are associated with a reduction in emissions exceeding 0.4

[15]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.

million tons one year after being actively shorted. Conversely, columns 4 to 6 reveal no significant reduction in carbon emissions for brown firms following a passive short. The coefficients for brown firms remain positive (with a 10% significance in three years), suggesting that brown firms continue to emit more following a passive short strategy. These results underline the asymmetric impact of active versus passive shorting on the emissions of brown firms. The control variables are of interest, too. Unsurprisingly, larger firms tend to reduce more carbon emissions. Past changes in carbon emissions exhibit positive momentum and predict future changes, though this effect is only significant at a one-year horizon. Interestingly, institutional divestment shows almost no impact on carbon reduction, with a negative coefficient but weak significance. This supports findings from prior studies (Berk and Van Binsbergen, 2021; Edmans and Kacperczyk, 2022; Atta-Darkua et al., 2023) that divestment strategies have little effect on firms' environmental performance.

One potential concern with the interpretation of our results is that they may be driven by hedge funds divesting from the "long" side of those brown firms rather than by shorting the brown firms. This is possible because active short selling includes both decrease in the ownership from the long side and increase of short selling from the short side. If the results are driven by hedge funds divestment only, we would also expect to see the similar effect of emission reduction on brown firms.

To disentangle between these two channels, we investigate the relationship between changes in hedge fund ownership and changes in emissions over several years, controlling for the level of short interest. Table A2 in the Appendix presents regressions where the dependent variable is the change in emissions over one, two, and three years. The variable of interest is the interaction term between the percentage change in hedge fund ownership and a dummy variable representing brown and green firms. Our analysis reveals no significant effects on the coefficient of hedge fund ownership for brown and green firms. Additionally, the coefficient on short interest is also insignificant. These findings suggest that divestment from brown firms alone does not correlate with reductions in carbon emissions in subsequent years. This supports the notion that an active short-selling strategy, combining both an increase in shorts and a decrease in long positions simultaneously, is associated with a decrease in carbon emissions from brown firms.

## 3.4. 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: downsizing of operations and improvement in the production process.

### *3.4.1. Downsizing in operations*

We first analyze whether brown firms downsize operations in response to being actively shorted, and subsequently decrease their carbon emissions. 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 or industry to reduce operations, potentially leading to its decline and the eventual elimination of its emissions. If brown firms are downsizing in response to financial pressures from short selling, we would expect to see a decrease in operational activities such as sales volume and earnings before interest and taxes (EBIT). This 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.

To test this channel, we explore the impact of active short selling on firm operations by capturing the changes in sales and earnings in the following years. We first analyze the log of sales for these firms following active and passive short selling. In our analysis, as presented in Table A3, columns 1-3 show a positive and significant coefficient for active short selling on brown firms. Contrary to expectations that active short selling would lead to a reduction in operations and consequently a drop in sales, brown firms actually exhibit an increase in sales following active short selling. This suggests that, in the short term, these firms may not be downsizing their dirty operations as anticipated. The effects of passive short selling, shown in columns 4-6, also indicate a positive impact on sales, although these results are not statistically significant.

Additionally, we consider whether a reduction in operations might lead to decreased earnings. We thus examine earnings before interest and taxes (EBIT) in Table A4. We notice the positive coefficients for active short selling on brown firms but all coefficients are insignificant. This obser-

vation corroborates our sales findings, indicating that there is no significant decrease in earnings for brown firms post-active short selling. Overall, our analysis does not support the hypothesis that operational downsizing drives reductions in carbon emissions. Instead, we observe a slight increase in sales and no significant change in earnings for brown firms.

### *3.4.2. Improvement in production process*

To reduce carbon emissions, brown firms can opt for alternatives to downsizing operations: they can shift to cleaner production methods or adopt green energy. This section examines whether improving the production process is a viable pathway for brown firms to reduce emissions. Specifically, we investigate two approaches to enhancing the production line: through green innovation and through investment in production technology.[16] We aim to determine if these methods can effectively lower emissions while maintaining or enhancing operational efficiency in traditionally high-pollution firms.

We begin by examining whether brown firms can reduce carbon emissions by enhancing their green innovation and issuing more green patents following active short selling. Cohen et al. (2020) highlight that brown energy firms often produce the most highly cited green patents. Nonetheless, the actual impact of these patents on reducing carbon emissions remains a debated issue in existing literature. Bolton et al. (2022) find little evidence that green innovation leads to significant carbon emission reductions in the innovating firms or others within the same sector. In contrast, Hege et al. (2023) suggest that reductions in emissions may occur across supply chain networks. They find that climate innovations aid customer firms in lowering their carbon emissions, with the primary impact driven by innovations incorporated into the supplier's products. We examine whether brown firms boost their green innovations following active short selling. The results are reported in Table 6. In column (1)-(3), there is 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 in green firms. In columns (4)-(6), although a similar positive relationship is noted with passive short selling for brown firms, it lacks statistical significance. These results align with the findings by Choi et al. (2024), who find that carbon-intensive public firms are likely to decrease their carbon

[16]Environmental regulations, taxes, and subsidies can also motivate firms to shift their focus from dirty to clean innovation. This redirection of technical change is supported by studies such as Acemoglu (2002), Acemoglu et al. (2012), and Aghion et al. (2016).

emissions and enhance their green patenting activities in response to market pressures.[17]

Green innovation might contribute to long-term carbon emission reduction, but a more immediate approach is transitioning to greener production processes. Examples include the use of semiconductors, which boost the efficiency of end products; copper, which is vital for producing batteries and renewable energy systems; and electricity transmission lines, which are essential for the successful expansion of renewable energy. Since shifting to greener production often involves brown firms adopting new technologies and equipment different from their existing investments, it typically requires significant capital investment. Companies making these transitions might see their capital expenditures rise as they invest in new technologies and infrastructure. Therefore, we hypothesize that brown firms experiencing active short selling are associated with increased capital expenditures.[18]

To test this hypothesis, we compare the capital expenditures (CapEx) of brown and green firms following active and passive short selling. The results presented in Table 7 indicate that capital expenditures for brown firms increase after active short selling but not after passive short selling. This supports our hypothesis that brown firms experiencing active short selling are associated with increased capital expenditures. These firms are likely investing in cleaner production methods to reduce carbon emissions. Because transitioning to cleaner production involves a departure from existing methods, it requires significant capital investment and thus is associated with increased capital expenditures in the following years.

To summarize, our findings indicate that brown firms reduce emissions by enhancing their production processes rather than by downsizing operations. Specifically, they boost green innovation by issuing more green patents and increasing capital expenditures to invest in production technology. We observe these changes following active short selling but not after passive short selling.

[17]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.

[18]Capital expenditures are funds used by a company to acquire, upgrade, and maintain physical assets such as property, plants, buildings, technology, or equipment.

# 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, addressing three key questions: (1) Do short sellers consider a firm's environmental performance when making decisions? (2) What drives the short selling of environmentally unfriendly "brown firms"? (3) Does short selling encourage firms to reduce carbon emissions? Our research shows that short sellers do consider firms' sustainability. We observe a negative correlation between short interest and a firm's environmental performance, with this relationship intensifying after a firm experiences a negative ESG news shock. Furthermore, 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 hypothesize that active short selling of environmentally unfriendly ("brown") firms is primarily driven by financial gains, and our findings support this hypothesis at both the firm and short seller levels. At the firm level, brown firms experience lower returns when actively shorted. At the short seller level, using hedge funds as a proxy for active short sellers, we find that funds shorting brown firms generate higher returns and alphas. These results suggest that the primary motivation for active short sellers targeting brown firms is to capitalize on trading profits. Lastly, our findings indicate that active short selling of brown firms is linked to reduced carbon emissions, while passive short sellers have minimal impact. We explore two potential mechanisms: operational downsizing and improvements in production processes. The evidence strongly supports the latter, showing that actively shorted brown firms increase green patents and capital expenditures on cleaner production methods. Importantly, there is no significant evidence of operational downsizing in these firms following active short selling. 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.

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**Figure 1. Average Short Interest by Firm Environmental Metrics**

This figure plots the average annual short interest over time sorted by firm environmental metrics. Each year we sort firms into tertiles according to their environmental scores (E scores). Firms in the lowest tertile are defined as low environmental score firms. Firms in the highest tertile are defined as high environmental score firms. Annual short interest is the average of monthly short interest. Monthly 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. Our sample ranges from January 2012 to December 2020.

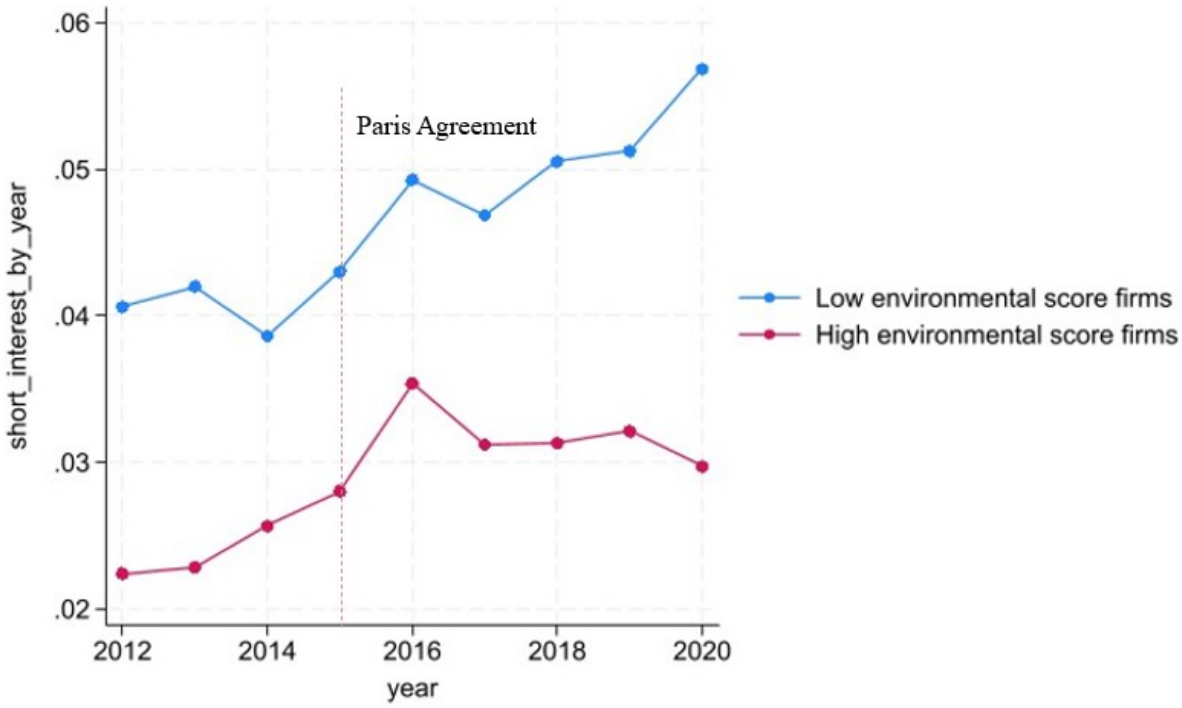


**Table 1: Summary Statistics**

This table presents descriptive statistics. Panel A 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. Abnormal short interest is equal to short interest in the current month minus the average short interest in the past 12 months. ESG score is annual environmental, social, and governance performance score from Refinitiv. Environmental score is environmental pillar of ESG score from Refinitiv. Carbon emission is the total emissions measured as million tons of $CO_2$ equivalents from Refinitiv. Number of green patents is the number of green patents a firm files per year. Total number of patents is the number of all patents a firm files per year. Log asset is the logarithm of firm's total assets. 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. Capex is firm's annual capital expenditure. Leverage is the ratio of company's average total assets to its average shareholders' equity. 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. Panel B presents the average carbon emissions (in million tons) of firms by industry. The industry is classified according to Fama-French 12 industries code based on firms' four-digit SIC code. Panel C reports the Pearson correlations among different variables.

Panel A: Firm Characteristics

| Variables | N | Mean | Min | Max | Median | SD |
|---|---|---|---|---|---|---|
| Short interest | 18,967 | 0.045 | 0 | 1.029 | 0.026 | 0.054 |
| Abnormal short interest | 18,967 | 0.001 | -1 | 14.877 | -0.341 | 1.100 |
| ESG score | 18,967 | 40.848 | 0.316 | 94.242 | 36.747 | 20.238 |
| Environmental score | 18,956 | 25.258 | 0 | 99.122 | 11.642 | 28.923 |
| Carbon emission (million) | 6,035 | 5.735 | 0 | 348.224 | 0.416 | 19.358 |
| # Green patents | 7,879 | 5.700 | 0 | 799 | 0 | 37.622 |
| Total # of patents | 7,879 | 69.713 | 0 | 9101 | 0 | 366.409 |
| Log asset | 18,577 | 8.190 | 5.916 | 15.035 | 8.150 | 2.016 |
| Book to market | 18,502 | 0.521 | -16.990 | 264.074 | 0.401 | 2.040 |
| ROA | 18,576 | -0.011 | -31.350 | 2.073 | 0.026 | 0.343 |
| Capex (thousand) | 15,037 | 0.668 | 0 | 13.330 | 0.0758 | 1.877 |
| Leverage | 16,212 | 0.280 | 0 | 3.892 | 0.247 | 0.239 |
| Active short | 18,967 | 0.177 | 0 | 1 | 0 | 0.382 |
| Passive short | 18,967 | 0.412 | 0 | 1 | 0 | 0.492 |

Panel B: Carbon Emission by Industry

| Fama-French industry | Emission (million) |
|---|---|
| Utilities | 24.50 |
| Oil, Gas, and Coal Extraction and Products | 18.60 |
| Manufacturing | 7.83 |
| Chemicals and Allied Products | 6.23 |
| Other – Mines, Constr, BldMt, Trans, Hotels, Bus Serv, Entertainment | 5.25 |
| Wholesale, Retail, and Some Services | 4.98 |
| Telephone and Television Transmission | 2.89 |
| Consumer Non-Durables | 1.48 |
| Consumer Durables | 1.41 |
| Business Equipment | 0.58 |
| Healthcare, Medical Equipment, and Drugs | 0.51 |
| Finance | 0.23 |
| Average | 5.74 |

Panel C: Correlation Matrix

| | Short interest | Abnormal short interest | Hedge fund owner-ship | ESG score | E score | Carbon emission | # Green patents | Log asset | Return | Book to market | ROA | Capex |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Short interest | 1 | | | | | | | | | | | |
| Abnormal short interest | 0.857 | 1 | | | | | | | | | | |
| Hedge fund ownership | -0.116 | -0.094 | 1 | | | | | | | | | |
| ESG score | -0.177 | -0.164 | 0.356 | 1 | | | | | | | | |
| E score | -0.188 | -0.172 | 0.363 | 0.870 | 1 | | | | | | | |
| Carbon emission | -0.081 | -0.053 | 0.0271 | 0.068 | 0.081 | 1 | | | | | | |
| # Green patents | -0.043 | -0.048 | 0.257 | 0.166 | 0.173 | 0.004 | 1 | | | | | |
| Log asset | -0.222 | -0.118 | 0.432 | 0.591 | 0.576 | 0.200 | 0.209 | 1 | | | | |
| Return | -0.004 | -0.003 | -0.004 | -0.008 | -0.007 | -0.007 | -0.014 | -0.003 | 1 | | | |
| Book to market | -0.036 | -0.018 | 0.022 | 0.001 | 0.004 | 0.145 | -0.017 | 0.053 | 0.001 | 1 | | |
| ROA | -0.146 | -0.176 | 0.055 | 0.094 | 0.067 | -0.037 | 0.017 | 0.069 | 0.081 | -0.210 | 1 | |
| Capex | -0.146 | -0.127 | 0.302 | 0.305 | 0.331 | 0.376 | 0.335 | 0.451 | -0.004 | 0.028 | 0.015 | 1 |

**Table 2: Short Interest and Environmental Metrics**

This table investigates the relationship between short interest and firm environmental score. The dependent variable in column (1) and (2) is firm's annual short interest (SI) and that of column (3) and (4) is the annual abnormal short interest (ASI). SI is calculated as the ratio (in percentage) between the number of shares sold short at the end of the month and the total number of shares outstanding. ASI is defined as short interest in the current month minus the average short interest in the past 12 months (in percentage). We take the average of 12 monthly SI and ASI to calculate annual SI and ASI, respectively. The Environmental Score is a metric from Refinitiv that evaluates a company's performance in environmental sustainability. The ESG Score is a metric from Refinitiv that evaluates a company's overall performance in environmental, social, and governance practices. Book to market ratio is the ratio of company's book value to its market capitalization. Return is firm's annual return. Log asset is the logarithm of firm's total assets. ROA is the ratio of company's net income to its total assets. All regressions include industry 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.

| | Short interest | | Abnormal short interest | |
|---|---|---|---|---|
| VARIABLES | (1) | (2) | (3) | (4) |
| Environmental score | -0.031*** | | -0.640*** | |
| | (-8.30) | | (-8.28) | |
| ESG score | | -0.035*** | | -0.745*** |
| | | (-6.83) | | (-6.63) |
| Book to market ratio | -0.054** | -0.054** | -1.265** | -1.271** |
| | (-2.35) | (-2.34) | (-2.10) | (-2.09) |
| Return | -0.001 | -0.001* | -0.017 | -0.017 |
| | (-1.50) | (-1.65) | (-1.28) | (-1.39) |
| Log assets | -0.098* | -0.149*** | -2.721** | -3.723*** |
| | (-1.69) | (-2.53) | (-2.16) | (-2.86) |
| ROA | -1.656*** | -1.548*** | -26.286*** | -24.081** |
| | (-2.71) | (-2.60) | (-2.59) | (-2.45) |
| Year FE | YES | YES | YES | YES |
| Industry FE | YES | YES | YES | YES |
| Observations | 17,059 | 17,069 | 17,059 | 17,069 |
| R-squared | 0.1447 | 0.1412 | 0.0403 | 0.0366 |

**Table 3: ESG negative News and Short Interest**

This table investigates the relationship between short interest and ESG negative news. The dependent variable in columns (1) to (3) is the firm's monthly short interest (SI) measured at the current month, one month, and three months following ESG negative news coverage. The dependent variable in columns (4) to (6) is the firm's monthly abnormal short interest (ASI) measured at the current month, one month, and three months following ESG negative news coverage. ESG negative news is the aggregate of media reports about a company's practices in violation of principled environmental, social, and governance behaviors. Other news coverage is the total news coverage excluding ESG negative news. Return is firm's monthly return in the month of the negative news. Book to market ratio is the ratio of company's book value to its market capitalization. Log asset is the logarithm of firm's total assets. ROA is the ratio of company's net income to its total assets. All regressions include industry 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.

| | Short interest | | | Abnormal short interest | | |
|---|---|---|---|---|---|---|
| | $t=0$ | $t+1$ | $t+3$ | $t=0$ | $t+1$ | $t+3$ |
| VARIABLES | (1) | (2) | (3) | (4) | (5) | (6) |
| ESG negative news | 0.034*** | 0.033*** | 0.031*** | 0.006*** | 0.006*** | 0.006*** |
| | (9.82) | (9.56) | (9.14) | (9.66) | (9.36) | (8.91) |
| Other news coverage | 0.731*** | 0.719*** | 0.699*** | 0.136*** | 0.134*** | 0.130*** |
| | (11.45) | (11.21) | (10.82) | (11.18) | (10.92) | (10.52) |
| Return | -0.002 | -0.008*** | -0.009*** | -0.001 | -0.001*** | -0.001*** |
| | (-1.13) | (-4.78) | (-5.70) | (-0.73) | (-3.79) | (-4.87) |
| Book to market ratio | -0.543*** | -0.566*** | -0.579*** | -0.128*** | -0.134*** | -0.140*** |
| | (-2.73) | (-2.79) | (-2.79) | (-3.28) | (-3.42) | (-3.55) |
| Log assets | -0.382*** | -0.380*** | -0.375*** | -0.066*** | -0.066*** | -0.065*** |
| | (-6.36) | (-6.30) | (-6.17) | (-5.36) | (-5.30) | (-5.20) |
| ROA | -2.830*** | -2.838*** | -2.856*** | -0.552*** | -0.560*** | -0.567*** |
| | (-4.80) | (-4.73) | (-4.68) | (-5.36) | (-5.34) | (-5.32) |
| Year-month FE | YES | YES | YES | YES | YES | YES |
| Industry FE | YES | YES | YES | YES | YES | YES |
| Observations | 172,752 | 171,142 | 168,664 | 172,752 | 171,142 | 168,664 |
| R-squared | 0.139 | 0.139 | 0.138 | 0.070 | 0.068 | 0.065 |

**Table 4: Firm Return after Short Selling**

This table investigates the relationship between firm annual return and short selling activity. The dependent variable is firm's annual return in the year of the short selling. We regress the dependent variable on the interactions between measures of active short/passive short and indicators for whether the firm is brown or green. We divide firms into tertiles based on their level of emissions in each year. Brown firms are defined as the firms in the highest tertile. Green firms are defined as the firms in the lowest tertile. Active short is assigned a value of one when there is a decrease in hedge fund ownership from year $t-1$ to year $t$ coupled with an increase in short interest during the same period, and zero otherwise. Passive short is assigned a value of one when there is an increase in hedge fund ownership from year $t-1$ to year $t$ coupled with an increase in short interest during the same period, and zero otherwise. Book to market ratio is the ratio of company's book value to its market capitalization. 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. ESG negative news is the aggregate of media reports about a company's practices in violation of principled environmental, social, and governance behaviors. Other news coverage is the total news coverage excluding ESG negative news. All regressions include industry 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 | | | |
|---|---|---|---|---|
| VARIABLES | (1) | (2) | (3) | (4) |
| Brown active short | -0.072*** | -0.062*** | | |
| | (-4.31) | (-3.14) | | |
| Green active short | -0.007 | -0.027 | | |
| | (-0.36) | (-1.33) | | |
| Brown passive short (hedge) | | | -0.002 | 0.020 |
| | | | (-0.09) | (1.03) |
| Green passive short (hedge) | | | -0.015 | -0.027 |
| | | | (-0.87) | (-1.50) |
| ROA | | 0.154 | | 0.159 |
| | | (1.44) | | (1.48) |
| Log asset | | -0.008* | | -0.011*** |
| | | (-1.88) | | (-2.61) |
| Book to market ratio | | -0.165*** | | -0.166*** |
| | | (-7.22) | | (-7.22) |
| Leverage | | -0.108*** | | -0.113*** |
| | | (-3.08) | | (-3.21) |
| ESG negative news | | -0.045** | | -0.049** |
| | | (-2.18) | | (-2.36) |
| Other news coverage | | -0.205 | | -0.206* |
| | | (-1.64) | | (-1.72) |
| Year FE | YES | YES | YES | YES |
| Industry FE | YES | YES | YES | YES |
| Observations | 5,376 | 4,683 | 5,376 | 4,683 |
| R-squared | 0.176 | 0.229 | 0.173 | 0.227 |

## Table 5: Impact on Carbon Emission

This table shows the relationship between changes in firms' emissions and short selling activities. The dependent variable is the 1-year, 2-year and 3-year change in greenhouse gas emissions, measured in million tons of $CO_2$ equivalents emitted per year. We regress the dependent variable on the interactions between measures of active short/passive short and indicators for whether the firm is brown or green. We divide firms into tertiles based on their level of emissions in each year. Brown firms are defined as the firms in the highest tertile. Green firms are defined as the firms in the lowest tertile. Active short is assigned a value of one when there is a decrease in hedge fund ownership from year $t-1$ to year $t$ coupled with an increase in short interest during the same period, and zero otherwise. Passive short is assigned a value of one when there is an increase in hedge fund ownership from year $t-1$ to year $t$ coupled with an increase in short interest during the same period, and zero otherwise. Book to market ratio is the ratio of company's book value to its market capitalization. Return is firm's annual return. Log asset is the logarithm of firm's total assets. ROA is the ratio of company's net income to its total assets. Past $\Delta$ Emission is the change in firm emissions from the previous year. Institutional divestment is a dummy variable that equals one if there is a decrease in institutional ownership and zero otherwise. All regressions include industry 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 | $\Delta$ Emission | | | | | |
|---|---|---|---|---|---|---|
| | 1 year | 2-year | 3-year | 1 year | 2-year | 3-year |
| | (1) | (2) | (3) | (4) | (5) | (6) |
| Brown active short | -0.408** | -0.537* | -0.686* | | | |
| | (-2.24) | (-1.68) | (-1.90) | | | |
| Green active short | -0.024 | -0.005 | -0.100 | | | |
| | (-1.07) | (-0.09) | (-1.03) | | | |
| Brown passive short (hedge) | | | | 0.103 | 0.360 | 0.693** |
| | | | | (0.59) | (1.15) | (2.03) |
| Green passive short (hedge) | | | | -0.027 | -0.059 | -0.091 |
| | | | | (-1.01) | (-0.98) | (-1.06) |
| Book to market | 0.057 | 0.242 | 0.450 | 0.064 | 0.311 | 0.528* |
| | (0.64) | (1.18) | (1.57) | (0.72) | (1.55) | (1.89) |
| Return | -0.090 | -0.123 | -0.293 | -0.029 | 0.291* | 0.222 |
| | (-0.57) | (-0.42) | (-0.63) | (-0.66) | (1.86) | (0.92) |
| Log assets | -0.058*** | -0.117*** | -0.187*** | -0.075*** | -0.156*** | -0.243*** |
| | (-3.10) | (-2.86) | (-3.41) | (-4.29) | (-3.69) | (-3.69) |
| ROA | 0.257 | 0.242 | 0.438 | 0.270* | 0.295 | 0.560 |
| | (1.62) | (0.59) | (0.48) | (1.87) | (1.35) | (0.83) |
| Past $\Delta$ Emission | 0.123*** | 0.094 | 0.085 | 0.122*** | 0.033 | -0.054 |
| | (3.78) | (1.20) | (0.25) | (3.73) | (0.67) | (-0.83) |
| Institutional divestment | -0.129 | -0.245* | -0.143 | -0.131 | -0.257* | 0.177 |
| | (-1.56) | (-1.75) | (0.77) | (1.57) | (1.82) | (0.77) |
| Year FE | YES | YES | YES | YES | YES | YES |
| Industry FE | YES | YES | YES | YES | YES | YES |
| Observations | 3,634 | 2,900 | 2,304 | 3,634 | 2,893 | 2,292 |
| R-squared | 0.067 | 0.070 | 0.078 | 0.064 | 0.072 | 0.094 |

**Table 6: Impact on Green Innovation**

This table shows the relationship between green innovation and short selling activities. The dependent variable is the number of green patents issued in 1-year, 2-year and 3-year following the short sell. We regress the dependent variable on the interactions between measures of active short/passive short and indicators for whether the firm is brown or green. We divide firms into tertiles based on their level of emissions in each year. Brown firms are defined as the firms in the highest tertile. Green firms are defined as the firms in the lowest tertile. Active short is assigned a value of one when there is a decrease in hedge fund ownership from year $t-1$ to year $t$ coupled with an increase in short interest during the same period, and zero otherwise. Passive short is assigned a value of one when there is an increase in hedge fund ownership from year $t-1$ to year $t$ coupled with an increase in short interest during the same period, and zero otherwise. Book to market ratio is the ratio of company's book value to its market capitalization. Return is firm's annual return. Log asset is the logarithm of firm's total assets. ROA is the ratio of company's net income to its total assets. Past total # patents is the total patents issued in the previous year. Institutional divestment is a dummy variable that equals one if there is a decrease in institutional ownership and zero otherwise. All regressions include industry 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 | # Green patents | | | | | |
|---|---|---|---|---|---|---|
| | 1 year | 2-year | 3-year | 1 year | 2-year | 3-year |
| | (1) | (2) | (3) | (4) | (5) | (6) |
| Brown active short | 0.134** | 0.156*** | 0.135* | | | |
| | (2.54) | (2.62) | (1.95) | | | |
| Green active short | -0.030 | 0.027 | 0.056 | | | |
| | (-0.57) | (0.44) | (0.69) | | | |
| Brown passive short (hedge) | | | | 0.046 | 0.063 | 0.078 |
| | | | | (0.94) | (1.12) | (1.29) |
| Green passive short (hedge) | | | | -0.033 | 0.038 | 0.057 |
| | | | | (-0.69) | (0.65) | (0.83) |
| Book to market | -0.051 | -0.094 | -0.218* | -0.051 | -0.096 | -0.193* |
| | (-1.00) | (-1.29) | (-1.92) | (-1.00) | (-1.31) | (-1.79) |
| Return | -0.004 | -0.014 | -0.020* | -0.008 | -0.018* | -0.020* |
| | (-0.37) | (-1.39) | (-1.75) | (-0.70) | (-1.82) | (-1.67) |
| Log assets | 0.137*** | 0.153*** | 0.206*** | 0.140*** | 0.158*** | 0.171*** |
| | (4.73) | (4.57) | (4.72) | (4.83) | (4.74) | (4.66) |
| ROA | -0.156 | 0.024 | -0.140 | -0.145 | 0.041 | -0.136 |
| | (-0.46) | (0.06) | (-0.33) | (-0.33) | (0.08) | (-0.35) |
| Past total # patents | 0.404*** | 0.405*** | 0.411*** | 0.405*** | 0.405*** | 0.394*** |
| | (19.85) | (17.94) | (15.29) | (17.90) | (16.07) | (16.07) |
| Institutional divestment | -0.033 | -0.040 | -0.031 | -0.039 | -0.039 | -0.051 |
| | (0.94) | (0.94) | (0.92) | (0.94) | (0.95) | (1.05) |
| Year FE | YES | YES | YES | YES | YES | YES |
| Industry FE | YES | YES | YES | YES | YES | YES |
| Observations | 3,146 | 2,375 | 1,896 | 3,146 | 2,375 | 1,896 |
| R-squared | 0.756 | 0.757 | 0.743 | 0.754 | 0.756 | 0.750 |

## Table 7: Impact on Capital Expenditure

This table shows the relationship between capital expenditure and short selling activities. The dependent variable is firm's capital expenditure in 1-year, 2-year and 3-year following the short sell. We regress the dependent variable on the interactions between measures of active short/passive short and indicators for whether the firm is brown or green. We divide firms into tertiles based on their level of emissions in each year. Brown firms are defined as the firms in the highest tertile. Green firms are defined as the firms in the lowest tertile. Active short is assigned a value of one when there is a decrease in hedge fund ownership from year $t-1$ to year $t$ coupled with an increase in short interest during the same period, and zero otherwise. Passive short is assigned a value of one when there is an increase in hedge fund ownership from year $t-1$ to year $t$ coupled with an increase in short interest during the same period, and zero otherwise. Book to market ratio is the ratio of company's book value to its market capitalization. Return is firm's annual return. Log asset is the logarithm of firm's total assets. ROA is the ratio of company's net income to its total assets. Institutional divestment is a dummy variable that equals one if there is a decrease in institutional ownership and zero otherwise. All regressions include industry 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 | # Capex | | | | | |
|---|---|---|---|---|---|---|
| | 1 year | 2-year | 3-year | 1 year | 2-year | 3-year |
| | (1) | (2) | (3) | (4) | (5) | (6) |
| Brown active short | 0.542*** | 0.624*** | 0.618*** | | | |
| | (3.50) | (3.66) | (3.16) | | | |
| Green active short | 0.027 | 0.090 | 0.012 | | | |
| | (0.21) | (0.60) | (0.06) | | | |
| Brown passive short (hedge) | | | | 0.189 | 0.102 | 0.079 |
| | | | | (1.24) | (0.55) | (0.41) |
| Green passive short (hedge) | | | | 0.127 | 0.109 | 0.133 |
| | | | | (1.26) | (0.82) | (0.83) |
| Book to market | -0.149 | -0.245 | -0.243 | -0.151 | -0.238 | -0.237 |
| | (-0.87) | (-1.13) | (-1.00) | (-0.88) | (-1.09) | (-0.97) |
| Return | 0.066*** | 0.008* | 0.008** | 0.059** | 0.008** | 0.008** |
| | (2.71) | (1.95) | (2.13) | (2.39) | (2.06) | (2.26) |
| Log assets | 1.053*** | 1.128*** | 1.146*** | 1.071*** | 1.153*** | 1.177*** |
| | (12.57) | (11.35) | (10.27) | (12.77) | (11.53) | (10.43) |
| ROA | -0.267 | -0.142 | 0.479 | -0.273 | -0.159 | 0.397 |
| | (-0.47) | (-0.18) | (0.46) | (-0.48) | (-0.20) | (0.38) |
| Institutional divestment | -0.088 | -0.103 | -0.114 | -0.080 | -0.095 | -0.112 |
| | (0.84) | (0.80) | (0.75) | (0.77) | (0.72) | (0.74) |
| Observations | 4,087 | 2,965 | 2,331 | 4,087 | 2,965 | 2,331 |
| R-squared | 0.551 | 0.558 | 0.560 | 0.548 | 0.555 | 0.557 |
| Year FE | YES | YES | YES | YES | YES | YES |
| Industry FE | YES | YES | YES | YES | YES | YES |

# Appendix

### Table A1: Short Sellers' Performance

This table reports the regression results of hedge fund performance on a dummy variable that equals one if the hedge fund is a green hedge 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. All regressions include time fixed effects and fund investment style fixed effects. 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.

| | (1) | (2) | (3) | (4) |
|---|---|---|---|---|
| VARIABLES | Fund excess return | Fund excess return | Fund alpha | Fund alpha |
| Short seller (Green hedge fund) | 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 A2: Change in Hedge Fund Holding and Firm Carbon Emission**

This table shows the relationship between changes in firms' emissions and changes in hedge fund holding. The dependent variable is the 1-year, 2-year and 3-year change in greenhouse gas emissions, measured in million tons of $CO_2$ equivalents emitted per year. We regress the dependent variable on the interactions between measures of active short/passive short and indicators for whether the firm is brown or green. We divide firms into tertiles based on their level of emissions in each year. Brown firms are defined as the firms in the highest tertile. Green firms are defined as the firms in the lowest tertile. $\Delta$ hedge fund ownership is the percentage change in hedge fund holding in a firm. Book to market ratio is the ratio of company's book value to its market capitalization. Return is firm's annual return. Log asset is the logarithm of firm's total assets. ROA is the ratio of company's net income to its total assets. Past $\Delta$ Emission is the change in firm emissions in the previous year. Institutional divestment is a dummy variable that equals one if there is a decrease in institutional ownership and zero otherwise. All regressions include industry 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 | $\Delta$ Emission | | |
|---|---|---|---|
| | 1 year | 2 years | 3 years |
| | (1) | (2) | (3) |
| Brown $\times$ $\Delta$ hedge fund ownership | 0.042 | 0.026 | 0.063 |
| | (1.56) | (0.45) | (0.71) |
| Green $\times$ $\Delta$ hedge fund ownership | 0.002 | 0.005 | 0.001 |
| | (0.67) | (0.55) | (0.14) |
| Short interest | -0.359 | -0.193 | 0.070 |
| | (-0.63) | (-0.15) | (0.04) |
| Book to market | 0.092 | 0.306 | 0.570* |
| | (0.95) | (1.30) | (1.87) |
| Return | 0.033 | -0.023 | 0.045 |
| | (0.28) | (-0.10) | (0.25) |
| Log assets | -0.084*** | -0.172*** | -0.251*** |
| | (-4.43) | (-4.22) | (-3.86) |
| ROA | 0.302* | 0.454 | 0.969 |
| | (1.81) | (1.12) | (0.94) |
| Past $\Delta$ Emission | 0.119*** | 0.029 | -0.069 |
| | (3.45) | (0.58) | (-0.93) |
| Institutional divestment | -0.164* | -0.304* | -0.182 |
| | (-1.90) | (-1.85) | (-0.79) |
| Year FE | YES | YES | YES |
| Industry FE | YES | YES | YES |
| Observations | 3,307 | 2,590 | 2,037 |
| R-squared | 0.075 | 0.078 | 0.098 |

**Table A3: Impact on Sales**

This table shows the relationship between firm sales and short selling activities. The dependent variable is firm's sales (log of total revenue) in 1-year, 2-year, and 3-year following the short sell. We regress the dependent variable on the interactions between measures of changes in hedge fund ownership and indicators for whether the firm is brown or green. We divide firms into tertiles based on their level of emissions in each year. Brown firms are defined as the firms in the highest tertile. Green firms are defined as the firms in the lowest tertile. Active short is assigned a value of one when there is a decrease in hedge fund ownership from year $t-1$ to year $t$ coupled with an increase in short interest during the same period, and zero otherwise. Passive short is assigned a value of one when there is an increase in hedge fund ownership from year $t-1$ to year $t$ coupled with an increase in short interest during the same period, and zero otherwise. Book to market ratio is the ratio of company's book value to its market capitalization. Return is firm's annual return. Log asset is the logarithm of firm's total assets. ROA is the ratio of company's net income to its total assets. Institutional divestment is a dummy variable that equals one if there is a decrease in institutional ownership and zero otherwise. All regressions include industry 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 | Sales | | | | | |
|---|---|---|---|---|---|---|
| | 1-year | 2-year | 3-year | 1-year | 2-year | 3-year |
| | (1) | (2) | (3) | (4) | (5) | (6) |
| Brown active short | 0.076** | 0.069** | 0.104** | | | |
| | (2.38) | (1.99) | (2.49) | | | |
| Green active short | 0.017 | -0.086 | -0.006 | | | |
| | (0.39) | (-1.25) | (-0.09) | | | |
| Brown passive short (hedge) | | | | 0.035 | 0.037 | 0.045 |
| | | | | (1.06) | (1.03) | (1.05) |
| Green passive short (hedge) | | | | -0.106** | -0.124*** | -0.154*** |
| | | | | (-2.41) | (-2.80) | (-2.98) |
| Book to market | -0.216*** | -0.205*** | -0.187*** | -0.216*** | -0.204*** | -0.185*** |
| | (-5.18) | (-3.63) | (-3.09) | (-5.11) | (-3.56) | (-3.00) |
| Return | -0.010 | -0.000 | -0.001 | -0.011 | -0.000 | -0.001 |
| | (-0.55) | (-0.15) | (-0.63) | (-0.65) | (-0.23) | (-0.79) |
| Log asset | 0.896*** | 0.869*** | 0.848*** | 0.893*** | 0.866*** | 0.842*** |
| | (69.07) | (56.63) | (49.04) | (70.00) | (54.68) | (48.33) |
| ROA | 0.852*** | 0.965*** | 1.198*** | 0.854*** | 0.970*** | 1.224*** |
| | (3.72) | (3.80) | (4.13) | (3.66) | (3.73) | (4.24) |
| Institutional divestment | 0.045* | 0.040 | 0.020 | 0.045* | 0.039 | 0.016 |
| | (-1.82) | (-1.39) | (-0.56) | (-1.85) | (-1.38) | (-0.59) |
| Year FE | YES | YES | YES | YES | YES | YES |
| Industry FE | YES | YES | YES | YES | YES | YES |
| Observations | 4,083 | 2,963 | 2,328 | 4,083 | 2,963 | 2,328 |
| R-squared | 0.890 | 0.874 | 0.864 | 0.889 | 0.874 | 0.865 |

**Table A4: Impact on EBIT**

This table shows the relationship between earnings before interest and taxes (EBIT) and short selling activities. The dependent variable is firm's EBIT in 1-year, 2-year and 3-year following the short sell. We regress the dependent variable on the interactions between measures of active short/passive short and indicators for whether the firm is brown or green. We divide firms into tertiles based on their level of emissions in each year. Brown firms are defined as the firms in the highest tertile. Green firms are defined as the firms in the lowest tertile. Active short is assigned a value of one when there is a decrease in hedge fund ownership from year $t-1$ to year $t$ coupled with an increase in short interest during the same period, and zero otherwise. Passive short is assigned a value of one when there is an increase in hedge fund ownership from year $t-1$ to year $t$ coupled with an increase in short interest during the same period, and zero otherwise. Book to market ratio is the ratio of company's book value to its market capitalization. Return is firm's annual return. Log asset is the logarithm of firm's total assets. ROA is the ratio of company's net income to its total assets. Institutional divestment is a dummy variable that equals one if there is a decrease in institutional ownership and zero otherwise. All regressions include industry 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.

| | EBIT | | | | | |
|---|---|---|---|---|---|---|
| VARIABLES | 1 year | 2 years | 3 years | 1 year | 2 years | 3 years |
| | (1) | (2) | (3) | (4) | (5) | (6) |
| Brown active short | 0.058 | 0.239 | 0.201 | | | |
| | (0.14) | (0.50) | (0.41) | | | |
| Green active short | -0.122 | 0.011 | -0.213 | | | |
| | (-0.57) | (0.04) | (-0.61) | | | |
| Brown passive short (hedge) | | | | 0.109 | -0.009 | 0.167 |
| | | | | (0.42) | (-0.03) | (0.40) |
| Green passive short (hedge) | | | | 0.218 | 0.125 | 0.181 |
| | | | | (1.13) | (0.45) | (0.54) |
| Book to market | -1.124*** | -1.458*** | -1.299** | -1.126*** | -1.456*** | -1.300** |
| | (-4.04) | (-3.25) | (-2.50) | (-4.05) | (-3.23) | (-2.50) |
| Return | 0.117*** | 0.010* | 0.005 | 0.116*** | 0.010* | 0.005 |
| | (2.63) | (1.70) | (0.96) | (2.62) | (1.72) | (0.99) |
| Log asset | 1.979*** | 2.196*** | 2.240*** | 1.987*** | 2.084*** | 2.257*** |
| | (8.14) | (6.91) | (6.05) | (8.32) | (6.98) | (6.14) |
| ROA | 1.588 | 0.223 | 2.094 | 1.587 | 0.200 | 2.060 |
| | (0.68) | (0.08) | (0.58) | (0.68) | (0.07) | (0.57) |
| Institutional divestment | -0.159 | -0.245 | -0.452 | -0.157 | -0.242 | -0.454 |
| | (0.65) | (0.89) | (1.47) | (0.65) | (0.89) | (1.48) |
| Year FE | YES | YES | YES | YES | YES | YES |
| Industry FE | YES | YES | YES | YES | YES | YES |
| Observations | 4,093 | 2,970 | 2,334 | 4,093 | 2,970 | 2,334 |
| R-squared | 0.386 | 0.379 | 0.368 | 0.386 | 0.379 | 0.368 |