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Low Carbon Mutual Funds

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March 2023

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Abstract

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Keywords: Behavioral finance, climate change, eco-labels, investor preferences, mutual funds, sustainable finance

JEL Classifications: D03, G02, G12, G23

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Low carbon mutual funds *

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Abstract

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1 Introduction

How should investors behave in the face of climate-related risks and the energy transition to a low carbon world? To answer this question, it is important to recognize that accounting for climate risks in investment decisions brings investors both benefits and costs.

On the one hand, shunning carbon-intensive, "brown" assets can reduce an investor's exposure to climate risks. These risks have yet to fully materialize, both in terms of physical consequences and societal reactions, and many observers believe they are currently underestimated in asset prices (Stroebel and Wurgler, 2021). On the other hand, in our not-yet-low carbon economy, excluding "brown" assets and investing only in those considered "green" requires investors to forego opportunities to diversify. This trade-off is particularly salient in asset management, where portfolio diversification, not only the features of individual securities, plays a crucial role in reducing overall investment risk (Markowitz, 1952).

In this paper, we study how investors and asset managers navigate this trade-off. We focus on the mutual fund industry, which represents an important share of global financial markets,[1] and exploit a quasi-natural experiment involving a sudden increase in both the availability and salience of information on carbon risk (climate transition risk), i.e., the class of risk deriving from the transition to a lower carbon economy. As we describe in more detail in Section 2, on April 30, 2018, Morningstar, the most important data provider in the

[1] In 2020, open-end mutual funds had some USD 63 trillion in assets under management worldwide, representing around 26% of equity and debt securities outstanding (Investment Company Institute, 2021).

mutual fund industry, released a new Portfolio Carbon Risk Score derived from firm-level data provided by Sustainalytics, which Morningstar has controlled since 2017. The novelty of Morningstar's Portfolio Carbon Risk Score is highlighted by the fact that it correlates only mildly with other portfolio metrics, based on previously available environmental scores from Sustainalytics, Refinitiv, and MSCI KLD. Based on its new carbon risk score, combined with relatively standard information on firms' fossil fuel involvement, Morningstar also issued an eco-label for mutual funds – the Low Carbon Designation (LCD). We use a large sample of active European and US mutual funds to study investors' and fund managers' reactions to these information shocks produced by the publication of Morningstar's Portfolio Carbon Risk Score and its associated LCD eco-label.

We develop the conceptual framework guiding our empirical analyses in Section 3. We first confirm that, in line with extant literature (e.g., Bolton and Kacperczyk, 2021a; Engle et al., 2020), individual low carbon securities are less risky than other firms, both in terms of exposure to negative climate change news and realized return volatility. We then shift our focus to the portfolio level. One may naively think that the risk properties of low carbon funds should mirror those of their low carbon holdings. Such, we find, is not the case. The investment risk of a portfolio depends not only on the variance of its individual holdings' returns, but also on the covariance of these returns (Markowitz, 1952). Empirically, while low carbon funds have lower exposure to climate risks, their volatility is not lower than that of more conventional funds. In fact, we find that the mutual funds with the lowest carbon risk

scores have higher volatility than those with median scores. The source of this result is the high degree of industry concentration (Kacperczyk, Sialm, and Zheng, 2005) of low carbon funds. These funds overweight IT, retail, and healthcare firms, while they underweight energy, materials, and utility firms. Beyond the industry concentration, the fact that low carbon funds hold fewer stocks does not significantly further explain their surprisingly high volatility. Overall, low carbon funds hold assets that, although individually less risky, have a high degree of covariance, limiting risk-sharing.

In Section 4, we study the reactions of mutual fund investors to the April 2018 information shock. By the end of the month, funds receiving the "Low Carbon Designation" enjoyed a substantial increase in their monthly flows relative to other funds. The economic impact of the LCD label corresponds to an increase in flows of approximately 36 basis points each month; this increase is equal to about two-thirds of the effect on flows caused by a one-standard-deviation stronger monthly financial performance.

Before the new data became available, investors likely used Morningstar's sustainability Globes as an imperfect proxy for exposure to carbon risk. Intuitively, if a fund with few Globes received the LCD, it would come as a larger surprise to investors; consistent with this logic, we find larger effects on flows in such situations. In addition, LCD-labeled funds with strong risk-adjusted performance experienced a more pronounced flow premium. Moreover, after the publication of the LCD list – but not before – qualifying for the low carbon eco-label resulted in particularly large extra flows in months of greater attention to climate change, as

measured by Google search intensity. All these results are consistent with investors taking both the benefits and the costs into account when investing in low carbon funds.

In Section 5, we employ a dataset of monthly portfolio holdings to study the reactions of fund managers to the release of Morningstar's portfolio and firm-level carbon risk information. We show that, after April 2018, fund managers actively rebalanced their portfolios to reduce their carbon risk. On average, relative to the period before the publication of Morningstar's carbon risk metrics, mutual funds reduced their position in the average high carbon risk firm by about 0.17 basis points of their assets under management per month. This effect is economically meaningful, considering that the median monthly position change is zero for the whole sample and 2.8 basis points for non-zero position changes.

Managers reacted to carbon risk not only with a one-shot rebalancing of their portfolios, but also by integrating the new information into their flow-driven investment decisions after the initial shock. In particular, we observe that funds experiencing large negative net flows sold high carbon risk assets more aggressively than did other funds, while funds experiencing high inflows increased their stakes in low carbon risk assets.

Further cross-sectional evidence indicates that, as we expected, funds with higher ex-ante industry concentration reacted more strongly to the release of the new carbon risk information. For these funds, shifting to lower carbon risk assets is less likely to decrease (and may even increase) their diversification. They are also likely to serve clients who are less interested in broad diversification in the first place. Importantly, we find that when

managers reduced their positions in stocks with a score of medium or high carbon risk, they did so more aggressively for those with a higher return covariance with the remainder of the portfolio, consistent with an attempt to preserve diversification.

This paper contributes, first, by providing insights into the benefits and costs of green investment products. Existing research suggests that firms with better environmental performance have lower exposure to climate-related risks, and are priced accordingly (e.g., Bolton and Kacperczyk, 2021a,b; Engle et al., 2020; Ilhan, Sautner, and Vilkov, 2021; Hsu, Li, and Tsou, 2022; Huynh and Xia, 2021; Ramelli et al., 2021). However, how the risk properties of individual green securities translate to the portfolio level is still largely unexplored and, as we show, not obvious. The trade-off at the portfolio level that we highlight in this context is consistent with the theoretical literature on green investing.[2]

Second, we complement the literature on whether and why investors prefer socially responsible investment products (e.g., Anderson and Robinson, 2022; Barber, Morse, and Yasuda, 2021; Bassen et al., 2018; Bauer, Ruof, and Smeets, 2021; Bollen, 2007; Geczy, Stambaugh, and Levin, 2021; Hartzmark and Sussman, 2019; Renneboog, Ter Horst, and

[2]In Heinkel, Kraus, and Zechner (2001) and Pástor, Stambaugh, and Taylor (2020b), for instance, divestment from "brown" assets is negatively related to investor risk aversion, because deviating from the market portfolio implies incurring diversification risks. Similarly, Boyle et al. (2012) explore the effects on optimal portfolios of the need to balance asset diversification ("Markowitz's view") and asset familiarity ("Keynes' view"). Wagner (2011) develops a model in which investors forgo diversification benefits to hedge liquidation risks. Pedersen, Fitzgibbons, and Pomorski (2021) analyze optimal portfolios when considering environmental, social, and governance (ESG) risks and preferences. In contemporaneous work, Hambel, Kraft, and der Ploeg (2022) theoretically explore the interplay between governmental climate actions and portfolio diversification from a macro-finance perspective. Of course, low carbon investing can come in different shapes. For instance, Andersson, Bolton, and Samama (2016) and Bolton, Kacperczyk, and Samama (2022) outline approaches to reducing carbon risk with small tracking errors and sector-weighted deviations.

Zhang, 2011; Riedl and Smeets, 2017). The quasi-natural experiment that we analyze takes into account both the costs and benefits of socially responsible investment products, crucial for understanding the complexity of investor behavior on sustainability issues. In terms of costs, low carbon investing asks investors to pay a price in terms of lower sectoral diversification, at least in the short term. Generic sustainable ratings/products, by contrast, are usually based on "best in class" approaches precisely to allow investors to not give up any sectoral diversification. In terms of benefits, the event we analyze allows a focus on investors' specific climate-related preferences. As documented by Hartzmark and Sussman (2019), the investors we study had already self-selected into funds based on their generic sustainability preferences. Our results indicate that both the cost and benefit sides of low carbon investing shape investor responses.

Third, we complement the literature on professional money manager behavior. Several studies consider fund manager behavior as a function of traditional financial performance metrics, but in recent years, ESG factors, and climate-related considerations in particular, have gained importance in the industry. For instance, Krüger, Sautner, and Starks (2020) and Ilhan et al. (2023) provide survey evidence on the importance of climate risks for institutional investors. Bolton and Kacperczyk (2021a) show that institutional investors apply carbon-related screens, and Choi, Gao, and Jiang (2023) document a decrease in institutional investors' exposure to carbon-intensive domestic firms after 2015. Fund managers change their holdings after shifts in climate risk perception due to natural disasters (Alok, Kumar,

and Wermers, 2020) or extreme heat events (Alekseev et al., 2021). Gantchev, Giannetti, and Li (2021) study fund managers' trading behavior with respect to firms' sustainability, focusing on the price pressure implications on individual stocks. Our paper contributes to this literature by studying how fund managers actively changed their portfolio holdings following increased transparency on climate risks in the mutual fund industry.

2 Empirical setting and data

2.1 Empirical setting

On April 30, 2018, Morningstar launched on its platform the Portfolio Carbon Risk Score, a measure designed to help its clients better assess a portfolio's exposure to carbon risk (also known as climate transition risk), i.e., the risk due to the transition from a fossil fuel reliant economy to a lower carbon economy.[3] On the same day, Morningstar assigned its Low Carbon Designation (LCD) label to funds with low carbon risk scores and low levels of fossil fuel exposure; this heuristic is aimed at helping clients easily identify mutual funds whose portfolios align with the transition to a low carbon economy.[4] Figure 1 shows the portfolio carbon risk score and the LCD label, as seen on Morningstar's fund report. Details

[3]Morningstar's carbon risk metrics do not reflect a portfolio's exposure to extreme weather events caused by climate change, although these are likely to impact firms' assets and operations and hence cause investors significant losses. For an overview of the differences between carbon risk and physical risk, see, for instance, Task Force on Climate-related Financial Disclosures, TCFD (2017).

[4]See Morningstar, "Morningstar launches portfolio carbon risk score to help investors evaluate funds' carbon-risk exposure," May 1, 2018.

on the methodology underlying these metrics are in Morningstar (2018a,b).

- Figure 1 -

The portfolio carbon metrics are based on *firm-level* carbon risk scores from the ESG data provider Sustainalytics; these scores were also disclosed for the first time at the end of April 2018.[5] The simultaneous release of firm-level and fund-level carbon risk scores was possible because Morningstar has controlled Sustainalytics since 2017 (initially with a 40% stake, which increased to 100% in 2020). According to the two data providers, the firm-level carbon risk score quantifies a company's exposure to, and management of, material climate transition risk. It attempts to capture the degree to which a firm's economic value is at risk in the transition to a low carbon economy (Morningstar, 2018b). Table A1 in the Online Appendix provides summary statistics of firm-level carbon risk scores in each Global Industry Classification Standard (GICS) sector. Firms in high-emitting sectors (e.g., Energy, Materials, and Utilities) have the highest mean carbon risk scores, but there is substantial variability in this measure within all sectors.

To receive the LCD label, a fund has to comply with two criteria: (1) a 12-month average Portfolio Carbon Risk Score below 10 (out of 100); and (2) a 12-month average Fossil Fuel Involvement rating below 7%. As of April 2018, having a Portfolio Carbon Risk Score below 10 implies being among the 29% best-performing funds on this dimension. A 12-month

[5]To compute its Portfolio Carbon Risk Scores, Morningstar weights the firm-level carbon risk scores by the total investment (debt and equity) that a fund holds in a given company at the end of the quarter. A Portfolio Carbon Risk Score is calculated if more than 67% of the fund's portfolio assets have a firm-level carbon risk score.

portfolio fossil fuel involvement rating below 7% represents a 33% under-weighting of fossil fuel-related companies, relative to the global equity universe.[6]

The release of Morningstar's carbon metrics thus represented a double shock to investors: a shock to the availability of carbon-related information through the firm-level and fund-level carbon risk scores, and a shock to its salience through the LCD label. The arrival of these new data is potentially relevant both to fund managers and to their clients.[7] Morningstar representatives have confirmed to us that they did not communicate the release of these metrics to either fund managers or clients in advance of their publication on April 30, 2018. As seen further below, our analyses of pre-publication trends of investor and fund manager behavior are indeed consistent with the release of the new data not being anticipated.

2.2 Data

We base our analyses on two main datasets, covering the period from April 2017 (one year before our main event of interest) through September 2019: Fund-level month-end information (from Morningstar Direct) and individual historical portfolio holdings (from Morningstar On

[6]Sustainalytics/Morningstar classify a firm as fossil-fuel involved if it derives at least 5% of its revenue from thermal coal extraction, thermal coal power generation, or oil and gas production or power generation, or at least 50% of its revenues from oil and gas products and services (Morningstar, 2018b).

[7]Morningstar (2018a) suggests that "*Understanding portfolio carbon risk gives investors the ability to make strategic decisions to mitigate carbon risk and a basis for measuring carbon risk reduction. This applies to asset managers as well as asset owners and fund investors. An asset manager can use carbon risk information to inform buy-sell and portfolio-construction decisions, to make decisions on which companies to engage with to better understand their climate-risk mitigation strategies and to communicate with clients and other stakeholders about their activities. An asset owner or fund investor can use carbon risk information to better understand how climate risks affect their investments overall and as a basis for action to reduce their exposure to climate risks. This information allows fund investors to take climate risks into consideration as they monitor, compare, and select funds and asset managers.*"

Demand). We complement these two datasets with firm-level characteristics from Compustat Capital IQ and Sustainalytics. In what follows, we briefly describe our data.

2.2.1 Fund-level characteristics

From Morningstar Direct, we obtain survivorship-bias-free data (all in USD) for all active open-end mutual funds domiciled in Europe and the US. To work with a relatively homogeneous sample, we drop funds classified by Morningstar as pure fixed income, sector-specific, or investing exclusively outside the US and Europe. We are left with 20 categories of equity and balanced funds.[8]

While mutual funds issue several share classes to target specific investor groups or geographies, the underlying portfolio is the same regardless of class. Consequently, we conduct our main analyses at the fund level. In aggregating data from the share class to the fund level, we compute funds' returns and volatility as value-weighted average values across different share classes. Fund assets (in USD) are the sum of a fund's assets under management in all its share classes. We require funds to have at least one million USD in assets under management and to be at least one year old. We retrieve other fund-level information from each fund's largest share class.

[8]The 20 categories in our sample are: Aggressive Allocation, Allocation Miscellaneous, Cautious Allocation, Equity Miscellaneous, Europe Emerging Markets Equity, Europe Equity Large Cap, Flexible Allocation, Global Equity Large Cap, Global Equity Mid/Small Cap, Long/Short Equity, Moderate Allocation, Target Date, UK Equity Large Cap, UK Equity Mid/Small Cap, US Equity Large Cap Blend, US Equity Large Cap Growth, US Equity Large Cap Value, US Equity Mid Cap, US Equity Small Cap, and Europe Equity Mid/Small Cap. Our results also hold when using the full sample of funds domiciled in Europe and the US, or when just focusing on pure equity funds.

Following Sirri and Tufano (1998), we compute flows as the monthly growth of assets under management, net of reinvested returns. We winsorize flows at the 1st and 99th percentiles. Following Hartzmark and Sussman (2019), we also compute a measure of normalized flows: First, we split the sample into deciles of fund size; second, we rank funds according to net flows within each size decile and compute percentiles of the net flow rankings. These percentiles correspond to the normalized flow variable.

Return is the total monthly return (in percentage points), as reported by Morningstar. We estimate the return volatility as the standard deviation of returns over the past 12 months. We also collect other information about each fund, including its age, its Morningstar category, its financial performance rating (the Morningstar Stars, on a 1-5 scale, with 5 indicating a top financial performer), and its generic sustainability rating (the Morningstar Globes, on a 1-5 scale, with 5 indicating a top sustainability performer).

To account for the impact on flows of changes in a fund's financial performance rating (Del Guercio and Tkac, 2008), we define the variable $\Delta Stars$ to indicate an upgrade (1) or a downgrade (-1) in the fund's Stars rating from the previous month. Similarly, to account for the impact on flows of changes in a fund's generic sustainability rating (Ammann et al., 2018; Hartzmark and Sussman, 2019), we define the variable $\Delta Globes$ to indicate an upgrade (1) or a downgrade (-1) in the fund's Globes rating from the previous month. We classify observations with missing Stars or Globes as no change.

- Table 1 -

Panel A of Table 1 shows summary statistics for fund-month observations, from April 2017 through September 2019, for which information on flows is available. Panel B provides a snapshot of the statistics as of the end of April 2018. The sample covers some 13,600 funds, of which 17-18% obtained Morningstar's LCD eco-label.

Panel A in Table A2 in the Online Appendix shows the geographical distribution of our sample as of April 2018. Around 9,000 funds are domiciled in Europe and 4,000 in the US, of which 18% received the initial LCD. Panels B and C in the same table show the share of low carbon funds for different values of Morningstar's generic sustainability ratings (Globes) and overall financial performance ratings (Stars). High Globes and high Stars funds are more likely to receive the LCD. However, even among funds with one or two Globes, or one or two Stars, a significant fraction obtained the low carbon eco-label.

Table A3 in the Online Appendix explores the correlations of the new data with previously available firm-level environmental scores. It shows that the Portfolio Carbon Risk Score only mildly correlates with metrics investors may have self-computed, based on existing information (we calculated these measures based on portfolio holdings as of April 2018). In particular, the Portfolio Carbon Risk Score has a correlation of -0.27 with a portfolio's Sustainalytics' environmental score, -0.08 with a portfolio's Refinitiv's environmental score, and -0.19 with a portfolio's MSCI–KLD's environmental score. Overall, the low correlation of the Portfolio Carbon Risk Score with prior environmental metrics confirms the relevance of the April 2018 information shocks.

2.2.2 Portfolio holdings data

From Morningstar On Demand, we obtain the monthly portfolio holdings from April 2017 through September 2019 of mutual funds (both from Europe and the US) with available Portfolio Carbon Risk Scores. We keep only funds that report their holdings monthly and focus exclusively on their equity positions. We denote the number of shares held by fund f in stock i in month t as $NumberShares_{f,i,t}$.

To study fund managers' trading decisions, we compute the position change, expressed in basis points of assets under management (AUM) in the prior month, as:

$$Position\ change_{i,f,t} = \frac{Price_{i,t-1}(NumberShares_{f,i,t} - NumberShares_{f,i,t-1})}{AUM_{f,t-1}} \times 10^4$$

This variable is defined as in Gantchev, Giannetti, and Li (2021), for example. We trim position change at the 1st and 99th percentiles. Panel C of Table 1 reports summary statistics of the position changes and other portfolio firm-level variables. The median position change is zero, as fund managers keep most of their positions unchanged from one month to the next. For the non-zero position changes, that is, for actual trades, the median monthly position change is about 2.8 basis points. The median firm represents about 0.33% of a fund's portfolio.

The average portfolio firm has a firm-level carbon risk score of 11. Following the Sustainalytics (2018) methodology, we classify individual firms into three carbon risk (CR) ratings:

Low (carbon risk score between 0 and 9.99), Medium (carbon risk score between 10 and 29.99), and High (carbon risk score above 29.99). We define the corresponding firm indicators *Low CR (firm)*, *Medium CR (firm)*, and *High CR (firm)*. Similarly, we also consider the indicator *FFI (firm)* equal to 1 for firms deriving a significant share of their revenues from fossil fuel-related activities. On average, firms classified as having a high carbon risk represent 6% of each portfolio, while firms involved in fossil fuel activities represent 10%.

The total buys and sells of the average fund in a given month are USD 26 million and USD 27 million, respectively, and the average churn rate is 0.09, meaning that about 5% of positions are turned over during a month.[9]

3 Conceptual framework

In this section, we develop the conceptual framework that guides our empirical investigations. We support this framework with descriptive analyses of funds' and their holdings' characteristics as of April 2018.[10]

Let us first briefly consider the role of carbon risk for individual securities. Several contributions in the literature indicate that green assets have insurance-like properties against climate risks (e.g., Bolton and Kacperczyk, 2021a; Engle et al., 2020; Hsu, Li, and Tsou, 2022; Ilhan, Sautner, and Vilkov, 2021; Ramelli et al., 2021). In Figure 2, we confirm this

[9]This trading behavior is similar to that observed by Gaspar, Massa, and Matos (2005), who find that 20% of positions are turned over during one quarter.

[10]Table A4 in the Online Appendix reports summary statistics of the additional variables used in this section.

to be the case using the firm-level carbon risk metrics published by Morningstar. Panel A shows the relation between a firm's carbon risk score and its return loading on negative climate-related news. For approximately 2,500 international firms covered by Sustainalytics, we regress each firm's monthly returns on the three Fama-French global factors and the standardized news-based climate change risk index from Engle et al. (2020).[11] The estimated coefficient *Loading on negative climate news (firm)* represents the firm-specific sensitivity to negative climate news (akin to a "climate beta"), net of the effect of the market, size, and value factors. Consistently with (Engle et al., 2020), a firm's carbon risk relates negatively with the loading on negative climate news ($p < 0.001$), that is, low carbon risk firms outperform other firms in months with higher levels of negative climate-related news.

Panel B shows that firms with lower carbon risk also display lower average realized volatility. Indeed, *Loading on negative climate news (firm)* negatively relates to return volatility ($p < 0.001$) and explains approximately 2.75% of its variation.

- Figure 2 -

How do the risk-management properties of low carbon firms translate to the fund level? The answer to this question is not obvious. While the expected return of a portfolio is simply

[11] Engle et al. (2020) find that environmentally responsible firms – based on Sustainalytics' environmental scores – outperform non-environmentally responsible firms in months with more climate-related news. For our analysis, we use the negative news-based risk index the authors obtained from the data provider Crimson Hexagon (CH) ("CH Negative Climate Change News Index"), which focuses exclusively on negative climate news, and is available from January 2008 through May 2018. We thank Stefano Giglio and Johannes Stroebel for making these data available on their websites. We base our estimation on the period from January 2015 through April 2018, with a minimum of 12 monthly return observations, and we winsorize the estimated loadings at the 1st and 99th percentiles.

the weighted average of the expected returns of its individual holdings, the risk of a portfolio depends both on the variance of the individual securities and their covariances (Markowitz, 1952). In Figure 3, we illustrate what this basic principle implies for the riskiness of funds by analyzing the cross-section, as of April 2018, of 6,310 mutual funds with available 12-month average Portfolio Carbon Risk Scores. All graphs in Figure 3 are binned scatterplots employing 30 equal-sized bins.

Panel A shows that funds with lower scores hold, on average, less volatile firms. This result follows intuitively from their tilt toward low carbon firms, which, as we noted above, are generally less risky, as well as being less exposed to climate-related risks.[12] However, as Panel B illustrates, the relation between fund-level carbon risk and portfolio volatility is not at all monotonic: Funds with lower levels of carbon risk hold less risky assets, but their overall portfolios are not less risky – and can even be riskier – than those near the market average, that is, close to a Portfolio Carbon Risk Score of 10.[13] (Recall that to qualify for the LCD eco-label requires a Portfolio Carbon Risk Score under 10.)

- Figure 3 -

[12]Figure A2 in the Online Appendix shows (again, in binned scatter plots with 30 equal-sized bins) that the portfolios of low carbon funds have, on average, less negative exposure to negative climate news; on the contrary, they tend to deliver higher returns under those conditions. This result also follows naturally from the firm-level results in Figure 2 and confirms that low carbon funds provide investors with a better hedge against climate risks, as the portfolios constructed in Engle et al. (2020) and Alekseev et al. (2021) propose to do.

[13]Regression results available on request confirm this graphical intuition. When regressing fund volatility on carbon risk for the sub-sample of funds with carbon risk scores above 10, we observe a positive relationship (0.07, $p < 0.001$): a lower carbon risk score is associated with lower fund volatility. However, for the sub-sample of funds with carbon risk scores below 10 (i.e., low carbon funds), the same relationship is negative (-0.02, $p < 0.001$): a lower carbon risk score is associated with higher fund volatility.

Why does this non-monotonic relationship arise? A candidate explanation is that low carbon funds hold assets with a high degree of covariance, which limits risk-sharing from a mean-variance perspective. We probe this interpretation by considering two measures of portfolio diversification. *Normalized portfolio volatility*, proposed by Goetzmann and Kumar (2008), is computed by dividing a portfolio's total volatility by the average volatility of the individual stocks it contains. The higher this measure, the more unexploited opportunities exist to diversify the portfolio and reduce its volatility. Panel C in Figure 3 shows that low carbon funds have a relatively high normalized portfolio volatility.

The second measure we employ, the *Industry concentration index* proposed by Kacperczyk, Sialm, and Zheng (2005), is computed as the sum of the squared deviations of a fund's GICS industry weights, relative to the industry weights of the global equity market portfolio. Panel D in Figure 3 displays the relationship between funds' carbon risk and industry concentration, controlling for fund size and category. The resulting U-shaped curve confirms that the volatility of low carbon funds reflects significantly less sectoral diversification.[14]

To probe the quantitative importance of industry concentration, we run OLS regressions of fund volatility on quintile category indicators of Portfolio Carbon Risk Score, as shown in Table 2. In Column 1, we observe that funds in the bottom quintile of carbon risk –

[14]This result holds when we match our dataset with data from Pástor, Stambaugh, and Taylor (2020a), producing a sample of 915 US domestic equity mutual funds with available diversification data for 2014. Our results (available on request) show that funds classified as low carbon in April 2018 have a statistically significant lower "balance," i.e., the resemblance of firm-level portfolio weights relative to market cap weights, even after controlling for category fixed effects. We thank Lucian Taylor for making these data available on his website.

that is, low carbon funds – exhibit significantly higher portfolio volatility than do median carbon risk funds. (As is to be expected, funds in the top quintiles of carbon risk also have higher volatility than do median funds.) However, when we control for the funds' industry concentration (Column 2), the volatility difference between bottom quintile and median carbon risk funds becomes statistically insignificant and even turns slightly negative (-0.01). In this specification, the relationship between fund volatility and carbon risk is similar to that observed at the individual security level (Figure 2, Panel B).

In Columns 3 and 4, we also account for the funds' number of holdings (linearly, and also in quadratic form, due to the non-linear relationship between volatility and the number of holdings), which reduces the coefficient on the first quintile of carbon risk further, but only mildly. Based on these estimates, industry concentration appears to account for around 75% of the extra higher volatility of bottom-quintile-carbon-risk funds, while the number of holdings accounts for the remaining 25%.[15]

- Table 2 -

The industry imbalance of low carbon funds is also visible in their portfolio composition. Figure 4 provides descriptive evidence on the composition of low carbon funds by GICS

[15]When we control for industry concentration, the coefficient of 0.05 on the *1st quintile CR* in Column 1 is reduced to -0.01 in Column 2, i.e., by 0.06. When we add a linear and squared term for the number of holdings, it falls by another 0.02 to -0.03 in Column 3, for a total difference of 0.08. Therefore, 75% (0.06/0.08) of the unusually high volatility of funds in the first quintile of carbon risk is explained by their high industry concentration, whereas 25% (0.02/0.08) is explained by the number of their holdings. The fact that low carbon funds' higher volatility does not strongly depend on the number of their holdings confirms that it reflects a higher average asset covariance and can not be reduced simply by bundling many low carbon mutual funds (Markowitz, 1976).

industry groups. As expected, these funds overweight IT, retail, and healthcare firms, while they underweight energy, materials, and utility firms. Figure A1 in the Online Appendix shows that low carbon funds have a geographical exposure similar to that of other funds. We also observe no substantial differences in terms of exposure to the market or size factors. However, as may be expected, low carbon funds have lower exposure to the value factor, given their significant overweighting of growth sectors, a fact consistent with the observation in Pástor, Stambaugh, and Taylor, 2020a that green securities tend to be growth-oriented.

- Figure 4 -

Overall, these analyses illustrate the fundamental trade-off investors and fund managers face: On the one hand, by overweighting green securities, they reduce their exposure to climate risks. On the other hand, by moving away from the status quo in our not-yet-low carbon world, they miss opportunities to diversify.

Studying how investors and fund managers behave when confronted with this trade-off is crucial to understanding the role of financial markets in the energy transition. However, this task is complicated by several empirical challenges. Investors with different preferences tend to self-select into different types of funds. Similarly, fund managers' decisions are driven by many forward-looking considerations, making it difficult to isolate the effect of one specific firm characteristic on their trading behavior. We address these challenges by studying the reactions of mutual fund clients and managers to the introduction of Morningstar's carbon

metrics in April 2018, which produced a shock both to the availability and to the salience of climate-related information in the mutual fund industry.

4 Investor responses

This section explores the reactions of mutual funds investors to the April 2018 publication of Morningstar's Portfolio Carbon Risk Score and its Low Carbon Designation (LCD) eco-label. While other studies have documented investors' reactions to a fund's generic sustainability features (e.g., Hartzmark and Sussman, 2019), we exploit this quasi-natural experiment to provide insights into the behavior of mutual fund clients when confronted by carbon risk.

4.1 Main results

We start by visually studying the pattern of investment in low carbon funds. Figure 5 shows the average equally weighted monthly net flows from April 2017 through December 2018 for funds that were labeled LCD at the end of April 2018, and for other funds.[16]

- Figure 5 -

During the pre-publication period (April 2017 to April 2018), the net flows in Europe-domiciled funds (Panel A) that would be designated low carbon are very similar to the flows

[16]In this section, we end the post-publication period in December 2018 to document the initial reshuffling of flows caused by the release of the LCD label. To work in a non-staggered difference-in-differences setting, we exclude funds that experienced an LCD upgrade or downgrade in August or November 2018 (although our results also hold when including them). As will be discussed, we study the fund flow effects of LCD upgrades and downgrades through September 2019 separately.

in other funds. After April 2018, low carbon funds start enjoying a persistent increase in flows, compared to other funds. In the US (Panel B), low carbon funds show lower flows than conventional funds in the pre-publication period, but again follow similar fluctuations. Here, too, the information shock triggered a relative boost of flows for LCD funds.

To formally test this perceived effect on flows, we run difference-in-differences regressions of fund i's flows in month t, from April 2017 through December 2018, of the following type:

$$Flows_{i,t} = \alpha + \beta_1\ LCD_i\ \times\ Post_t + \beta_2\ LCD_i + \gamma' \mathbf{X_{i,t-1}} + \delta_{\mathbf{i,t}} + \eta_i + \ \epsilon_{i,t}.$$

The main variable of interest is the interaction term $LCD \times Post$. LCD identifies funds that received the LCD label upon its initial release in April 2018, while $Post_t$ is an indicator variable equal to 1 for observations after that date.[17] $\mathbf{X_{i,t-1}}$ is a vector of time-varying lagged fund-level controls that, based on previous literature, may influence fund flows. These controls are: monthly returns in the previous three months, the logarithm of assets under management, return volatility, the fund's age, and changes in its generic sustainability rating (Globes) and in its overall financial performance rating (Stars).[18] $\delta_{\mathbf{i,t}}$

[17]Since no LCD label was available before April 2018, the interaction term $LCD \times Post$ may also be interpreted as a change indicator (ΔLCD) equal to 1 for funds classified as low carbon, and 0 otherwise.

[18]These results also hold when controlling for the absolute number of Globes and Stars. In our main specifications, we use the change in these ratings because, as also noted in Hartzmark and Sussman (2019), if these rating systems are in equilibrium – e.g., existing investors have already self-sorted into low and high sustainability funds – then there is no reason to expect a continued flow effect. The same reasoning applies to the LCD. Upon its initial release, looking at reactions to it means studying the effects of a change. However, researchers looking at the label's effects over the long run may want to consider changes in LCD status, as we do later in this section when we look at the effects of LCD upgrades and downgrades.

represents month-by-category fixed effects and η_i country-of-domicile fixed effects. $\epsilon_{i,t}$ is the error term. We double-cluster standard errors along months and categories to account for cross-sectional and cross-time dependence between observations.

Table 3 reports our results. In Column 1, the coefficient on the diff-in-diff interaction term of interest is positive and statistically significant. Assignment of the LCD label is associated with an average 0.36 percentage points higher net flows, compared to the pre-publication period. This effect is economically important when compared to the effect of returns (which has been the main focus of much of the mutual funds literature). A one standard deviation stronger performance in monthly returns yields $3.31 \times 0.16 = 0.53$ percentage points more flows. In other words, the LCD is worth around two-thirds ($0.36/0.53 = 68\%$) of a standard deviation in returns. When compounded over the period from May through December 2018, the LCD flow effect can be quantified as an increase of 2.9% in assets under management.[19]

- Table 3 -

In Column 2, we add to our regression the two scores used to allocate the LCD – the

[19]We thank the Editor for suggesting two non-exclusive interpretations of the low carbon fund flow effect. The first is that increased information about mutual funds' climate friendliness made pre-existing ethical investor preferences or norm-based constraints more salient and actionable, triggering a re-sorting of climate conscious investors into low carbon funds; as a result, the pool of investors in low carbon funds changed. The second is that the information shock caused a treatment not only of the fund but also of its investors. As a result, the same pool of clients became more likely to increase their stake in low carbon funds (and less likely to decrease it). Data on individual investor position changes would be required to discriminate between these two interpretations. As a first step, in analyses available on request, we observe that in the post-publication period, flows into low carbon funds became more sensitive to lagged positive returns and less sensitive to lagged negative returns (this second result is not statistically significant), consistent with the findings of Bollen (2007) on the behavior of socially responsible investors. Assuming that investor preferences remained the same, these results indicate that marginal climate-concerned investors re-sorted into low carbon funds.

Portfolio Carbon Risk Score (CR) and fossil fuel involvement (FFI) – and their interaction with *Post*. These two underlying criteria do not appear to have additional explanatory power when pooling all funds, while the interaction of LCD with Post remains virtually unchanged.

However, retail and institutional investors contribute differently to this overall effect on flows. In Table A5 in the Online Appendix, we replicate our main regression at the share-class level, allowing us to distinguish between institutional and retail share classes. In Column 1, we find that the LCD significantly affects flows for both share classes. Columns 2 and 4 provide a more nuanced picture of the behavior of these two types of investors. While retail clients only reacted to the LCD label (consistent with the extant literature on the importance of financial heuristics, e.g., Evans and Sun, 2021; Ben-David et al., 2022; Hartzmark and Sussman, 2019), institutional investors reacted to the underlying carbon risk score, which represented a new source of information.[20] As expected, neither retail nor institutional clients responded to a fund's fossil fuel involvement, as it was not new information.

Returning to Table 3, in Column 3, we interact all our control variables with *Post* to allow for potential changes over time in the effects that other fund characteristics may have on flows. The coefficient of interest remains unchanged. To limit the potential effects of a fund's size in determining its monthly flows, we also re-run the above analyses using normalized

[20]The estimated extra retail flows of the LCD may partially reflect a marketing effort by individual funds or by Morningstar itself and should be viewed in this context. Still, it is unclear how clients react to such advertising, especially in light of the costs, in terms of sectoral diversification, that we emphasize.

flows as a dependent variable (Columns 4 through 6). The effect of the LCD label is again statistically and economically significant: Net of the effects of control variables, low carbon funds move up 1.99 percentiles in net flows, on average, after April 2018.

Our results are robust to several alternative specifications. Table A6 in the Online Appendix shows that the estimated effect of the LCD label remains almost unchanged when we weight observations by fund size. Table A7 shows the LCD's effect to be even higher (54 basis points extra monthly net flows) when we add fund fixed effects. In Table A8, we repeat our analyses using a "pseudo" LCD, computed by applying the two LCD criteria to the historical portfolio holdings *before* April 2018, and presuming this information was available to investors then. The resulting *LCD (pseudo)* indicator has no explanatory power on flows before May 2018, thus addressing two potential doubts. First, it excludes the suggestion that our results are due to low carbon funds having had a substantially different portfolio composition in the pre-publication period. Second, it confirms that the LCD represents new information, i.e., information that was not publicly available before the shock.

Finally, in Table A9 in the Online Appendix, we document the effect on flows of LCD status updates in an extended post-publication period through September 2019.[21] As Panel A shows, although the great majority of funds had their LCD status confirmed, every quarter a small fraction of funds did switch from LCD to not-LCD, or vice-versa. For each fund, we define the indicators *LCD Downgrade* and *LCD Upgrade*, equal to 1 for the months following

[21] Morningstar updates the LCD quarterly, with a one-month delay from the end of the quarter. The sample period through September 2019 covers five updates.

an LCD downgrade or upgrade, respectively. We find that LCD updates also significantly impact fund flows.

Overall, our results confirm the strong appeal of low carbon funds and investors' reluctance to invest in those parts of the economy most exposed to carbon risk.

4.2 Heterogeneity across funds and time

Inspired by our conceptual framework in Section 3, we investigate four sources of cross-sectional heterogeneity in investor responses.

First, we assume that before April 2018, mutual fund clients may have used Morningstar's sustainability Globes as a proxy for a fund's exposure to carbon risk. In other words, the effect of Globes on flows (Hartzmark and Sussman, 2019) may have been partially motivated by carbon risk considerations. Hence, we can expect the low carbon flow effect to be more pronounced among funds with a low Globes rating, given that for these low sustainability funds the LCD represents a more considerable information shock.[22] In line with this conjecture, in Column 1 of Table 4, we find that the effect of the LCD label on flows is significantly higher among funds with lower Globes ratings.

- Table 4 -

Second, we expect the low carbon flow effect to be more pronounced among funds with

[22]In principle, a "brown" label assigned to a high-sustainability fund (with 4 or 5 Globes) should also matter greatly to investors. However, there is no such label in our setting: Funds either receive the LCD or do not. We can therefore expect investors to react more to the LCD when they expected it less.

higher risk-adjusted financial performance, for the following reasons. At the margin, investors should attempt to strike a balance between the risk benefits of portfolio diversification and those of low carbon investing. Of two otherwise-equal LCD-labeled funds, investors should prefer the one with higher perceived risk-adjusted returns. We employ the Morningstar Stars rating as a proxy for a fund's risk-adjusted financial performance, as perceived by investors (Del Guercio and Tkac, 2008; Evans and Sun, 2021; Chen, Cohen, and Gurun, 2021; Ben-David et al., 2022). Morningstar assigns 1 to 5 Stars based on a quantitative assessment of past returns and volatility (with a look-back horizon from 3 to 10 years, depending on the fund's age), without any specific considerations related to climate risks. Column 2 in Table 4 shows that, as expected, low carbon funds with higher Stars ratings experienced a significantly higher fund flow effect than those with lower Stars ratings.[23]

Third, although we do not have detailed data at the investor level, marginal investors do reveal preferences for funds with certain characteristics, i.e., growth or value assets, with arguably more short-horizon investors self-selecting into value-oriented funds (Cronqvist, Siegel, and Yu, 2015; Betermier, Calvet, and Sodini, 2017). We expect the LCD label to have a stronger effect on funds whose marginal investors are growth-oriented. In line with this conjecture, in Column 3 of Table 4, we find the low carbon flow effect to equal a premium that is significantly higher for funds with higher loading on the growth factor, which we use

[23]Results available on request confirm that similar inferences regarding the heterogeneity of the LCD fund flow effect hold when splitting the sample into funds with low (1 or 2), medium (3), and high (4 or 5) Globes or Stars ratings.

as a proxy for the growth orientation of the investor base.[24]

Finally, we examine the variation in the low carbon flow effect over time. Investors should be particularly eager to invest in low carbon funds in periods of high salience of climate risks. To test this prediction, in Column 4, we use the expanded post-publication period of April 2018 through September 2019. Then, following the approach employed in Ilhan, Sautner, and Vilkov (2021) and Choi, Gao, and Jiang (2020), we interact *LCD* with *Post* and the standardized monthly global Google Trends search value index (SVI) for the topic "climate change." After the publication of the LCD (but not before), low carbon funds enjoy even higher additional flows in months of greater attention to climate change.[25] As expected, the perceived benefits of low carbon funds vary with the varying perception of climate risks.

[24]We compute the fund loading on the growth factor (equal to minus the loading on the traditional value factor) by regressing monthly returns, from December 2016 through April 2018, on the Fama-French global factors retrieved from Kenneth French's website. Similar results also hold when we proxy a fund's growth orientation by the mean market-to-book ratio of its individual equity holdings as of April 2018, or when we employ the Morningstar Value-Growth score, which underlies the widely used Morningstar Style Box. In this last case, we include only month fixed effects, instead of date-by-category fixed effects, since categories are also determined based on the Value-Growth score.

[25]During our sample period, the public debate around climate change was significantly influenced by rising climate activism in society, especially by young people. Two events were particularly relevant: the surprising success of the first "global climate strike" on March 15, 2019 (which, according to the Fridays for Future movement, saw the participation of around 1.4 million people, mostly in Europe), and the series of international climate strikes held in September 2019 under the name "Global Week for Future" (between 6 and 7.6 million attendees globally). These two events likely influenced investors' attitudes toward climate risks (Ramelli, Ossola, and Rancan, 2021). In analyses available on request, we confirm that, as expected, low carbon funds received extra flows in March 2019 (only in Europe, where the first global climate strike had the most success) and September 2019.

5 Mutual fund responses

This section investigates the reaction of mutual funds to the release of Morningstar's portfolio and firm-level carbon risk information. When climate risk information is available, a fund's optimal portfolio should tilt more toward low carbon assets than in a benchmark case with no available information. Assuming that fund managers act in the interest of their clients, we expect them to have reacted to the shock by reducing their fund exposures to carbon risk, while maintaining an adequate level of diversification.

5.1 Main results

Figure 6 shows the cumulative average monthly position changes in high carbon risk firms (i.e., *High CR (firm)* equal to 1) from April 2017 through September 2019, after controlling for lagged firm-level stock returns, industry, and fund category.[26] In the pre-publication period (April 2017 to April 2018), mutual funds' average position changes in high CR firms remained stable overall at around 0. After April 2018, the funds appear to have systemically reduced their stakes in high CR firms. Figure A3 in the Online Appendix shows a similar absence of pre-trends when we conduct the same analysis with respect to fossil fuel involvement. This figure also suggests that the funds reduced their exposure to fossil fuel involvement, albeit less decisively.

– Figure 6 –

[26] All our results also hold when using a shorter sample period, from April 2017 through December 2018.

To formally test the significance of these fund reactions, we run the following regression of each fund f's position change of firm i in month t:

$$Position\ change_{i,f,t} = \alpha + \beta_1 High\ CR\ (firm)_i \times Post_t + \beta_2 Low\ CR\ (firm)_i \times Post_t +$$

$$\beta_3 High\ CR\ (firm)_i + \beta_4 Low\ CR\ (firm)_i + \gamma' \mathbf{X_{f,t-1}} + \delta' \mathbf{Y_{i,t-1}} + \mu_{\mathbf{i,t}} + \epsilon_{i,f,t}.$$

The main coefficients of interest are the coefficients on the interaction terms $High\ CR_i \times Post_t$ and $Low\ CR_i \times Post_t$, where $Post_t$ is an indicator variable equal to 1 for months following April 2018. $\mathbf{X_{f,t-1}}$ includes these lagged fund-level controls: the logarithm of total buys and sells during a month, monthly fund flows, and the fund's churn rate (Gaspar, Massa, and Matos, 2005). $\mathbf{Y_{i,t-1}}$ includes these lagged firm-level controls: the firm's past returns and its weighting in the fund's portfolio. $\mu_{\mathbf{i,t}}$ includes month-by-category and country fixed effects. $\epsilon_{i,f,t}$ is the error term. Standard errors are clustered along both months and funds to account for cross-sectional dependence between observations.

Table 5 reports our results. In Column 1, the interaction term between *High CR* and *Post* is negative and highly statistically significant. It indicates that after April 2018, mutual funds reduced their exposure to the average high CR firm by 0.17 basis points of their assets under management per month. This effect is economically meaningful, considering that the median position change is zero and the median non-zero position change is 2.8 basis points. For the average fund with assets under management of USD 1,700 million, this reduction corresponds to around USD 28,900 worth of stock in the average high CR firm every month.[27]

[27] $(0.17/10^{-4}) \times$ USD 1,700 $\times\ 10^6 =$ USD 28,900

The coefficient of interest remains virtually unchanged when we interact all controls with *Post* (Column 2).

– Table 5 –

These findings are consistent with the new information about carbon risk driving fund managers' trading decisions. An alternative interpretation is that fund managers attempted to strategically meet the low carbon criteria to obtain the LCD label. Two additional tests support the important role of information.

First, consider the role of fossil fuel involvement (FFI), information that was effectively known before the shock but still important as one of the two criteria for the LCD label. Initially, Columns 3 and 4 in Table 5 appear to show a similar trading pattern for firm-level FFI as for carbon risk.[28] After April 2018, fund managers shifted about 0.13 basis points of their portfolios away from the average firm with fossil fuel involvement. However, when we simultaneously account for the interaction effects of both *CR* and *FFI* (see Columns 5 and 6), the role of firm-level FFI is significantly reduced and no longer statistically significant. In other words, fund managers did not sell holdings solely because they were fossil fuel involved. If strategic responses were the exclusive drivers, a firm's fossil fuel involvement would have explained the funds' position changes even net of the effect of carbon risk, despite not bringing fund managers significant new information.

[28]We start, in Column 3, without industry fixed effects because FFI strongly varies by industry. When we include industry fixed effects in Column 4, the estimated coefficient on FFI increases slightly, but our coefficient of interest on the interaction term $FFI \times Post$ remains unchanged.

Second, we find that funds with high portfolio carbon risk, that is, funds unlikely to easily qualify for the LCD, also reduced high-CR positions after April 2018. Specifically, when focusing on the sub-sample of funds with a Portfolio Carbon Risk Score above 11, the estimated coefficient on the interaction term *High CR (firm)* $\times$ *Post* is -0.37 ($p < 0.001$). Obviously, this does not exclude that some funds close to the threshold may have responded strategically to obtain the label.[29] Overall, the results point to the important role of carbon risk metrics' informational content in steering portfolio managers' trading decisions.

Our findings are robust to several alternative specifications. Table A10 in the Online Appendix confirms that our main findings on fund managers' reactions are not driven by unobserved heterogeneity at the fund or firm level. Specifically, including firm and fund fixed effects does not alter our results. As shown in the same table, our results also hold when including time-varying firm characteristics, such as firm size, book-to-market ratio, leverage, and return on assets. Analyses available on request confirm that when we carry forward firms' carbon risk metrics as they were in 2017, that is, before the metrics were publicly available, our results remain unchanged. This rules out that the results are due to firm-level changes in climate risk, i.e., fewer firms being classified as high carbon risk over time. Further analyses available on request show that adding country-by-month or

[29]In analyses available on request, we focus on the sub-sample of these close-to-the-threshold funds, i.e., those with portfolio carbon risk between 9 and 11. Within this group, it was those with portfolio fossil fuel involvement already below the LCD threshold that reduced carbon risk the most, consistent with an attempt to obtain the label. However, different from what one would expect under the strategic response interpretation, among funds close to the fossil fuel involvement threshold, we find no evidence that funds reduce FFI more strongly if they already met the carbon risk criterion for obtaining the LCD.

sector-by-month fixed effects also does not affect our inference. The results are also robust to additionally clustering the standard errors at the firm level.

Overall, the above findings are consistent with the insight that the optimal portfolio, when accounting for carbon risks, is less tilted toward high carbon assets than in the benchmark case with no climate risk information. After a shock in the availability of information on carbon risk, fund managers re-balanced their portfolios in a lower carbon direction.

5.2 Heterogeneity across funds and portfolio holdings

To shed more light on how managers reacted, we first test the relationship between portfolio changes and fund flows. Flows (either positive or negative) force managers to make active trading decisions and offer opportunities for portfolio rebalancing. In Columns 1-3 of Table 6, we split the sample into funds with low, medium, or high flows in the previous month. The average (median) flows in the three groups are -1.05 (-0.90), -0.07 (-0.17), and 1.38 (0.93), respectively. We find that funds experiencing large negative net flows sold high carbon assets more aggressively than did other funds (Column 1), while funds experiencing high inflows increased their stake in low carbon assets (Column 3). Notably, even managers of funds with average flows, facing no particular selling or buying pressure, increased their positions in low carbon assets while reducing their exposure to high carbon ones (Column 2).

– Table 6 –

Next, we test the key insight of our conceptual framework that, in shifting toward lower

carbon assets, fund managers should be particularly mindful of diversification goals. Two aspects of heterogeneity speak to this issue.

First, we consider the role of a fund's ex-ante sectoral diversification. For a fully diversified fund, moving away from high carbon firms necessarily means giving up some of its diversification. By contrast, ex-ante industry-concentrated funds can reduce their carbon risk while keeping their diversification unchanged, or even increasing it. In addition, based on revealed preferences, ex-ante industry-concentrated funds are more likely to serve clients who are less interested in broad diversification.[30] For these reasons, we expect funds with a higher industry concentration to tilt away from high carbon firms more aggressively than do highly sectoral diversified funds. The results in Columns 4-6 of Table 6 confirm this intuition: Funds with the highest level of industry concentration reduced their position in high carbon risk firms more than did other funds.

Second, we investigate the heterogeneity of our results across individual portfolio holdings. Fund managers should prefer to divest from high carbon assets that offer lower diversification benefits. In other words, when reshuffling their portfolios in a lower carbon direction, fund managers should sell more high-CR assets with a more positive return covariance with the rest of the portfolio. To test this prediction, for each fund-firm combination, we estimate the measure *FirmFundBeta* as the coefficient obtained when regressing individual firms' stock returns on each fund's returns over an estimation period from December 2016

[30]We thank the anonymous referee for suggesting this alternative interpretation.

through April 2018.

– Table 7 –

Table 7 reports the results of regressions of monthly position changes on the interaction between *Post* and *FirmFundBeta* for three sub-samples of individual holdings: low, medium, and high carbon risk. We observe that, among holdings with medium or high carbon risk (Columns 2 and 3), in the post-publication period, fund managers divested more aggressively from those assets which had a higher covariance with their portfolio, that is, with a higher *FirmFundBeta*. By contrast, as expected, we do not observe any differential behavior of fund managers based on *FirmFundBeta* for firms with low levels of carbon risk.

Taken together, these cross-sectional tests indicate that not every fund has the same incentive to reduce their exposure to high carbon assets, and not every high carbon asset is the same in the eyes of fund managers. Our results confirm that, when reacting to climate risks, fund managers take into account the trade-off between minimizing their exposure to those risks and maximizing their opportunities to diversify.

6 Conclusion

What are the implications of climate risks for portfolio investing and management? We provide conceptual and empirical evidence of the fundamental trade-off investors face between minimizing their exposure to carbon risk, i.e., the class of climate risk deriving from the

transition to a lower carbon economy, and maximizing their diversification opportunities in our not-yet-low carbon world.

Studying the behavior of market participants confronted with such a trade-off is crucial to better understand the role of financial markets in the energy transition. Using a large sample of European and US mutual funds, we analyze the reactions of investors and fund managers to the April 2018 release of Morningstar's carbon risk metrics, which produced a shock to the availability of climate risk information in the mutual fund industry.

Funds newly labeled by Morningstar as "low carbon" enjoyed a substantial flow increase, relative to otherwise similar funds. This flow effect was more pronounced among funds with higher risk-adjusted returns, consistent with the idea that marginal investors struck a balance between climate risks and conventional ones. The effect was also higher for funds with arguably longer-horizon investors and during periods of high salience of climate risks.

Fund managers also reacted to the new information. After April 2018, fund managers actively reduced their positions in high carbon risk firms. This low carbon shift was more pronounced for funds with less to lose in portfolio diversification. Moreover, among high carbon firms, fund managers sold more aggressively those securities which had a higher return covariance with their portfolio, that is, those less useful for diversification purposes.

Overall, our results confirm climate risks to be a key consideration in the mutual fund industry and provide new insights into how climate-related information can re-orient capital flows in a low carbon direction. By highlighting the existing tension – at least in the short

run – between the management of climate risks and traditional mean-variance portfolio considerations, we hope to stimulate further research into the behavior of investors and fund managers during the transition to a low carbon economy.

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Figures

Figure 1: Morningstar Direct snapshot

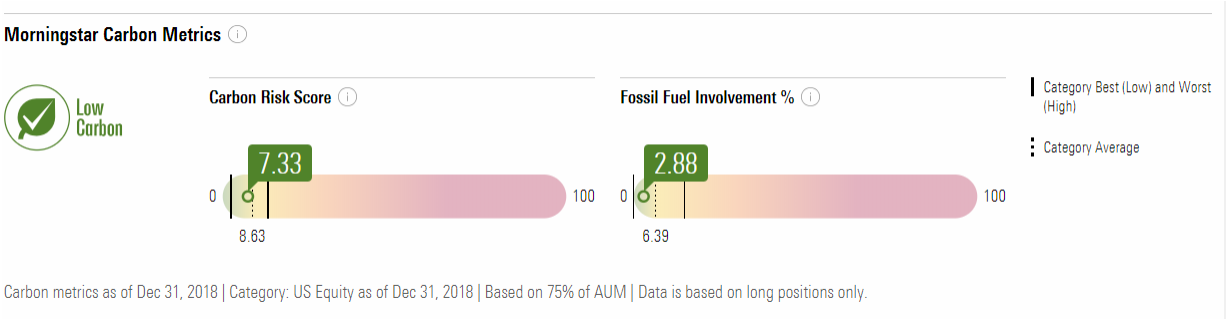


Figure 2: Low carbon firms are less risky
These graphs show binned scatter plots of firm-level *Loading on negative climate news (firm)* and stock volatility, against firm-level carbon risk scores from Sustainalytics. Both graphs' plots employ 25 equal-sized bins (the maximum allowed, given the distribution of the x-axis variable). The sample includes 2,499 international firms for which Sustainalytics carbon metrics and stock prices from Compustat IQ are available. *Negative climate news beta (firm)* is the coefficient on the standardized negative news-based climate risk index used in Engle et al. (2020) when regressing, for each stock with at least 12 monthly observations, the monthly returns from January 2015 through April 2018 on that index and on the three Fama-French global factors. *Volatility (firm)* is the standard deviation of monthly returns over the same period.

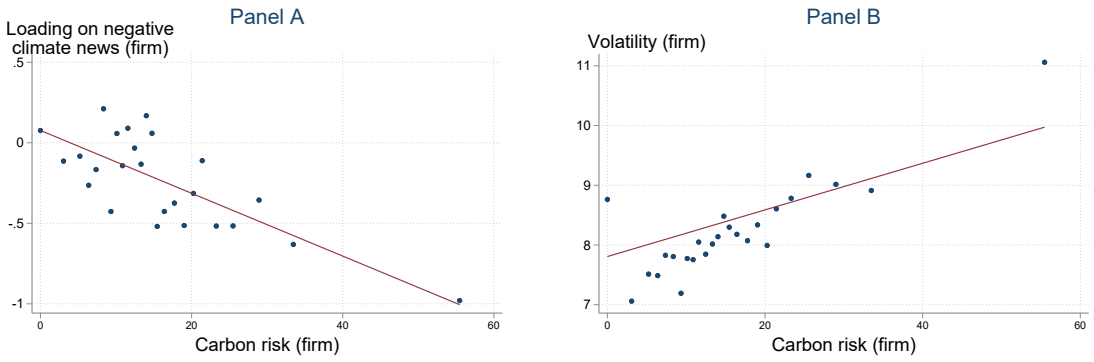


Figure 3: The trade-off of low carbon funds

These graphs show binned scatter plots of fund-level *Average volatility (firm)* (Panel A), *Volatility (fund)* (Panel B), *Normalized portfolio volatility* (Panel C), and *Industry concentration index* (Panel D), all against fund-level 12-month-average Portfolio Carbon Risk Scores. All graphs employ 30 equal-sized bins. The sample includes 6,310 US and European funds with available carbon risk scores, fund flows, and individual portfolio holdings data as of April 2018. All graphs control for fund size and category fixed effects. The solid vertical lines indicate the carbon risk score threshold for a fund to be labeled "low carbon" by Morningstar. *Average volatility (firm)* is the asset-weighted average volatility of a fund's individual equity holdings. *Volatility (fund)* is the standard deviation of portfolio monthly returns from December 2016 through April 2018, with at least 12 available observations. *Normalized portfolio volatility* is the ratio of the portfolio volatility over the asset-weighted average volatility of individual equity holdings. *Industry concentration index* is the sum of the squared deviation of a fund's GICS group industry weights, relative to the global equity market portfolio.

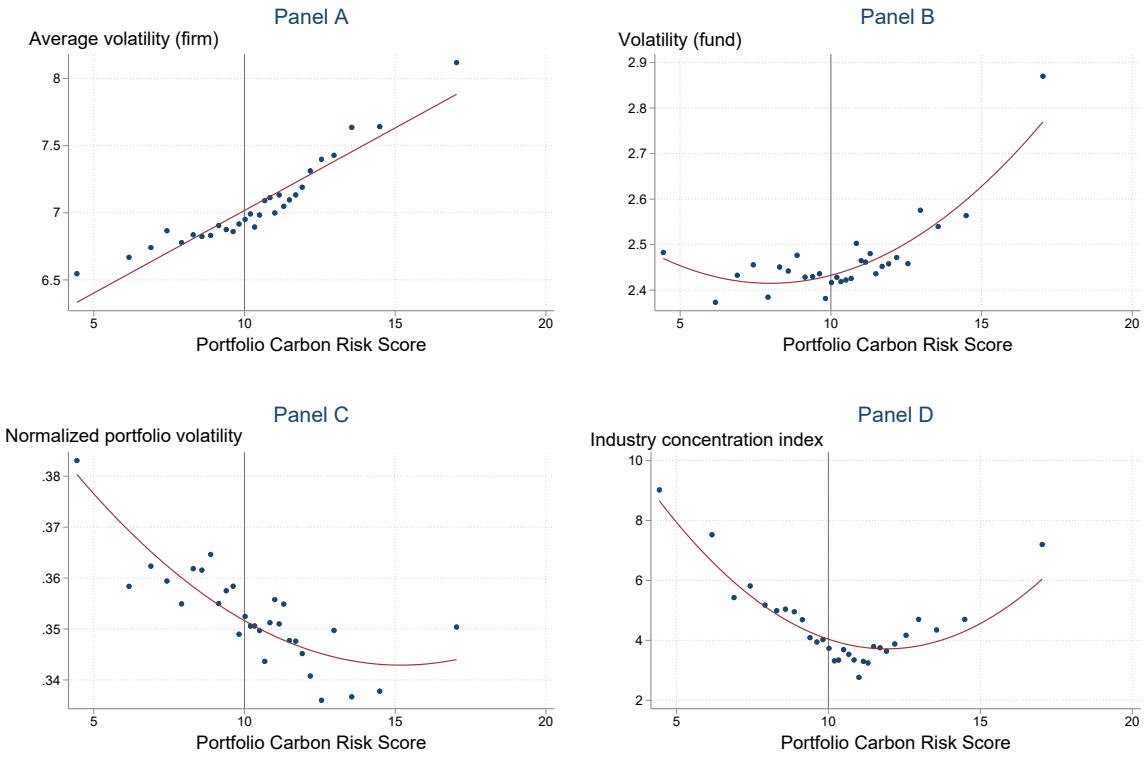


Figure 4: Industry exposures of low carbon funds
This figure shows the average asset-weighted exposures to GICS industry group firms of funds classified by Morningstar as low carbon and not low carbon. The exposures are based on the portfolios, as of April 2018, of 6,310 European and US mutual funds with available holdings and carbon risk data.

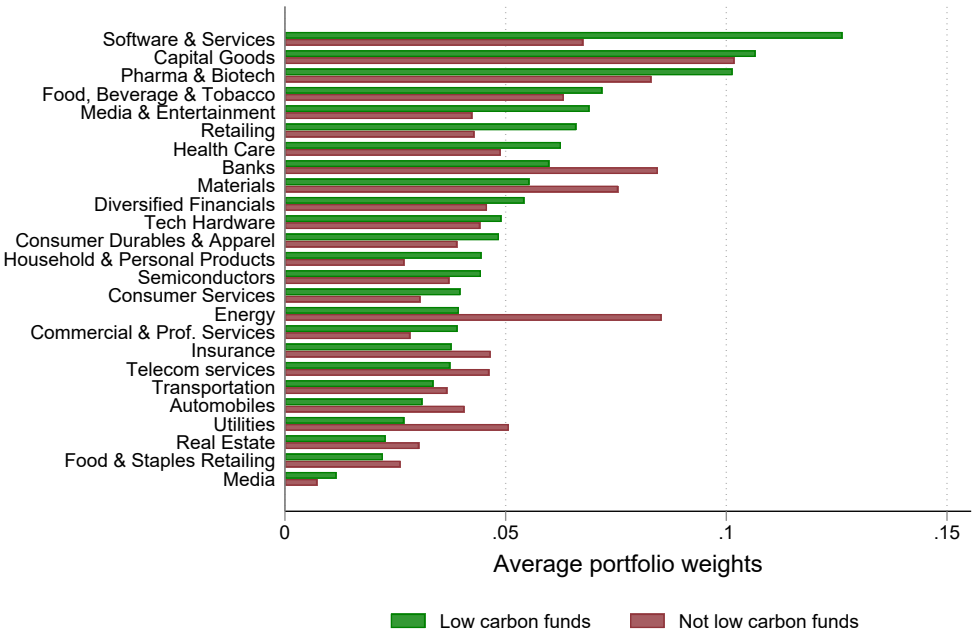


Figure 5: Evolution of flows into low carbon and not-low carbon funds
These graphs show the equally weighted average monthly net flows of funds designated low carbon at the end of April 2018 (solid green lines) and conventional funds (dashed red line) domiciled in Europe (Panel A) and the US (Panel B), from April 2017 through December 2018. Flows are computed as of the end of the month.

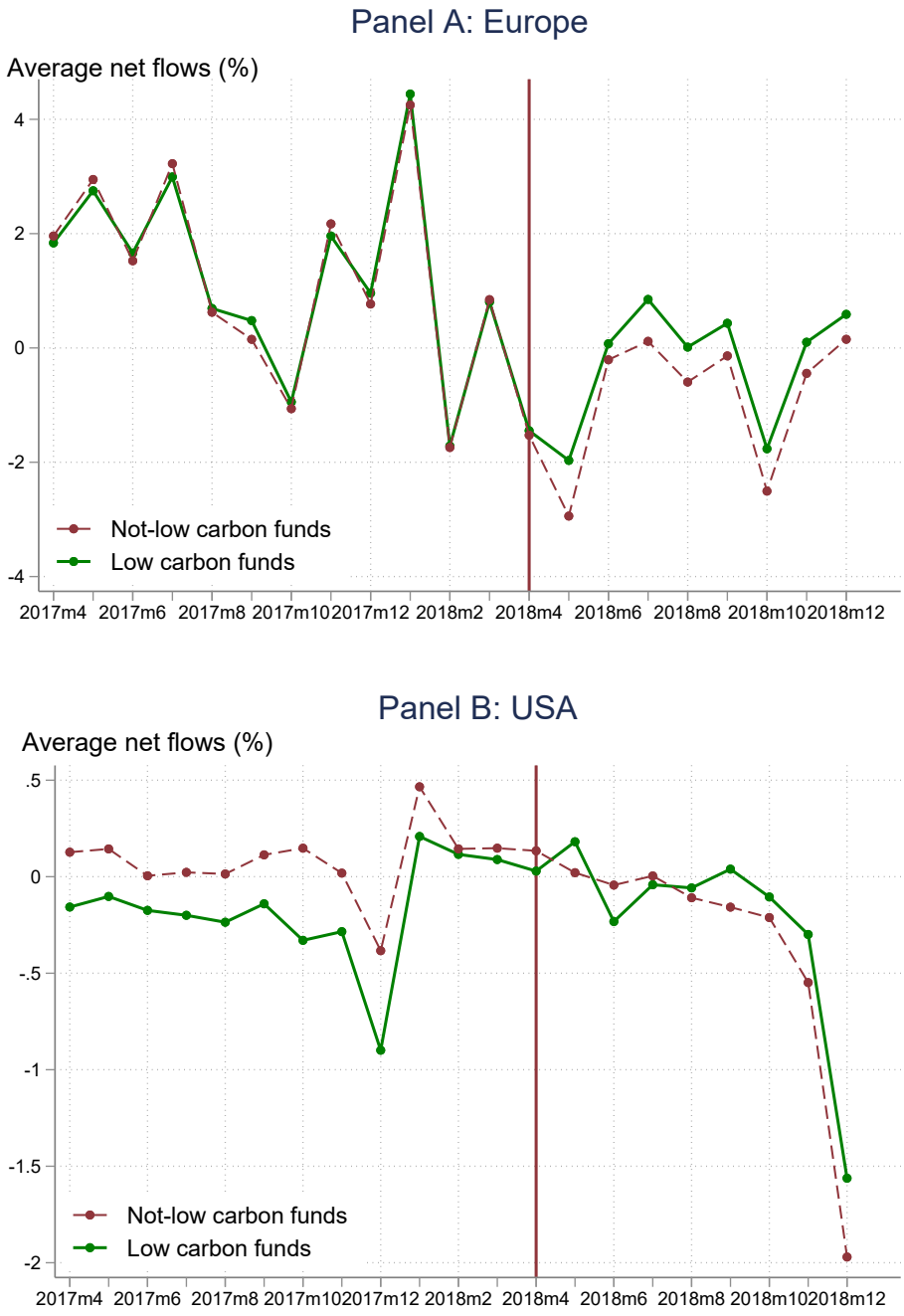
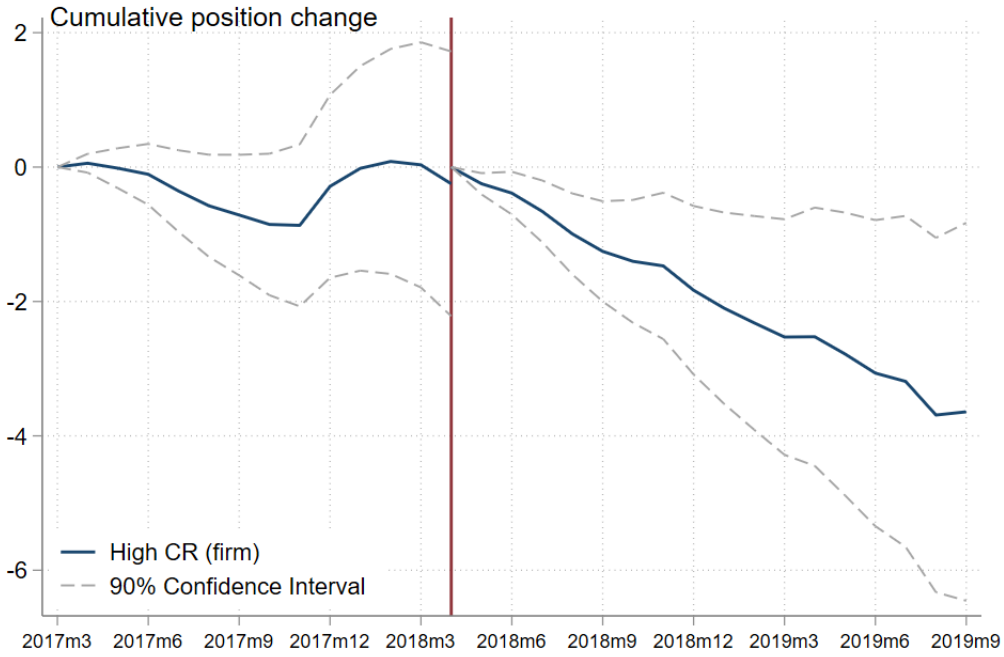


Figure 6: Effect of firm-level carbon risk on funds' position changes
This figure shows the cumulative effect of the firm-level indicator for high carbon risk on monthly firm-fund-level position changes from April 2017 through September 2019. The cumulation of the estimates and confidence intervals is re-set to zero after April 2018. The estimates are computed based on monthly cross-sectional regressions of position changes on *High CR (firm)*, an indicator equal to 1 for firms with carbon risk scores equal to or above 30, controlling for lagged stock return, industry, and fund category. The dashed lines indicate the 90% confidence interval, based on robust standard errors.



Tables

Table 1: Descriptive statistics

Descriptive statistics of active mutual funds domiciled in Europe and the US for which information on Morningstar's Low Carbon Designation (LCD) and flows is available. Panel A covers all fund-month observations from April 2017 through September 2019, while Panel B is a snapshot from the end of April 2018. Panel C covers all fund-firm-month observations from April 2017 through September 2019. *LCD* is an indicator equal to 1 for funds that obtained the LCD label at the end of April 2018. *CR* and *FFI* are Morningstar's Portfolio Carbon Risk and Fossil Fuel Involvement scores. *Flows* (in percentage points) is the monthly growth of assets, net of reinvested returns. *Normalized flows* are computed following Hartzmark and Sussman (2019). *Return* is the monthly net return. *Log assets* is the log of assets under management, in USD. *Volatility* is the standard deviation of returns in the previous 12 months. *Age* is the number of years since the inception of the oldest share class. *Globes* is the Morningstar sustainability rating, on a 1-5 scale. *Stars* is the Morningstar overall financial performance rating, on a 1-5 scale. Δ*Globes* and Δ*Stars* indicate if a fund received a downgrade (-1) or an upgrade (1) in the Morningstar Globes rating or Stars rating, respectively. *Position change* (in basis points) is the change in the number of shares held by fund f in stock i from month *t-1* to month t, valued at the price of month *t-1*, divided by assets under management in month *t-1*. *Low CR (firm)*, *Medium CR (firm)*, and *High CR (firm)* are indicators equal to 1 for firms with carbon risk scores between 0 and 9.99 (low), between 10 and 29.99 (medium), or above 29.99 (high), and 0 otherwise. *FFI (firm)* is an indicator equal to 1 for firms deriving a significant share of their revenues from fossil fuel related activities. *Churn rate* is a measure of how frequently fund managers rotate their positions on all the stocks in a portfolio. *Position weight* is the percentage of assets under management invested in a firm.

Panel A: Fund-level variables, from April 2017 through September 2019

	N	min	p25	mean	p50	p75	max	sd
LCD	379,086	0.00	0.00	0.18	0.00	0.00	1.00	0.39
CR	237,303	0.23	8.39	10.15	10.06	11.46	45.60	3.44
FFI	334,901	0.00	3.06	7.01	6.20	9.55	84.22	5.85
Flows	379,086	-19.53	-1.60	-0.03	-0.29	1.21	32.82	4.74
Normalized flows	379,086	1.00	27.00	49.38	49.00	72.00	100.00	27.24
Return	379,086	-90.60	-1.09	0.41	0.61	2.24	28.49	3.31
Log assets	379,086	13.82	16.82	18.40	18.35	19.86	26.02	2.06
Volatility	379,076	0.04	1.74	2.78	2.51	3.57	26.53	1.46
Age	379,086	1.00	6.26	14.01	12.65	18.89	119.32	10.12
Globes	275,778	1.00	2.00	3.05	3.00	4.00	5.00	1.13
Stars	237,315	1.00	2.00	3.15	3.00	4.00	5.00	1.06
ΔGlobes	379,086	-1.00	0.00	0.00	0.00	0.00	1.00	0.32
ΔStars	379,086	-1.00	0.00	-0.00	0.00	0.00	1.00	0.30

Panel B: Fund-level variables, snapshot at the end of April 2018

	N	min	p25	mean	p50	p75	max	sd
LCD	13,056	0.00	0.00	0.18	0.00	0.00	1.00	0.39
CR	8,997	0.23	9.03	10.70	10.62	11.94	45.58	3.47
FFI	13,013	0.00	2.95	6.70	5.92	9.08	70.99	5.53
Flows	13,056	-19.53	-2.24	-0.88	-1.60	-0.04	32.82	4.88
Normalized flows	13,056	1.00	26.00	48.80	47.00	71.00	100.00	27.44
Return	13,056	-9.79	0.47	2.04	1.82	3.45	13.91	2.11
Log assets	13,056	13.86	16.84	18.42	18.36	19.89	25.93	2.05
Volatility	13,056	0.12	1.73	2.24	2.30	2.72	8.65	0.80
Age	13,056	1.00	5.80	13.63	12.25	18.52	118.24	10.14
Globes	9,358	1.00	2.00	3.02	3.00	4.00	5.00	1.14
Stars	9,887	1.00	2.00	3.16	3.00	4.00	5.00	1.05

Panel C: Portfolio holdings

	N	min	p25	mean	p50	p75	max	sd
Position change	12,786,149	-82.51	0.00	-0.07	0.00	0.00	83.72	13.23
Position weight	12,398,436	0.00	0.06	0.78	0.33	1.11	46.20	1.10
CR (firm)	12,786,149	-0.00	1.35	11.05	9.06	15.64	81.09	11.37
High CR (firm)	12,786,149	0.00	0.00	0.06	0.00	0.00	1.00	0.24
Medium CR (firm)	12,786,149	0.00	0.00	0.40	0.00	1.00	1.00	0.49
Low CR (firm)	12,786,149	0.00	0.00	0.54	1.00	1.00	1.00	0.50
FFI (firm)	12,786,149	0.00	0.00	0.10	0.00	0.00	1.00	0.30
Return (firm)	12,500,884	-0.37	-0.04	0.01	0.01	0.05	1.00	0.08
Volatility (firm)	9,737,999	2.65	5.43	7.20	6.62	8.31	39.07	2.72
Total buys (USDmm)	101,728	0.00	0.70	25.95	4.45	20.72	634.74	61.39
Total sells (USDmm)	101,461	0.00	0.75	27.08	4.73	21.91	654.85	62.81
Churn rate	101,728	0.00	0.03	0.09	0.06	0.11	6.19	0.12

Table 2: Carbon risk and fund volatility

This table shows the results of OLS cross-sectional regressions of fund volatility on portfolio carbon risk (CR), controlling for fund size and category fixed effects. Column 2 includes the *Industry concentration index*, while Column 3 adds the number of holdings (in hundreds) in a fund's portfolio and Column 4 adds its quadratic term. The sample includes 6,310 US and European funds with available carbon risk scores, fund flows, and individual portfolio holdings data as of April 2018. t-statistics, based on robust standard errors, are reported in parentheses. ***, **, and * indicate that the parameter estimate significantly differs from zero at the 1%, 5%, and 10% level, respectively.

Dep. variable:	Fund volatility			
	(1)	(2)	(3)	(4)
1st quintile CR	0.05***	-0.01	-0.02	-0.03
	(2.64)	(-0.73)	(-1.19)	(-1.45)
2nd quintile CR	0.02	0.01	-0.00	-0.00
	(1.36)	(0.43)	(-0.01)	(-0.23)
4th quintile CR	0.05***	0.04**	0.04**	0.04**
	(2.75)	(2.33)	(2.30)	(2.18)
5th quintile CR	0.21***	0.18***	0.18***	0.17***
	(9.23)	(8.02)	(8.00)	(7.83)
Industry concentration index		0.02***	0.02***	0.02***
		(7.39)	(6.86)	(6.57)
Number of holdings			-0.01***	-0.02***
			(-7.13)	(-5.22)
Number of holdings^2				0.00**
				(2.26)
Log assets	-0.01***	-0.01***	-0.01**	-0.01**
	(-4.27)	(-3.26)	(-2.32)	(-2.02)
Observations	6,310	6,310	6,310	6,310
R-squared	0.30	0.31	0.32	0.32
Category FE	Yes	Yes	Yes	Yes
Constant & size	Yes	Yes	Yes	Yes

Table 3: The low carbon flow effect

This table shows the results of OLS difference-in-differences (DID) regressions of monthly flows (Columns 1-3) and normalized flows (Columns 4-6), from April 2017 through December 2018, on Low Carbon Designation (*LCD*) and the interaction of this variable with a dummy *Post*, equal to 1 for the months following April 2018. The models in Columns 2 and 5 also include the portfolio carbon risk (*CR*) and fossil fuel involvement (*FFI*) scores and their interactions with *Post*. The models in Columns 3 and 6 include the interaction of all control variables with *Post*. The sample includes active equity and balanced mutual funds domiciled in Europe or the US, excluding funds that experienced an LCD upgrade or downgrade in August or November 2018. The regressions control for lagged fund characteristics and for month-by-category and country fixed effects. t-statistics, based on robust standard errors clustered at the category and month level, are reported in parentheses. ***, **, and * indicate that the parameter estimate significantly differs from zero at the 1%, 5%, and 10% level, respectively.

Dep. variable:	Flows			Normalized flows		
	(1)	(2)	(3)	(4)	(5)	(6)
LCD × Post	0.36***	0.30**	0.36***	2.67***	2.48***	2.76***
	(4.52)	(2.45)	(3.11)	(3.62)	(3.39)	(2.93)
LCD	0.07	-0.11	0.07	0.66	-1.07*	0.64
	(0.67)	(-1.24)	(0.65)	(0.84)	(-1.89)	(0.80)
CR × Post		-0.02			0.08	
		(-0.52)			(0.36)	
FFI × Post		0.01			-0.01	
		(0.88)			(-0.15)	
Return	0.16***	0.12***	0.19***	1.02**	0.82*	1.17**
	(4.19)	(2.99)	(3.80)	(2.71)	(1.96)	(2.12)
Return t-2	0.14***	0.11***	0.13**	0.98***	0.80**	0.66
	(4.74)	(3.06)	(2.70)	(3.39)	(2.26)	(1.44)
Return t-3	0.16***	0.13**	0.22***	1.26***	1.12**	1.76***
	(3.86)	(2.85)	(3.68)	(3.15)	(2.49)	(3.09)
Log assets	-0.03	-0.04*	-0.07**	0.80**	0.72*	0.92**
	(-1.55)	(-1.81)	(-2.76)	(2.32)	(2.01)	(2.44)
Volatility	0.08	0.14	-0.02	0.56	1.08*	-0.24
	(1.16)	(1.55)	(-0.23)	(0.94)	(1.80)	(-0.40)
Age	-0.04***	-0.03***	-0.04***	-0.35***	-0.32***	-0.37***
	(-6.09)	(-5.45)	(-6.86)	(-8.09)	(-8.04)	(-9.02)
ΔGlobes	0.02	0.03	-0.03*	0.17	0.18	0.00
	(0.66)	(0.97)	(-2.00)	(1.24)	(1.02)	(0.02)
ΔStars	0.08*	0.06	0.08	0.27	0.08	0.35
	(2.00)	(1.61)	(1.39)	(1.00)	(0.49)	(1.01)
CR		-0.02			-0.22	
		(-0.85)			(-1.42)	
FFI		-0.03***			-0.20***	
		(-2.98)			(-3.32)	
Observations	252,060	163,218	252,060	252,060	163,218	252,060
R-squared	0.13	0.12	0.13	0.13	0.13	0.13
Month-category FE	Yes	Yes	Yes	Yes	Yes	Yes
Country FE	Yes	Yes	Yes	Yes	Yes	Yes
Month-category clustered SE	Yes	Yes	Yes	Yes	Yes	Yes
All controls × Post	No	No	Yes	No	No	Yes

Table 4: Heterogeneity of the low carbon flow effect

This table shows the results of OLS regressions of monthly flows from April 2017 through December 2018, exploring the differential effect on funds of Morningstar's LCD label alongside its Globes rating (Column 1), its Stars rating (Column 2), and a fund's standardized loading on the growth factor (Column 3). *Loading on growth* is equal to minus the estimated coefficient on the high-minus-low value factor when regressing, for each fund, the monthly returns from December 2016 through April 2018 on the Fama-French three global factors, standardized to have mean 0 and unit standard deviation. Column 4 shows the results of OLS regressions of monthly flows from April 2017 through September 2019 on *LCD* and its interaction with *Post* and *SVI Climate change*. *SVI Climate change* is the Google Trends global search value index for the topic "climate change," over the periods from April 2017 through April 2018 (pre-publication) and from May 2018 through September 2019 (post-publication), standardized to have a mean 0 and unit standard deviation. The regressions include control variables (returns in the previous three months, volatility, log assets, age, and changes in Globes and Stars ratings) and the double interactions and direct effects involved in the triple interaction of interest, as well as month-by-category and country fixed effects. t-statistics, based on robust standard errors clustered at the category and month level, are reported in parentheses. ***, **, and * indicate that the parameter estimate significantly differs from zero at the 1%, 5%, and 10% level, respectively.

	(1)	(2)	(3)	(4)
Dep. variable:		Flows		
LCD × Post × Globes	-0.15***			
	(-2.45)			
LCD × Post × Stars		0.21***		
		(4.11)		
LCD × Post × Loading on growth			0.21**	
			(2.83)	
LCD × Post × SVI Climate change				0.25*
				(1.92)
Observations	180,020	139,591	250,645	376,030
R-squared	0.11	0.12	0.13	0.12
Month-category FE	Yes	Yes	Yes	Yes
Country FE	Yes	Yes	Yes	Yes
Month-category clustered SE	Yes	Yes	Yes	Yes

Table 5: Mutual funds' active responses to carbon risk

This table shows the results of OLS regressions of monthly position changes on indicators for firms' carbon risk (Columns 1 and 2), fossil fuel involvement (Columns 3 and 4), and both (Columns 5 and 6), from April 2017 through September 2019, interacted with the dummy *Post*, equal to 1 for months following April 2018. *High CR (firm)* is an indicator equal to 1 for firms with a carbon risk score of 30 or higher, while *Low CR (firm)* is an indicator equal to 1 for firms with a carbon risk score below 10. The remaining, medium carbon risk firms are the benchmark. The sample includes active equity and balanced mutual funds domiciled in Europe or the US. The regressions control for lagged firm and fund characteristics, and month-by-category, country, and industry fixed effects. t-statistics, based on robust standard errors clustered at the month and fund level, are reported in parentheses. ***, **, and * indicate that the parameter estimate significantly differs from zero at the 1%, 5%, and 10% level, respectively.

Dep. variable:	Position change					
	(1)	(2)	(3)	(4)	(5)	(6)
High CR (firm) × Post	-0.17***	-0.17***			-0.19***	-0.12*
	(-3.07)	(-2.90)			(-2.78)	(-1.81)
Low CR (firm) × Post	0.03	0.03			0.01	0.03
	(0.83)	(0.80)			(0.17)	(0.62)
High CR (firm)	0.09	0.08			0.15**	0.06
	(1.55)	(1.51)			(2.65)	(0.84)
Low CR (firm)	0.03	0.03			0.06*	0.04
	(0.89)	(1.08)			(1.93)	(1.21)
FFI (firm) × Post			-0.13**	-0.13**	-0.05	-0.08
			(-2.06)	(-2.18)	(-0.71)	(-1.06)
FFI (firm)			0.13***	0.19***	0.12*	0.18***
			(2.99)	(4.07)	(1.87)	(3.21)
Observations	10,883,324	10,883,324	11,234,222	10,990,912	11,125,818	10,883,324
R-squared	0.04	0.04	0.04	0.04	0.04	0.04
Controls	Yes	Yes	Yes	Yes	Yes	Yes
All controls × Post	No	Yes	No	No	No	No
Month-category FE	Yes	Yes	Yes	Yes	Yes	Yes
Country FE	Yes	Yes	Yes	Yes	Yes	Yes
Industry FE	Yes	Yes	No	Yes	No	Yes
Month-fund clustered SE	Yes	Yes	Yes	Yes	Yes	Yes

Table 6: Fund-level heterogeneity of mutual funds' reactions to carbon risk
This table shows the results of OLS regressions of monthly position changes on indicators for firms' carbon risk, from April 2017 through September 2019, interacted with the indicator *Post*, equal to 1 for months following April 2018. *High CR (firm)* is an indicator equal to 1 for firms with a carbon risk score of 30 or higher, while *Low CR (firm)* is an indicator equal to 1 for firms with a carbon risk score below 10. The first three columns show sample splits along the funds' net flows in the previous month. The last three columns show splits along the funds' *Industry concentration index*, relative to other funds in the same category. The sample includes active equity and diversified mutual funds domiciled in Europe or the US. The regressions control for lagged firm and fund characteristics, and month-by-category, country, and industry fixed effects. t-statistics, based on robust standard errors clustered at the fund and time level, are reported in parentheses. ***, **, and * indicate that the parameter estimate significantly differs from zero at the 1%, 5%, and 10% level, respectively.

Dep. variable:	Position change					
	Flows			Industry concentration index		
	Bottom 33%	Middle	Top 33%	Bottom 33%	Middle	Top 33%
	(1)	(2)	(3)	(4)	(5)	(6)
High CR (firm) × Post	-0.32***	-0.07	-0.09	-0.02	-0.21*	-0.60***
	(-3.46)	(-1.09)	(-1.49)	(-0.36)	(-1.96)	(-3.14)
Low CR (firm) × Post	0.04	0.12***	0.13**	-0.01	0.05	0.24**
	(0.64)	(2.93)	(2.48)	(-0.28)	(0.72)	(2.13)
High CR (firm)	0.25***	0.04	-0.03	0.08	0.01	0.21
	(3.73)	(0.60)	(-0.32)	(1.37)	(0.15)	(1.44)
Low CR (firm)	-0.05	-0.04	0.06	0.10***	0.05	-0.11
	(-0.98)	(-1.27)	(1.23)	(4.26)	(0.93)	(-1.33)
Observations	3,612,043	3,468,237	3,264,834	6,721,595	2,793,794	1,622,697
R-squared	0.05	0.03	0.05	0.04	0.05	0.09
Controls	Yes	Yes	Yes	Yes	Yes	Yes
Month-category FE	Yes	Yes	Yes	Yes	Yes	Yes
Country FE	Yes	Yes	Yes	Yes	Yes	Yes
Industry FE	Yes	Yes	Yes	Yes	Yes	Yes
Month-fund clustered SE	Yes	Yes	Yes	Yes	Yes	Yes

Table 7: Firm-level heterogeneity of mutual funds' reactions to carbon risk
This table shows the results of OLS regressions of monthly position changes on a dummy *Post*, equal to 1 for months following April 2018 interacted with *FirmFundBeta*, a measure of the covariance between the return of a fund's portfolio and that of an individual holding. Specifically, *FirmFundBeta* is the coefficient obtained when regressing individual stock returns on each fund's returns over an estimation period from December 2016 through April 2018. Column 1 covers low carbon risk firms, i.e., those with a carbon risk score below 10. Column 2 covers medium carbon risk firms (CR between 10 and 30), while column 3 covers high carbon risk firms (CR of 30 or higher). The sample includes active equity and diversified mutual funds domiciled in Europe or the US. The regressions control for lagged firm and fund characteristics, and month-by-category, country, and industry fixed effects. t-statistics, based on robust standard errors clustered at the fund and time level, are reported in parentheses. ***, **, and * indicate that the parameter estimate significantly differs from zero at the 1%, 5%, and 10% level, respectively.

Dep. variable:	Position change		
	Low CR	Med CR	High CR
	(1)	(2)	(3)
Post × FirmFundBeta	0.01	-0.07***	-0.08*
	(0.23)	(-3.02)	(-2.01)
FirmFundBeta	0.03	0.05***	0.00
	(1.31)	(2.83)	(0.09)
Observations	5,690,891	4,170,704	646,158
R-squared	0.05	0.04	0.04
Controls	Yes	Yes	Yes
Month-category FE	Yes	Yes	Yes
Country FE	Yes	Yes	Yes
Industry FE	Yes	Yes	Yes
Month-fund clustered SE	Yes	Yes	Yes

Online Appendix

Figure A1: Geographical and factor exposures of low carbon funds
Panel A shows the average asset-weighted exposures to firms in different geographical areas of low carbon and not-low carbon funds. Panel B shows the average asset-weighted firm-level Fama-French factor loadings. Both graphs are based on the portfolios as of April 2018 of around 7,392 European and US mutual funds with available holdings data.

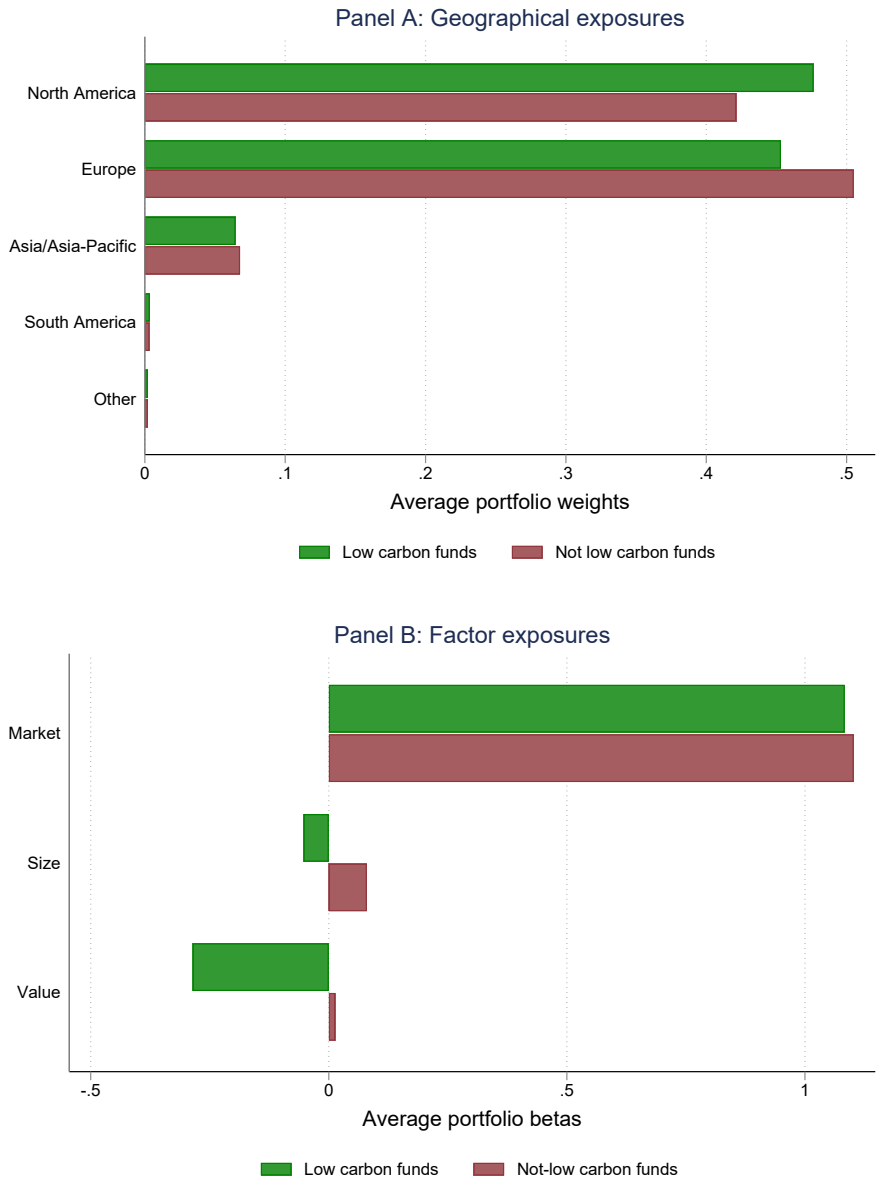


Figure A2: Low carbon funds and negative climate news

These graphs show binned scatter plots of fund-level *Loading on negative climate news (fund)* against portfolio-level carbon risk (Panel A) and fossil fuel involvement (Panel B). Both graphs employ 30 equal-sized bins. The sample includes 6,310 US and European funds as of April 2018 with available fund-level carbon risk scores, fund flows, and portfolio holdings. The solid vertical lines indicate the carbon risk score and FFI thresholds for a fund to be labeled "low carbon" by Morningstar. *Loading on negative climate news (fund)* is the coefficient on the standardized negative news-based climate risk index used in Engle et al. (2020) when regressing for each fund the monthly returns, from December 2016 through April 2018, on that index and on the Fama-French three global factors. The graphs control for fund size and category fixed effects.

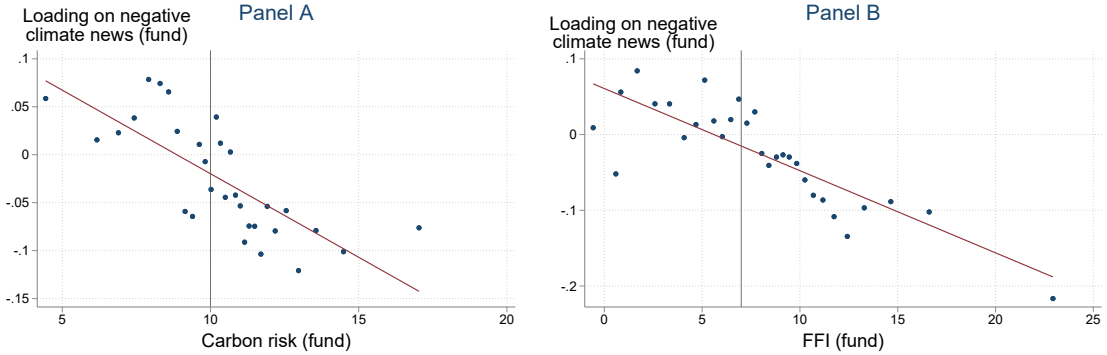


Figure A3: Effect of firm-level fossil fuel involvement on funds' position changes This figure shows the cumulative effect of the firm-level indicator for fossil fuel involvement on monthly firm-fund-level position changes from April 2017 through September 2019. The cumulation of the estimates and confidence intervals is re-set to zero after April 2018. The estimates are computed based on monthly cross-sectional regressions of position changes on *FFI (firm)*, an indicator equal to 1 for firms involved in fossil fuel activities, controlling for lagged stock return, firm industry, and fund category. The dashed lines indicate the 90% confidence interval based on robust standard errors.

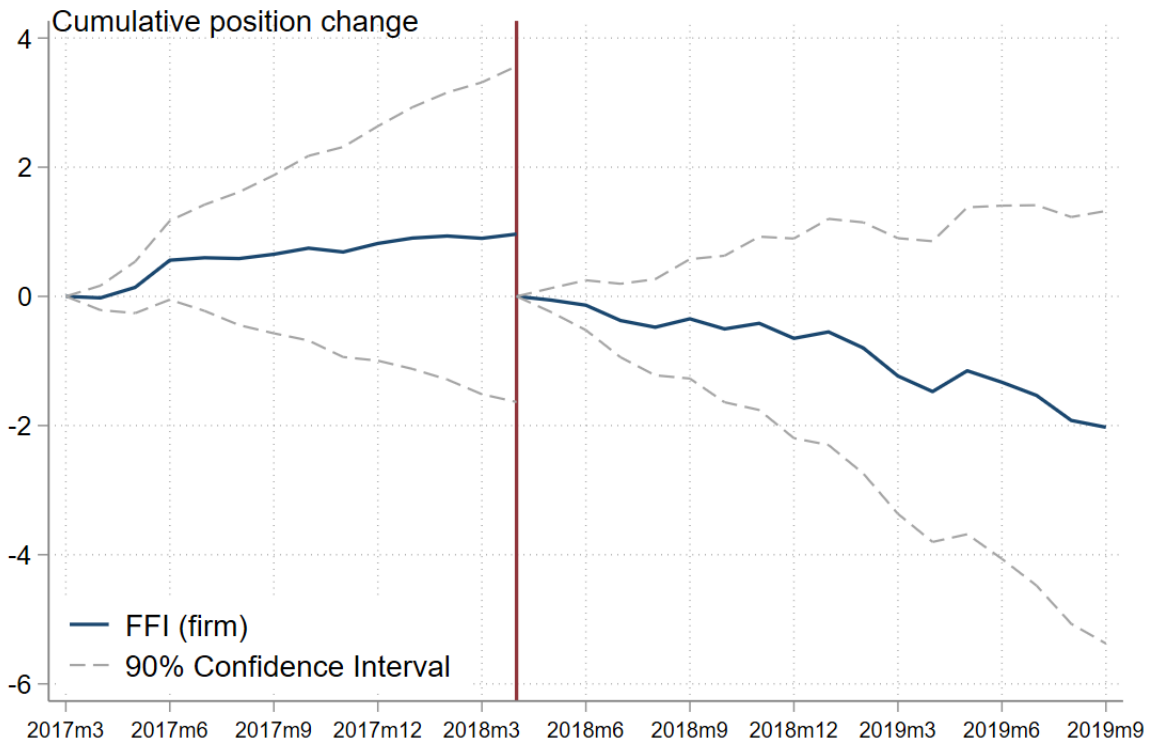


Table A1: Firm-level carbon risk scores by GICS sectors

This table shows the descriptive statistics of firm-level carbon risk scores by GICS sectors. The sample includes all global firms covered by Sustainalytics for 2017. According to Sustainalytics, the carbon risk score captures the remaining unmanaged carbon risk after taking into account a firm's carbon risk management activities (for details, see Morningstar, 2018b). Morningstar uses the firm-level carbon risk scores from Sustainalytics (which Morningstar has controlled since 2017) to compute its value-weighted fund-level Portfolio Carbon Risk Scores. The firm-level carbon risk scores were first released at the end of April 2018, contemporaneously with the release of Morningstar's portfolio carbon metrics.

	N	min	p25	mean	p50	p75	max	sd
Energy	152	8.89	28.44	42.13	44.10	55.35	81.09	17.41
Material	303	1.59	13.90	19.59	19.60	24.35	48.40	7.03
Industrials	520	0.00	8.56	15.74	15.64	23.06	37.00	9.66
Consumer discretionary	399	0.00	0.00	10.15	9.59	14.59	43.75	9.56
Consumer staples	229	0.00	5.84	10.73	10.55	15.29	34.10	6.45
Health Care	243	0.00	0.00	2.94	0.00	5.93	15.31	4.94
Financials	433	0.00	8.21	11.50	12.07	15.00	25.20	5.09
IT	297	0.00	0.00	5.10	1.22	9.72	31.95	6.30
Communication	196	0.00	0.00	6.41	5.97	12.01	22.54	6.82
Utilities	125	0.00	14.25	21.98	23.42	29.35	65.19	11.11
Real Estate	214	0.00	9.49	13.16	13.13	18.00	21.60	5.01
Total	3,111	0.00	5.09	13.20	11.73	18.72	81.09	11.71

Table A2: Geographical distribution of LCD funds and relation to Globes and Stars ratings

Panel A shows the geographical distribution of funds in the sample as of April 2018, with the share of funds that obtained the Morningstar Low Carbon Designation and basic descriptive statistics. Panels B and C show the absolute frequencies of funds with and without the Low Carbon Designation (LCD) as of April 2018, along with the Morningstar sustainability "Globes" ratings and the Morningstar overall "Stars" ratings.

Panel A: Geographical distribution of funds

			Flows			
Area of domicile	N	Fraction of LCD funds	p25	p50	p75	sd
Europe	8,992	0.18	-2.63	-1.80	-0.96	5.13
USA	4,064	0.18	-1.04	-0.28	0.69	4.10
Total	13,056	0.18	-2.24	-1.60	-0.04	4.88

Panel B: Morningstar sustainability ratings ("Globes")

LCD	1	2	3	4	5	Total
0	822	1,619	2,527	1,585	664	7,217
1	181	366	671	581	342	2,141
Total	1,003	1,985	3,198	2,166	1,006	9,358
% of LCD funds	18.04%	18.44%	20.98%	26.82%	34.00%	22.88%

Panel C: Morningstar overall ratings ("Stars")

LCD	1	2	3	4	5	Total
0	499	1,620	2,915	2,068	739	7,841
1	86	369	693	605	293	2,046
Total	585	1,989	3,608	2,673	1,032	9,887
% of LCD funds	14.70%	18.55%	19.21%	22.63%	28.39%	20.69%

Table A3: Correlations between Portfolio Carbon Risk Score and previously available portfolio Environmental scores

This table shows the correlations between Morningstar's Portfolio Carbon Risk Score (released in April 2018 based on new firm-level carbon risk scores from Sustainalytics) and alternative portfolio metrics computed based on previously available firm-level environmental scores from Sustainalytics, Refinitiv, and MSCI–KLD. The sample includes portfolios as of April 2018 of European and US mutual funds with available holdings data. * indicates that the parameter estimate is significantly different from zero at the 1% level.

Variables	1	2	3
1. Portfolio Carbon Risk Score			
2. Portfolio Environmental score (Sustainalytics)	-0.27*		
3. Portfolio Environmental score (Refinitiv)	-0.08*	0.86*	
4. Portfolio Environmental score (MSCI–KLD)	-0.19*	0.81*	0.88*

Table A4: Summary statistics of additional variables

Descriptive statistics of the additional variables used in Section 3. In Panel A (firm-level variables), the sample includes all international firms covered by Sustainalytics in 2017, for which financial data from Compustat Capital IQ (NA and Global) is available. *CR (firm)* is the firm-level carbon risk score first released in April 2018 and used by Morningstar to compute portfolio carbon metrics. *Loading on negative climate news (firm)* is estimated by regressing each firm's monthly returns from January 2015 through April 2018 on the three Fama-French global factors and the news-based climate change risk index from Engle et al. (2020), standardized to have zero mean and unit standard deviation. *Volatility (firm)* is the standard deviation of monthly returns over the same period. In Panel B (portfolio-level variables), the sample includes all European and US active open-end funds for which portfolio holdings as of April 2018 and 12-month average portfolio carbon risk score are available. *Portfolio Carbon Risk Score* is Morningstar fund-level carbon risk score. *Loading on negative climate news (firm)* is estimated by regressing each fund's monthly returns from December 2016 through April 2018 on the three Fama-French global factors and the standardized news-based climate change risk index from Engle et al. (2020). *Average volatility (firm)* is the asset-weighted volatility of the portfolio's equity holdings, while *Volatility (fund)* is the portfolio's return volatility. *Normalized portfolio volatility* is the ratio between the portfolio volatility and the average volatility of its equity holdings. *Industry concentration index* is the sum of the squared deviations of a fund's GICS industry weights relative to the industry weights of the global market portfolio. Finally, *Number of holdings* is the number of firms a fund holds, in hundreds.

Panel A: Firm-level variables

	N	min	p25	mean	p50	p75	max	sd
CR (firm)	2,449	0.00	5.22	13.40	11.89	18.92	81.09	12.04
Loading on negative climate news (firm)	2,449	-13.26	-0.95	-0.18	-0.05	0.74	11.50	1.87
Volatility (firm)	2,449	1.96	4.93	7.20	6.49	8.71	36.11	3.21

Panel B: Portfolio-level variables

	N	min	p25	mean	p50	p75	max	sd
Portfolio Carbon Risk Score	6,310	1.14	8.51	10.35	10.20	11.71	36.60	3.48
Loading on negative climate news (fund)	6,310	-1.12	-0.29	-0.03	-0.05	0.18	1.28	0.43
Average volatility (firm)	6,310	3.09	6.34	7.06	6.90	7.61	10.92	1.06
Volatility (fund)	6,310	0.21	2.15	2.47	2.42	2.73	10.51	0.57
Normalized portfolio volatility	6,310	0.15	0.30	0.35	0.35	0.40	0.56	0.07
Industry concentration index	6,310	0.13	1.89	4.51	3.24	5.54	29.60	4.26
Number of holdings	6,310	0.01	0.40	1.53	0.60	1.14	77.52	3.53 ¿

Table A5: Institutional and retail investor reactions at the share class level
This table shows the results of OLS regressions of monthly flows at the share class level from April 2017 through December 2018 on the interaction between Low Carbon Designation (LCD) and the indicator $Post$ equal to 1 for months following April 2018. The regressions in Columns 2 and 3 also include the interactions between a fund's Portfolio Carbon Risk Score (CR) and fossil fuel involvement (FFI) and $Post$. The sample includes active equity and balanced share classes domiciled in Europe or US. t-statistics, based on robust standard errors clustered at the style and month level, are reported in parentheses. ***, **, and * indicate that the parameter estimate significantly differs from zero at the 1%, 5%, and 10% levels, respectively.

Dep. variable:	Flows (share class)			
	Retail		Institutional	
	(1)	(2)	(3)	(4)
LCD × Post	0.50***	0.39**	1.02***	0.22
	(3.57)	(2.52)	(3.93)	(0.53)
LCD	0.27	0.09	0.22	0.00
	(0.91)	(0.51)	(1.07)	(0.01)
CR × Post		-0.02		-0.10**
		(-0.44)		(-2.40)
FFI × Post		0.00		0.00
		(0.02)		(0.11)
CR		0.02		-0.07**
		(0.53)		(-2.45)
FFI		-0.04		-0.04***
		(-1.47)		(-3.43)
Observations	681,702	306,452	165,259	76,430
R-squared	0.04	0.03	0.03	0.03
Month-category FE	Yes	Yes	Yes	Yes
Country FE	Yes	Yes	Yes	Yes
Month-category clustered SE	Yes	Yes	Yes	Yes

Table A6: The low-carbon fund flow effect: Asset weighted regressions
This table shows the results of OLS difference-in-differences (DID) regressions of monthly flows (Columns 1-3) and normalized flows (Columns 4-6) from April 2017 through December 2018 on Low Carbon Designation (LCD), the interaction of this variable with the indicator *Post* equal to 1 for months following April 2018. Observations are weighted by the log of assets under management. All regressions control for lagged fund characteristics (returns in the previous three months, log assets, volatility, age, and changes in sustainability Globes and Stars rating), month-by-category, and country fixed effects. t-statistics, based on robust standard errors clustered at the category and month level, are reported in parentheses. ***, **, and * indicate that the parameter estimate significantly differs from zero at the 1%, 5%, and 10% level, respectively.

Dep. variable:	Flows			Normalized flows		
	(1)	(2)	(3)	(4)	(5)	(6)
LCD × Post	0.36***	0.31**	0.36***	2.72***	2.54***	2.80***
	(4.83)	(2.69)	(3.23)	(3.88)	(3.72)	(3.00)
CR × Post		-0.01			0.09	
		(-0.46)			(0.38)	
FFI × Post		0.01			-0.01	
		(0.80)			(-0.29)	
Observations	252,060	163,218	252,060	252,060	163,218	252,060
R-squared	0.12	0.12	0.13	0.13	0.14	0.13
Controls	Yes	Yes	Yes	Yes	Yes	Yes
Controls × Post	No	No	Yes	No	No	Yes
Month-category FE	Yes	Yes	Yes	Yes	Yes	Yes
Country FE	Yes	Yes	Yes	Yes	Yes	Yes
Month-category clustered SE	Yes	Yes	Yes	Yes	Yes	Yes
Asset weighted	Yes	Yes	Yes	Yes	Yes	Yes

Table A7: The low-carbon flow premium: Adding fund fixed effects
This table shows the results of OLS difference-in-differences (DID) regressions of monthly flows (Columns 1-3) and normalized flows (Columns 4-6) from April 2017 through December 2018 on Low Carbon Designation (LCD), the interaction of this variable with the indicator *Post* equal to 1 for months following April 2018. All regressions control for lagged fund characteristics (returns in the previous three months, log assets, volatility, age, and changes in sustainability Globes and Stars rating), month-by-category, and fund fixed effects. t-statistics, based on robust standard errors clustered at the category and month level, are reported in parentheses. ***, **, and * indicate that the parameter estimate significantly differs from zero at the 1%, 5%, and 10% level, respectively.

Dep. variable:	Flows			Normalized flows		
	(1)	(2)	(3)	(4)	(5)	(6)
LCD × Post	0.54***	0.37**	0.47***	3.09***	2.54***	2.80***
	(5.94)	(2.72)	(4.05)	(4.18)	(3.28)	(3.17)
CR × Post		-0.04			-0.02	
		(-1.18)			(-0.10)	
FFI × Post		0.00			-0.00	
		(0.19)			(-0.07)	
Observations	252,059	163,132	252,059	252,059	163,132	252,059
R-squared	0.30	0.29	0.30	0.38	0.37	0.38
Controls	Yes	Yes	Yes	Yes	Yes	Yes
Controls × Post	No	No	Yes	No	No	Yes
Month-category FE	Yes	Yes	Yes	Yes	Yes	Yes
Fund FE	Yes	Yes	Yes	Yes	Yes	Yes
Month-category clustered SE	Yes	Yes	Yes	Yes	Yes	Yes

Table A8: The low-carbon fund flow effect: Pseudo LCD in the pre-publication period

This table shows the results of OLS difference-in-differences (DID) regressions of monthly flows (Columns 1-3) and normalized flows (Columns 4-6) from December 2017 through December 2018 on "pseudo" Low Carbon Designation (*LCD (pseudo)*), the interaction of this variable with the indicator *Post* equal to 1 for months following April 2018. *LCD (pseudo)* is a variable constructed by applying the LCD criteria to the historical portfolio holdings before April 2018. It is available only from December 2017 as it requires at least 12 months of past portfolio holdings. All regressions control for lagged fund characteristics (returns in the previous three months, log assets, volatility, age, and changes in sustainability Globes and Stars rating), month-by-category, and country fixed effects. t-statistics, based on robust standard errors clustered at the category and month level, are reported in parentheses. ***, **, and * indicate that the parameter estimate significantly differs from zero at the 1%, 5%, and 10% level, respectively.

Dep. variable:	Flows			Normalized flows		
	(1)	(2)	(3)	(4)	(5)	(6)
LCD (pseudo) × Post	0.28***	0.28**	0.30**	2.17**	1.68*	2.44*
	(3.28)	(2.73)	(2.46)	(2.21)	(1.79)	(2.00)
LCD (pseudo)	0.10	-0.08	0.09	0.79	-0.55	0.74
	(0.71)	(-0.72)	(0.59)	(0.74)	(-0.69)	(0.64)
CR × Post		0.00			0.00	
		(0.08)			(0.03)	
FFI × Post		0.00			-0.01	
		(0.57)			(-0.34)	
Observations	157,440	106,599	157,440	157,440	106,599	157,440
R-squared	0.16	0.16	0.16	0.12	0.13	0.12
Controls	Yes	Yes	Yes	Yes	Yes	Yes
Controls × Post	No	No	Yes	No	No	Yes
Month-category FE	Yes	Yes	Yes	Yes	Yes	Yes
Country FE	Yes	Yes	Yes	Yes	Yes	Yes
Month-category clustered SE	Yes	Yes	Yes	Yes	Yes	Yes

Table A9: Flow effects of LCD upgrades and downgrades

Panel A summarizes the results of the quarterly LCD updates between May 2018 and September 2019 at a quarterly frequency, based on the portfolio holdings at the end of each quarter. Panel B shows the results of OLS regressions of monthly fund flows (Column 1) and normalized fund flows (Column 2) from May 2018 through September 2019 (post-publication period) *LCD Downgrade* and *LCD Upgrade*, indicators equal to 1 for months following an LCD upgrade or downgrade, and 0 otherwise. The regressions control for returns in the previous three months, volatility, log asset, age, ΔGlobes, and ΔStars), as well as month-by-category and country fixed effects. t-statistics, based on robust standard errors clustered at the month and category level, are reported in parentheses. ***, **, and * indicate that the parameter estimate is significantly different from zero at the 1%, 5%, and 10% levels, respectively.

Panel A: LCD changes after April 2018

LCD updates	Aug 2018 (Q2-2018)	Nov 2018 (Q3-2018)	Feb 2019 (Q4-2018)	May 2019 (Q1-2019)	Aug 2019 (Q2-2019)
Downgrades	211	169	161	265	150
Confirmations	13,289	13,273	12,938	13,183	13,684
Upgrades	145	208	246	243	283

Panel B: Flow effects of LCD downgrades and upgrades

Dep. variable:	(1) Flows	(2) Normalized flows
LCD downgrade	-0.17*	-0.80
	(-2.07)	(-1.37)
LCD upgrade	0.29**	1.73**
	(2.91)	(2.57)
Observations	233,375	233,375
R-squared	0.07	0.11
Month-category FE	Yes	Yes
Country FE	Yes	Yes
Month-category clustered	Yes	Yes

Table A10: Mutual funds' responses to carbon risk: Additional controls
This table shows the results of OLS regressions of monthly position changes on indicators for firms' carbon risk and fossil fuel involvement from April 2017 through September 2019 interacted with a dummy Post equal to 1 for months following April 2018. *High CR (firm)* is an indicator equal to 1 for firms with a carbon risk score of 30 or higher, while *Low CR (firm)* is an indicator equal to 1 for firms with a carbon risk score below 10. The remaining, medium carbon risk firms are the benchmark. The sample includes active equity and diversified mutual funds domiciled in Europe or in the US. All regressions control for lagged firm and fund characteristics, and month-by-category and country fixed effects. Columns 1 and 3 control for additional firm-level variables: book-to-market, leverage, ROA, and the logarithm of market capitalization. Columns 2 and 4 add firm fixed effects, and Columns 3 and 6 also include fund fixed effects. t-statistics, based on robust standard errors clustered at the fund and time level, are reported in parentheses. ***, **, and * indicate that the parameter estimate significantly differs from zero at the 1%, 5%, and 10% level, respectively.

Dep. variable:	Position change				
	(1)	(2)	(3)	(4)	(5)
High CR (firm) × Post	-0.19***	-0.18***	-0.20***	-0.17***	-0.15**
	(-3.32)	(-2.98)	(-3.58)	(-2.84)	(-2.45)
Low CR (firm) × Post	0.03	-0.02	-0.03	-0.02	-0.03
	(0.77)	(-0.51)	(-0.81)	(-0.69)	(-0.78)
High CR (firm)	0.08	0.07	0.10	0.13	0.12
	(1.29)	(1.16)	(0.47)	(0.57)	(0.53)
Low CR (firm)	-0.00	0.03	0.19***	0.18***	0.18***
	(-0.01)	(0.98)	(3.06)	(2.86)	(2.91)
FFI (firm) × Post					-0.02
					(-0.36)
FFI (firm)					0.30*
					(1.99)
Observations	9,343,371	9,343,371	9,343,371	9,395,410	9,395,410
R-squared	0.05	0.05	0.05	0.06	0.06
Extended Controls	Yes	No	No	No	No
Extended Controls × Post	No	Yes	Yes	Yes	Yes
Firm FE	No	No	Yes	Yes	Yes
Month-category FE	Yes	Yes	Yes	Yes	Yes
Fund FE	No	No	No	Yes	Yes
Country FE	Yes	Yes	Yes	No	No
Industry FE	Yes	Yes	No	No	No
Month-fund clustered SE	Yes	Yes	Yes	Yes	Yes

Appendix to the reply to the Editor

Table RE-1: Institutional and retail investor reactions at the share class level
This table shows the results of OLS regressions of monthly flows at the share class level from April 2017 through December 2018 on the interaction between Low Carbon Designation (LCD) and the indicator *Post* equal to 1 for months following April 2018. The regressions in Columns 2 and 3 also include the interactions between a fund's Portfolio Carbon Risk Score (CR) and fossil fuel involvement (FFI) and *Post*. The sample includes active equity and balanced share classes domiciled in Europe or US. t-statistics, based on robust standard errors clustered at the style and month level, are reported in parentheses. ***, **, and * indicate that the parameter estimate significantly differs from zero at the 1%, 5%, and 10% levels, respectively.

Dep. variable:	Flows (share class)			
	Retail		Institutional	
	(1)	(2)	(3)	(4)
LCD × Post	0.50***	0.39**	1.02***	0.22
	(3.57)	(2.52)	(3.93)	(0.53)
LCD	0.27	0.09	0.22	0.00
	(0.91)	(0.51)	(1.07)	(0.01)
CR × Post		-0.02		-0.10**
		(-0.44)		(-2.40)
FFI × Post		0.00		0.00
		(0.02)		(0.11)
CR		0.02		-0.07**
		(0.53)		(-2.45)
FFI		-0.04		-0.04***
		(-1.47)		(-3.43)
Observations	681,702	306,452	165,259	76,430
R-squared	0.04	0.03	0.03	0.03
Month-category FE	Yes	Yes	Yes	Yes
Country FE	Yes	Yes	Yes	Yes
Month-category clustered SE	Yes	Yes	Yes	Yes

Table RE-2: The LCD flow effect in different regions of sale

This table shows the results of OLS regressions of monthly flows at the share-class level from April 2017 through December 2018 on the interaction between Low Carbon Designation (LCD) and the indicator $Post$, which is equal to 1 for the months following April 2018. The regression in Column 1 employs the sub-sample of share classes distributed in the US, the regression in Column 2 employs the sub-sample of share classes distributed in Europe (Europe cross-country), while the one in Column 3 employs the sub-sample of share classes distributed in Europe and other countries like Singapore, Hong Kong, or South Korea (global cross-border). t-statistics, based on robust standard errors clustered at the style and month level, are reported in parentheses. ***, **, and * indicate that the parameter estimate is significantly different from zero at the 1%, 5%, and 10% levels, respectively.

Dep. variable:	Flows (share class)		
	United States	Europe cross-border	Global cross-border
	(1)	(2)	(3)
LCD × Post	0.45***	0.83***	0.90**
	(3.00)	(4.37)	(2.59)
LCD	-0.09	0.54	0.55
	(-0.28)	(1.54)	(1.61)
Observations	304,177	207,024	92,839
R-squared	0.03	0.03	0.04
Month-category FE	Yes	Yes	Yes
Country FE	Yes	Yes	Yes
Month-category clustered SE	Yes	Yes	Yes

Table RE-3: Mutual funds' responses to carbon risk: Clustering at the firm level, in addition to fund and month

This table shows the results of OLS regressions of monthly position changes on indicators for firms' carbon risk (Columns 1 and 2), fossil fuel involvement (Columns 3 and 4), and both (Columns 5 and 6), from April 2017 through September 2019 interacted with a dummy Post equal to 1 for months following April 2018. *High CR (firm)* is an indicator equal to 1 for firms with a carbon risk score of 30 or higher, while *Low CR (firm)* is an indicator equal to 1 for firms with a carbon risk score below 10. The remaining, medium carbon risk firms are the benchmark. The sample includes active equity and balanced mutual funds domiciled in Europe or in the US. The regressions control for lagged firm and fund characteristics, and month-by-category, country, and industry fixed effects. t-statistics, based on robust standard errors clustered at the month, fund, and firm level, are reported in parentheses. ***, **, and * indicate that the parameter estimate significantly differs from zero at the 1%, 5%, and 10% level, respectively.

Dep. variable:	Position change					
	(1)	(2)	(3)	(4)	(5)	(6)
High CR (firm) × Post	-0.17**	-0.17**			-0.19**	-0.12*
	(-2.76)	(-2.62)			(-2.72)	(-1.78)
Low CR (firm) × Post	0.03	0.03			0.01	0.03
	(0.74)	(0.69)			(0.15)	(0.54)
High CR (firm)	0.09	0.08			0.15**	0.06
	(1.28)	(1.24)			(2.13)	(0.77)
Low CR (firm)	0.03	0.03			0.06	0.04
	(0.71)	(0.86)			(1.55)	(0.97)
FFI (firm) × Post			-0.13*	-0.13**	-0.05	-0.08
			(-2.00)	(-2.12)	(-0.73)	(-1.07)
FFI (firm)			0.13**	0.19**	0.12*	0.18**
			(2.47)	(2.53)	(1.73)	(2.14)
Observations	10,883,324	10,883,324	11,234,222	10,990,912	11,125,818	10,883,324
R-squared	0.04	0.04	0.04	0.04	0.04	0.04
Controls	Yes	Yes	Yes	Yes	Yes	Yes
All controls × Post	No	Yes	No	No	No	No
Month-category FE	Yes	Yes	Yes	Yes	Yes	Yes
Country FE	Yes	Yes	Yes	Yes	Yes	Yes
Industry FE	Yes	Yes	No	Yes	No	Yes
Month-fund clustered SE	Yes	Yes	Yes	Yes	Yes	Yes
Firm clustered SE	Yes	Yes	Yes	Yes	Yes	Yes

Table RE-4: Mutual funds' responses to carbon risk: Adding country-time FEs
This table shows the results of OLS regressions of monthly position changes on indicators for firms' carbon risk (Columns 1 and 2), fossil fuel involvement (Columns 3 and 4), and both (Columns 5 and 6), from April 2017 through September 2019 interacted with a dummy Post equal to 1 for months following April 2018. *High CR (firm)* is an indicator equal to 1 for firms with a carbon risk score of 30 or higher, while *Low CR (firm)* is an indicator equal to 1 for firms with a carbon risk score below 10. The remaining, medium carbon risk firms are the benchmark. The sample includes active equity and balanced mutual funds domiciled in Europe or in the US. The regressions control for lagged firm and fund characteristics, and month-by-category, country-by-month, and industry fixed effects. t-statistics, based on robust standard errors clustered at the month and fund level, are reported in parentheses. ***, **, and * indicate that the parameter estimate significantly differs from zero at the 1%, 5%, and 10% level, respectively.

Dep. variable:	Position change					
	(1)	(2)	(3)	(4)	(5)	(6)
High CR × Post	-0.16***	-0.16**			-0.18***	-0.11
	(-2.82)	(-2.67)			(-2.81)	(-1.65)
Low CR × Post	0.01	0.00			-0.02	0.00
	(0.33)	(0.14)			(-0.52)	(0.08)
High CR	0.08	0.08			0.14***	0.05
	(1.48)	(1.45)			(2.82)	(0.79)
Low CR	0.05	0.05			0.08**	0.06*
	(1.54)	(1.69)			(2.64)	(1.91)
FFI (Firm) × Post			-0.12*	-0.12*	-0.06	-0.09
			(-1.91)	(-1.95)	(-0.88)	(-1.19)
FFI (Firm)			0.13***	0.18***	0.12**	0.19***
			(2.95)	(4.01)	(2.14)	(3.52)
Observations	11,233,861	11,233,861	11,599,696	11,344,293	11,488,373	11,233,861
R-squared	0.05	0.05	0.04	0.05	0.04	0.05
Controls	Yes	Yes	Yes	Yes	Yes	Yes
All controls × Post	No	Yes	No	No	No	No
Month-category FE	Yes	Yes	Yes	Yes	Yes	Yes
Country-month FE	Yes	Yes	Yes	Yes	Yes	Yes
Industry FE	Yes	Yes	No	Yes	No	Yes
Month-fund clustered SE	Yes	Yes	Yes	Yes	Yes	Yes

Table RE-5: Mutual funds' responses to carbon risk: Industry FEs
This table shows the results of OLS regressions of monthly position changes on indicators for firms' carbon risk from April 2017 through September 2019 interacted with a dummy Post equal to 1 for months following April 2018. *High CR (firm)* is an indicator equal to 1 for firms with a carbon risk score of 30 or higher, while *Low CR (firm)* is an indicator equal to 1 for firms with a carbon risk score below 10. The remaining, medium carbon risk firms are the benchmark. The first three columns show results for the full sample of funds. Column 4 shows only funds with a high Industry concentration index (top 33% of funds), while Column 5 shows funds with a medium Industry concentration index (funds that are between the top and bottom 33%), and Column 6 shows the remaining funds. The sample includes active equity and diversified mutual funds domiciled in Europe or in the US. All regressions control for lagged firm and fund characteristics, and month-by-category and country fixed effects. The first model controls for sector fixed effects while the second adds sector-by-moth fixed effects instead. Models 3 to 5 include more granular industry-by-month fixed effects. t-statistics, based on robust standard errors clustered at the fund and time level, are reported in parentheses. **, **, and * indicate that the parameter estimate significantly differs from zero at the 1%, 5%, and 10% level, respectively.

Dep. variable:	Position change (bp)					
	All Funds			High ICI	Med ICI	Low ICI
	(1)	(2)	(3)	(4)	(5)	(6)
High CR (firm) × Post	-0.25***	-0.21**	-0.13	-0.67**	-0.15	0.01
	(-4.88)	(-2.33)	(-1.45)	(-2.74)	(-1.03)	(0.10)
Low CR (firm) × Post	0.00	-0.04	-0.05	0.08	0.00	-0.08**
	(0.09)	(-1.00)	(-1.26)	(0.73)	(0.02)	(-2.40)
High CR (firm)	0.11**	0.08	0.06	0.25	-0.02	0.06
	(2.27)	(1.04)	(0.79)	(1.39)	(-0.19)	(0.71)
Low CR (firm)	0.06*	0.08***	0.08***	-0.01	0.08	0.13***
	(2.01)	(3.04)	(2.99)	(-0.13)	(1.52)	(6.08)
Observations	11,131,786	11,131,786	11,233,869	1,622,697	2,793,794	6,721,595
R-squared	0.05	0.05	0.04	0.09	0.05	0.04
Controls	Yes	Yes	Yes	Yes	Yes	Yes
Month-category FE	Yes	Yes	Yes	Yes	Yes	Yes
Country FE	Yes	Yes	Yes	Yes	Yes	Yes
Sector FE	Yes	No	No	No	No	No
Sector-month FE	No	Yes	No	No	No	No
Industry-month FE	No	No	Yes	Yes	Yes	Yes
Month-fund clustered SE	Yes	Yes	Yes	Yes	Yes	Yes

Appendix to the reply to the Referee

Table RR-1: Portfolio carbon risk and portfolio volatility
This table shows the results of cross-sectional OLS regressions of fund volatility on portfolio carbon risk (CR), controlling for fund size and category fixed effects. The regression in Column 2 employs funds with CR above 10, while the regression in Column 2 employs funds with CR below or equal to 10 (i.e., low carbon funds). The sample includes US and European funds with available carbon risk scores, fund flows, and individual portfolio holdings data as of April 2018. t-statistics, based on robust standard errors, are reported in parentheses. ***, **, and * indicate that the parameter estimate significantly differs from zero at the 1%, 5%, and 10% level, respectively.

Dep. variable:	Fund volatility	
	Carbon Risk (CR) $>$ 10	Carbon Risk (CR) $\leq$ 10
	(1)	(2)
Carbon Risk (CR)	0.07***	-0.02***
	(11.13)	(-3.43)
Log assets	-0.02***	0.00
	(-5.68)	(0.74)
Constant	1.63***	2.10***
	(15.33)	(19.18)
Observations	3,412	2,898
R-squared	0.40	0.23
Category FE	Yes	Yes

Table RR-2: Fund flow results with a "dynamic" diff-in-diff specification
This table replicates the regressions in Table 3 of the paper with a dynamic difference-in-differences setting. The sample includes active equity and balanced mutual funds domiciled in Europe or US, including funds that experienced an LCD upgrade or downgrade in August or November 2018. *LCD (d)* is an indicator equal to 1 for funds that obtained the Low Carbon Designation at the end of April 2018, but it can change in the post-publication periods following LCD upgrades or downgrades. All regressions control for lagged fund characteristics and month-by-category and country fixed effects. t-statistics, based on robust standard errors clustered at the category and month level, are reported in parentheses. ***, **, and * indicate that the parameter estimate significantly differs from zero at the 1%, 5%, and 10% level, respectively.

Dep. variable:	Flows			Normalized flows		
	(1)	(2)	(3)	(4)	(5)	(6)
LCD (d) × Post	0.36***	0.30***	0.37***	2.60***	2.25***	2.65***
	(5.19)	(3.24)	(3.44)	(3.95)	(3.88)	(3.06)
LCD (d)	0.01	-0.18**	0.01	0.21	-1.39***	0.20
	(0.15)	(-2.57)	(0.14)	(0.30)	(-2.86)	(0.27)
CR × Post		-0.02			0.08	
		(-0.55)			(0.35)	
FFI × Post		0.01			-0.02	
		(0.93)			(-0.65)	
Observations	266,375	176,305	266,375	266,375	176,305	266,375
R-squared	0.12	0.12	0.12	0.13	0.13	0.13
Month-Style FE	Yes	Yes	Yes	Yes	Yes	Yes
Country FE	Yes	Yes	Yes	Yes	Yes	Yes
Clustered SE month-style	Yes	Yes	Yes	Yes	Yes	Yes

Table RR-3: Mutual funds' responses to carbon risk: Keeping firm-level carbon risk scores constant

This table shows the results of OLS regressions of monthly position changes on indicators for firms' carbon risk (Columns 1 and 2) and both carbon risk and fossil fuel involvement (Columns 3 and 4) from April 2017 through September 2019 interacted with a dummy Post equal to 1 for months following April 2018. The firm-level carbon risk indicators (*High CR (firm)* and *high CR (firm)*) and fossil fuel involvement (*FFI (firm)*) metrics are as of April 2017 and are carried forward for the remainder of the sample. *High CR (firm)* is an indicator equal to 1 for firms with a carbon risk score of 30 or higher, while *Low CR (firm)* is an indicator equal to 1 for firms with a carbon risk score below 10. The remaining, medium carbon risk firms are the benchmark. The sample includes active equity and diversified mutual funds domiciled in Europe or in the US. All regressions control for lagged firm and fund characteristics, and month-by-category, country, and industry fixed effects. t-statistics, based on robust standard errors clustered at the fund and time level, are reported in parentheses. **, **, and * indicate that the parameter estimate significantly differs from zero at the 1%, 5%, and 10% level, respectively.

Dep. variable:	Position change			
	(1)	(2)	(3)	(4)
High CR (firm) × Post	-0.17***	-0.17***	-0.19***	-0.12*
	(-3.51)	(-3.31)	(-2.81)	(-1.77)
Low CR (firm) × Post	0.01	0.01	-0.02	0.00
	(0.30)	(0.15)	(-0.46)	(0.09)
High CR (firm)	0.07	0.07	0.12**	0.03
	(1.28)	(1.22)	(2.11)	(0.45)
Low CR (firm)	0.01	0.01	0.06**	0.02
	(0.39)	(0.53)	(2.27)	(0.75)
FFI (firm) × Post			-0.06	-0.08
			(-0.74)	(-1.07)
FFI (firm)			0.13*	0.19***
			(1.98)	(3.31)
Observations	10,584,428	10,584,428	10,754,435	10,529,484
R-squared	0.04	0.04	0.04	0.04
Controls	Yes	Yes	Yes	Yes
All controls × Post	No	Yes	No	No
Month-category FE	Yes	Yes	Yes	Yes
Country FE	Yes	Yes	Yes	Yes
Industry FE	Yes	Yes	No	Yes
Month-fund clustered SE	Yes	Yes	Yes	Yes

Table RR-4: Mutual funds' responses to carbon risk: Close to the threshold
This table shows the results of OLS regressions of monthly position changes on indicators for firms' carbon risk (Column 1) and fossil fuel involvement (Column 2) from April 2017 through September 2019, interacted with a dummy Post equal to 1 for months following April 2018, interacted with an indicator variable for funds whose FFI (Column 1) or CR (Columns 2) is below the threshold. *High CR (firm)* is an indicator equal to 1 for firms with a carbon risk score of 30 or higher, while *Low CR (firm)* is an indicator equal to 1 for firms with a carbon risk score below 10. The remaining, medium carbon risk firms are the benchmark. The sample in Column 1 includes active mutual funds domiciled in Europe or in the US with a portfolio carbon risk score (*CR*) in the range between 9 and 11. In Column 2 it includes funds with a portfolio fossil fuel involvement (*FFI*) between 6 and 8. All regressions control for lagged firm and fund characteristics, and month-by-category, country, and industry fixed effects. t-statistics, based on robust standard errors clustered at the fund and time level, are reported in parentheses. **, **, and * indicate that the parameter estimate significantly differs from zero at the 1%, 5%, and 10% level, respectively.

Dep. variable:	Position change	
	CR ∈ [9,11]	FFI ∈ [6,8]
	(1)	(2)
High CR (firm) × Post × FFI<7	-0.34**	
	(-3.37)	
Low CR (firm) × Post × FFI<7	0.17	
	(1.86)	
High CR (firm) × Post	0.01	
	(0.25)	
Low CR (firm) × Post	-0.12	
	(-2.05)	
Post × FFI<7	-0.41**	
	(-3.29)	
High CR (firm)	0.08	
	(1.40)	
Low CR (firm)	0.12*	
	(2.12)	
FFI<7	0.49**	
	(3.08)	
FFI (Firm) × Post × CR<10		-0.07
		(-0.39)
FFI (Firm) × CR<10		0.05
		(0.29)
FFI (Firm) × Post		0.16
		(1.44)
Post × CR<10		0.07
		(0.26)
FFI (Firm)		-0.13
		(-1.34)
CR<10		0.41
		(1.59)
Observations	3,010,183	1,463,118
R-squared	0.04	0.04
Controls	Yes	Yes
Month-category FE	Yes	Yes
Country FE	Yes	Yes
Industry FE	Yes	Yes
Month-fund clustered SE	Yes	Yes

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