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JEL Classification: D03, G02, G12, G23

Keywords: behavioral finance, climate change, eco-labels, investor preferences, Mutual funds, Sustainable Finance

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Low-carbon mutual funds *

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May 3, 2022

Abstract

Climate change poses new challenges for portfolio management. Investors face a trade-off between minimizing climate risk exposure and maximizing the risk benefits of portfolio diversification in a not-yet-low-carbon world. This paper investigates investors' and financial intermediaries' responses to this *risk-risk trade-off*. We analyze the fund flows and position changes of a large sample of European and US mutual funds after the release of Morningstar's carbon risk metrics in April 2018, a shock to the availability of information on climate transition risks. Funds labeled as "low carbon" experienced a significant increase in investor demand, especially those compensating for their under-diversification with high risk-adjusted returns. Fund managers actively reduced their exposure to high-carbon risk firms, especially when less costly for portfolio diversification. These findings shed light on whether and how climate-related information can re-orient capital flows in a low-carbon direction.

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1 Introduction

Climate change is one of the key economic challenges of our time. Policy-makers and regulators increasingly recognize the potential role of financial markets in either accelerating a smooth transition to a lower-carbon economy or, by contrast, amplifying the systemic risks of climate change. One often-proposed strategy is to improve the information available to market participants regarding the climate-related risks of their investments. But does the availability of climate-related information effectively increase investor demand for low-carbon products? Does it urge financial intermediaries such as mutual fund managers to reduce their exposure to climate-related risks? The answers are not obvious because the decision not to invest in high-climate-risk assets is likely to bring both benefits and costs for investors.

On the one hand, excluding these assets can reduce an investor's exposure to climate-related risks. These risks have still to materialize in their full potential, both in terms of physical consequences and societal reactions, and many observers believe that they are currently underestimated in asset prices (Stroebel and Wurgler, 2021). On the other hand, low-carbon investing requires investors to forego fully exploiting diversification opportunities in a not-yet-low-carbon economy. This *risk-risk trade-off* is particularly salient in asset management, where portfolio diversification, and not only the features of individual securities, plays a crucial role in reducing risk (Markowitz, 1952).

Studying how market participants behave with respect to such a risk-risk trade-off is usually difficult. For instance, without exogenous variation in a fund's climate friendliness or the salience of this information, it is hard to quantify the effect of investors' climate-related preferences on fund flows. It is similarly difficult to isolate the role of firm-level climate risk in fund managers' portfolio decisions. In this paper, we exploit a quasi-natural experiment that led to variation in the availability of information on climate transition risk (or carbon 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 mutual fund industry, released on its platform new portfolio carbon risk metrics derived from new firm-level information from the ESG data provider Sustainalytics (which Morningstar controls since 2017). These metrics include the portfolio carbon risk score and the Low Carbon Designation (LCD), an eco-label for mutual funds. This event, not announced in advance to either fund managers or investors, increased the availability and salience of information on climate-related risks in the mutual fund industry. This industry represents an important share of global financial markets.[1]

In Section 3, we develop the conceptual framework guiding our empirical analysis. We first confirm that, in line with extant literature (e.g., Bolton and Kacperczyk, 2021a; Engle et al., 2020), individual low-carbon-risk securities are generally less risky, both in terms of exposure to negative climate change news and realized volatility. We then shift our focus to the portfolio level. One may naively think that the risk properties of low-carbon funds should mirror the risk properties of their low-carbon holdings. This is not the case because the risk

[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).

of a portfolio depends not only on the return variance of individual portfolio holdings but also on their return covariances (Markowitz, 1952). Indeed, while low-carbon funds have lower exposure to climate risks (similar to the climate-risk-hedging portfolio developed in Engle et al., 2020), their volatility is not lower than that of funds with carbon risk closer to the market average. This is because they hold assets that, although individually less risky, have a high degree of covariance, limiting risk-sharing. Consistent with this interpretation, we show that low-carbon portfolios exhibit high degrees of industry concentration (Kacperczyk, Sialm, and Zheng, 2005) and portfolio volatility normalized by the mean volatility of individual holdings (Goetzmann and Kumar, 2008). Overall, we establish that market participants face a fundamental risk-risk trade-off between reducing their exposure to climate risks and exploiting diversification opportunities in a not-yet-low-carbon economy. We expect this trade-off to influence investors' and fund managers' behavior.

In Section 4, we study the reactions of mutual fund investors after the shock in the availability of climate-related information. Funds that were labeled as "low carbon" at the end of April 2018 enjoyed a substantial increase in their monthly flows relative to other funds. The economic impact corresponds to around 22 basis points higher flows every month, equal to about half of the effect on flows caused by a one-standard-deviation stronger monthly financial performance. The effect is stronger for low-carbon funds with low generic sustainability ratings (due to a larger information shock), better risk-adjusted financial performance (which compensates investors for under-diversification), and higher "growth-to-value" orientation (due to a clientele more concerned with the long term). In the post-publication period from April 2018 through September 2019, we also identify variation of the low-carbon flow premium with the varying salience of climate risk over time.

In Section 5, we study the reactions of fund managers, employing monthly portfolio holdings data. We show that, after April 2018, fund managers actively rebalanced their portfolios in a lower-carbon direction. Every month, relative to the pre-publication period, mutual funds reduced their position in the average high carbon risk firm by about 0.17 basis points of their assets under management. 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. But not every fund reacted in the same way, and not every high carbon asset was treated equally. Funds with higher ex-ante industry concentration reacted more strongly, presumably because their low-carbon shift is less costly for portfolio diversification. Among high-carbon holdings, fund managers decreased their positions more in higher-volatility stocks. This makes sense, as these stocks are less useful for diversification than lower-volatility ones. Overall, fund managers seem to take the risk-risk trade-off of low-carbon investing into account.

Our paper contributes, first, by documenting the benefits and costs of low-carbon investment products. Existing research suggests that firms with better environmental performance have lower exposure to climate-related risks, and are hence 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 *risk-risk trade-off* that we highlight in this context is consistent with the theoretical literature on green investing.[2] We contribute by studying investors' and fund managers' reactions to the low-carbon risk-risk trade-off by exploiting variation in the availability of climate-related information in the mutual fund industry.

Second, we complement the literature on whether and why investors prefer socially responsible investment products (e.g., Anderson and Robinson, 2021; 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 Zhang, 2011; Riedl and Smeets, 2017). Accounting for both the costs and benefits of socially responsible investment products is crucial for a better understanding of the complexity of investor behavior on sustainability issues. The quasi-natural experiment that we analyze is appealing in this respect. In terms of costs, low-carbon investing almost explicitly asks investors to pay a clear price in terms of lower sectoral diversification, at least in the short term.

[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 diversifiable 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 (2020) 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 reduce carbon risk with small tracking errors and sector-weighted deviations.

This contrasts with the situation with generic sustainable products, where it is not clear how investors generally perceive them. In terms of benefits, the event we analyze allows a focus on investors' specific climate-related preferences. They already had the chance to self-select into funds on the basis of generic sustainability preferences, given the availability since 2016 of easy-to-process information about funds' ESG performance. 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. (2021) 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 (2021) document a decrease in institutional investors' exposure to domestic carbon-intensive 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 an increased transparency on climate transition risk 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 aimed at helping clients and portfolio managers better assessing a portfolio's exposure to climate transition risk (or carbon risk), i.e., the class of risk deriving from the transition from a fossil-fuel-reliant economy to a lower-carbon economy.[3] On the same day, Morningstar assigned to funds with low carbon-risk scores and low levels of fossil-fuel exposure the "Low Carbon Designation" (LCD), a label aimed at helping clients easily identify mutual funds with portfolios aligned with the transition to a low-carbon economy.[4] Figure 1 shows the portfolio carbon risk score and the LCD as visible on Morningstar's fund report. Details on the methodology underlying these metrics are in Morningstar (2018a,b).

- Figure 1 -

The portfolio carbon metrics are based on *issuer-level* carbon risk scores from the ESG data provider Sustainalytics, also disclosed for the first time at the end of April 2018.[5] Morn-

[3]Morningstar's portfolio carbon risk metrics do not aim at reflecting a portfolio's exposure to extreme weather events caused by global warming, which are likely to impact firms' assets and operations and hence cause significant losses for investors. For an overview on the categorization between climate transition 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.

[5]Morningstar computes the portfolio carbon risk scores by weighting the firm-level carbon risk scores by the total investment (debt and equity) that a fund holds at the end of the quarter in a given company. The portfolio carbon risk score is calculated if more than 67% of a fund's portfolio assets have a firm-level carbon risk score.

ingstar acquired a 40% stake in Sustainalytics in 2017, increased to 100% in 2020. According to Sustainalytics and Morningstar, the firm-level carbon risk score quantifies a company's exposure and management of material climate transition risk. It aims at capturing 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 available 2017 firm-level carbon risk scores by GICS sectors. Firms in high-emitting sectors (e.g., Energy, Materials, Utilities) have the highest mean carbon risk score, but within all sectors there is substantial variability of this measure.

To receive the LCD, a fund has to comply with two criteria: (1) a 12-month trailing average portfolio carbon risk score below 10 (out of 100); and (2) a 12-month trailing average "Fossil Fuel Involvement" below 7%. As of April 2018, having a portfolio carbon risk score below 10 implies being among the 29% of funds with the best performance on this dimension. At the same time, a 12-months trailing average portfolio fossil fuel involvement below 7% represents a 33% under-weighting of fossil fuel-related companies relative to the global equity universe. A firm is considered fossil-fuel involved if it derives at least 5% of its revenue from thermal coal extraction, thermal coal power generation, oil and gas production or power generation, or at least 50% of its revenues from oil and gas products and services.

Importantly, the release of Morningstar carbon metrics represented an arrival of new information for both fund clients and fund managers.[6] Morningstar representatives confirmed

[6]In particular, 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.*

to us that they did not communicate in advance the release of these metrics to either fund managers or their clients. Our analyses of pre-publication trends are indeed in line with the release of the new data not being anticipated.

2.2 Data

We base our analyses on two main data sets 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 Demand). We complement the data with firm-level characteristics from Compustat Capital IQ and Sustainalytics. In what follows, we briefly describe the data.

2.2.1 Fund-level characteristics

We obtain survivorship-bias-free data (all in USD) for all active open-end mutual funds domiciled in Europe and USA from Morningstar Direct. To work with a relatively homogeneous sample, we drop all funds classified by Morningstar in categories that are pure fixed income, sector-specific, or investing exclusively outside US and Europe. We remain with 20

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 risk affects their investments overall and as a basis for action to reduce their exposure to climate risk. This information allows fund investors to take climate risk into consideration as they monitor, compare, and select funds and asset managers".

categories composed of equity and balanced funds.[7]

Mutual funds issue several share classes to target specific investors groups or geographies. However, the underlying portfolio is the same across share classes. Consequently, we conduct our 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) is the sum of a fund's assets under management in its different share classes. Other fund-level information (including the portfolio carbon risk metrics) is retrieved from the largest share class of the funds.

Following Sirri and Tufano (1998), flows are computed as the monthly growth of assets under management net of reinvested returns. To limit the role of outliers, we trim flows at the 1st and 99th percentiles. We also compute a measure of normalized flows following Hartzmark and Sussman (2019): First, we split the sample into deciles of fund size. Second, we rank funds according to their net flows within their size decile and compute percentiles of the net flow rankings. These percentiles correspond to the normalized flows 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 including the net expense ratio, age, global category,

[7]Specifically, the 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 hold also when using the full sample of funds domiciled in Europe and USA, or just focusing on pure equity funds.

Morningstar's overall rating (the Morningstar "Stars", on a 1-5 scale, with 5 to indicate top financial performers), and its sustainability ratings (the Morningstar "Globes", on a 1-5 scale, with 5 to indicate top sustainability performers).

To account for the impact on flows of changes in Morningstar's "Stars" rating (Del Guercio and Tkac, 2008), we define the variable ΔStars indicating funds experiencing an upgrade (1) or a downgrade (-1) in this rating from the previous month. Similarly, to account for the impact on flows of changes in the generic sustainability rating (Ammann et al., 2018; Hartzmark and Sussman, 2019), we define the variables ΔGlobes indicating upgrades (1) or downgrades (-1) in sustainability Globes. We consider 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 of flows is available. Panel B provides a snapshot of the statistics as of the end of April 2018. The sample covers some 13,500 funds, of which around 18% obtained the Low Carbon Designation (LCD).

- Table A2 -

Panel A in Table A2 in the Online Appendix shows the geographical distribution of the sample as of April 2018. Around 9,300 funds are domiciled in Europe and 4,200 in the USA, of which respectively 18% and 17% of funds received the initial LCD. Panels B and C in the same table show the share of low-carbon funds for different values of Morningstars' sustainability ratings (Globes) and 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 label.

2.2.2 Portfolio holdings data

We obtain from Morningstar On Demand the monthly portfolio holdings from April 2017 through September 2019 of mutual funds (both from Europe and USA) with available portfolio carbon risk score. We keep only funds that report their holdings on a monthly basis, and focus exclusively on their equity positions. Denote the number of shares held by fund f in stock i in month t by $NumberShares_{f,i,t}$.

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:

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

To ensure the robustness of our analysis, we trim position change at the 1st and 99th percentiles. A similar measure is employed, for instance, in Gantchev, Giannetti, and Li (2021). Panel C of Table 1 reports summary statistics of 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 Sustainalytics' methodology (Sustainalytics, 2018), we classify individual firms into three carbon risk ratings: Low (carbon risk score between 0 and 9.99), Medium (carbon risk score between 10 and 29.99), and High carbon risk (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, 6% of a portfolio is made up of firms classified as having a high carbon risk, and 10% of firms involved in fossil fuel activities.

The total buys and sales 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.[8]

3 Conceptual framework

This section develops the conceptual framework that will guide our empirical investigations. We support this framework with descriptive analyses of the cross-sections of funds' and their

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

holdings' characteristics as of April 2018.[9]

Let us first briefly consider individual securities. Several contributions in the literature indicate that green assets have insurance-like properties against climate risk (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 to be the case also based on the firm-level carbon risk metrics supplied by Sustainalytics and employed by Morningstar. Panel A shows the relation between a firm's carbon risk score and its return loading on negative climate-related news. Specifically, for around 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).[10] 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), low-carbon-risk firms outperform other firms in months with more 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

[9]Table A3 in the Online Appendix reports summary statistics of the additional variables used in this section.

[10]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.

volatility ($p < 0.001$), and can explain alone around 2.75% of its variation.

- Figure 2 -

How do the risk-management properties of low-carbon firms translate at the (low-carbon) fund level? Portfolio theory implies that the answer to this question is not obvious. While the expected return of a portfolio is simply 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). We illustrate what this basic principle implies for the riskiness of low-carbon funds by analyzing the cross-section as of April 2018 of 6,310 mutual funds with available 12-month average portfolio carbon risk score.

Panel A in Figure 3 shows that funds with lower carbon risk scores hold, on average, less volatile firms. This result follows intuitively from their tilt towards low-carbon firms, which, as we saw, are generally less risky and less exposed to climate-related risk.[11] However, as Panel B illustrates, the relation between fund-level carbon risk and portfolio volatility is not at all linear: Low-carbon funds hold less risky assets, but their overall portfolios are not less risky (and can even be riskier) than the ones with a carbon exposure closer to the market average (which is close to a portfolio carbon risk score of 10).

- Figure 3 -

[11]Figure A1 in the Online Appendix shows in binned scatter plots that the portfolios of low-carbon funds have, on average, less negative exposure to negative climate news; that is, they tend to deliver higher returns when the climate risk factor hits. This result 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. This is what the portfolio constructed in Engle et al. (2020) and Alekseev et al. (2021) proposes to do.

A candidate explanation for this fact is that low-carbon funds hold assets with a high degree of covariance, which limits risk-sharing from a mean-variance perspective (Markowitz, 1952). We support this interpretation by considering two measures of portfolio diversification. The first is the *Normalized portfolio volatility* proposed by Goetzmann and Kumar (2008), computed by dividing a portfolio's volatility by the average volatility of stocks in its portfolio. The higher this measure is, the more unexploited diversification opportunities exist that would reduce portfolio volatility. Panel C in Figure 3 shows that, as expected, low-carbon funds have a relatively high normalized portfolio volatility, i.e., they miss diversification opportunities. Specifically, controlling for fund category and size, funds Morningstar labeled as "low carbon" in April 2018 have a one-seventh of a standard deviation higher normalized portfolio volatility ($p < 0.001$) than other funds. The same relation also holds when controlling for the number of holdings.[12]

The second measure of diversification we employ is the *Industry concentration index* proposed by Kacperczyk, Sialm, and Zheng (2005). This measure 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 relation between the industry concentration index and carbon risk, controlling for fund size and category. The resulting U-shaped relation confirms that the volatility of low-carbon funds reflects

[12]Low-carbon funds also hold, on average, a lower number of holdings. The fact that their higher normalized portfolio volatility does not depend on the number of holdings confirms that it reflects a higher average asset covariance. As such, it can not be reduced by simply bundling many low-carbon mutual funds (Markowitz, 1976).

a significantly smaller sectoral composition, which plays an important role in driving a portfolio's diversification.[13]

Overall, these analyses illustrate a central implication for investing and portfolio management. With climate risks, investors and fund managers face a fundamental *risk-risk trade-off*: On the one hand, by overweighting "green" securities, they can reduce their exposure to climate transition risks. On the other hand, by moving away from the status quo in a still-not-low-carbon world, they miss diversification opportunities. At the margin, we expect market participants to strike a balance so as to be indifferent between the traditional risk benefits of portfolio diversification and the benefits of low-carbon investing.

Studying how investors and portfolio managers behave when confronted with this risk-risk trade-off is crucial for a better understanding of the role of financial markets in the energy transition. However, the task is complicated by several empirical challenges. Investors with different preferences tend to self-select into different types of funds. Without exogenous variation in fund characteristics or their salience, it is hard to study the effects of investor preferences concerning climate risk. Similarly, fund managers' decisions are driven by many forward-looking considerations, in a way that complicates isolating the effect of a specific firm characteristic on their trading behavior. We address these empirical challenges by

[13] The same result holds when we employ data from Pástor, Stambaugh, and Taylor (2020a). By matching our dataset with their data, we remain with 915 US domestic equity mutual funds with available diversification data for 2014. 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 the market cap weights, even after controlling for category fixed effects. We thank Lucian Taylor for making these data available on his website.

studying the reaction of both mutual fund clients and fund managers to the introduction of Morningstar's carbon metrics in April 2018, a shock to the availability and salience of information on climate transition risks in the mutual fund industry.

4 Investor responses

This section explores the reaction of mutual funds investors to the release of carbon-related information. We focus on the effect of the Low Carbon Designation (LCD), a heuristic specifically meant at helping mutual fund clients to easily identify funds with portfolios aligned with the transition to a low-carbon economy.

4.1 Main results

We start by graphically depicting the evolution of flows for low-carbon funds. Figure 4 illustrates the average equally-weighted monthly net flows of funds that were categorized as low-carbon at the end of April 2018 and into funds that did not, from April 2017 through December 2018, with the low-carbon label becoming available at the beginning of May 2018.[14]

- Figure 4 -

[14] In this section, we focus on the post-publication period through December 2018 to document the initial reshuffling of flows caused by the release of the LCD. 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 hold also when including them). Section 4.3 investigates the fund flow effects of LCD over the period through September 2019, including the flow effect of LCD upgrades and downgrades.

Consider first Panel A, focusing on European funds. During the pre-publication period, the net flows in funds that would be later designated low-carbon are very similar to the average flows in other funds, and follow common trends. After April 2018, low-carbon-designated funds started enjoying a persistent increase in flows compared to other funds. In the USA (Panel B), low-carbon funds show lower flows than conventional funds in the pre-publication period, but again following similar fluctuations. Here, too, the informational shock seems to have triggered a relative boost of flows for low-carbon funds.

In Table 2 we formally test the investor reactions through difference-in-differences (DID) regressions of fund flows. The explanatory variable of interest is the interaction term $LCD \times Post$. LCD identifies funds that received the label at its initial release. $Post_t$ is an indicator variable equal to 1 for observations after April 2018. We control for lagged fund-level controls that are likely to have influenced fund flows. These are monthly returns in the previous three months, the logarithm of assets under management, return volatility, the fund's age, and changes in sustainability rating (Globes) and Morningstar's overall rating (Stars).[15] We also include country and month-by-category fixed effects, and cluster standard errors along both months and categories to account for cross-sectional dependence between observations.

In column (1), the coefficient on the DID interaction term of interest is positive and highly statistically significant. The assignment of the low carbon designation is associated

[15] We use the change in sustainability and overall ratings rather than the absolute value because, as also noted in Hartzmark and Sussman (2019), if these rating systems are in equilibrium – e.g., existing investors have already sorted in low and high-sustainability funds according to their preferences, after an initial phase of reallocation – there is no reason to expect a continued flows-effect of ratings without further changes. That said, the results also hold just controlling for the number of Globes and the number of Stars.

with an average 0.22 percentage points higher difference in net flows compared to the pre-publication period. This effect is economically important when compared to the effect of the main focus of the mutual funds literature so far, returns. A one standard deviation stronger performance in terms of monthly returns yields $3.33 \times 0.14 = 0.47$ percentage points more flows. In other words, the LCD is worth almost half ($0.22/0.47 = 47\%$) of a standard deviation in returns. When compounded over the eight months from May through December 2018, the flow premium associated with the LCD can be quantified in an increase of around 2% in assets under management.[16]

In column (2), we add to the regression the two scores used to allocate the LCD – the portfolio carbon risk (CR) and fossil fuel involvement (FFI) – and their interaction with Post. These two underlying criteria do not appear to have any additional explanatory power on flows. The interaction of LCD with Post remains virtually unchanged, confirming the importance of this heuristic in driving investor behavior. In column (3), we interact all control variables with Post to allow for potential changes over time of the effects on flows of fund characteristics other than the LCD. Again, the coefficient of interest remains unchanged.

[16]We thank the Editor for suggesting two main non-exclusive interpretations of the low-carbon fund flow premium. The first is that the LCD triggered a re-sorting of climate-concerned investors into low-carbon funds; as a result, the pool of investors in low-carbon funds changed. The second one is that the LCD 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 (and less likely to decrease it) into low-carbon funds. Data on individual investor position changes would be required to definitively discriminate among 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.

- Table 2 -

To limit the potential effects of size in determining monthly flows, we re-run the above analyses using normalized flows as dependent variable. The results are reported in columns (4) through (6) of Table 2. The effect of receiving the low-carbon label is again strongly statistically and economically significant: Net of the effects of control variables, on average, low-carbon funds move up 1.99 percentiles in net flows after April 2018.

Table A4 in the Online Appendix shows that the estimated effect of the LCD remains almost unchanged when weighting observations by fund size. Table A5 shows that it is even higher (41 basis points extra monthly net flows) when adding fund fixed effects. Finally, in Table A6, we repeat the analyses using a "pseudo" LCD computed by applying the two LCD criteria to the historical portfolio holdings *before* April 2018. This counterfactual confirms that the same low-carbon fund characteristic started attracting flows only *after* April 2018.

Overall, the results confirm the strong appetite of investors for low-carbon funds and their willingness to refrain from investing in the part of the economy most exposed to future realizations of climate risks.

4.2 Heterogeneity across funds and investors

We here investigate three relevant sources of cross-sectional heterogeneity of the investor responses. First, we expect the low-carbon flow premium to be more pronounced among funds with low sustainability globes, given that, for these funds, the LCD represents a more considerable informational shock. It is conceivable that before April 2018, mutual fund clients used Morningstar's sustainability Globes as an imperfect proxy for a fund's exposure to climate risks. In line with this conjecture, column (1) in Table 3 shows that the low-carbon flow premium is significantly higher among low-sustainability than among high-sustainability funds.

- Table 3 -

Second, we expect the flow premium to be more pronounced among funds with higher risk-adjusted financial performance. This is because marginal investors should behave so to be indifferent between climate-related risk and general portfolio risk. We employ the Morningstar overall ratings (Stars) to 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 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 forward-looking considerations related to climate risk. Column (2) in Table 3 shows that, as expected, high-Stars low-carbon funds experienced a significantly higher flow premium than low-Stars low-carbon funds.[17]

Third, although we do not have detailed data at the investor level, we can infer differences across funds of marginal investors based on their revealed preferences for certain fund charac-

[17]In the Online Appendix, Table A7 shows the heterogeneity of the low-carbon fund flow premium when splitting the sample in funds with low (1 or 2), medium (3), and high (4 or 5) Globes or Stars ratings.

teristics.[18] In particular, we utilize the existence of important clientele differences for growth and value assets, with arguably more short-horizon investors self-selecting in value-oriented funds (Cronqvist, Siegel, and Yu, 2015; Betermier, Calvet, and Sodini, 2017). We expect the LCD to have a stronger effect for funds whose marginal investors are growth-oriented. In line with this conjecture, in column (3) of Table 3, we find the low-carbon flow premium to be significantly higher for funds with higher loading on the growth factor, which we use to proxy for the growth orientation of the investor base.[19]

Overall, these results are consistent with the idea that investors act on a risk-risk trade-off between the exposure to climate risk and the exposure to traditional portfolio risk.

4.3 Heterogeneity across time

As an additional source of identification, we examine the variation in the low-carbon flow premium over time. For these analyses, we focus on the extended post-publication period

[18] The ideal data would allow researchers to observe the characteristics of individual mutual fund investors and their entire portfolios. For instance, we would expect investors holding many funds to find low-carbon investing less costly in terms of diversification than investors holding only one or two funds. The available data do not allow us to test this conjecture. The distinction between institutional and retail funds is not particularly helpful. While institutional investors are generally more diversified than retail investors (which predicts a stronger reaction to the LCD), they are also more likely to have had already some ways to partially assess climate risks (which predicts a weaker response to the LCD). In fact, we observe a similar flow premium for both institutional and retail mutual funds.

[19] 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 with the mean market-to-book ratio of its individual equity holdings as of April 2018, or when employing the Morningstar Value-Growth score, which underlies the widely-used Morningstar Style Box. In the latter case, we include only date fixed effects instead of date-by-category fixed effects since categories are also determined based on the Value-Growth score.

from April 2018 through September 2019.

Investors should be particularly eager to invest in low-carbon funds in periods of high salience of climate risks. In column (1) of Table 4, we interact the LCD indicator with the standardized value of the monthly global Google Trends search value index (SVI) for the topic "climate change", also employed in Ilhan, Sautner, and Vilkov (2021) and Choi, Gao, and Jiang (2020). As expected, in months of greater attention to climate change, low-carbon funds enjoy an even more significant flow premium.[20]

- Table 4 -

During our sample period, the public debate around climate change was significantly influenced by a rising climate activism in society, particularly by the younger generations. 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 to 7.6 million attendees globally), the largest climate protest to date.[21] In Table 4 columns (2) and (3), we investigate the flows into low-carbon funds following these two events likely to have influenced investors' attitude towards climate risks (Ramelli, Ossola, and Rancan,

[20]In analysis available on request, we confirm that flows into low-carbon funds are not influenced at all by public attention to climate change before the LCD became public information in April 2018.

[21]The New York Times, "Protesting Climate Change, Young People Take to Streets in a Global Strike", September 21, 2019. Estimations of the number of participants to the climate strikes are available on the website of the Fridays for Future movement: `https://www.fridaysforfuture.org/`.

2021). 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.

Finally, we explore the effect of LCD updates. Morningstar updates the LCD quarterly, with a one-month delay from the end of the quarter. Our sample period covers five quarterly updates in the post-publication period. As Table A8 in the Online Appendix 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 months following an LCD downgrade or upgrade, respectively, and 0 otherwise. For this analysis, we enlarge the sample also to switching funds. The results in column (4) of Table 4 indicate that LCD upgrades and downgrades also significantly impact net flows.

Overall, the analyses in this section confirm that the low-carbon flow premium varies over time with the varying perception of climate risks. Moreover, funds can access or lose climate-conscious investment flows depending on how they change their portfolios.

5 Mutual fund responses

With climate risks, a fund's optimal portfolio should be relatively more tilted towards low-carbon assets than in the benchmark case with no climate risks. Therefore, after the integration of firm-level and portfolio-level carbon risk metrics in Morningstar in April 2018, we expect fund managers to have rebalanced their portfolios in a lower carbon direction. In doing so, we expect them to also be mindful of diversification goals.

5.1 Main results

To initiate the analysis, Figure 5 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.[22] In the pre-publication period, mutual funds' average position changes in high CR firms remained overall stable around 0. This absence of a pre-trend is comforting. After April 2018, funds appear to have started to systemically reduce their stakes in high CR firms. Appendix Figure A2 shows a similar absence of pre-trends when conducting the same analysis with respect to fossil fuel involvement. That figure also suggests that funds reduce their exposure to this feature, albeit in a seemingly less decisive way.

– Figure 5 –

To formally test the significance of fund reactions, in Table 5 we conduct a regression analysis of monthly fund-firm position changes. Our main interest is on the coefficients on the interaction terms between the firm-level indicators $High\ CR\ (firm)$ and $Low\ CR\ (firm)$, and the indicator $Post_t$, equal to 1 for months following April 2018. We control for portfolio variables (the logarithm of total buys and sales during a month, monthly fund flows, and the portfolio churn rate Gaspar, Massa, and Matos, 2005) and basic firm characteristics

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

(lagged monthly return and weighting in the portfolio). We also include country, industry, and month-by-category fixed effects. We cluster standard errors along both months and funds to account for cross-sectional dependence between observations.

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.[23] The coefficient of interest remains virtually unchanged when we interact all controls with *Post* (column (2)).[24]

– Table 5 –

In columns (3) and (4), we show a similar trading pattern for firm-level fossil fuel involvement (FFI).[25] After April 2018, fund managers shifted about 0.13 basis points of their portfolios away from the average firm with fossil fuel involvement. Importantly, when we account for both the interaction effects of CR and FFI in the same regression (see columns

[23] $(0.17/10^{-4}) \times$ USD 1,700 $\times 10^6$ = USD 28,900

[24] In Online Appendix Table A9, we confirm that our main findings on fund managers' reactions are not driven by unobservable heterogeneity at the fund or firm level. Specifically, including firm and also fund fixed effects does not alter our results. As shown in the same table, our results also hold when including time-varying firm characteristics like (the log of) market capitalization, book-to-market ratio, leverage, and return on assets.

[25] 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.

(5) and (6)), the role of firm-level FFI is significantly reduced and is no longer statistically significant. In other words, once accounting for CR, fund managers did not sell holdings only because they were fossil fuel involved. This result indicates that the fund managers' reaction we document is not driven exclusively by an attempt to strategically meet the low-carbon criteria and enjoy the flow premium associated with it. If that were the case, a firm's fossil fuel involvement, which contributes to one of the two LCD criteria, would have explained position changes even net of the effect of carbon risk, despite not bringing significant new information to fund managers (as, after all, it is more or less known which firms are fossil fuel involved). Thus, this finding highlights the importance of the new information about carbon risk in explaining fund managers' trading decisions.

As a validation check, in Table A10 in the Online Appendix, we conduct two additional analyses. First, we show that the fund managers' shift away from high-carbon assets is stronger for funds indicated by Morningstar as having a portfolio carbon risk score higher than the category average. Information about carbon risk is arguably particularly salient for such funds. Second, we investigate the effect of differential degrees of informational shock at the firm level. In particular, we compute the difference between a firm's carbon risk and its environmental score from Sustainalytics, which was already available on Morningstar before April 2018 and may have been used by climate-concerned fund managers to proxy a firm's exposure to climate transition risk.[26] As expected, we find a stronger reaction of fund

[26]To make the two scores comparable we make two adjustments. First, we reverse the environmental score, such that a higher score represents a worse environmental performance. Second, we standardize both

managers when the two scores diverge the most.

Overall, the findings in this section are consistent with the insight that the optimal portfolio when accounting for climate transition risks has a lower exposure to high-carbon-risk assets than in the traditional setting with no such risks. After a shock in the availability of information on climate transition risk, fund managers shifted their portfolios accordingly in a lower-carbon direction.

5.2 Heterogeneity across funds and firms

The conceptual framework developed in Section 3 suggests that the degree of divestment from high-carbon-risk assets should depend on how costly that switch is for a fund in terms of diversification and hence volatility. This insight yields at least two testable predictions. First, for a fully-diversified fund, moving away from high-carbon firms necessarily means giving up part of its diversification. By contrast, a little-diversified fund can move in a low-carbon direction by maintaining the same diversification, or even improving it. Thus, we expect funds with a high industry concentration index to tilt away from high-carbon firms more aggressively than more sectoral diversified funds.

Second, when choosing how to rebalance the portfolio, fund managers should prefer to sell high-carbon-risk firms offering the lowest diversification benefits. Hence, after April

the carbon risk and the environmental scores. When the difference between the two metrics is positive, the firm's carbon risk is smaller than what would have been expected using only the environmental score as a proxy for climate risk.

2018, we expect fund managers to have sold high-CR-high-volatility firms more aggressively than high-CR-low-volatility firms, as an asset with higher standard deviation is less useful for diversification purposes.

In Table 6 we empirically test these predictions by splitting the sample within each category along funds' industry concentration index and firms' volatility. As predicted, funds with the highest level of industry concentration reduced their carbon risk exposure more than more diversified funds (see columns (1) through (3)).

A similar pattern emerges for the heterogeneity within portfolios across firms' volatility (see columns (4) through (6)). Pronounced rebalancing occurs among high CR firms with high or medium volatility. By contrast, the divestment from high-CR-low-volatility firms is small and not statistically significant.[27]

– Table 6 –

Taken together, these cross-sectional tests indicate that not every fund has the same incentives in reducing the exposure to high-carbon assets, and not every high-carbon asset is the same in the eyes of fund managers. Overall, they confirm the importance of the risk-risk trade-off in explaining differences in fund managers' reactions to climate transition risks.

[27]In analyses available upon request, we confirm that the economic findings from Table 6 hold also when employing a triple-interaction approach, i.e., when interacting High CR $\times$ Post with the Industry concentration index and firm volatility.

6 Conclusion

What are the implications of climate risks for portfolio investing and management? We provide conceptual and empirical evidence indicating that investors face and act according to a fundamental trade-off between minimizing exposure to climate transition risks and maximizing diversification opportunities in a still-not-low-carbon economy.

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

Funds labeled as "low-carbon" enjoyed a substantial increase in flows relative to otherwise similar funds. This premium is more pronounced among funds with higher risk-adjusted returns, consistent with the marginal investors striking a balance between climate and conventional risks. The premium is also higher in 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 is more pronounced for funds with less to lose in terms of portfolio diversification. Moreover, among high-carbon firms, fund managers sold high-volatility securities, which are less useful for diversification purposes, more aggressively.

Overall, our results confirm climate risks as a key consideration in the mutual fund industry, and they 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 on the behavior of different types of investors and fund managers in the transition to a low-carbon economy. Moreover, unpacking conflicting mutual fund objectives is potentially important to explain not only trading decisions, but also other dimensions of fund manager behavior, such as engagement, voting, and potential green-washing activities.

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Figures

Figure 1: Morningstar Direct snapshot

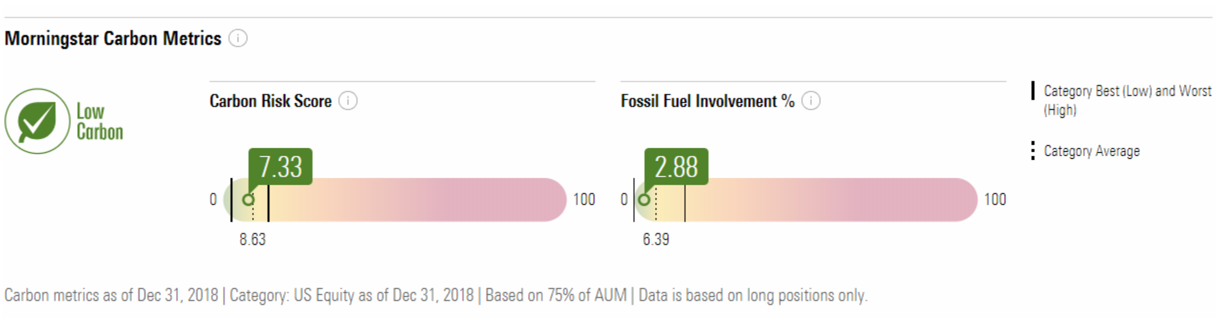


Figure 2: Low-carbon firms are less risky

These figures show binned scatter plots of firm-level *Loading on negative climate news (firm)* and stock volatility against firm-level carbon risk score from Sustainalytics. 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, the monthly returns from January 2015 through April 2018 on that index and the three Fama-French global factors from Kenneth French's website, with at least 12 monthly observations. *Volatility (firm)* is the standard deviation of monthly returns over the same period.

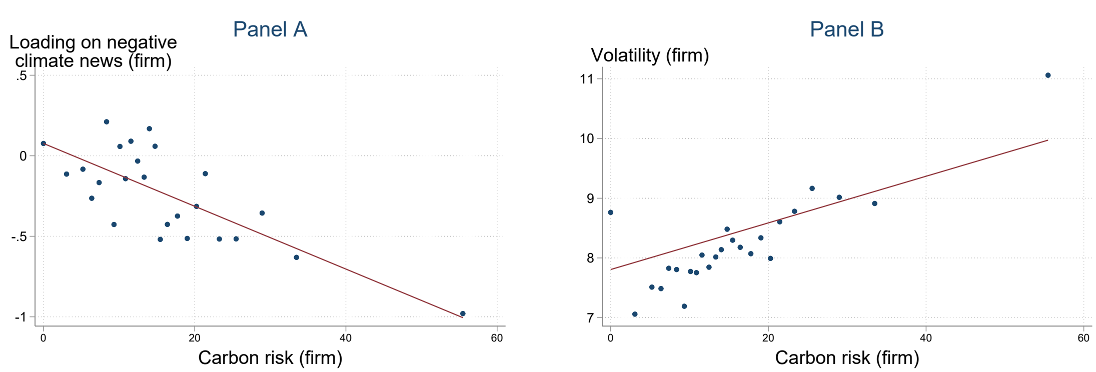


Figure 3: The risk-risk trade-off of low-carbon funds

These figures 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 score. The sample includes 6,310 US and European funds as of April 2018 with available carbon risk score, fund flows, and individual portfolio holdings data. 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 returns. *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.

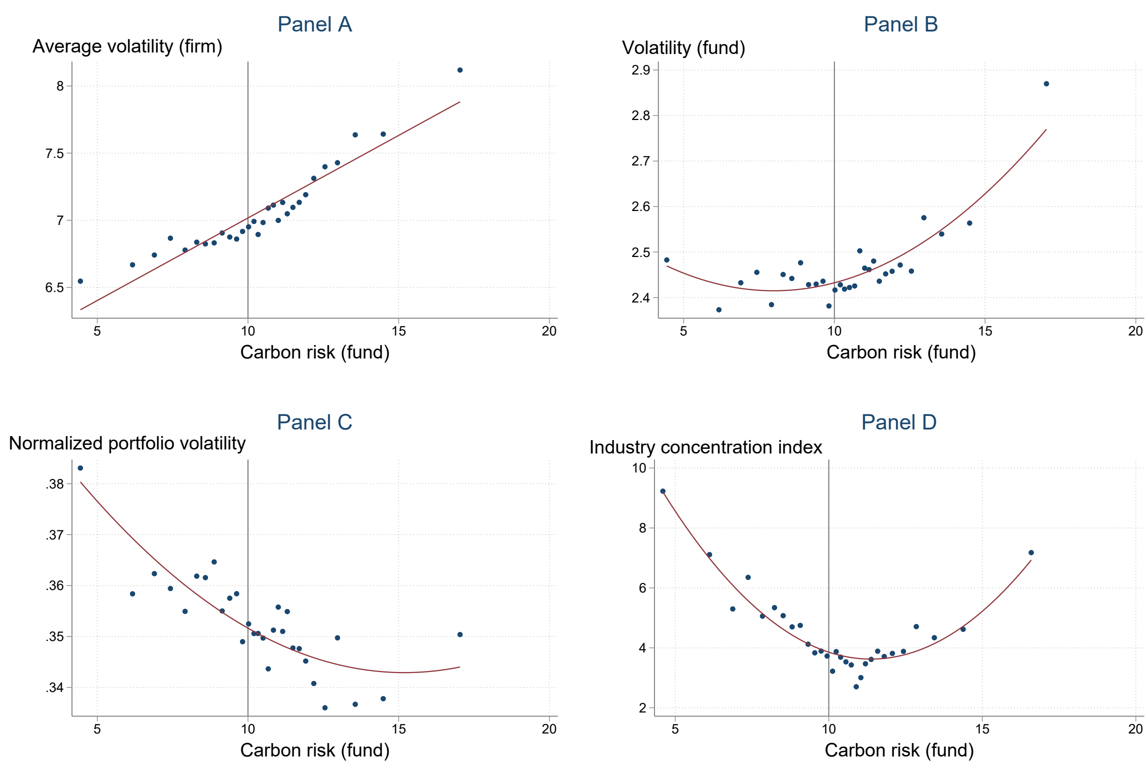
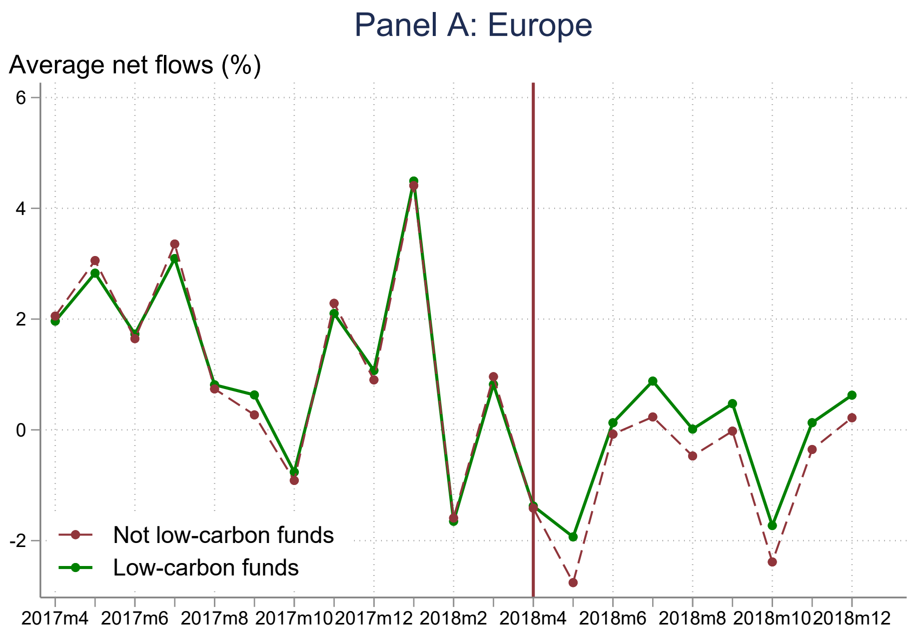


Figure 4: Evolution of flows into low-carbon and not-low-carbon funds
These figures show the equally-weighted average monthly net flows of funds designated low-carbon at the end of April 2018 (solid green lines) and conventional funds (dashed red line) domiciled in Europe (Panel A) and USA (Panel B), from April 2017 through December 2018. Flows are computed as of end of the month. The Low Carbon Designation was introduced at the end of April 2018.



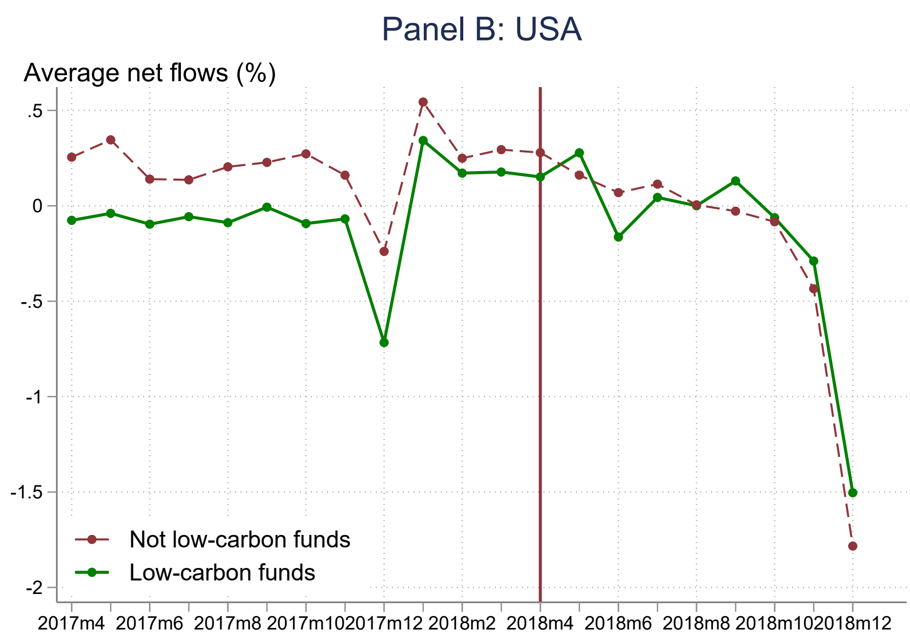
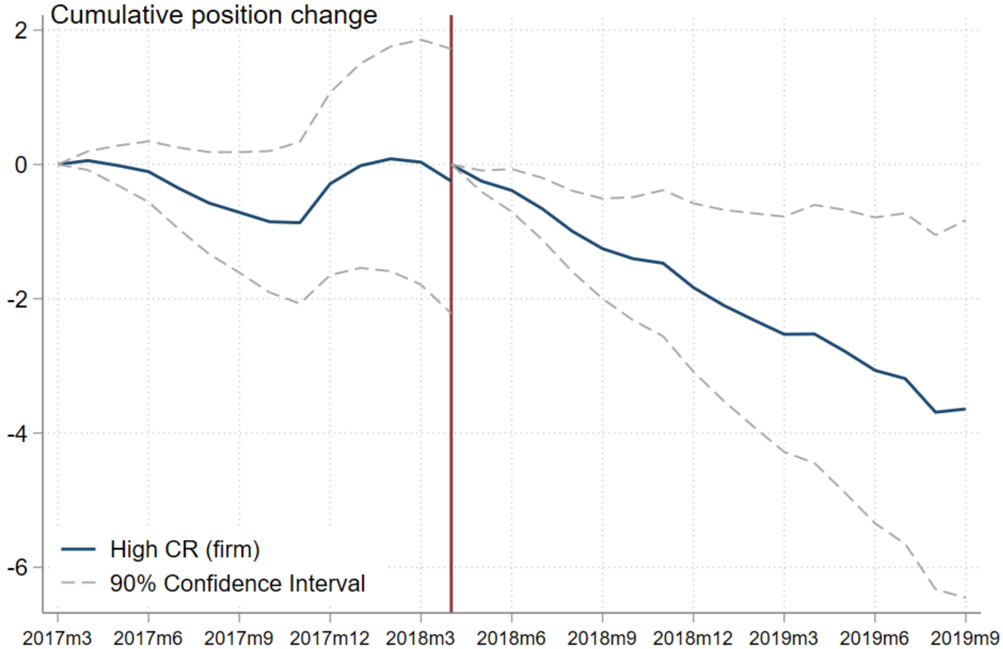


Figure 5: Effect of firm-level carbon risk on funds' position changes
This figure shows the cumulative effect of the firm-level indicator for high carbon risk on monthly firm-fund-level position changes from April 2017 through September 2019. The cumulation of the estimates and confidence intervals is 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 score equal or above 30, controlling for lagged stock return, industry, and 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 USA for which information on the Low Carbon Designation (LCD) and flows is available. Panel A covers all fund-month observations from April 2017 through September 2019, while Panel B provides a snapshot as of the end of April 2018. Panel C covers all fund-firm-month observations from April 2017 through September 2019. LCD is a dummy variable indicating funds that obtained the Low Carbon Designation at the end of April 2018. CR and FFI are the portfolio carbon risk and fossil fuel involvement. 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 AUM 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 overall Morningstar rating on a 1-5 scale. ΔStars and ΔGlobes indicate if a fund received a downgrade (-1) or an upgrade (1) in the Morningstar "overall" performance rating (Stars) or Morningstar sustainability rating (Globes), 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 score 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 their 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	392,417	0.00	0.00	0.18	0.00	0.00	1.00	0.38
CR	244,879	0.23	8.37	10.13	10.05	11.44	45.60	3.42
FFI	346486	0.00	3.03	6.98	6.17	9.50	92.73	5.83
Flows	392,417	-19.54	-1.53	0.07	-0.23	1.29	30.66	3.99
Normalized flows	392,417	1.00	27.00	50.27	50.00	73.00	100.00	27.20
Return	392,417	-99.71	-1.08	0.41	0.61	2.23	26.21	3.33
Log assets	392,417	4.69	16.76	18.34	18.30	19.82	26.02	2.10
Volatility	392,417	0.01	1.73	2.78	2.51	3.57	28.72	1.48
Age	392,417	0.16	5.49	13.47	12.08	18.66	119.32	10.26
Globes	284,513	1.00	2.00	3.05	3.00	4.00	5.00	1.13
Stars	235,777	1.00	2.00	3.15	3.00	4.00	5.00	1.06
ΔGlobes	392,417	-1.00	0.00	0.00	0.00	0.00	1.00	0.32
ΔStars	392,417	-1.00	0.00	-0.00	0.00	0.00	1.00	0.30

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

	N	min	p25	mean	p50	p75	max	sd
LCD	13,465	0.00	0.00	0.18	0.00	0.00	1.00	0.38
CR	9,251	0.23	9.02	10.68	10.61	11.92	45.58	3.44
FFI	13,419	0.00	2.92	6.66	5.89	9.05	70.99	5.50
Flows	13,465	-19.27	-2.20	-0.89	-1.55	-0.00	30.48	3.87
Normalized flows	13,465	1.00	27.00	49.68	49.00	73.00	100.00	27.33
Return	13,465	-9.79	0.47	2.04	1.81	3.45	13.91	2.10
Log assets	13,465	7.14	16.79	18.36	18.32	19.85	25.93	2.09
Volatility	13,465	0.07	1.73	2.25	2.30	2.73	9.20	0.81
Age	13,465	0.16	5.07	13.11	11.71	18.33	118.24	10.28
Globes	9,595	1.00	2.00	3.02	3.00	4.00	5.00	1.14
Stars	9,842	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 sales (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: The low-carbon flow premium

This table shows 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 a dummy Post equal to 1 for months following April 2018. Models in columns (2) and (5) also include portfolio carbon risk (CR) and fossil fuel involvement (FFI) and their interactions with Post. Models in columns (3) and (6) interact all control variables with Post. The sample includes active equity and balanced mutual funds domiciled in Europe or USA, excluding funds that experienced an LCD upgrade or downgrade in August or November 2018. 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 is significantly different from zero at the 1%, 5%, and 10% level, respectively.

Dep. variable:	Flows			Normalized flows		
	(1)	(2)	(3)	(4)	(5)	(6)
LCD × Post	0.22***	0.23**	0.22**	1.99**	1.91**	2.08**
	(3.16)	(2.61)	(2.56)	(2.53)	(2.77)	(2.15)
LCD	0.11	-0.06	0.11	0.78	-0.76	0.76
	(0.99)	(-0.79)	(0.97)	(0.94)	(-1.31)	(0.90)
CR × Post		0.01			0.11	
		(0.30)			(0.51)	
FFI × Post		0.01*			0.00	
		(1.96)			(0.11)	
Return	0.14***	0.10**	0.17***	0.98**	0.77*	1.12*
	(3.86)	(2.63)	(3.41)	(2.60)	(1.83)	(2.03)
Return t-2	0.12***	0.10***	0.11**	0.95***	0.79**	0.62
	(4.38)	(2.91)	(2.33)	(3.26)	(2.21)	(1.33)
Return t-3	0.15***	0.13***	0.22***	1.25***	1.11**	1.74***
	(3.67)	(2.87)	(3.64)	(3.12)	(2.45)	(3.08)
Log assets	-0.04*	-0.05*	-0.07**	0.60*	0.55	0.75*
	(-1.92)	(-1.87)	(-2.38)	(1.79)	(1.60)	(2.00)
Volatility	0.05	0.11	-0.05	0.50	0.98	-0.31
	(0.69)	(1.45)	(-0.57)	(0.82)	(1.64)	(-0.48)
Age	-0.04***	-0.04***	-0.05***	-0.40***	-0.36***	-0.42***
	(-7.14)	(-6.31)	(-8.07)	(-8.77)	(-8.48)	(-9.61)
ΔGlobes	0.00	0.01	-0.03	0.10	0.12	-0.05
	(0.12)	(0.34)	(-1.63)	(0.68)	(0.60)	(-0.33)
ΔStars	0.06*	0.05*	0.06	0.23	0.04	0.23
	(2.08)	(2.05)	(1.57)	(0.84)	(0.21)	(0.62)
CR		-0.02			-0.20	
		(-1.01)			(-1.27)	
FFI		-0.03***			-0.20***	
		(-3.33)			(-3.43)	
Observations	261,361	168,821	261,361	261,361	168,821	261,361
R-squared	0.17	0.16	0.17	0.13	0.14	0.14
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 3: Cross-sectional heterogeneity of the low-carbon flow premium
This table shows results of OLS regressions of monthly flows from April 2017 through December 2018 exploring the differential effect of the LCD along funds' Morningstar sustainability Globes (column (1)), Morningstar Stars (column (2)), and 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. All regressions include control variables (returns in the previous three months, volatility, log asset, age, ΔGlobes, and ΔStars), 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 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% level, respectively.

	(1)	(2)	(3)
Dep. variable:		Flows	
LCD × Post	0.67***	-0.35**	-0.02
	(4.48)	(-2.37)	(-0.11)
LCD × Post × Globes	-0.15***		
	(-3.55)		
LCD × Post × Stars		0.20***	
		(6.44)	
LCD × Post × Loading on growth			0.16***
			(4.57)
Observations	185,535	138,955	259,212
R-squared	0.15	0.16	0.17
Controls	Yes	Yes	Yes
Month-category FE	Yes	Yes	Yes
Country FE	Yes	Yes	Yes
Month-category clustered SE	Yes	Yes	Yes

Table 4: Time series heterogeneity of the low-carbon flow premium
This table shows results of OLS regressions of monthly flows from May 2018 through September 2019 (post-publication period) on LCD and its interaction with *SVI Climate change* (column (1)) and indicators for March 2019 and September 2019, in correspondence of the first global climate strike in March 2019, and the "Global Week for Future" protest in September 2019 (columns (2) and (3)). Column (4) investigates the effect of LCD updates, adding LCD switching funds to the sample. All regressions include control variables (returns in the previous three months, volatility, log asset, age, ΔGlobes, and ΔStars), as well as month-by-category and country fixed effects. Column (3) also includes the double interactions of *USA* with *LCD* and *Mar 2019*. *SVI Climate change* is the Google Trends global search value index for the topic "climate change" over the period May 2018 through September 2019, standardize to have mean 0 and unit standard deviation. *LCD Downgrade* and *LCD Upgrade* are dummy variables equal to 1 for months following an LCD downgrade or upgrade, and 0 otherwise. 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% level, respectively.

	(1)	(2)	(3)	(4)
Dep. variable:		Flows		
LCD	0.43***	0.37***	0.41***	
	(4.53)	(3.46)	(4.33)	
LCD × SVI Climate change	0.11***			
	(7.95)			
LCD × Mar 2019		0.38**		
		(2.34)		
LCD × Mar 2019 × USA		-0.30*		
		(-1.83)		
LCD × Sept 2019			0.31***	
			(9.66)	
LCD Downgrade				-0.18**
				(-2.57)
LCD Upgrade				0.21**
				(2.62)
Observations	192,229	192,229	192,229	228,446
R-squared	0.11	0.11	0.11	0.10
Controls	Yes	Yes	Yes	Yes
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 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 carbon risk (CR) firms have a carbon risk score of 30 or higher while low CR firms have a carbon risk score below 10. The remaining, medium CR firms are the benchmark. The sample includes active equity and balanced mutual funds domiciled in Europe or USA. 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 is significantly different 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 × Post			-0.13**	-0.13**	-0.05	-0.08
			(-2.06)	(-2.18)	(-0.71)	(-1.06)
FFI			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: Cross-sectional heterogeneity of mutual funds' responses to carbon risk This table shows 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 carbon risk (CR) firms have a carbon risk score of 30 or higher while low CR firms have a carbon risk score below 10. The remaining, medium CR firms are the benchmark. The first three columns show sample splits along funds' Industry concentration index relative to other funds in the same category. The last three columns show splits along the volatility of portfolio firms. The sample includes active equity and diversified mutual funds domiciled in Europe or USA. 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 is significantly different from zero at the 1%, 5%, and 10% level, respectively.

Dep. variable:	Position change					
	Industry concentration index			Volatility (firm)		
	Bottom 33% (1)	Middle (2)	Top 33% (3)	Bottom 33% (4)	Middle (5)	Top 33% (6)
High CR (firm) × Post	-0.03	-0.21*	-0.63***	-0.09	-0.19**	-0.19***
	(-0.58)	(-1.97)	(-3.29)	(-1.10)	(-2.52)	(-2.81)
Low CR (firm) × Post	-0.01	0.07	0.26**	0.01	0.08	0.01
	(-0.22)	(1.11)	(2.17)	(0.22)	(1.63)	(0.12)
High CR (firm)	0.08	0.01	0.25	-0.04	0.07	0.14**
	(1.41)	(0.15)	(1.65)	(-0.55)	(1.06)	(2.21)
Low CR (firm)	0.09***	0.02	-0.12	0.04	-0.01	0.06
	(3.91)	(0.45)	(-1.36)	(0.81)	(-0.34)	(1.40)
Observations	6,510,897	2,708,823	1,571,619	2,455,280	2,702,296	5,633,763
R-squared	0.04	0.05	0.09	0.05	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
Industry FE	Yes	Yes	Yes	Yes	Yes	Yes
Month-fund clustered SE	Yes	Yes	Yes	Yes	Yes	Yes

Online Appendix

Figure A1: Low-carbon funds and negative climate news
These figures show binned scatter plots of fund-level *Loading on negative climate news (fund)* against fund-level carbon risk (Panel A) and fossil fuel involvement (Panel B). The sample includes 6,310 US and European funds as of April 2018 with available fund-level carbon risk score, 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 the Fama-French three global factors. The graphs control for fund size and category fixed effects.

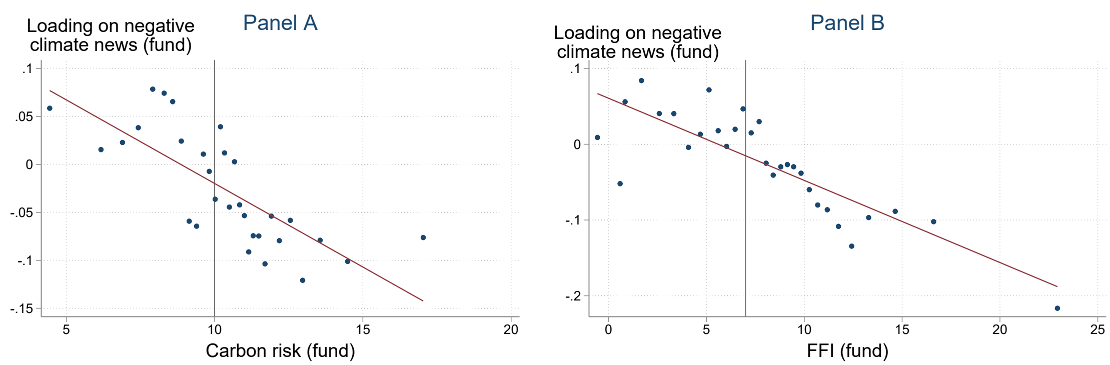

Figure A2: Effect of firm-level fossil fuel involvement on funds' position changes This figure shows the cumulative effect of the firm-level indicator for fossil fuel involvement on monthly firm-fund-level position changes from April 2017 through September 2019. The cumulation of the estimates and confidence 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.

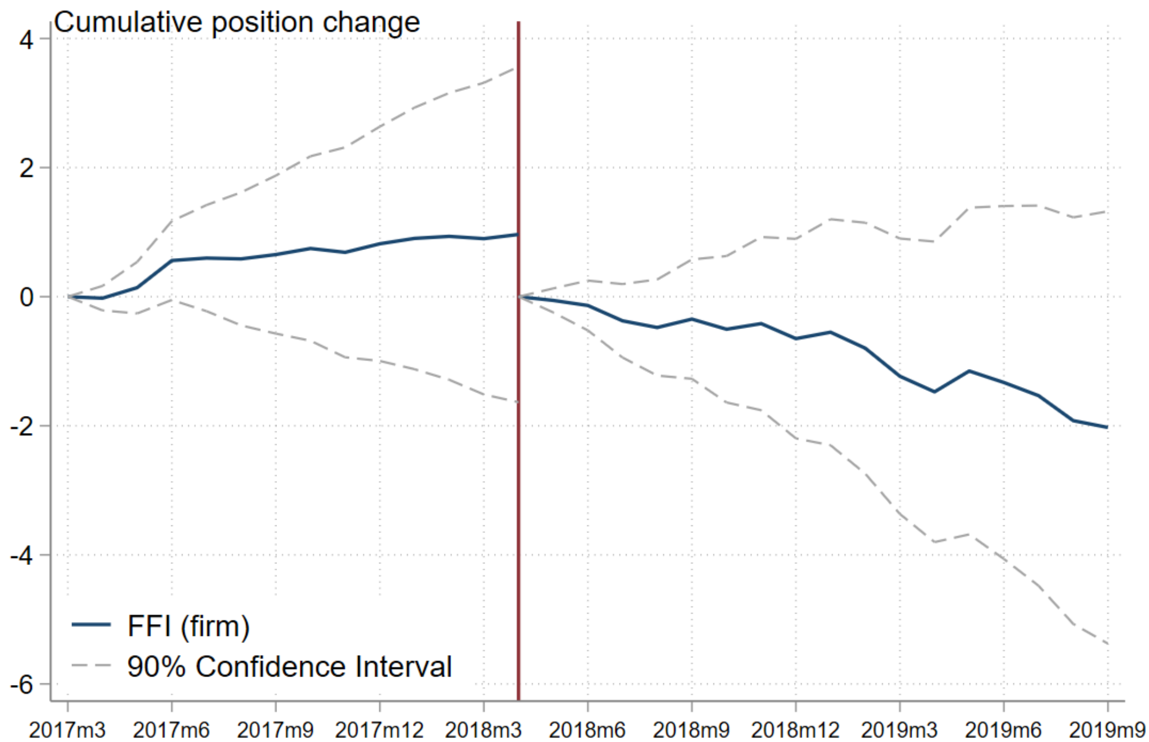

Table A1: Firm-level carbon risk scores by GICS sectors

This table shows the descriptive statistics of firm-level carbon risk scores from the ESG research provider Sustainalytics, by GICS sector. The sample includes all global firms covered by Sustainalitcs for 2017. According to Sustainalytics, the carbon risk score capture 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 controls since 2017) to compute the value-weighted fund-level carbon risk scores. The firm-level carbon risk scores were first released at the end of April 2018, contemporaneously to the release of the Morningstar 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 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	9,266	0.18	-2.58	-1.80	-0.87	3.90
USA	4,199	0.17	-1.00	-0.23	0.75	3.51
Total	13,465	0.18	-2.20	-1.55	-0.00	3.87

Panel B: Morningstar sustainability ratings ("Globes")

LCD	1	2	3	4	5	Total
0	858	1,671	2,595	1,619	703	7,446
1	183	366	677	581	342	2,149
Total	1,041	2,037	3,272	2,200	1,045	9,595
% of LCD funds	17.58%	17.97%	26.09%	26.41%	32.72.41%	22.40%

Panel C: Morningstar overall ratings ("Stars")

LCD	1	2	3	4	5	Total
0	497	1,618	2,898	2,062	736	7,811
1	86	368	682	604	291	2,031
Total	583	1,986	3,580	2,666	1,027	9,842
% of LCD funds	14.75%	18.53%	19.05%	22.66%	28.33%	20.64%

Table A3: 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 USA active open-end funds for which portfolio holdings as of April 2018 and 12-month average portfolio carbon risk score are available. *CR (fund)* is the portfolio 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. Finally, *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.

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
CR (fund)	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

Table A4: The low-carbon flow premium: Asset-weighted regressions
This table shows 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 a dummy 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 is significantly different from zero at the 1%, 5%, and 10% level, respectively.

Dep. variable:	Flows			Normalized flows		
	(1)	(2)	(3)	(4)	(5)	(6)
LCD × Post	0.23***	0.25***	0.23***	2.08**	2.02***	2.16**
	(3.41)	(3.08)	(2.97)	(2.79)	(3.30)	(2.50)
LCD	0.11	-0.07	0.10	0.76	-0.91	0.75
	(0.98)	(-0.99)	(0.95)	(0.93)	(-1.59)	(0.89)
CR × Post		0.01			0.12	
		(0.36)			(0.54)	
FFI × Post		0.01			-0.00	
		(1.54)			(-0.11)	
Observations	261,361	168,821	261,361	261,361	168,821	261,361
R-squared	0.17	0.16	0.17	0.14	0.14	0.14
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 A5: The low-carbon flow premium: Adding fund fixed effects
This table shows 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 a dummy 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 is significantly different from zero at the 1%, 5%, and 10% level, respectively.

Dep. variable:	Flows			Normalized flows		
	(1)	(2)	(3)	(4)	(5)	(6)
LCD × Post	0.41***	0.37***	0.35***	2.77***	2.42***	2.52**
	(5.61)	(4.36)	(4.24)	(3.44)	(3.34)	(2.75)
CR × Post		-0.00			0.02	
		(-0.10)			(0.10)	
FFI × Post		0.01			0.02	
		(1.53)			(0.36)	
Observations	261,361	168,728	261,361	261,361	168,728	261,361
R-squared	0.37	0.36	0.37	0.39	0.38	0.39
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 A6: The low-carbon flow premium: Pseudo LCD in the pre-publication period

This table shows 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), the interaction of this variable with a dummy 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, even 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 is significantly different from zero at the 1%, 5%, and 10% level, respectively.

Dep. variable:	Flows			Normalized flows		
	(1)	(2)	(3)	(4)	(5)	(6)
LCD (pseudo) × Post	0.26***	0.26**	0.28***	2.02*	1.52*	2.29**
	(3.51)	(3.02)	(3.26)	(2.09)	(1.92)	(2.34)
LCD (pseudo)	0.00	-0.21**	-0.00	0.31	-1.06	0.25
	(0.01)	(-2.34)	(-0.02)	(0.29)	(-1.50)	(0.24)
CR × Post		-0.00			-0.01	
		(-0.01)			(-0.11)	
FFI × Post		0.01			0.01	
		(0.88)			(0.10)	
Observations	165,187	111,521	165,187	165,187	111,521	165,187
R-squared	0.15	0.15	0.16	0.12	0.13	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

Table A7: Heterogeneity of the low-carbon flow premium: Globes and Stars
This table shows results of OLS regressions of monthly flows from April 2017 through December 2018 exploring the differential LCD effect along Globes (sustainability) ratings, columns (1)-(3), and Stars (financial performance) ratings, columns (4)-(6). The regressions control for fund characteristics, 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 statistical significance at the 1%, 5%, and 10% level, respectively.

	(1)	(2)	(3)	(4)	(5)	(6)
Dep. variable:	Flows					
	1-2 Globes	3 Globes	4-5 Globes	1-2 Stars	3 Stars	4-5 Stars
LCD × Post	0.34**	0.21*	0.09	0.08	0.30***	0.44***
	(2.48)	(2.07)	(0.68)	(0.83)	(3.11)	(6.15)
LCD	0.11	0.16	0.26***	0.07	-0.08	-0.04
	(0.65)	(1.01)	(3.43)	(0.46)	(-1.15)	(-0.27)
Observations	59,246	64,012	62,274	36,069	50,918	51,968
R-squared	0.16	0.16	0.16	0.15	0.16	0.15
Controls	Yes	Yes	Yes	Yes	Yes	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 A8: LCD changes after April 2018 through September 2019
This table summarizes the results of the quarterly LCD updates that took place between May 2018 and September 2019 at a quarterly frequency, based on the portfolio holdings as at the end of each quarter.

LCD updates	Aug 2018 (Q2-2018)	Nov 2018 (Q3-2018)	Feb 2019 (Q4-2018)	May 2019 (Q1-2019)	Aug 2019 (Q2-2019)
Downgrades	206	324	412	555	593
Confirmations	13,045	12,625	12,280	12,388	12,215
Upgrades	140	302	474	582	733

Table A9: Mutual funds' responses to carbon risk: Additional controls
This table shows results of OLS regressions of monthly position changes on indicators for firms' carbon risk (columns (1) to (3)) and both carbon risk and fossil fuel involvement (columns (4) to (6)) from April 2017 through September 2019 interacted with a dummy Post equal to 1 for months following April 2018. High carbon risk (CR) firms have a carbon risk score of 30 or higher while low CR firms have a carbon risk score below 10. The remaining, medium CR firms are the benchmark. The sample includes active equity and diversified mutual funds domiciled in Europe or USA. All regressions control for lagged firm and fund characteristics, and month-by-category and country fixed effects. Columns (1) and (3) additionally control for 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) additionally control also for 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 is significantly different 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 × Post					-0.02
					(-0.36)
FFI					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

Table A10: Cross-sectional heterogeneity of mutual funds' responses - The role of information

This table shows 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. High carbon risk (CR) firms have a CR of 30 or higher while low CR firms have a CR below 10. The remaining, medium CR firms are the benchmark. The first three columns show sample splits along funds' portfolio CR relative to other funds in the same category. The last three columns show sample splits alongside the difference between firm-level standardized Sustainalytics E-Score and CR scores. The coefficient of High CR × Post cannot be estimated in column (6) since there are no high CR firms with a large, positive rating surprise. The sample includes active equity and diversified mutual funds domiciled in Europe or USA. 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 is significantly different from zero at the 1%, 5%, and 10% level, respectively.

Dep. variable:	Position change					
	Portfolio CR (fund)			Rating surpise (firm)		
	Bottom 33%	Middle	Top 33%	Bottom 33%	Middle	Top 33%
	(1)	(2)	(3)	(4)	(5)	(6)
High CR (firm) × Post	-0.04	-0.07	-0.22***	-0.22*	-0.18***	
	(-0.28)	(-0.93)	(-2.83)	(-1.91)	(-3.24)	
Low CR (firm) × Post	-0.00	-0.05	0.10**	0.00	0.02	0.24**
	(-0.02)	(-1.07)	(2.32)	(0.02)	(0.49)	(2.24)
High CR (firm)	-0.10	0.04	0.17**	-0.20	0.12**	
	(-0.94)	(0.52)	(2.52)	(-1.56)	(2.07)	
Low CR (firm)	0.06	0.05	-0.02	0.09	0.04	-0.15
	(1.12)	(1.42)	(-0.62)	(0.91)	(1.03)	(-1.55)
Observations	2,118,663	4,210,790	4,461,886	770,702	9,368,565	744,056
R-squared	0.08	0.04	0.04	0.05	0.04	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
Industry FE	Yes	Yes	Yes	Yes	Yes	Yes
Month-fund clustered SE	Yes	Yes	Yes	Yes	Yes	Yes