Carbon Risk Exposure in the Mutual Fund Industry

Huan Kuang
Isenberg School of Management, University of Massachusetts Amherst
121 Presidents Drive, Amherst, MA 01002
hkuang@umass.edu

Bing Liang
Isenberg School of Management, University of Massachusetts Amherst
121 Presidents Drive, Amherst, MA 01002
bliang@isenberg.umass.edu

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Abstract

We construct a novel carbon risk measure for mutual funds based on stock holding data and explore how carbon risk affects mutual funds' performance, risk, and flows. We find that funds with higher carbon risk exposure have lower performance and higher unexplained risk in factor models. Furthermore, carbon risk is not fully captured in traditional Environmental, Social, and Governance (ESG) measures. We also find that institutional investors take carbon risk more seriously than retail investors do. Institutional funds with higher carbon risk exposure experience a negative flow shock in the subsequent period and their flow–performance relation is more sensitive. Moreover, when there is more news coverage on climate change, carbon risk exposure affects fund flows more negatively. These findings do not apply to retail funds.

Keywords: Climate finance; Carbon risk; Mutual fund performance; Socially responsible investing

JEL Classification: G11; G14; G23

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We construct a novel carbon risk measure for mutual funds based on stock holding data and explore how carbon risk affects mutual funds' performance, risk, and flows. We find that funds with higher carbon risk exposure have lower performance and higher unexplained risk in factor models. Furthermore, carbon risk is not fully captured in traditional Environmental, Social, and Governance (ESG) measures. We also find that institutional investors take carbon risk more seriously than retail investors do. Institutional funds with higher carbon risk exposure experience a negative flow shock in the subsequent period and their flow–performance relation is more sensitive. Moreover, when there is more news coverage on climate change, carbon risk exposure affects fund flows more negatively. These findings do not apply to retail funds.

1. Introduction

Climate change is posing "immediate and severe danger" to our society and will be one of the significant challenges facing the financial industry in the coming decades. The financial industry faces direct physical and transition risk exposure to climate change. For instance, a 2020 Network of Central Banks and Supervisors for Greening the Financial System (NGFS) report estimates that total annual economic costs from natural disasters around the world have frequently exceeded the 30-year average of $140 billion in the last 10 years.[1] The Toronto Centre's 2020 report estimates that global warming of around 4°C could result in a present value loss of US$4.2 trillion in financial assets globally.[2] The Global Risks Report 2020 from the World Economic Forum estimates that "climate change will put at risk around 2 percent of global financial assets and a worst-case scenario could see up to 10 percent of global financial assets being at risk by 2100."[3] Meanwhile, the financial industry plays a crucial role in our society's transition to a low-carbon economy. The International Capital Market Association (ICMA) states in the 2020 *Climate Transition Finance Handbook* that capital markets are critical in enabling the climate transition by ensuring the efficient flow of financing from investors to issuers wishing to address climate change risk issues.[4] The Royal Geographical Society in the United Kingdom considers the financial industry the leading actor in achieving the "net-zero" carbon emissions.[5]

The United Nations Framework Convention on Climate Change (UNFCCC) defines climate finance as "local, national, or transnational financing drawn from public, private, and

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[1] Feridun and Güngör (2020).
[2] The cost of inaction: Recognising the value at risk from climate change (https://res.torontocentre.org/guidedocs/Supervisors%20Response%20to%20Climate%20FINAL.pdf).
[3] The Global Risks Report 2020, World Economic Forum (http://www3.weforum.org/docs/WEF_Global_Risk_Report_2020.pdf).
[4] 2020 *Climate Transition Finance Handbook*, International Capital Market Association.
[5] Financing net zero: How can investment meet the climate challenge? (https://www.rgs.org/geography/advocacy-and-impact/impact/financing-net-zero/).

alternative sources of financing—that seeks to support mitigation and adaptation actions that will address climate change." (Hong, Karolyi, and Scheinkman, 2020). Given the importance and urgency of this matter, climate finance research is attracting great interest. Researchers have explored a variety of topics on climate finance, including how it could affect asset returns and risk (Bolton and Kacperczyk, 2021; In, Park, and Monk, 2019; Berkman, Jona, and Soderstrom, 2019), the stability of the finance sector (Monasterolo, 2020), corporate investment decisions (Lin, Schmid, and Weisbach, 2019), and investment strategy (Karydas and Xepapadeas, 2019; Engle, Giglio, Kelly, Lee, and Stroebel, 2020).

We argue that it is important to examine how climate change affects institutional investors such as the mutual fund industry.[6] First, as the largest group of institutional investors, mutual funds are directly exposed to climate change risk through their holdings of public companies and have a large impact on the capital markets. Second, by allocating assets among various companies, the mutual fund industry can play a crucial role in incentivizing companies to transition to a low-carbon business model. Third, the research on socially responsible investment (SRI) may not necessarily cover climate change risk. Therefore, studying mutual funds' carbon risk exposure can enhance our understanding of sustainable investments. In this paper, we construct a novel measure of mutual fund carbon risk exposure and explore how carbon risk affects mutual funds' performance, risk, and flows.

[6] "We are in the foothills of a long climb. Tackling the world's systemically important carbon emitters is ambitious and necessary. It requires partnership from all sides: investors, companies, policymakers, and civil society. The results from Climate Action 100+ show what can be achieved, and what still lies ahead, for us to drive the transition to net zero by 2050," said Anne Simpson, CalPERS Managing Investment Director, Board Governance & Sustainability and Climate Action 100+ Global Steering Committee member (https://www.calpers.ca.gov/page/investments/about-investment-office/investment-office-senior-team/anne-simpson). Climate Action 100+ is an investor-led initiative for reducing gas emission and consists of 545 global investors with more than $52 trillion in assets under management across 33 markets (https://www.climateaction100.org/whos-involved/investors/).

First, we study how carbon risk affects mutual funds' risk and returns. We find that carbon risk exposure negatively predicts future fund performance, as measured by both raw and risk-adjusted returns. We also find that mutual funds with higher carbon risk exposure have higher unexplained risk measured by factor models. Second, we study whether carbon risk changes investors' preferences. In particular, we find that investors become more responsive to past performance when their investment funds have higher carbon risk exposure. Carbon risk is negatively associated with future fund flows and positively associated with a more sensitive fund flow–performance relation. These findings show that investors consider carbon risk when evaluating mutual funds. It is increasingly important for institutional investors to be more prudent in investing sustainably, since their fiduciary duty or social responsibility requires them to do so.[7] To further examine how different investors may react to carbon risk differently, we split our sample into institutional investor funds and retail investor funds. We find that the above results apply only to institutional funds. This finding is consistent with Ilhan, Krueger, Sautner, and Starks (2020) regarding how institutional investors view climate change risk as a valid concern in their investment decisions.

Third, we examine how climate news affects investors' attitudes toward carbon risk, by interacting climate news sentiment with funds' carbon risk exposure. Using a climate news series constructed by Engle et al. (2020), we find that fund flows become even more sensitive to fund performance when the sentiment of news coverage on climate change becomes more negative. This result is consistent with Ilhan, Sautner, and Vilkov (2021) regarding how news reports shape investors' attitudes toward climate change. Our results show that mutual fund investors follow climate change news and pay close attention to funds' carbon risk exposure. Finally, we distinguish

[7] Fiduciary Duty in the 21st Century Final Report by the United Nations Environment Program Finance Initiative and Principles for Responsible Investment.

mutual funds' carbon risk exposure from conventional Environmental, Social, and Governance (ESG) measures. We show that climate change risk is not fully captured by traditional ESG measures. We follow El Ghoul and Karoui (2017) to construct an asset-weighted composite ESG score for each fund. Our calculations show that carbon risk exposure is weakly correlated with the ESG score, and the correlation varies in different periods. The average correlation is around -0.172 with a standard deviation of 0.207. Even after controlling for the ESG score, our previous empirical findings remain significant. This implies that our novel carbon risk measure adds value to existing ESG measures.

Our study contributes to the current literature in three ways. First, our study complements the current research on climate change risk and the mutual fund industry. Ceccarelli, Ramelli, and Wagner (2021) show that funds with Morningstar's Low Carbon Designation" draw investors' flows, and funds initially missed the designation shift their holdings toward less carbon-intensive firms. Ho (2021) shows that mutual funds with a higher correlation with climate change news outperform funds with a lower correlation. To our best knowledge, this is the first paper that constructs a large panel of data to directly measure mutual funds' carbon risk exposure. The panel data setting and direct identification of carbon risk allow us to track the impact of carbon risk on the mutual fund industry directly and over an extensive period. The methodology we use to calculate mutual funds' carbon risk scores can be used in future studies.

Second, our results reveal that carbon risk is real and significant in negatively affecting fund performance, reducing the attractiveness of a fund and increasing its unexplained risk in factor models. Other researchers find that firms' carbon risk affects firms' financial risk and return (Berkman et al., 2019; Bolton and Kacperczyk, 2021; Choi, Gao, and Jiang, 2020; In et al., 2019).

Our study shows that firm-level carbon risk is transferred to mutual funds through their holdings. Such risk cannot be diversified away through traditional portfolio construction.

Third, our study contributes to the growing literature on socially responsible investing and investors' social screening of mutual funds. Although researchers have extensively studied mutual funds' ESG investing (Van Duuren, Plantinga, and Scholltens, 2016, Riedl and Smeets, 2017, El Ghoul and Karoui 2017; Dyck et al., 2019; Pedersen, Fitzgibbons, and Pomorski, 2020; Döttling and Kim 2021), we show that climate change risk is not fully covered in traditional ESG measures. It is important for both investors and mutual fund managers to consider climate change risk as a new risk source. Investors, especially institutional investors, also demonstrate a strong social preference for investing in mutual funds with low carbon risk on top of the ESG investment strategy. These findings provide important insights for researchers, mutual fund managers, investors, and regulators.

The remainder of the paper is organized as follows. Section 2 reviews the literature and develops the testing hypotheses. Section 3 describes the data, variables, and methodologies used in the study. Section 4 presents the empirical results. Section 5 provides robustness tests. Lastly, Section 6 concludes the paper.

2. Literature Review and Hypothesis Development

2.1. Climate Change Risk

Generally, two types of risks are related to climate change: 1) physical risks, that is, risks related to the physical impact of a long-term shift in climate patterns, and 2) transition risks, namely, risks related to the transition to a lower-carbon economy. Regarding physical risks, drastic changes in climate patterns mean that we could face more frequent or severe weather events (e.g., hurricanes, wildfires, flooding, and drought). These physical risks can have financial implications for corporations, such as direct damages to assets, disruptions of supply chains, and increases in uncertainties in operations. Regarding transition risks, transitioning to a low-carbon economy is essential for our society to combat climate change. This process could entail extensive policies, liabilities, technologies, and market changes to corporations and financial institutions. Firms with higher carbon emissions are facing increasing scrutiny from regulators, investors, and consumers.[8] The change in social preferences could strand carbon-intensive assets and affect the value of other financial instruments (Colas, Khaykin, and Pyanet, 2019). In our paper, we focus on the transition risk of climate change as measured by fund-level carbon risk exposure.

2.2. Literature Review on Climate Finance

Researchers have been studying climate finance in a variety of areas. Choi et al. (2020) find that people revise their beliefs about climate change after experiencing extreme warm temperatures. Accordingly, stocks of carbon-intensive firms underperform firms with low carbon emissions in abnormally warm weather. Shive and Forster (2020) find that, among public firms, there exists a negative association between emissions and mutual fund ownership and board size, suggesting that increased oversight may decrease carbon emission externalities. Alok, Kumar, and Wermers (2020) show that local managers within a major disaster region underweight disaster zone stocks to a much greater degree than distant managers. The authors argue that these findings suggest fund managers may overreact to large climate disasters. Baldauf, Garlappi, and Yanelis (2020) model the equilibrium housing choice in which agents have different elasticities in terms of climate risk. They show that houses projected to be underwater in neighborhoods that believe in climate change sell at a discount, compared to houses in denier neighborhoods, suggesting that house prices reflect heterogeneity in beliefs about long-run climate change risk. Engle et al. (2020)

[8] See Recommendations of the Task Force on Climate-related Financial Disclosures.

propose hedging climate change risk through building a hedging portfolio by extracting climate-related innovations from climate news reports. Murfin and Spiegel (2020) compare housing prices based on the impact of sea level rise and find that the effect of sea level rise on housing prices is limited. Ilhan et al. (2020) survey institutional investors about their climate risk perceptions and document their concerns about climate risk, especially from a regulatory perspective. The authors find that large and long-term investors consider engagement, rather than diversification, to be the better approach to addressing climate risk. Brock and Hansen (2019) use insights from decision theory under uncertainty to explore research challenges in climate economics. Hsu, Li, and Tsou (2020) show that a long–short portfolio with high versus low toxic emission intensities yields a significant and positive abnormal return. They argue that high-emission firms are facing more exposure to regulatory shift risk and are expected to earn higher returns.

Other papers take a closer look at financial assets' exposure to climate change risk and investor behaviors. Ilhan, Sautner, and Vilkov (2021) show that climate policy uncertainty is priced in the option market. Firms with high carbon intensity face more questions from analysts about the uncertainty and risk, and the cost of protection is magnified whenever the public's attention to climate change spikes. Bolton and Kacperczyk (2021) explore whether carbon emissions affect the cross section of U.S. stock returns. They find that the stocks of firms with higher carbon intensity earn higher abnormal returns. Their findings suggest that investors are aware of the risk associated with carbon emissions and demand a corresponding risk premium. Jiang, Li, and Qian (2020) examine how banks perceive and price the effect of climate change on corporations. They show that the risk of sea level rise increases the spread of the long-term loans of affected firms. He, Kahraman, and Lowry (2020) find that shareholder proposals related to environmental and social issues have been gaining support, and virtually none has received the minimum threshold support rate to pass. The authors also find that failed environmental and social proposals with higher investor support significantly predict future firm risk, as measured by extreme negative stock returns and real events such as negative environmental and social incidents. The paper most related to ours is that of Ceccarelli et al. (2021). They exploit Morningstar's introduction of an eco-label for mutual funds in 2018 as a natural shock. They find an abnormal fund flow to funds labeled with the Low Carbon Designation, suggesting that investors consider climate issue an important dimension when making investment decisions. In addition, managers of active funds that missed the label upon its initial release shift their holdings to more climate-friendly firms.

2.3. Hypothesis Development

2.3.1. Carbon Risk Exposure and Mutual Fund Performance

Current literature finds mixed results on the relation between firm-level carbon risk and stock returns. Choi et al. (2020) show that the stocks of carbon-intensive firms underperform those of firms with low carbon emissions in abnormally warm weather. In et al. (2019) show that an investment strategy of long carbon-efficient firms and short carbon-inefficient firms would earn positive abnormal returns. On the other hand, Bolton and Kacperczyk (2021) find that the stocks of firms with higher carbon emissions earn higher abnormal returns. Berkman et al. (2019) find significantly negative returns to a hedging portfolio that is long (short) on firms with high (low) levels of climate risk, based on 10-K disclosures of firm-specific climate risk exposure. Meanwhile, Görgen, Jacob, Nerlinger, Riordan, Rohleder, and Wilkens (2020) construct a carbon risk factor–mimicking portfolio but find no evidence of a carbon risk premium. One difficulty that researchers are facing is constructing a direct and robust measure to capture firm-level carbon risk. The above papers all use different metrics and data to measure a firm's carbon risk.[9] In our paper, we adopt the firm-level carbon risk measure of a leading data vendor, and we state the advantages of this measure in the next section. We believe that the risk measure used in our study is well established and widely accepted in the financial industry.

Bolton and Kacperczyk (2021) propose three hypotheses on how the financial market prices carbon dioxide emission risk. First, the financial market adopts the emission risk as a systematic risk and prices it accordingly. Second, the financial market is inefficient at pricing the emission risk. Third, investors' avoidance of so-called "sin stocks" will push them away from high-emission firms, unless these firms provide a higher return. In our paper, we focus our analysis on carbon risk. We argue that the financial market understands and prices carbon risk through an adaptive process.[10] First, the climate change and global warming reality is evolving. There have been more extreme weather events in recent years compared to previous years. As climate change risk becomes more emergent and the scientific studies on climate change reveal more facts, the financial market will price carbon risk with more severity. Second, the public's understanding of carbon risk is evolving as well. As shown in the 2020 "Explore Climate Change in the American Mind" report from Yale University and George Mason University, the percentage of people who believe that climate change is happening and are concerned about the issue has been increasing over the years. Furthermore, more and more people think that climate change is impacting our

[9] Choi et al. (2020) use industry emissions as a proxy for firms' carbon sensitivity levels. In et al. (2019) use revenue-adjusted greenhouse gas emissions at the firm level as the main environmental performance measure, using emission data from the Trucost database. Bolton and Kacperczyk (2021) construct the firm-level carbon emissions data assembled by seven main providers, namely, the Carbon Disclosure Project, Trucost, MSCI, Sustainalytics, Thomson Reuters, Bloomberg, and Institutional Shareholder Services. Berkman et al. (2019) use the climate risk measure from the CERES database, which is based on textual analysis of extracts from 10-K disclosures that describe different aspects of climate risk. We explain in the next section why the carbon risk measure used in our paper stands out compared to others.
[10] See Lo (2019).

lives now rather than in a distant future.[11] Third, environmental policies and public scrutiny of carbon risk are evolving. Researchers find that macro policy changes are related to investors' perspectives on firm carbon risk (Ilhan et al., 2021). Generally, policymakers around the world are increasingly worried about climate change and are gradually adopting stricter environment policies. Studies also show that institutional shareholders are starting to move away from high–carbon risk firms since the 2016 Paris Agreement (Choi et al., 2021). The adaptive process of financial market participants in understanding and pricing carbon risk will thus create constant negative pressure on high–carbon risk firms.[12] The price discovery process of carbon risk induces firms with high carbon risk to underperform the market. Finally, these negative pressures are transferred to mutual funds through their holdings of the underlying stocks. Based on the above arguments, we propose the first hypothesis as follows.

H1: Mutual funds with higher carbon risk exposure perform significantly worse than funds with lower carbon risk exposure.

2.3.2. Carbon Risk Exposure and Mutual Fund Risk

Researchers are also exploring whether firm-level carbon risk affects firms' tail risk. Hong, Li, and Xu (2019) use data from 31 countries with publicly traded food companies to show that the stock prices of food companies do not fully reflect climate risk. Ilhan et al. (2021) show that the cost of option protection against downside tail risk is greater for firms with more carbon-

[11] In Table A4 of the Appendix, we present the results of Americans' view on climate change from 2008 to 2018. To better understand Americans' views on climate change, the Yale Program on Climate Change Communication (YPCCC) and the George Mason University Center for Climate Change Communication (Mason 4C) have conducted nationally representative surveys of U.S. adults twice a year for over a decade.

[12] Table A1 of the Appendix reports the firm characteristics and performance of high– and low–carbon risk firms. We find that firms with lower carbon risk have higher profitability, higher stock returns, higher leverage, and smaller size. A higher percentage of shares of these firms are held by institutional shareholders, and the institutional holdings are less concentrated. These firms also have a larger board size, younger and more diversified board members, and are less likely to have a Chief Executive Officer (CEO) serving as the chair of the board. Our findings are consistent with those of Choi et al. (2021).

intensive business models. These studies suggest that carbon risk could increase firms' tail risk and that such risk cannot be diversified away using a simple diversification strategy. Thus, we argue that common risk factors cannot explain mutual funds' carbon risk exposure. We propose the following hypothesis accordingly:

H2: Mutual funds with higher carbon risk exposure have higher unexplained risk but no difference in explained risk in factor models.

2.3.3. Carbon Risk Exposure and Mutual Fund Flows

Perhaps the most interesting question is how investors react to mutual funds' carbon risk exposure. Specifically, does fund-level carbon risk exposure affect fund flows and flow–performance sensitivity? A vast stream of the literature has been studying investors' preferences toward socially responsible investing. Hartzmark and Sussman (2019) find that low-sustainability funds suffer significant net outflows, whereas high sustainability leads to net inflows. El Ghoul and Karoui (2017) use an asset-weighted composite corporate social responsibility (CSR) fund score to study the effect of CSR on fund performance and flows. They find that high-CSR funds have weaker performance–flow relations compared to low-CSR funds. Döttling and Kim (2021) investigate investor ESG preferences during economic distress. Using the COVID-19 pandemic as an unexpected shock, they show that high-ESG funds have been experiencing a sharper decline in fund flows compared to other funds during the crisis.

We hypothesize that investors have an unfavorable attitude toward funds with high carbon risk exposure. In addition, since retail investors and institutional investors have different preferences and levels of access to carbon risk data, they could react to carbon risk differently. Specifically, we argue that institutional investors have a better understanding of climate change risk, are under more pressure from outside investors, and have better access to firm-level carbon risk data. Bolton and Kacperczyk (2021) find that institutional investors implement exclusionary screening based on carbon risk emissions, whereas retail investors do not use such screening. We assume that institutional investors will act more promptly, compared to retail investors, to mutual fund carbon risk exposure. We thus propose the following hypotheses.

H3: Mutual funds with higher carbon risk exposure have lower fund flows, after controlling for fund performance.

H4: Mutual funds with higher carbon risk exposure have higher flow–performance sensitivity.

2.3.4. Carbon Risk Exposure, Climate News Sentiment, and Institutional Investors

Finally, researchers also show that news reports can shape investors' attitudes toward climate change (Griffin, Lont, and Lubberink, 2019). On the one hand, media coverage reflects the current status of the urgency of climate change; on the other hand, such coverage can also further change investors' assessment of climate change risk. When the news media cover climate change news more extensively or the news sentiment is more negative, investors can have stronger concerns about climate change risk. Moreover, institutional investors have advantages in accessing proprietary fund- and firm-level carbon risk information compared to retail investors.[13] Research also shows that institutional investors view climate change risk as a valid concern in their investment decisions (Ilhan et al., 2020). We therefore propose the following hypotheses.

H5: Both the relations in H3 and H4 will be intensified when there is more news coverage of climate-related topics or when the news coverage is more negative.

H6: The effect in H5 is stronger among institutional funds than retail funds.

[13] For example, the Morningstar Portfolio Carbon Risk Score is only accessible by investors who are subscribed to related services.

3. Data, Sample, and Key Variables

We use the Center for Research in Security Prices (CRSP) Mutual Fund Database and the Sustainalytics Carbon Risk Rating (Sustainalytics) database to construct a sample of mutual fund carbon risk scores. Sustainalytics is a leading provider of ESG and corporate governance research, ratings, and analysis.[14] It provides Carbon Risk Ratings for a large sample of public and private firms in order to measure their exposure to and management of transition risk. The Carbon Risk Ratings span more than 4,000 public companies, encompassing 147 subindustries globally, and capture a variety of carbon signals in a single quantitative assessment. Compared to carbon emission data (which is a static measure of a firm's current state of carbon intensity), this measure is forward looking and can capture a firm's ability to transition to a low-carbon economy more dynamically. In addition, it has been widely adopted by industry practitioners to assess firms' carbon risk. The Carbon Risk Ratings are adopted by Morningstar to create the Morningstar Portfolio Carbon Risk Score, a measure that helps investors evaluate a portfolio's exposure to carbon risk.[15] To distinguish our carbon risk scores from the traditional ESG measure, we use MSCI ESG KLD STATS (henceforth KLD) to access firm-level ESG ratings. KLD, one of the most extensive and established ESG databases, provides annual datasets of positive and negative ESG performance indicators applied to a universe of publicly traded companies.

To measure each fund's carbon risk exposure, we match the CRSP Mutual Fund holdings data with the stock carbon risk scores from Sustainalytics. However, given that Sustainalytics

[14] Sustainalytics was acquired by Morningstar, Inc. in 2020. Since 2016, Morningstar and Sustainalytics have teamed up to supply investors a series of new metrics on fund-level ESG and carbon risk assessments, including the industry's first sustainability rating for funds.

[15] The Morningstar Portfolio Carbon Risk Scores is available from Morningstar Direct since 2017. We match the mutual funds in our sample with the mutual funds in Morningstar Direct. Out of the 1,695 mutual funds in our sample, we successfully match 1,005 (60%). Next, we calculate the correlation coefficient between our mutual fund carbon risk score and that of Morningstar Direct during the overlapping sample period from 2017 to 2019. The overall correlation coefficient is 0.95 and statistically significant at 1%. Table A2 of the Appendix reports the detailed analysis.

provides information on just a portion of U.S. stocks, a portion of the stocks held by mutual funds are left unrated. The average sum of the stock weights of the fund portfolios covered by Sustainalytics is around 80%. To construct a meaningful measure of mutual funds' carbon risk, we follow Cremers and Petajisto (2009) and El Ghoul and Karoui (2017) and require that the sum of equity weights with a carbon risk score account for at least 67% of the portfolio. This approach yields an average sum of stock weights equal to 86% for the selected fund portfolios. Moreover, we require that funds have at least two years of reported holdings and exclude mutual funds with less than $15 million assets under management. The final sample comprises 1,695 U.S. equity domestic active funds and covers the period from 2012 to 2019. We use the same methodology to construct a simple holdings-based measure to assess the level of a fund's ESG rating.

The risk-adjusted performance of mutual funds in our main analysis is measured as the four-factor alpha (α_i) estimated from the Fama–French and Carhart (1997) model:

$$R_{i,t} - R_{f,t} = \alpha_i + \beta_{i,m}(R_{m,t} - R_{f,t}) + \beta_{i,s}SMB_t + \beta_{i,h}HML_t + \beta_{i,mom}MOM_t + \varepsilon_{i,t} \tag{1}$$

where, for fund *i* in month *t*, $R_{i,t} - R_{f,t}$ is the excess return of fund *i* in month *t* over the risk-free rate, $R_{m,t} - R_{f,t}$ is the market excess return, SMB is the return difference between small- and large-capitalization stock portfolios, HML is the return difference between stock portfolios with high and low book-to-market ratios respectively, and MOM is the return difference between the portfolios of stocks with high and low past returns, respectively. In robustness tests, we also use the Fama–French (2015) five-factor model to estimate fund alphas, as follows:

$$R_{i,t} - R_{f,t} = \alpha_i + \beta_{i,m}(R_{m,t} - R_{f,t}) + \beta_{i,s}SMB_t + \beta_{i,h}HML_t + \beta_{iRMW}RMW_t + \beta_{iCMA}CMA_t + \varepsilon_{i,t} \tag{2}$$

where the additional factor RMW is the return difference between the portfolios of stocks with a robust return and with a weak return, and CMA is the return difference between portfolio of stocks that invest conservatively and that invest aggressively. The data for the market return, risk-free rate, and all the risk factors are obtained from Kenneth French's Data Library.

Fund flows are measured under the assumption that all the dividends and other distributions are reinvested at the realized return, as follows:

$$Fund\ flows_{i,t} = \frac{[TNA_{i,t} - TNA_{i,t-1}(1 + R_{i,t})]}{TNA_{i,t-1}} \tag{3}$$

where, mutual fund *i*, $TNA_{i,t}$ and $TNA_{i,t-1}$ are the total net assets (TNA) of mutual fund *i* at times *t* and *t*–1, respectively, and $R_{i,t}$ is the realized return from time *t*–1 to *t*. CRSP reports fund assets, performance, and other fund characteristics by share class. We calculate the $TNA_{i,t}$ of each fund i by aggregating assets in different share classes, using the unique fund ID at time *t*.

We calculate $R_{i,t}$, expense ratio, and turnover ratio of each fund by averaging them over different share classes using the unique fund ID at time *t*. Expense ratio is the ratio of TNA that shareholders pay for the fund's operating expenses, which include 12b-1 fees. Turnover is the minimum of aggregated sales or aggregated purchases of securities, divided by the average 12-month TNA of the fund. Volatility is the annualized fund return volatility. Number of stocks is the number of stocks held in the fund portfolio for each fund *i* at time *t*. Fund age is the number of years, at time *t,* since the fund's inception.

Table I reports the summary statistics of fund characteristics in our sample. The average fund carbon risk score is equal to 7.508, with a standard deviation of 4.055. The average fund excess return is positive and equal to 0.028, while the annualized risk-adjusted return (alpha) is negative and equal to -0.001.[16] During this period, fund flows, on average, are negative, with a

[16] The average annualized return of our sample is 11.2%, which is lower than the annualized return of the Standard & Poor's (S&P) 500 index (13.16%) during our sample period. Several industry reports show that actively managed mutual funds have been tailing behind the S&P index in recent years (https://www.cnbc.com/2019/03/15/active-fund-managers-trail-the-sp-500-for-the-ninth-year-in-a-row-in-triumph-for-indexing.html).

mean equal to -0.006 and a median equal to -0.018, reflecting the recent trend of investors moving away from actively managed mutual funds. The average fund age is 20 years, and the mean of assets under management is $2.227 billion. The average number of stocks held by mutual funds each quarter is 153.

[Insert Table I Here.]

Table II reports the correlation coefficients between carbon risk scores and fund characteristics. The carbon risk score is significantly correlated with all fund characteristics, except fund flows. The carbon risk score is negatively correlated with fund alpha and is positively correlated with return volatility and unexplained risk, suggesting that higher carbon risk exposure suppresses fund performance and results in an increase in risk. The carbon risk score is negatively correlated with both expense ratio and turnover ratio. It is also negatively correlated with the number of stocks in the portfolio. The carbon risk score is positively correlated with fund age and assets.

[Insert Table II Here.]

4. Empirical Results

4.1. Fund Carbon Risk and Fund Characteristics

4.1.1. Univariate Analysis

We sort funds by their carbon risk exposure each quarter into five quintiles and then compare the average fund characteristics between the first quintile (the group with the lowest carbon risk scores) and the fifth quintile (the group with the highest carbon risk scores). Table III shows the univariate comparison. The results show that funds with low carbon risk exposure have higher excess returns, at a mean of 2.89%, and higher risk-adjusted alphas, at a mean of -0.04%. Funds with low carbon risk have lower total volatility and attract more fund flows. These funds also have lower expense ratios and turnover ratios. Meanwhile, funds with high carbon risk have more assets under management and are older. All differences are statistically significant at the 1% level.

[Insert Table III Here.]

4.1.2. Multivariate Analysis

Next, we examine separately the relations between the fund carbon risk score and fund characteristics and between the fund carbon risk score and risk factors. We run the following two regressions:

$$Carbon\ risk\ score_{j,t} = \beta_0 + \beta_1 * Fund\ Performance_{j,t} + \beta_2 * Flows_{j,t} + \beta_3 * Log(TNA)_{j,t} + \beta_4 * Volatility_{j,t} + \beta_5 * Expense\ ratio_{j,t} + \beta_6 * Turnover_{j,t} + \beta_7 * Fund\ age_{j,t} + \beta_8 * Log(Number\ of\ stocks)_{j,t} + \text{Fund FE} + \text{Year FE} + \text{Strategy FE} + \varepsilon_{j,t} \quad (4)$$

and

$$Carbon\ risk\ score_{j,t} = \beta_0 + \beta_1 * Alpha + \beta_2 * Market\ risk\ premium_{j,t} + \beta_3 * SMB_{j,t} + \beta_4 * HML_{j,t} + \beta_5 * MOM_{j,t} + Controls_{j,t} + Fund\ FE + Year\ FE + Strategy\ FE + \varepsilon_{j,t} \quad (5)$$

for fund j in quarter *t*. All the variables are defined in Section 3 and are winsorized at the 1st and 99th percentiles. We control for fund, year, and style fixed effects (FE). Standard errors are clustered at the fund level.

Table IV reports the regression results. In Models (1) and (2), we focus on the relation between the fund carbon risk score and fund characteristics. Fund raw returns load insignificantly on the fund carbon risk score, but fund alphas load negatively and significantly on it. The coefficient is -0.0077, suggesting that a one standard deviation increase in the fund risk-adjusted return is associated with a decrease of 0.0077 in the fund carbon risk score. Fund flow is also negatively and significantly correlated with the fund carbon risk score. Consistent with the univariate analysis, fund volatility and fund age load positively and significantly on the fund carbon risk score, and fund age is also positively and significantly correlated with the fund carbon risk score. The coefficients on the fund turnover ratio and the number of stocks held are insignificant.

In Models (3) and (4) in Table IV, we focus on the relation between the carbon risk score and risk factors. We first regress the fund carbon risk score on the risk factors in the Fama–French and Carhart (1997) model and then further include several control variables. As shown in Model (4), the carbon risk score is significantly related to the market risk premium, the growth factor, and the momentum factor. The R-squared of this model is around 3%, suggesting that the current risk factors have weak explanatory power over fund carbon risk exposure. This finding further supports our argument that mutual fund carbon risk exposure is not captured by popular factor models and hence worth studying.

[Insert Table IV Here.]

4.2. Carbon Risk Score and Fund Performance

Next, we investigate the predictive power of fund carbon risk exposure on fund performance. We examine both raw performance, as measured by excess returns, and risk-adjusted performance, as measured by the four-factor alpha. Specifically, we estimate the following regression model:

$$Fund\ performance_{j,t+1} = \beta_0 + \beta_1 * Carbon\ risk_{j,t} + \beta_2 * Flows_{j,t} + \beta_3 * Volatility_{j,t} + \beta_4 * Log(TNA)_{j,t} + \beta_5 * Expense\ ratio_{j,t} + \beta_6 * Turnover_{j,t} + \beta_7 * Fund\ age_{j,t} + \beta_8 * Log(Number\ of\ stocks)_{j,t} + \text{Fund FE} + \text{Year FE} + \text{Strategy FE} + \varepsilon_{j,t} \quad (6)$$

Table V reports the regression results. The results show that fund performance deteriorates as fund carbon risk exposure increases. When fund performance is measured by excess returns, the results are more significant. Specifically, a one standard deviation increase in the carbon risk score will result in a 0.0108 decrease in next quarter's excess return. This finding is both statistically and economically significant. When using the risk-adjusted performance, we find that the negative predictivity of fund carbon risk exposure on fund performance is still significant at the 10% level. Specifically, a one standard deviation increase in the carbon risk score will result in a 0.0114 decrease in fund risk-adjusted performance. Overall, the results largely support H1, that mutual funds with higher carbon risk exposure perform significantly worse than funds with lower carbon risk exposure. This finding is also aligned with the results in Table A1 the Appendix, which show that firms with high carbon risk perform significantly worse than firms with low carbon risk.

Regarding the other variables, fund flows and fund assets are negatively correlated with future fund performance. Fund volatility loads positively with future fund performance. A higher expense ratio, turnover ratio, and number of stocks held by funds all affect future fund performance negatively. Fund age is not significantly correlated with future fund performance. These results are largely consistent with those of El Ghoul and Karoui (2017) and other mutual fund studies.

[Insert Table V Here.]

4.3. Carbon Risk Score and Fund Risk

Next, we switch our analysis to fund risk. We examine fund total risk, explained risk, and unexplained risk. Total risk is equal to the variance of returns. Unexplained risk is equal to the variance of the residuals from the Fama–French and Carhart (1997) four-factor model. Explained risk is the difference between total risk and unexplained risk. The variable of interest is the fund carbon risk score. Specifically, we estimate the following regression model:

$$Fund\ Risk_{j,t+1} = \beta_0 + \beta_1 * Carbon\ risk_{j,t} + \beta_2 * Flows_{j,t} + \beta_3 * Log(TNA)_{j,t} + \beta_4 * Expense\ ratio_{j,t} + \beta_5 * Turnover_{j,t} + \beta_6 * Fund\ age_{j,t} + \beta_7 * Log(Number\ of\ stocks)_{j,t} + \text{Fund FE} + \text{Year FE} + \text{Strategy FE} + \varepsilon_{j,t} \quad (7)$$

Results are reported in Table VI. As expected, fund total risk and explained risk load insignificantly on fund carbon risk exposure, while unexplained risk loads significantly and positively on fund carbon risk exposure. Specifically, a one standard deviation increase in the carbon risk score will result in a 0.0207 increase in fund unexplained risk. The coefficient is significant at the 1% level. The results confirm H2, that carbon risk is a new type of risk that is not captured by existing factor models.

Regarding the other variables, fund flow and turnover ratio are positively correlated with all three risk measures, but the only significantly with unexplained risk. Fund size and expense ratio are positively associated with all three risk measures. The number of stocks held by a mutual fund is negatively associated with total risk and unexplained risk, but positively associated with explained risk.

[Insert Table VI Here.]

4.4. Carbon Risk Score and Fund Flow

Perhaps the most interesting question is how investors respond to mutual funds' carbon risk exposure. To answer this question, we first examine how mutual funds' carbon risk exposure affects fund flows and the flow–performance relation. Then we further investigate how general climate change news sentiment, as measured by Engel et al. (2020), could affect investors' utility functions. Finally, we separate our sample into institutional funds and retail funds. Previous research shows that fund flows are sticky (Sialm, Starks, and Zhang, 2015). Therefore, we control for previous period fund flows. We run the following regression:

$$Fund\ Flows_{j,t+1} = \beta_0 + \beta_1 * Carbon\ risk_{j,t} + \beta_2 * Carbon\ risk_{j,t} * Performance_{j,t} + \beta_3 * Performance_{j,t} + \beta_4 * Fund\ Flows_{j,t} + \beta_5 * Volatility_{j,t} + \beta_6 * Log(TNA)_{j,t} + \beta_7 * Expense\ Ratio_{j,t} + \beta_8 * Turnover\ Ratio_{j,t} + \beta_9 * Fund\ age_{j,t} + \beta_{10} * Log(Number\ of\ stocks)_{j,t} + \text{Fund FE} + \text{Year FE} + \text{Strategy FE} + \varepsilon_{j,t} \quad (8)$$

Table VII reports the regression results. In both the raw performance and risk-adjusted performance models, fund flows respond positively and significantly to the last period's performance. Funds with higher carbon risk exposure in the current period subsequently experience a negative shock on fund flows. Specifically, a one standard deviation increase in carbon risk score will result in a decrease of 0.0769 (0.0702 when using alphas) in the standard deviation of fund flows the next period. The coefficient is significant at the 1% level. The interaction term between fund carbon risk exposure and performance is positive and significant at the 10% level when the performance is measured by raw returns. These findings suggest that investors respond negatively to fund carbon risk. Furthermore, for funds with higher carbon risk exposure, the flow–performance relation is more sensitive. The results in Table VII support H4. Regarding the other variables, fund flows in the previous period are highly correlated with those in the next period, showing that fund flows are sticky. The previous period's fund performance is highly correlated with the next period's fund flows, suggesting that investors are chasing well-performing mutual funds. Fund assets, expense ratio, and turnover ratio are negatively correlated with future fund flows. Fund volatility negatively predicts future fund flows, and the coefficient is significant at the 1% level when the performance is measured by alphas.

[Insert Table VII Here.]

Next, we examine how climate change news sentiment affects investors' investment behavior. Since we argue that climate change risk is new to the financial market and market participants, investors' attitudes toward climate change can be affected by news coverage. Media coverage can alert investors to the severity and urgency of climate change risk and thus change their investment behavior. Engle et al. (2020) construct an index to measure climate change news coverage (WSJ Index) and climate change news sentiment (CH Negative News Index) through the textual analysis of news reports. We expect negative news coverage on climate change to affect investors' preferences more than general news coverage, so we use the CH Negative News Index in our analysis. Specifically, we estimate the following regression:

$$Fund\ Flows_{j,t+1} = \beta_0 + \beta_1 * Carbon\ risk_{j,t} + \beta_2 * Carbon\ risk_{j,t} * Climate\ Index_{j,t} * Performance_{j,t} + \beta_3 * Performance_{j,t} + \beta_4 * Climate\ Index_{j,t} + \beta_5 * Carbon\ risk_{j,t} * Performance_{j,t} + \beta_6 * Carbon\ risk_{j,t} * Climate\ Index_{j,t} + \beta_7 * Climate\ Index_{j,t} * Performance_{j,t} + \beta_8 * Fund\ Flows_{j,t} + \beta_9 * Volatility_{j,t} + \beta_{10} * Log(TNA)_{j,t} + \beta_{11} * Expense\ Ratio_{j,t} + \beta_{12} * Turnover\ Ratio_{j,t} + \beta_{13} * Fund\ age_{j,t} + \beta_{14} * Log(Number\ of\ stocks)_{j,t} + \text{Fund FE} + \text{Year FE} + \text{Strategy FE} + \varepsilon_{j,t} \quad (9)$$

Table VIII reports the results. Consistent with the results in Table VII, higher carbon risk exposure leads to lower fund flows in the next period. As fund carbon risk exposure increases, the fund flow–performance relation becomes more sensitive. The main variable of interest is the triple interaction term. As expected, when the sentiment of news coverage on climate change is more negative, the fund flow–performance relation becomes more sensitive as fund carbon risk exposure increases. The beta coefficient is positive and statistically significant at the 10% level for excess returns, and at 5% for risk-adjusted returns. The results in Table VIII confirm H5.

[Insert Table VIII Here.]

Previous study finds a negative association between emissions and institutional ownership and board size, suggesting that institutional investors care about climate change risk and could play a role in decreasing carbon emission externalities (Shive and Forster, 2020). Institutional investors also have better access to mutual fund carbon risk assessment data. To further examine how different types of investors react to carbon risk, we split our sample into institutional funds and retail funds. We classify a fund as an institutional (retail) fund if more than 75% of its TNA are held in an institutional (retail) share class, based on the CRSP institutional (retail) fund share class name. A total of 704 funds is classified as institutional funds, which accounts for 41.5% of the total number of funds in our sample; 829 funds are classified as retail funds, which accounts for 48.9% of the total number of funds in our sample; and 9.6% of the funds cannot be classified and are excluded from the analysis in this section. We rerun the regression analysis in Equation (9) on the two groups separately.

The results are reported in Table IX. The significant and negative effect of fund carbon risk exposure on its subsequent period fund level is only found in the institutional fund group. In addition, the positive effect of fund carbon risk exposure on the flow–performance relation only applies to institutional funds. Finally, the triple interaction term, which measures how climate change news sentiment affects investors' attitudes toward fund carbon risk exposure, is positive and significant only in the institutional fund group. The results in Table IX confirm H6.

[Insert Table IX Here.]

4.5. Carbon Risk Exposure and the ESG Score

In this section, we examine whether traditional ESG measures cover mutual fund carbon risk exposure. We follow El Ghoul and Karoui (2017) and match mutual fund holdings with the KLD dataset and assign each fund an ESG score. Our calculation shows that fund carbon risk exposure is negatively correlated with the fund ESG score, suggesting that funds with higher ESG ratings have lower carbon risk. However, the correlation coefficient is only around -0.172, with a standard deviation of 0.207.[17] Next, we repeat the previous analysis by adding the ESG score as a control variable.

Table X reports the regression results. Panel A reports the results for fund performance on the lagged fund carbon risk score. Consistent with El Ghoul and Karoui (2017), funds with higher ESG scores have lower future returns. Our variable of interest is fund level carbon risk exposure, *Carbon risk*. The results show that, after controlling for fund ESG scores, our previous findings still hold. Fund-level carbon risk exposure negatively predicts future fund performance. When measuring fund performance through excess returns, the beta coefficient is significant at the 1% level. When measuring fund performance through alphas, the beta coefficient is significant at the 10% level.

Panel B of Table X reports the results for fund risk on the lagged fund carbon risk score. The results show that fund ESG scores are negatively correlated with both fund total risk and explained risk. Meanwhile, the ESG scores are marginally correlated with unexplained risk. We find consistent results for the relation between fund carbon risk exposure and fund risk. Funds with higher carbon risk exposure have higher unexplained risk, but no significant difference in total risk or explained risk.

Panel C of Table X reports the results for fund flows on the lagged fund carbon risk score. The results show that, after controlling for the fund ESG score, the effects of carbon risk on fund flows and the flow–performance relation still stand. Funds with higher carbon risk experience a

[17] Morningstar also provides the Morningstar Portfolio ESG Risk Score, available from Morningstar Direct since 2015. We match the mutual funds in our sample with those in Morningstar Direct. Of the 1,695 mutual funds in our sample, we successfully match 1,147 (68%). Next, we calculate the correlation coefficient between our mutual fund carbon risk score and the mutual fund ESG risk score from Morningstar Direct during the overlapping sample period from 2015 to 2019. The overall correlation coefficient is 0.30. We also calculate the correlation coefficient between our mutual fund carbon risk score and the three subdimension risk scores (E, S, and G). The correlation coefficient between the carbon risk score and the environmental risk score is the highest among the three, at 0.19. The results further confirm that mutual fund carbon risk is correlated but not fully covered by traditional ESG measures. Table A3 of the Appendix reports the detailed analysis.

negative shock in the next period's fund flow. At the same time, while a high ESG score is linked to a weaker performance–flow relation, investors are more sensitive to the performance attribute in funds with higher carbon risk. Panel D reports the results of fund flows on the lagged fund carbon risk score, the climate change news index, and other characteristics. The results are also consistent with our previous findings after controlling for the ESG score. Overall, our findings demonstrate that carbon risk is a new risk source and not fully captured in the traditional ESG measure.

[Insert Table X Here.]

5. Conclusion

In this paper, we study how climate change affects the mutual fund industry. Specifically, we examine how carbon risk affects mutual funds' performance, risk, and flows on a sample of U.S. domestic equity active funds. We merge mutual fund holdings and firm-level carbon risk exposure data to build a mutual fund carbon risk measure. We find that mutual funds with higher carbon risk generate lower raw and risk-adjusted performance. Higher carbon risk also leads to more unexplained risk. We also show that institutional investors respond to carbon risk promptly. Institutional funds with higher carbon risk experience a negative shock in fund flows in subsequent periods. These funds also have a more sensitive flow–performance relation. Both findings are intensified when news coverage on climate change is more negative. On the contrary, we do not observe the same results in the retail funds. Finally, we show that traditional ESG measures do not capture carbon risk. Our empirical findings hold after controlling for fund ESG ratings.

Our study introduces to the literature how climate change affects the mutual fund industry. We reveal that carbon risk is a new and crucial risk factor for mutual funds. Our empirical results provide important insights for mutual fund managers, investors, and regulators. The methodology used to calculate mutual funds' carbon risk score can be extended to future studies. Our mutual fund carbon risk measure covers a long period and spans across several important climate change events (e.g., the 2015 Paris Agreement, the 2016 U.S. presidential election, the 2018 Intergovernmental Panel on Climate Change report release). Other researchers can utilize our measure to advance the study on mutual funds and climate change risk.

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Table I. Descriptive Statistics

This table presents descriptive statistics for the sample of actively managed equity mutual funds over the period 2012–2019. The main sample has 1,696 funds and 33,403 quarterly observations. This table reports the mean, median, standard deviation, minimum, and maximum of the fund-level carbon risk score, fund raw return, fund risk-adjusted performance (alpha), flow, volatility, TNA in millions of dollars, number of stocks, expense ratio, turnover ratio, and fund age. The fund carbon risk score is calculated from quarterly fund holdings. The performance measures are the excess returns and risk-adjusted alphas from the Fama–French and Carhart (1997) four-factor models. Fund flow is the percentage change in TNA after adjusting for the fund's total return, as in Equation (3). Volatility is the variance of 12-month returns. Unexplained risk is total risk minus systematic risk. A fund is excluded from the sample for a given month if its size is less than $15 million. The percentage of coverage of the carbon risk score in the quarterly holding must be greater than 67%. A fund must have data for the previous 24 months' returns to estimate risk and risk-adjusted returns and TNA. The first 12 months' returns of each of the funds since their inception are excluded.

	N	Mean	Median	S.D.	Min	Max
Carbon Risk	33,403	7.508	7.835	4.055	0.020	16.448
Excess Return	33,403	0.028	0.033	0.060	-0.180	0.165
Alpha	33,403	-0.001	-0.001	0.004	-0.014	0.014
Fund Flow	33,403	-0.006	-0.018	0.110	-0.359	0.604
Volatility	33,403	0.033	0.031	0.011	0.012	0.073
Unexplained Risk	33,403	0.007	0.007	0.004	0.001	0.022
Fund Assets (millions)	33,403	2,227	575	4,760	11	30,000
Expense Ratio	33,403	0.014	0.015	0.006	0.001	0.025
Turnover Ratio	33,403	0.638	0.500	0.519	0.030	3.250
Fund Age	33,403	20	18	13	2	80
Number of Stocks	33,403	153	79	237	20	1,830

Table II. Correlation Analysis

This table presents the correlation coefficients between the main variables. The performance measures are the excess returns and alphas from the Fama–French and Carhart (1997) four-factor models. Fund flow is the percentage change in TNA after adjusting for the fund's total return, as in Equation (3). Volatility is the variance of 12-month returns. Unexplained risk is total risk minus systematic risk. A fund is excluded from the sample for a given month if its size is less than $15 million. The percentage of coverage of the carbon risk score in the quarterly holding must be greater than 67%. To be included in the sample, a fund must have data on the previous 24 months' returns to estimate risk and risk-adjusted returns, as well as next month's return and TNA. The first 12 months' returns of each of the funds since their inception are excluded. ***, **, and * indicate significance at the 1%, 5%, and 10% levels, respectively.

	Carbon Risk	Raw Return	Alpha	Fund Flow	Volatility	Unexp. risk	Net Assets	Expense Ratio	Turnover Ratio	Fund Age
Excess Return	-0.007									
Alpha	-0.049***	0.112***								
Fund Flow	-0.011	0.071***	0.189***							
Volatility	0.306***	-0.064***	-0.048***	-0.058***						
Unexplained Risk	0.267***	0.008	-0.015*	-0.037***	0.383***					
Net Assets	0.079***	0.006	0.065***	0.007	-0.049***	-0.102***				
Expense Ratio	-0.099***	0.009	-0.051***	-0.094***	0.034***	0.161***	-0.167***			
Turnover Ratio	-0.058***	-0.006	-0.076***	-0.058***	0.051***	0.131***	-0.204***	0.142***		
Fund Age	0.023***	0.000	-0.003	-0.105***	-0.006	-0.059***	0.284***	0.162***	-0.101***	
Number of Stocks	-0.090***	-0.007	0.014*	0.071***	0.027***	-0.269***	0.095***	-0.309***	-0.063***	-0.125***

Table III. Carbon Risk Score and Fund Characteristics: Univariate Analysis

This table reports the univariate analysis of fund characteristics and carbon risk exposure. Each quarter, funds are categorized into five groups based on their carbon risk scores. Higher (lower) scores indicate higher (lower) carbon risk exposure. The first two columns report the average fund characteristics for low carbon risk score (quintile one) and high carbon risk score (quintile five) funds, respectively. The fund characteristics are its raw return, risk-adjusted performance (alpha), flow, volatility, TNA in millions of dollars, number of stocks, expense ratio, turnover ratio, and age. The third column reports the mean difference in characteristics between the high– and low–carbon risk score funds. The *t*-statistics for the difference in means are also reported in the fourth column. ***, **, and * indicate significance at the 1%, 5%, and 10% levels, respectively.

	Low–Carbon Risk Funds (Group = 1)	High–Carbon Risk Funds (Group = 5)	Low − High	*t*-statistics
Excess Return	2.889%	2.542%	0.347%***	3.18
Alpha	-0.040%	-0.096%	0.055%***	7.42
Flow	-0.100%	-0.557%	0.457%***	2.25
Volatility	3.061%	3.938%	-0.878%***	(-45.84)
Unexplained Risk	0.611%	0.859%	-0.248%***	(-40.41)
Net Assets (millions)	1,185	2,376	-1,190***	(-18.13)
Expense Ratio (%)	1.473%	1.303%	0.171%***	15.76
Turnover Ratio (%)	71.669%	61.091%	10.578%***	12.07
Age	18.415	19.886	-1.472***	(-7.26)
Number of Stocks	224.532	138.271	86.261***	18.67

Table IV. Carbon Risk Score and Fund Characteristics: Multivariate Analysis

This table reports the regression results of the carbon risk score on fund characteristics (Models (1) and (2)) and of the carbon risk score on the Fama–French and Carhart four-factor (1997) factor loadings (Models (3) and (4)). The fund characteristics are its raw returns, risk-adjusted performance (alpha), flow, volatility, TNA in millions of dollars, number of stocks, expense ratio, turnover ratio, and age. The risk factors include β_{MRP}, β_{SMB}, β_{HML}, and β_{MOM}. In Model (4), the regression includes the control variables for volatility, the natural logarithm of TNA, the natural logarithm of the number of stocks, the expense ratio, the turnover ratio, and fund age. All variables are winsorized at the 1st and 99th percentiles. The regressions control for fund, year, and strategy fixed effects. Standard errors are clustered at the fund level and are presented in parentheses. ***, **, and * indicate significance at the 1%, 5%, and 10% levels, respectively.

	Fund Characteristics		Risk Factors	
	(1)	(2)	(3)	(4)
Excess Return	0.0004			
	(0.26)			
Alpha		-0.0077**	-0.0122**	-0.0102**
		(-2.20)	(-2.57)	(-2.18)
Fund Flow	-0.0131***	-0.0121***		-0.0111***
	(-3.48)	(-3.29)		(-3.08)
Volatility	0.0244***	0.0261***		0.0319***
	(4.08)	(4.58)		(5.83)
Log of Fund Assets	-0.0130	-0.0140		-0.0150
	(-0.87)	(-0.93)		(-1.00)
Expense Ratio	-0.0007*	-0.0007*		-0.0007*
	(-1.76)	(-1.78)		(-1.70)
Turnover Ratio	0.0274	0.0265		0.0208
	(1.09)	(1.06)		(0.83)
Fund Age	0.0971***	0.0969***		0.0970***
	(5.12)	(5.15)		(5.16)
Log of Number of Stocks	0.0331	0.0332		0.0278
	(0.93)	(0.93)		(0.79)
Market Risk Premium			0.0354	0.0665***
			(1.41)	(2.64)
SMB			-0.0091	-0.0058
			(-0.54)	(-0.35)
HML			0.1224***	0.1171***
			(6.72)	(6.44)
MOM			-0.1279***	-0.1295***
			(-7.33)	(-7.42)
Constant	-2.3051***	-2.2836***	-0.6135**	-2.3534***
	(-5.17)	(-5.16)	(-2.36)	(-5.41)
Observations	33,321	33,321	33,321	33,321
R-Squared	1.72%	1.76%	1.80%	2.62%
Fund, Strategy, Year FE	YES	YES	YES	YES

Table V. Carbon Risk Score and Fund Performance

This table reports the regression results of the fund performance on the lagged fund carbon risk score and other characteristics. The independent variable in Models (1) and (2) is $Excess\ Return$, which is the fund return minus the risk-free rate. The independent variable in Models (3) and (4) is $Alpha$, which is the intercept from the Fama–French and Carhart (1997) four-factor model. The dependent variable is in period $t + 1$ and all the independent variables are in period t. The regression includes the following control variables: return volatility, the natural logarithm of TNA, the natural logarithm of the number of stocks, the expense ratio, the turnover ratio, and fund age. All the variables are winsorized at the 1st and 99th percentiles. The regressions control for fund, year, and strategy fixed effects. Standard errors are clustered at the fund level and are presented in parentheses. ***, **, and * indicate significance at the 1%, 5%, and 10% levels, respectively.

	$Excess\ Return_{t+1}$		$Alpha_{t+1}$	
	(1)	(2)	(3)	(4)
Carbon Risk	-0.0141***	-0.0108***	-0.0109*	-0.0114*
	(-5.35)	(-3.81)	(-1.77)	(-1.68)
Fund Flow		-0.0274***		-0.0351***
		(-4.98)		(-4.40)
Volatility		0.3743***		0.0733***
		(39.43)		(3.31)
Log of Fund Assets		-0.1651***		-0.2590***
		(-15.65)		(-9.10)
Expense Ratio		-0.0710***		-0.0914
		(-3.15)		(-1.50)
Turnover Ratio		-0.0671***		-0.0706
		(-4.03)		(-1.54)
Fund Age		-0.0129		0.0599
		(-0.92)		(1.37)
Log of Number of Stocks		-0.0557***		-0.0921*
		(-2.64)		(-1.76)
Constant	1.6177***	3.1016***	0.1090	0.8891
	(12.70)	(10.30)	(0.42)	(0.84)
Observations	32,336	32,336	28,497	28,497
R-Squared	16.70%	20.10%	4.56%	6.38%
Fund, Strategy, Year FE	YES	YES	YES	YES

Table VI. Carbon Risk Score and Fund Risk

This table reports the regression results of fund risk on the lagged fund carbon risk score and other characteristics. The independent variable in Models (1) and (2) is $Total\ Risk$, which is the variance of the 12-month returns. The independent variable in Models (3) and (4) is $Unexplained\ Risk$, which is the variance of the residuals from the Fama–French and Carhart (1997) four-factor model. The independent variable in Models (5) and (6) is $Explained\ Risk$, which is the difference between total risk and unexplained risk. The dependent variable is in period $t + 1$ and all the independent variables are in period t. The regression includes the following control variables: the natural logarithm of TNA, the natural logarithm of the number of stocks, the expense ratio, the turnover ratio, and fund age. All the variables are winsorized at the 1st and 99th percentiles. The regressions control for fund, year, and strategy fixed effects. Standard errors are clustered at the fund level and are presented in parentheses. ***, **, and * indicate significance at the 1%, 5%, and 10% levels, respectively.

	$Total\ Risk_{t+1}$		$Unexplained\ Risk_{t+1}$		$Explained\ Risk_{t+1}$	
	(1)	(2)	(3)	(4)	(5)	(6)
Carbon Risk	-0.0007	-0.0005	0.0226***	0.0207***	0.0066	0.0062
	(-0.21)	(-0.14)	(3.49)	(3.28)	(0.45)	(0.42)
Fund Flow		0.0064		0.0153**		0.0019
		(1.49)		(2.44)		(0.35)
Log of Fund Assets		0.0467***		0.0192		0.0439*
		(4.49)		(0.97)		(1.89)
Expense Ratio		0.0821***		0.1088**		0.0528
		(3.19)		(2.39)		(1.71)
Turnover Ratio		0.0294		0.0773**		0.0064
		(1.60)		(2.10)		(0.36)
Fund Age		0.0202		-0.0507		0.0381
		(1.29)		(-0.98)		(1.62)
Log of Number of Stocks		-0.0509**		-0.4026***		0.0760***
		(-2.00)		(-8.49)		(2.88)
Constant	-0.0870	-0.6600*	0.0109	2.3776**	-0.0970	-1.4803**
	(-0.44)	(-1.85)	(0.03)	(2.33)	(-0.39)	(-2.80)
Observations	28,497	28,497	28,497	28,497	28,497	28,497
R-Squared	59.90%	60.00%	11.30%	12.70%	65.10%	65.20%
Fund, Strategy, Year FE	YES	YES	YES	YES	YES	YES

Table VII. Flow–Performance Relation with the Carbon Risk Score

This table reports the regression results of fund flow on the lagged fund carbon risk score and other characteristics. The dependent variable is fund flow, which equals the percentage change in TNA after adjusting for the fund's total return, as in Equation (3). The dependent variable is in period $t+1$ and all the independent variables are in period t. In Model (2), we include fund $Excess\ Return$, the fund carbon risk score, and their interaction term. In Model (3), we include the fund $Alpha$, the carbon risk score, and their interaction term. The variable $Excess\ Return$ equals the fund return minus the risk-free rate, and $Alpha$ equals the intercept from the Fama–French and Carhart (1997) four-factor model. The regression includes the following control variables: fund flow, return volatility, the natural logarithm of TNA, the natural logarithm of the number of stocks, the expense ratio, the turnover ratio, and fund age. All the variables are winsorized at the 1st and 99th percentiles. The regressions control for fund, year, and strategy fixed effects. Standard errors are clustered at the fund level and are presented in parentheses. ***, **, and * indicate significance at the 1%, 5%, and 10% levels, respectively.

	Without controls	Perf. = Excess Return	Perf. = Alpha
	(1)	(2)	(3)
Carbon Risk	-0.0836***	-0.0769***	-0.0702***
	(-3.10)	(-3.65)	(-3.28)
Carbon Risk*Perf.		0.0095*	-0.0014
		(1.80)	(-0.20)
Perf.		0.0526***	0.0824***
		(3.54)	(13.06)
Fund Flow		0.1544***	0.1456***
		(8.22)	(10.29)
Volatility		-0.0287	-0.0325***
		(-1.19)	(-3.06)
Log of Fund Assets		-0.4231***	-0.4159***
		(-10.12)	(-16.11)
Expense Ratio		-0.1674***	-0.1560***
		(-3.42)	(-2.99)
Turnover Ratio		-0.0892***	-0.0828***
		(-4.01)	(-2.82)
Fund Age		0.0199	0.0221
		(1.61)	(1.27)
Log of Number of Stocks		-0.0449	-0.0468
		(-1.39)	(-1.09)
Constant	0.0807	2.2071**	1.9700***
	(0.46)	(2.73)	(5.16)
Observations	32,336	32,336	32,336
R-Squared	2.38%	10.19%	10.65%
Fund, Strategy, Year FE	YES	YES	YES

Table VIII. Flow–Performance Relation with the Carbon Risk Score and Climate Change News

This table reports the regression results of fund flow on the lagged fund carbon risk score, the climate change news index, and other characteristics. The dependent variable is fund flow, which equals the percentage change in TNA after adjusting for the fund's total return, as in Equation (3). The dependent variable is in period $t + 1$ and all the independent variables are in period t. The variable $Excess\ Return$ equals the fund return minus the risk-free rate, and $Alpha$ equals the intercept from the Fama–French and Carhart (1997) four-factor model. The climate change news index is from Engle et al. (2020), and the CH Negative News Index measures the innovation in the CH Negative Climate Change News Index and ends in May 2018. The regression includes the following control variables: fund flow, return volatility, the natural logarithm of TNA, the natural logarithm of the number of stocks, the expense ratio, the turnover ratio, and fund age. All the variables are winsorized at the 1st and 99th percentiles. The regressions control for fund, year, and strategy fixed effects. Standard errors are clustered at the fund level and are presented in parentheses. ***, **, and * indicate significance at the 1%, 5%, and 10% levels, respectively.

	Perf. = Excess Return	Perf. = Alpha
	(1)	(2)
Carbon Risk	-0.0459***	-0.0380**
	(-3.75)	(-2.33)
Carbon Risk*Perf.*Climate Index	0.0149*	0.0588***
	(1.99)	(3.31)
Perf.	0.1769***	0.0708***
	(6.28)	(7.78)
Climate Index	-0.0162	-0.0102
	(-1.35)	(-1.02)
Carbon Risk*Perf.	0.0188*	0.0247**
	(1.85)	(2.45)
Carbon Risk*Climate Index	0.0210	0.0096
	(0.88)	(0.61)
Climate Index*Perf.	0.0911**	-0.0077
	(2.78)	(-0.29)
Fund Flow	0.1372***	0.1306***
	(5.29)	(6.51)
Volatility	-0.1249***	-0.0814***
	(-6.26)	(-4.87)
Log of Fund Assets	-0.4950***	-0.4926***
	(-5.94)	(-6.16)
Expense Ratio	-0.1983***	-0.1972***
	(-4.10)	(-4.10)
Turnover Ratio	-0.0840***	-0.0868***
	(-4.03)	(-5.92)
Fund Age	0.0320**	0.0392***
	(2.22)	(3.23)
Log of Number of Stocks	-0.0000	-0.0571**
	(-0.05)	(-2.20)
Constant	2.1130***	2.1574***
	(4.15)	(5.72)

Observations	27,884	27,884
R-Squared	11.12%	11.04%
Fund, Strategy, Year FE	YES	YES

Table IX. Flow–Performance Relation and Investor Type

This table reports the regression results of fund flow on the lagged fund carbon risk score, the climate change news index, and other characteristics for institutional investors and retail investors, separately. A fund is classified as an institutional (retail) fund if more than 75% of its TNA are held in an institutional (retail) share class, based on CRSP institutional (retail) fund share class name. The dependent variable is in period $t+1$ and all the independent variables are in period t. The variable $Excess\ Return$ equals the fund return minus the risk-free rate, and $Alpha$ equals the intercept from the Fama–French and Carhart (1997) four-factor model. The climate change news index is from Engle et al. (2020), and the CH Negative News Index measures the innovation in the CH Negative Climate Change News Index and ends in May 2018. The regression includes the following control variables: fund flow, return volatility, the natural logarithm of TNA, the natural logarithm of the number of stocks, the expense ratio, the turnover ratio, and fund age. All the variables are winsorized at the 1st and 99th percentiles. The regressions control for fund, year, and strategy fixed effects. Standard errors are clustered at the fund level and are presented in parentheses. ***, **, and * indicate significance at the 1%, 5%, and 10% levels, respectively.

	Perf. = Excess Return		Perf. = Alpha	
	Institutional	Retail	Institutional	Retail
	(1)	(2)	(3)	(4)
Carbon Risk	-0.0881***	-0.0067	-0.0951**	-0.0021
	(-4.65)	(-0.19)	(-2.80)	(-0.06)
Carbon Risk*Perf.*Climate Index	0.0792***	0.0265	0.1399***	-0.0185
	(5.31)	(0.82)	(3.17)	(-0.80)
Perf.	0.1990***	0.1435***	0.0604***	0.0729***
	(6.72)	(6.81)	(6.25)	(3.97)
Climate Index	-0.0056	0.0014	-0.0229	-0.0533
	(-0.29)	(0.09)	(-0.65)	(-0.77)
Carbon Risk*Perf.	0.0570***	0.0035	0.0336**	0.0065
	(2.93)	(0.14)	(2.06)	(0.90)
Carbon Risk*Climate Index	0.0181	0.0295	0.0339*	0.0124
	(1.19)	(1.64)	(1.85)	(0.42)
Climate Index*Perf.	0.1180***	0.0612**	0.0115	-0.0196
	(2.88)	(2.10)	(0.22)	(-1.12)
Fund Flow	0.0861***	0.0906***	0.0807***	0.0821**
	(3.14)	(3.10)	(2.83)	(2.14)
Volatility	-0.1413***	-0.1369***	-0.0869***	-0.0851*
	(-7.49)	(-7.15)	(-4.66)	(-2.01)
Log of Fund Assets	-0.1539*	-0.1465*	-0.5180***	-0.6055***
	(-2.05)	(-1.82)	(-10.00)	(-4.03)
Expense Ratio	0.0010	-0.0856**	-0.0014*	-0.0023*
	(0.05)	(-2.28)	(-1.68)	(-1.90)
Turnover Ratio	0.1962**	0.0012	-0.1262***	-0.0461
	(2.18)	(0.04)	(-2.67)	(-1.05)
Fund Age	0.0001	-0.0003	0.0098	0.1903
	(0.83)	(-1.63)	(0.33)	(1.60)
Log of Number of Stocks	2.3813***	3.2967***	-0.0851	-0.0205
	(3.09)	(4.65)	(-1.63)	(-0.30)
Constant	-0.1539*	-0.1465*	3.4739***	2.4919*

	(-2.05)	(-1.82)	(4.70)	(1.83)
Observations	9,266	11,496	9,266	11,496
R-Squared	10.30%	9.43%	10.20%	9.51%
Fund, Strategy, Year FE	YES	YES	YES	YES

Table X. Carbon Risk Score and ESG Score

This table presents the results of the analysis including the ESG score. The fund ESG score is calculated following El Ghoul and Karoui (2017) and ends in December 2018. In all four panels, the dependent variable is in period $t+1$ and all the independent variables are in period t. All the variables are winsorized at the 1st and 99th percentiles. The regressions control for fund, year, and strategy fixed effects. Standard errors are clustered at the fund level and are presented in parentheses. ***, **, and * indicate significance at the 1%, 5%, and 10% levels, respectively. Panel A reports the regression results for fund performance on the lagged fund carbon risk score, the fund ESG score, and other characteristics. The dependent variable in Models (1) and (2) is $Excess\ Return$, which is the fund return minus the risk-free rate. The dependent variable in Models (3) and (4) is $Alpha$, which is the intercept from the Fama–French and Carhart (1997) four-factor model. Panel B reports the regression results for fund risk on the lagged fund carbon risk score, the fund ESG score, and other characteristics. The dependent variable in Models (1) and (2) is $Total\ Risk$, which is the variance of the 12-month returns. The dependent variable in Models (3) and (4) is $Unexplained\ Risk$, which is the variance of the residuals from the Fama–French and Carhart (1997) four-factor model. The dependent variable in Models (5) and (6) is $Explained\ Risk$, which is the difference between total risk and unexplained risk. Panel C reports the regression results of fund flow on the lagged fund carbon risk score, the fund ESG score, and other characteristics. The dependent variable is fund flow, which equals the percentage change in TNA after adjusting for the fund's total return, as in Equation (3). The variable $Excess\ Return$ equals the fund return minus the risk-free rate, and $Alpha$ equals the intercept from the Fama–French and Carhart (1997) four-factor model. Panel D reports the regression results of fund flow on the lagged fund carbon risk score, the fund ESG score, the climate change news index, and other characteristics. The independent variable is fund flow, which equals the percentage change in TNA after adjusting for the fund's total return, as in Equation (3). The variable $Excess\ Return$ equals the fund return minus the risk-free rate, and $Alpha$ equals the intercept from the Fama–French and Carhart (1997) four-factor model. The climate change news index is from Engle et al. (2020), and the CH Negative News Index measures the innovation in the CH Negative Climate Change News Index and ends in May 2018.

Panel A: Fund Performance

	$Excess\ Return_{t+1}$			$Alpha_{t+1}$		
	(1)	(2)	(3)	(4)	(5)	(6)
Carbon Risk	-0.0109***		-0.0092***	-0.0118*		-0.0119*
	(-3.87)		(-2.93)	(-1.74)		(-1.75)
ESG Score		-0.3671***	-0.3683***		-0.0371	-0.0385
		(-4.91)	(-17.30)		(-0.74)	(-0.77)
Fund Flow	-0.0272***	-0.0274**	-0.0278***	-0.0348***	-0.0345***	-0.0348***
	(-4.94)	(-2.58)	(-4.79)	(-4.35)	(-4.32)	(-4.35)
Volatility	0.3745***	0.4361**	0.4347***	0.0721***	0.0760***	0.0752***
	(39.40)	(2.15)	(42.82)	(3.25)	(3.32)	(3.30)
Log of Fund Assets	-0.1664***	-0.1782***	-0.1784***	-0.2554***	-0.2550***	-0.2554***

	(-15.59)	(-4.70)	(-15.39)	(-8.93)	(-8.95)	(-8.94)
Expense Ratio	-0.0009***	-0.0008	-0.0008***	-0.0008	-0.0008	-0.0008
	(-3.40)	(-1.67)	(-2.90)	(-1.13)	(-1.07)	(-1.13)
Turnover Ratio	-0.0626***	-0.0718**	-0.0701***	0.0051	0.0042	0.0062
	(-3.47)	(-2.52)	(-3.38)	(0.10)	(0.08)	(0.12)
Fund Age	-0.0120	-0.0012	0.0028	0.0591	0.0541	0.0592
	(-0.86)	(-0.08)	(0.16)	(1.35)	(1.23)	(1.35)
Log of Number of Stocks	-0.0546***	-0.0602	-0.0588***	-0.0901*	-0.0914*	-0.0894*
	(-2.58)	(-1.38)	(-2.65)	(-1.72)	(-1.75)	(-1.71)
Constant	3.0545***	2.6205***	2.5943***	0.7814	0.7827	0.7496
	(10.19)	(4.78)	(6.73)	(0.75)	(0.75)	(0.72)
Observations	32,336	30,317	30,317	28,497	28,497	28,497
R-Squared	21.40%	20.10%	21.40%	6.35%	6.32%	6.34%
Fund, Strategy, Year FE	YES	YES	YES	YES	YES	YES

Panel B: Fund Risk

	$Total\ Risk_{t+1}$			$Explained\ Risk_{t+1}$			$Unexplained\ Risk_{t+1}$		
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Carbon Risk	-0.0005		-0.0016	0.0062		0.0049	0.0207***		0.0205***
	(-0.03)		(-0.11)	(0.42)		(0.33)	(3.28)		(3.24)
ESG Score		-0.3769***	-0.3771***		-0.4282***	-0.4275***		0.0721*	0.0693*
		(-3.08)	(-3.08)		(-3.25)	(-3.23)		(1.95)	(1.88)
Fund Flow	0.0064	0.0059	0.0059	0.0019	0.0012	0.0013	0.0153**	0.0159***	0.0154**
	(1.42)	(1.35)	(1.32)	(0.35)	(0.23)	(0.25)	(2.44)	(2.58)	(2.45)
Log of Fund Assets	0.0467**	0.0463**	0.0462**	0.0439*	0.0432*	0.0434*	0.0192	0.0199	0.0193
	(2.12)	(2.15)	(2.16)	(1.89)	(1.90)	(1.90)	(0.97)	(1.00)	(0.97)
Expense Ratio	0.0821***	0.0866***	0.0862***	0.0528	0.0562*	0.0575*	0.1088**	0.1135**	0.1081**
	(3.68)	(4.17)	(4.09)	(1.71)	(2.02)	(2.00)	(2.39)	(2.46)	(2.37)
Turnover Ratio	0.0294	0.0387**	0.0390**	0.0064	0.0183	0.0174	0.0773**	0.0717*	0.0755**
	(1.52)	(2.23)	(2.30)	(0.36)	(1.12)	(1.08)	(2.10)	(1.95)	(2.05)

Fund Age	0.0202	0.0210	0.0217	0.0381	0.0419	0.0398*	-0.0507	-0.0598	-0.0510
	(1.01)	(0.93)	(1.11)	(1.62)	(1.61)	(1.74)	(-0.98)	(-1.16)	(-0.98)
Log of Number of Stocks	-0.0509*	-0.0466*	-0.0464*	0.0760***	0.0820***	0.0811***	-0.4026***	-0.4070***	-0.4034***
	(-1.90)	(-1.80)	(-1.82)	(2.88)	(3.15)	(3.19)	(-8.49)	(-8.58)	(-8.49)
Constant	-0.4795	-0.7989*	-0.8036**	-1.3641**	-1.7456***	-1.7315***	2.6169***	2.7356***	2.6764***
	(-1.11)	(-2.03)	(-2.11)	(-2.78)	(-3.87)	(-4.02)	(2.61)	(2.74)	(2.66)
Observations	28,497	28,497	28,497	28,497	28,497	28,497	28,497	28,497	28,497
R-Squared	67.80%	68.40%	68.40%	65.20%	65.90%	65.90%	12.70%	12.60%	12.80%
Fund, Strategy, Year FE	YES	YES	YES	YES	YES	YES	YES	YES	YES

Panel C: Fund Flow

	Perf. = Excess Return			Perf. = Alpha		
	(1)	(2)	(3)	(4)	(5)	(6)
Carbon Risk	-0.0774***		-0.0665***	-0.0707***		-0.0617**
	(-3.65)		(-3.27)	(-3.33)		(-2.79)
Carbon Risk.*Perf	0.0095*		0.0301***	-0.0017		-0.0080
	(1.79)		(4.55)	(-0.26)		(-1.20)
ESG		-0.1038***	-0.1011***		-0.1303***	-0.1341***
		(-3.00)	(-3.13)		(-3.80)	(-3.97)
ESG*Perf.		-0.0370***	-0.0482***		0.0035	0.0069
		(-7.35)	(-8.33)		(0.35)	(0.70)
Perf.	0.0532***	0.0703***	0.0857***	0.0826***	0.0842***	0.0815***
	(3.59)	(5.35)	(6.17)	(7.30)	(6.68)	(6.29)
Fund Flow	0.1545***	0.1478***	0.1475***	0.1456***	0.1389***	0.1384***
	(8.19)	(7.41)	(7.38)	(7.83)	(7.06)	(7.10)
Volatility	-0.0280	-0.0429*	-0.0594**	-0.0321	-0.0174	-0.0197
	(-1.18)	(-1.80)	(-2.65)	(-1.63)	(-0.78)	(-0.92)
Log of Fund Assets	-0.4258***	-0.4500***	-0.4489***	-0.4183***	-0.4445***	-0.4452***
	(-10.16)	(-9.44)	(-9.41)	(-9.70)	(-9.10)	(-9.14)
Expense Ratio	-0.0017***	-0.0017***	-0.0017***	-0.0016***	-0.0017***	-0.0018***

	(-3.32)	(-3.40)	(-3.37)	(-3.00)	(-3.37)	(-3.42)
Turnover Ratio	-0.1080***	-0.1088***	-0.1055***	-0.0993***	-0.1036***	-0.1014***
	(-5.24)	(-5.00)	(-4.82)	(-4.39)	(-4.57)	(-4.47)
Fund Age	0.0215*	0.0226	0.0282*	0.0236*	0.0276*	0.0334**
	(1.72)	(1.44)	(1.91)	(1.78)	(1.86)	(2.32)
Log of Number of Stocks	-0.0417	-0.0319	-0.0302	-0.0439	-0.0365	-0.0331
	(-1.27)	(-0.88)	(-0.86)	(-1.39)	(-1.03)	(-0.95)
Constant	2.1353**	2.0900**	1.9719**	1.9017**	1.8564**	1.6958**
	(2.58)	(2.63)	(2.42)	(2.36)	(2.45)	(2.16)
Observations	32,336	30,317	30,317	32,336	30,317	30,317
R-Squared	10.20%	10.10%	10.30%	10.70%	10.40%	10.40%
Fund, Strategy, Year FE	YES	YES	YES	YES	YES	YES

Panel D: Fund Flow and Climate Change News

	Perf. = Excess Return	Perf. = Alpha
	(1)	(2)
Carbon Risk	-0.0472***	-0.0419***
	(-3.83)	(-3.08)
Carbon Risk*Perf.*Climate Index	0.0151*	0.0577***
	(1.86)	(3.54)
Perf.	0.1172***	0.0698***
	(15.23)	(8.69)
Climate Index	-0.1170***	-0.0088
	(-4.30)	(-1.01)
Carbon Risk*Perf.	0.0106**	0.0236**
	(2.32)	(2.56)
Carbon Risk*Climate Index	0.0420***	0.0055
	(3.22)	(0.44)
Climate Index*Perf.	-0.1134**	-0.0093
	(-2.52)	(-0.39)
ESG Score	-0.0586***	-0.1105***
	(-4.63)	(-6.03)
Fund Flow	0.1374***	0.1308***
	(8.01)	(7.37)
Volatility	-0.1150***	-0.0724***
	(-7.37)	(-4.96)
Log of Fund Assets	-0.4987***	-0.4927***
	(-7.01)	(-6.69)
Expense Ratio	-0.1995***	-0.1972***
	(-4.52)	(-4.53)
Turnover Ratio	-0.0824***	-0.0844***
	(-5.69)	(-6.32)
Fund Age	0.0300**	0.0397***
	(2.46)	(3.53)
Log of Number of Stocks	-0.0000	-0.0554**
	(-0.03)	(-2.35)
Constant	2.1232***	2.0604***
	(6.09)	(5.94)
Observations	27,884	27,884
R-Squared	11.10%	11.08%
Fund, Strategy, Year FE	YES	YES

Appendix

Table A1. Carbon Risk Score and Firm Characteristics

This table reports the firm characteristics and performance for high– and low–carbon risk firms. For each year, the firms are sorted into five portfolios based on their carbon risk. A variety of firm characteristics and performance are compared between the portfolio with the lowest carbon risk and that with the highest. The variable *Log of Assets* is the natural logarithm of the firm's total assets; *Stock Return* is the firm's annual stock return adjusted for dividends and delisting return; *Leverage* is debt in current liabilities plus long-term debt, divided by total assets; *ROA* is the firm's net income divided by EBITDA; *INST Holdings%* is the percentage of shares outstanding owned by institutional investors; *INST Holdings CONC* is the Herfindahl–Hirschman Index of institutional ownership concentration; *Adjusted Board Size* is the number of board numbers adjusted by firm size; *Board Age* is the average age of the board members; *Independent Director%* is the percentage of independent directors serving on the board of directors; *Dual CEO* is a dummy variable that equals one if the firm CEO also serves as the chair of the board, and zero otherwise; *Female Director%* is the percentage of female directors serving on the board of directors; and *Minority Director%* is the percentage of non-white directors serving on the board of directors.

	Low Carbon Risk	High Carbon Risk	Low − High	*t*-statistics
Log of Assets	8.941	9.184	-0.243***	-3.25
Stock Return	0.164	-0.035	0.199***	10.05
Leverage	0.276	0.251	0.026***	3.20
ROA	0.134	0.111	0.024***	4.85
INST Holdings%	0.779	0.613	0.166***	7.55
INST Holdings CONC	0.077	0.176	-0.100***	-5.90
Adjusted Board Size	1.102	0.996	0.106***	7.85
Independent Director%	0.816	0.838	-0.022***	-3.30
Board Age	62.550	63.942	-1.391***	-6.60
Dual CEO	0.537	0.682	-0.145***	-3.00
Female Director%	0.201	0.139	0.063***	8.90
Minority Director%	0.134	0.067	0.068***	10.05

Table A2. Comparison of the CRSP Carbon Risk Score and the Morningstar Mutual Fund Carbon Risk Score

This table compares the CRSP carbon risk score and the Morningstar mutual fund carbon risk score, using the results from the following regression: $CRSP\ Carbon\ Risk\ Score_{i,t} = a_i + \beta_i * MD\ Carbon\ Risk\ Score_{i,t} + \varepsilon_{i,t}$.

The dependent variable is the mutual fund carbon risk score used in this paper. The independent variable is the mutual fund carbon risk score reported in Morningstar Direct. Models (1) to (4) report the pooled OLS regression results. Models (5) to (8) report the fixed effects regression results. Morningstar Direct started releasing the Morningstar Portfolio Carbon Risk Score in 2017. Out of the 1,695 mutual funds in our sample, 1,339 (79%) are successfully matched. The regression is run during the overlapping sample period from 2015 to 2019.

	Pooled OLS				Fixed Effects			
CRSP Carbon Risk Score	All	2017	2018	2019	All	2017	2018	2019
MD Carbon Risk Score	0.8387***	0.8057***	0.8535***	0.8616***	0.7767***	0.6960***	0.6017***	0.5513***
	(195.13)	(127.67)	(129.67)	(73.91)	(47.91)	(19.17)	(29.71)	(11.52)
Constant	0.5407***	0.9350***	0.3658***	0.2943***	1.1561***	2.0743***	2.8947***	3.0978***
	(14.16)	(16.24)	(6.15)	(3.10)	(7.18)	(5.50)	(14.23)	(7.16)
Observations	9,794	3,779	3,591	3,474	9,794	3,779	3,591	3,474
R-Squared	90.8%	89.5%	92.2%	89.9%	65.8%	53.1%	56.0%	51.6%
Fund FE	NO	NO	NO	NO	YES	YES	YES	YES

Table A3. Comparison of the CRSP Mutual Fund Carbon Risk Score and the Morningstar Mutual Fund ESG Risk Score

This table compares the CRSP carbon risk score and the Morningstar mutual fund ESG risk score. Panel A shows the results of the following regression equation:

$$CRSP\ Carbon\ Risk\ Score_{i,t} = a_i + \beta_i * MD\ ESG\ Overall\ Risk\ Score_{i,t} + \varepsilon_{i,t}.$$

The dependent variable is the mutual fund carbon risk score used in this paper. The independent variable is the mutual fund ESG risk score reported in Morningstar Direct. Morningstar Direct started releasing the Morningstar Portfolio ESG Risk Score in 2015.

Panel B reports the results of the following regression equation:

$$CRSP\ Carbon\ Risk\ Score_{i,t} = a_i + \beta_i * MD\ ESG\ Environment\ Risk\ Score_{i,t} + \varepsilon_{i,t}.$$

The dependent variable is the mutual fund carbon risk score used in this paper. The independent variable is the mutual fund ESG environment risk score reported in Morningstar Direct.

Panel C reports the results of the following regression equation:

$$CRSP\ Carbon\ Risk\ Score_{i,t} = a_i + \beta_i * MD\ ESG\ Society\ Risk\ Score_{i,t} + \varepsilon_{i,t}.$$

The dependent variable is the mutual fund carbon risk score used in this paper. The independent variable is the mutual fund ESG society risk score reported in Morningstar Direct.

Panel D reports the results of the following regression equation:

$$CRSP\ Carbon\ Risk\ Score_{i,t} = a_i + \beta_i * MD\ ESG\ Governance\ Risk\ Score_{i,t} + \varepsilon_{i,t}.$$

The dependent variable is the mutual fund carbon risk score used in this paper. The independent variable is the mutual fund ESG governance risk score reported in Morningstar Direct. Out of the 1,695 mutual funds in our sample, 1,339 (79%) are successfully matched. The regression is run during the overlapping sample period from 2015 to 2019.

Panel A: CRSP Carbon Risk Score and Morningstar ESG Risk Score

CRSP Carbon Risk Score	All	2015	2016	2017	2018	2019
MD ESG Overall Risk Score	0.2273***	0.3300***	0.6176***	0.6820***	0.6134***	0.0510***
	(39.23)	(13.30)	(32.34)	(38.74)	(32.32)	(7.71)
Constant	-2.2438***	-7.0759***	-19.7819***	-22.0775***	-19.5950***	4.6470***
	(-8.54)	(-5.95)	(-22.79)	(-28.60)	(-23.33)	(17.38)
Observations	21,912	3,847	4,684	5,090	4,886	4,425
R-Squared	9.3%	5.3%	19.0%	23.6%	19.0%	1.4%
Fund FE	NO	NO	NO	NO	NO	NO

Panel B: CRSP Carbon Risk Score and Morningstar ESG Environment Risk Score

CRSP Carbon Risk Score	All	2015	2016	2017	2018	2019
MD ESG Environment Risk Score	0.0730***	0.1342***	0.2688***	0.2244***	0.2098***	0.0063**
	(25.37)	(11.57)	(27.18)	(27.30)	(27.87)	(2.06)
Constant	4.2456***	1.4880**	-5.5464***	-3.4582***	-3.0462***	7.3165***
	(28.38)	(2.37)	(-10.66)	(-8.18)	(-7.90)	(52.82)
Observations	21,521	3,847	4,684	5,090	4,886	4,314
R-Squared	3.80%	2.97%	12.89%	12.26%	11.86%	0.11%
Fund FE	NO	NO	NO	NO	NO	NO

Panel C: CRSP Carbon Risk Score and Morningstar ESG Society Risk Score

CRSP Carbon Risk Score	All	2015	2016	2017	2018	2019
MD ESG Society Risk Score	0.0742***	0.3084***	0.3800***	0.2443***	0.2296***	0.0153***
	(20.79)	(23.58)	(24.45)	(20.57)	(22.01)	(4.08)
Constant	4.2559***	-7.0541***	-10.7032***	-4.2284***	-3.9221***	7.6809***
	(23.79)	(-10.53)	(-13.61)	(-7.14)	(-7.49)	(46.31)
Observations	21,521	3,847	4,684	5,090	4,886	4,314
R-Squared	2.7%	11.3%	13.2%	8.6%	9.3%	0.5%
Fund FE	NO	NO	NO	NO	NO	NO

Panel D: CRSP Carbon Risk Score and Morningstar ESG Governance Risk Score

CRSP Carbon Risk Score	All	2015	2016	2017	2018	2019
MD ESG Governance Risk Score	0.0492***	0.6967***	0.4220***	0.1478***	0.2770***	0.0153***

	(14.35)	(33.35)	(9.23)	(11.13)	(13.95)	(4.15)
Constant	5.4166***	-27.7163***	-13.4064***	0.2715	-6.4096***	7.6758***
	(31.51)	(-25.43)	(-5.72)	(0.41)	(-6.48)	(48.40)
Observations	21,521	3,847	4,684	5,090	4,886	4,314
R-Squared	1.2%	21.5%	5.2%	2.1%	8.7%	0.5%
Fund FE	NO	NO	NO	NO	NO	NO

Table A4. Americans' Views on Climate Change

The following tables present the survey results of selective questions from the Climate Change in the American Mind project managed by the Yale Program on Climate Change Communication (YPCCC) and the George Mason University Center for Climate Change Communication (Mason 4C). The sample period is from 2008 to 2018. The full survey data and survey methodologies can be found at https://climatecommunication.yale.edu/visualizations-data/americans-climate-views. Adjustments have been made for sample representativeness, using the sampling weight variable. The survey results are reported starting in 2010, since the 2009 survey data are missing and the 2008 survey results seem to be outliers.

Question 1: Do you think that global warming is happening? (Answers are shown in percentage.)

Year	No answer	No	Do not know	Yes
2010	0.57	19.05	21.54	58.83
2011	1.96	16.99	18.78	62.26
2012	0.40	13.06	18.61	67.94
2013	0.68	18.96	17.63	62.73
2014	0.05	17.43	17.63	64.89
2015	0.00	16.67	18.12	65.21
2016	0.00	11.87	17.85	70.28
2017	0.00	13.23	15.95	70.81
2018	0.03	13.85	14.64	71.48

Question 2: How worried are you about global warming? (Answers are shown in percentage.)

Year	No answer	Not at all worried	Not very worried	Somewhat worried	Very worried
2010	1.25	19.86	28.23	39.04	11.62
2011	1.72	17.25	28.79	41.71	10.53
2012	0.46	16.19	27.71	42.25	13.39
2013	0.71	19.27	28.08	37.65	14.29
2014	0.10	18.00	26.07	43.27	12.55
2015	0.00	17.41	27.77	41.09	13.73
2016	0.00	16.42	24.33	41.82	17.43
2017	0.00	15.45	24.52	40.55	19.48
2018	0.08	14.32	20.47	40.50	24.64

Question 3: When do you think global warming will start to harm people in the United States? (Answers are shown in percentage.)

Year	No answer	Never	In 100 years	In 50 years	In 25 years	In 10 years	Right now
2010	2.86	20.68	13.61	12.50	12.41	11.79	26.15
2011	2.35	17.53	13.03	13.48	13.02	10.40	30.20
2012	1.59	14.86	13.85	13.00	11.82	12.44	32.44
2013	1.53	17.27	12.49	11.41	12.79	10.20	34.31
2014	0.50	17.02	13.16	13.37	13.92	9.25	32.77
2015	0.13	18.61	11.80	11.19	13.63	11.78	32.87
2016	0.32	14.94	9.88	10.86	13.68	12.95	37.37

2017	0.08	13.79	11.64	12.22	12.79	11.12	38.37
2018	0.13	14.68	10.04	9.61	13.09	9.07	43.38

Question 4. How much do you support or oppose the following policies? Regulate carbon dioxide (the primary greenhouse gas) as a pollutant. (Answers are shown in percentage.)

Year	No answer	Strongly oppose	Somewhat oppose	Somewhat support	Strongly support
2010	2.89	12.28	13.04	47.42	24.38
2011	5.42	6.85	18.61	45.39	23.72
2012	5.52	10.04	15.90	46.09	22.44
2013	4.94	11.34	16.24	44.04	23.44
2014	2.22	10.89	14.59	45.62	26.68
2015	1.37	9.92	14.88	44.68	29.15
2016	1.10	9.85	15.00	44.74	29.31
2017	1.82	7.99	14.72	42.97	32.49
2018	1.79	6.65	13.60	45.15	32.82