Climate-triggered institutional price pressure: Does it affect firms' cost of equity?[*]

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Abstract

We document that climate-triggered institutional portfolio rebalancing affects S&P 500 firms' option-implied cost of equity over 2005-2021 by utilizing the incurred climate change price pressure (CCPP) as a channel. Our approach is direct and novel. We estimate stock-level CCPP stemming from physical and transition exposures in a demand-based asset pricing setting. A one-standard-deviation intensification in CCPP increases firms' cost of equity up to 6% of its average value. Banks and insurance companies primarily contribute to CCPP. Despite the higher cost of equity, firms do not decrease their future climate change exposures, unless media attention to climate change rises.

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1 Introduction

Evidence suggests that institutional investors take firms' climate change exposures into account when forming their portfolios.[1] Four important, still open, interrelated questions arise. Does institutional portfolio rebalancing triggered by firm-level climate change exposures affect firms' cost of equity? If it does, does this change firms' future climate change exposures? Is it physical or transition climate change exposures that matter for these effects and which types of institutional investors take them into account? We revisit these questions via the lens of institutional stock price pressure triggered by institutional portfolio rebalancing due to firm-level climate change exposures (termed climate change price pressure hereafter, CCPP). To the best of our knowledge, this paper is the first to directly address these questions in a unified setting by placing CCPP at the epicenter.[2] Our study takes a step back from Noh et al. (2023) who examine the effect of CCPP to firms' future environmental profile, as any effects of CCPP to the cost of equity constitute a channel for further real effects. We also differ from them in that we explore CCPP effects stemming from climate change exposures proxied by textual topics measures whose informational content is at a more granular level than that of ESG ratings and carbon emissions.

We derive a closed-form expression for the stock-specific CCPP within the Koijen and Yogo (2019) demand-based asset pricing setting, which is a natural choice for

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[1] As of 31 March 2022, 4,902 institutional investors with assets under management amounting to $121.3 trillion have signed in the "United Nations Principles for Responsible Investment" (UN PRI), the largest global network dedicated to the responsible investment. See https://www.unpri.org/annual-report-2022. Over time, more institutional investors have declared that sustainability is an important objective in portfolio allocation (Giglio et al. (2021)). In addition, survey studies report that institutional investors are concerned about the effects of climate change risks on their portfolios (e.g., Krueger et al. (2020), Stroebel and Wurgler (2021), and Ilhan et al. (2023)).

[2] Underweighting a stock due to a change in climate change exposures may impose a significant downward pressure on the stock price, thus increasing firm's cost of equity (Heinkel et al. (2001), Pedersen et al. (2020), Pástor et al. (2021, 2022); De Angelis et al. (2022), Zerbib (2022), Hong et al. (2023)). As a response, firms may change their future climate change exposures to mitigate the CCPP effect to their cost of equity, if the benefits outweigh the costs of such a reform (Heinkel et al. (2001), Edmans et al. (2023)). Similarly, some types of investors may contribute to CCPP more than others, being more sensitive to certain types of climate change exposures. More broadly, our paper relates to the literature on institutional price pressure stemming from any type of institutional investor trading beyond climate change-related trading. This literature links stock prices and returns to implicit proxies of price pressure, such as the institutional trading activities of certain types of investors (e.g., Shleifer (1986), Griffin et al. (2003), Coval and Stafford (2007), Frazzini and Lamont (2008), Lou (2012), Ben-David et al. (2022), Hartzmark and Solomon (2022), Pavlova and Sikorskaya (2023)).

the purposes of our analysis for two reasons. First, in equilibrium, each investor's optimal stock portfolio weight is a function of the respective stock's characteristics, which affect expected returns and risks. We incorporate firm-level climate change exposures as a stock characteristic. This allows us to derive a formula for CCPP which measures the percentage change in the stock price with respect to a one-standard-deviation change in its firm's climate change exposures. Second, the model is consistent with investors reacting differently to climate change exposures because they may differ in their views about how these are related to their perceived stock's expected return and risk.[3] An investor would overweight (underweight) a stock, if an increase in its climate change exposures is perceived to be positively (negatively) related to its expected return, or negatively (positively) related to its risk.

The stock-level CCPP formula holds in equilibrium, and hence it takes into account the heterogeneous characteristics of all investors, namely the sensitivities of each investor's portfolio weights to changes in climate change exposures, their stock's ownership, and demand elasticities. Thus, CCPP has two important properties. First, its magnitude is greater (smaller) for stocks owned by investors with a smaller (greater) demand elasticity. Second, it will be negative (positive) in the case where most investors underweight (overweight) the stock due to an increase in climate change exposures.

We estimate alternative stock-specific CCPP measures stemming from physical and transition climate exposures, respectively, given previous evidence on the diverse effects of different types of climate change exposures to stock prices (Faccini et al. (2023), Sautner et al. (2023b)). We measure firm-level climate change exposures by the four Sautner et al. (2023a) quarterly textual measures of total, physical, opportunity, and regulatory exposures, thus estimating four respective CCPP measures. These are extracted from each firm's quarterly earnings conference calls, a key corporate event, where there is an exchange of information between managers and analysts on material issues relevant to investing in the firm's stock. Hence, the use of these measures is a natural choice for the purposes of our analysis vis-à-vis measures of climate change exposures based on "hard" information, such as ESG

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[3] For instance, one investor may view an increase in the regulatory climate change exposure of a polluting energy company as positively related to its risk, whereas another may view it as positively related to its expected return, given that some polluting energy companies are also innovators of green technology (Cohen et al. (2020)).

ratings and carbon emissions. They measure total climate change exposures and their physical and transition dimensions at the most granular level and they capture the company's perspectives of climate risks.

We estimate each CCPP measure for each constituent stock of the S&P 500 and for every quarter over Q1 2005-Q4 2021 using Thomson Reuters Institutional (13F) portfolio holdings of U.S. stocks. S&P 500 constituent stocks account for 80% of the total market capitalization of U.S. public companies. In addition, the choice of sample and period ensures data quality requirements for our climate change exposures and cost of equity measures. The pooled average CCPP is negative. Stock prices decrease the most (least) with respect to the increase in total (physical) climate change exposures. A one-standard-deviation increase in the total (physical) climate change exposures, decreases on average the stock price by 7.9% (2.7%). The cross-sectional average CCPP is mostly negative over our sample period and reveals a downward trend (upward) trend for the pre (post)- 2016 period. These patterns are similar across the four CCPP measures, in line with the theoretical properties of the CCPP measure. We find that on average, investors underweight more (less) stocks with higher climate change exposure over the pre (post)-2016 period.

Next, we examine the effect of each CCPP measure to the respective firm's cost of equity over alternative horizons to also explore any term structure effects. Instead of relying on realized returns, we estimate firm's cost of equity by using Martin and Wagner (2019) and Chabi-Yo et al. (2023) option-based measures of expected excess returns. Option-implied cost of equity measures are real-time, forward-looking, market-based measures. Hence, they circumvent the limitation that inferences about expected returns using realized returns may lack informativeness, they properly update the cost of equity, and avoid any noise in accounting reports which alternative cost of equity measures may employ (Kim (2022), Pástor et al. (2022)).[4]

We document that CCPP has a negative and statistically significant impact on

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[4] S&P 500 index constituent stocks are optionable and the corresponding equity options are highly liquid; thus, the informational content of their option market prices to estimate firms' cost of equity is rich. Hence, this sample is a natural choice to apply option-based measures of the cost of equity to study the effects of CCPP. More generally, the informational content of the S&P 500 option market prices has shed light on addressing questions in asset management, prediction of economic growth, corporate finance, and climate finance (see e.g., Kostakis et al. (2011), Faccini et al. (2019), Kim (2022), Sautner et al. (2023b)).

firms' cost of equity, over and above standard controls. The firm's cost of equity increases as its stock CCPP becomes more negative. The negative relation holds in almost all cases regardless of the option-implied measure of the cost of equity and the type of climate change exposure that CCPP stems from, and it is economically significant. For instance, a one-standard-deviation decrease in CCPP stemming from total climate change exposures, decreases the option-implied Martin and Wagner (2019) cost of equity by 3% of the average monthly cost of equity. Once dissecting the climate change exposures, the size of this effect differs among the CCPP measures, with the greatest (smallest) effect encountered for CCPP stemming from opportunity and physical (regulatory) climate change exposures, being 4% (0.2%) of the average monthly cost of equity, respectively. The effects prevail over different horizons, being strongest for one and two quarters ahead, up to 6% of the respective average costs of equity for CCPP originating from opportunity exposures.

The documented sizable effect of CCPP is explained by the rebalancing activity of investors with respect to climate change exposures and by the aggregate inelastic demand for U.S. stocks over the examined period. Regarding the former effect, we find that banks (insurance companies) rebalance their portfolios the most with respect to changes in opportunity and regulatory (physical) climate change exposures. Regarding the latter effect, we estimate the aggregate demand elasticity to be 0.29, in line with similar estimates provided by Koijen and Yogo (2019) and Gabaix and Koijen (2022). Our findings confirm the theoretical predictions that firms face a higher cost of equity, when underweighted by ESG-motivated investors (Pedersen et al. (2020), Pástor et al. (2021, 2022), Zerbib (2022)).

Next, we examine whether CCPP affects firms' future climate change exposures. Firms may change their future climate change exposures to mitigate the CCPP effect to their cost of equity, only if the benefits outweigh the costs of such a reform (Heinkel et al. (2001), Edmans et al. (2023). We find that CCPP is insignificantly related to firms' future climate change exposures and carbon emission intensities, and this insignificance prevails even over longer horizons. Our empirical findings echo Berg et al. (2022) who find that the rebalancing of mutual funds portfolios due to ESG considerations does not improve firms' future environmental performance.

Further robustness tests, taking into account the presence of any reverse causality and conflating effects from green and brown firms, confirm the results of our baseline analysis. Interestingly, firms reduce their future climate change exposures and carbon emission intensities only over periods of increased media attention to climate change. Finally, we find that CCPP does not affect firms' future investment, innovation, and financing activities, confirming that firms take no action to change their future environmental profile, even though they are confronted with a higher cost of equity due to a negative CCPP.

Related literature and contributions. Our paper relates to the empirical literature on whether firms' cost of equity and future environmental profile are affected when institutional investors rebalance their portfolios as a response to climate change risks. Berg et al. (2022), Gantchev et al. (2022), Rohleder et al. (2022), Noh et al. (2023) and Choi et al. (2024) find that divestment by sustainable institutional investors decreases stock prices, interpreting this as evidence that the cost of equity increases, and van der Beck (2023) finds that capital flows into ESG funds are positively correlated with future realized returns of ESG stocks. Berk and van Binsbergen (2022) find no such effect, once they calibrate their model to a subset of stocks in the FTSE USA 4 Good Select Index over 2015-2020, yet Atta-Darkua et al. (2023) find that divestment affects the monthly cost of equity, once they calibrate the Berk and van Binsbergen (2022) model to a different asset universe (MSCI ACWI index stocks) and a longer time period (2006-2019). Similarly, the evidence on whether a negative CCPP improves firms' future environmental profile is mixed. Some studies support this prediction by considering the effect of explicit (i.e., model-based, Noh et al. (2023)) or implicit CCPP measures on firm's future emissions and E&S scores, whereas other studies do not support it by considering the effect of changes in ESG ratings (Berg et al. (2022)) and in sustainable investors' ownership (Heath et al. (2023)).[5]

Our main contribution to the above literature is two-fold. First, we consider *directly* the impact of climate-triggered institutional portfolio rebalancing on firms' cost of equity and future environmental profiles by using a closed-form, theoretically-based, stock-level CCPP measure. Our measure is formally related to investors'

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[5] Implicit measures of CCPP include measures based on mutual funds trades (Rohleder et al. (2022)), price impact measures (Gibson et al. (2021)), stock valuation measures (Li et al. (2023), Choi et al. (2024)), stock returns (Hwang et al. (2021), Gantchev et al. (2022), Shackleton et al. (2022)).

heterogeneous climate-triggered rebalancing activities and stock ownership. Second, our cost of equity measure is forward-looking rather than based on realized returns; inferences about expected returns using realized returns may not be informative (Pástor et al. (2022)).

Noh et al. (2023) and Sautner et al. (2023b) are the closest study to ours. Noh et al. (2023) calculate CCPP in Koijen and Yogo (2019) setting with respect to climate change risks measured by "hard" information (E scores, carbon emissions, and green patents, separately), and they examine how it relates to firms' future environmental performance. They find that investor's pressure for sustainability predicts future improvements in firm sustainability, albeit the magnitude is small. We take a step back and examine the impact of CCPP on the cost of equity, a channel via which CCPP may affect firms' future environmental profile. Notice that information on CCPP alone, does not inform us about the statistical and economic significance of its effect to the cost of equity, *unless* it is tested explicitly. In addition, we calculate CCPP with respect to "soft" information originating from information exchanges between managers and analysts dissected per climate change exposures topic, thus capturing insights not contained in firm-level exposure measures based on "hard" information. This may explain the lack of a significant relation between CCPP and future climate change exposures.[6]

Sautner et al. (2023b) find that climate change exposures are priced in the cross-section of S&P 500 stock returns, by employing the textual factors and option-based measures of expected returns that we also employ. They suggest shareholder engagement as an explanation for their finding. We complement their study by providing the climate-triggered institutional portfolio rebalancing as an alternative economic channel for their results. The significant effects of CCPP to the option-implied cost of equity prevail after controlling for their climate change exposures.

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[6] Gibson et al. (2021) and Koijen et al. (2023) also use the demand-based asset pricing setting in the context of sustainable investing, yet their focus is different. The former computes a price impact measure stemming from an aggregate demand shock, showing a positive correlation with firms' E&S scores. The latter examines how climate-induced institutional portfolio rebalancing affects firms' valuation ratios via a counterfactual analysis.

2 Theoretical model

We briefly review the Koijen and Yogo (2019) demand-based asset pricing setting and extend it by including firm-level climate change exposures. We derive the model-based stock-level CCPP and discuss its estimation.

2.1 Characteristics-based portfolio weights

Consider an economy with I investors, indexed by i=1, ..., I and N assets indexed by n=1,.., N. Each investor is endowed with wealth $A_{i,t}$ at time t. One of the investors is the household, assumed to hold the remaining shares for each stock at each time t that are not held by institutional investors. At each time t, investor i allocates her wealth across the assets in her investment universe set, $\mathcal{N}_{i,t} \subseteq \{1, \ldots, N\}$, and an outside asset, indexed by $n = 0$. The outside asset is the set of assets outside the N assets that are the subject of our study. Koijen and Yogo (2019) show that in market equilibrium, investor i's optimal portfolio weight (relative to the outside asset) on the nth stock ($n \in \mathcal{N}_{i,t}$) at time t is given by:

$$\forall i, t: \quad \frac{w_{i,t}(n)}{w_{i,t}(0)} = \exp\left\{\beta_{0,i,t} me_t(n) + \boldsymbol{\beta}'_{1,i,t}\mathbf{x}_t(n) + \beta_{2,i,t}\right\} \epsilon_{i,t}(n), \tag{1}$$

The relative optimal portfolio weight is an exponential function of log market equity ($me_t(n)$) and other stock characteristics ($\mathbf{x}_t(n)$), including log book equity, market beta, profitability, investment, and dividend-to-book equity. The error term captures investor i's demand for asset n's unobserved characteristics (latent demand). $\beta_{0,i,t}$ is the coefficient on the log market equity, $\boldsymbol{\beta}'_{1,i,t}$ is a vector of coefficients on other observed characteristics $\mathbf{x}_t(n)$, which capture how investor i's portfolio weight varies with respect to different equity characteristics, and $\beta_{2,i,t}$ is the intercept of model (1).

Optimal portfolio composition varies across investors because they are assumed to have heterogeneous beliefs about each stock's expected return and risk. This heterogeneity arises from the different views of investors on the assumed association of expected returns and risks with stock characteristics. Koijen and Yogo (2019), Proposition 1, shows that investors prefer stocks with characteristics that are associated with higher expected returns or lower risks. Hence, any employed stock characteristics should predict expected returns and risks (see Koijen and Yogo (2019), Assumption 1). Firm-level climate change exposures are found to be informative about expected returns and risks (Sautner et al. (2023b)), and thus, we extend the set of characteristics in equation (1) by adding firm-level climate change exposures,

$$\forall i, t: \quad \frac{w_{i,t}(n)}{w_{i,t}(0)} = \exp\left\{\beta_{0,i,t} me_t(n) + \beta_{1,i,t} cc_t(n) + \boldsymbol{\beta}'_{2,i,t}\mathbf{x}_t(n) + \beta_{3,i,t}\right\} \epsilon_{i,t}(n), \quad (2)$$

where $cc_t(n)$ denotes the climate change exposures for the stock n at time t and $\beta_{1,i,t}$ is the coefficient on climate change exposures. $\beta_{3,i,t}$ is the intercept of model (2). An investor would overweight (underweight) a stock, if an increase in firms' climate change exposures is perceived to be positively (negatively) related to expected returns or negatively (positively) related to risks.[7]

2.2 Stock-level pressure: The model-based measure

CCPP captures how the institutional portfolio rebalancing triggered by firms' climate change exposures affects the stock price, in equilibrium. To fix ideas, stock n's CCPP at time t is the percentage change in the stock price for a firm n (i.e., $P_t(n)$) with respect to a one-standard-deviation unit shift in its climate change exposure (we cross-sectionally standardize the climate change exposure) given by

$$CCPP_t(n) \equiv \frac{\partial p_t(n)}{\partial cc_t(n)} = \frac{\sum_i s_{i,t}(n)\beta_{1,i,t}\left(1 - w_{i,t}(n)\right)}{1 - \sum_i s_{i,t}(n)\beta_{0,i,t}\left(1 - w_{i,t}(n)\right)}, \quad (3)$$

where $p_t(n) = \log(P_t(n))$, and $s_{i,t}(n) = A_{i,t}w_{i,t}(n)/\sum_{i=1}^{I} A_{i,t}w_{i,t}(n)$ is the proportion of the total market capitalization held by investor i for stock n at time t (i.e., investor i's ownership of stock n at t). Appendix A.1 provides the proof for (3).

Equation (3) holds in market equilibrium, and hence it takes into account the heterogeneity of all investors. It shows that CCPP equals the ownership-weighted

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[7] Adding climate change exposures as a determinant of portfolio weights is also consistent with the literature which documents, in a linear panel regression setting, that climate change risks, proxied by ESG scores and carbon emissions, affect institutional investors' investments, measured by institutional portfolio holdings (e.g., Alok et al. (2020), Pástor et al. (2023)), or by institutional ownership (e.g., Chava (2014), Fernando et al. (2017), Nofsinger et al. (2019), Pedersen et al. (2020), Bolton and Kacperczyk (2021), Berg et al. (2022), Gantchev et al. (2022), Choi et al. (2024)).

sum of the coefficients on climate change exposures ($\beta_{1,i,t}$), divided by one minus the ownership-weighted sum of the coefficients on log market equity ($\beta_{0,i,t}$). $\beta_{1,i,t}$ captures how investor i rebalances her portfolios with respect to firm-level climate change exposure and $\beta_{0,i,t}$ relates to the demand elasticity of the number of shares held by investor i with respect to the stock price (Koijen and Yogo (2019), Equation (14)). The greater (smaller) the $\beta_{0,i,t}$, the smaller (greater) the investor's demand elasticity is. The denominator in equation (3) is the aggregate demand elasticity of the number of shares held across all investors with respect to the stock price (Koijen and Yogo (2019), Equation (15)).

The dependence of the model-based CCPP on $\beta_{1,i,t}$ and $\beta_{0,i,t}$ shows that CCPP is determined by two effects in an intuitive way. Investors adjust their demand for stock n, i.e. the stock's portfolio weights, when the firm-level climate change exposures change and this effect is captured by $\beta_{1,i,t}$. This change in demand creates a change in the stock price and this effect is determined by $\beta_{0,i,t}$. The greater (smaller) the investor's demand elasticity, the smaller (greater) the stock price change for a given change in demand.

Given the above, the stock CCPP has the following three properties. First, CCPP's magnitude is greater for stocks owned by investors with a smaller demand elasticity. This echoes the research suggesting that investors' demand elasticity affects the magnitude of stock CCPP (e.g, Broccardo et al. (2022), Gantchev et al. (2022), van der Beck (2023)). Second, CCPP can be either positive or negative, depending on the sign on the numerator of equation (3); its denominator is strictly positive under the restriction that $\beta_{0,i,t} < 1$, which ensures a unique market clearing equilibrium (Koijen and Yogo (2019)). If the majority of investors underweight (overweight) stock n, i.e. negative (positive) $\beta_{1,i,t}$, due to increasing climate change exposures, the stock will face a negative (positive) CCPP. Hereafter, the majority means either the number of investors and/or the biggest investors by stock ownership. Third, a stock will face more negative (positive) CCPP, when the majority of investors of the stock n underweight (overweight) it more, as its climate change exposure increases (i.e., more negative (positive) coefficient, $\beta_{1,i,t}$), and the majority of investors of the stock n have lower demand elasticity (i.e., higher coefficient, $\beta_{0,i,t}$).

2.3 GMM estimation

To estimate CCPP, one needs to estimate equation (2) first. Since we include the intercept term, $\beta_{3,i,t}$ in equation (2), $\mathbb{E}[\epsilon_{i,t}(n)] = 1$ can be assumed without loss of generality. However, $\epsilon_{i,t}(n)$ and $me_{i,t}(n)$ are not independent due to the endogeneity of stock prices, i.e. $\mathbb{E}\left[\epsilon_{i,t}(n) \mid me_{i,t}(n), \mathbf{cc}_t(n), \mathbf{x}_t(n)\right] \neq \mathbb{E}\left[\epsilon_{i,t}(n)\right]$. To address the endogeneity problem, we follow Koijen and Yogo (2019). At any point in time t, we estimate equation (2) for investor i by constructing a stock-specific instrument $\widehat{me}_{i,t}(n)$ for the log market equity of asset n, namely the log market equity for asset n as if all other investors (excluding i) hold equal-weighted portfolios within their investment universe (see Koijen and Yogo (2019), Equation (19)).

The exogeneity of the instrument for the log market equity yields the condition:

$$\forall i, t: \quad \mathbb{E}\left[\epsilon_{i,t}(n) \mid \widehat{me}_{i,t}(n), cc_t(n), \mathbf{x}_t(n)\right] = \mathbb{E}\left[\epsilon_{i,t}(n)\right] = 1, \tag{4}$$

which yields

$$\forall i, t: \quad \mathbb{E}_t\left[\left(\frac{w_{i,t}(n)}{w_{i,t}(0)} \exp\left\{-\tilde{\boldsymbol{\beta}}_{i,t}\tilde{\boldsymbol{x}}_{i,t}\right\} - 1\right)\boldsymbol{z}_{i,t}\right] = \mathbf{0} \tag{5}$$

where $\tilde{\boldsymbol{x}}_{i,t} = [me_t(n), cc_t(n), \mathbf{x}_t(n)', 1]'$, $\tilde{\boldsymbol{\beta}}_{i,t} = \left[\beta_{0,i,t}, \beta_{1,i,t}, \boldsymbol{\beta}'_{2,i,t}, \beta_{3,i,t}\right]'$, and $\boldsymbol{z}_{i,t} = [\widehat{\mathrm{me}}_{i,t}(n), cc_t(n), \mathbf{x}_t(n)', 1]'$.

We estimate equation (2) for each investor and at any time t by using the generalized method of moments (GMM). Note that the coefficients to be estimated in (2), vary across investors and over time, yet they are constant across assets. Hence, to estimate the model, we fix investor i and time t, and apply the moment conditions from equation (5) to her cross-sectional stock holdings at t.

3 Data and variable construction

Our stocks' sample comprises ordinary common shares (share codes 10, 11, 12, and 18) that trade on NYSE, AMEX, and Nasdaq (exchange codes 1, 2, and 3) which make up the investment universe. In line with Koijen and Yogo (2019), the outside asset includes the complement set of stocks, which are either foreign (i.e., share code 12), real estate investment trusts (i.e., share code 18), or have missing characteristics or returns. We use quarterly data (except for annual carbon emissions data) from Q1 2005 to Q4 2021 obtained from four different sources.

3.1 Institutional stock holdings

We obtain quarterly data on U.S. stock holdings by institutional investors from the Thomson Reuters Institutional (13F) Holdings database (s34) via Wharton Research Data Services (WRDS) from Q1 2005 to Q4 2021. The U.S. Securities and Exchange Commission (SEC) requires all institutional investors who manage more than \$100 million of Section 13(f) securities to report their quarter-end long-side holdings at the end of each year. 13F institutional investors include both U.S. investors and foreign investors.

Thomson Reuters database classifies institutional investors into five groups: (1) banks; (2) insurance companies; (3) investment companies (including mutual funds and hedge funds); (4) investment advisors; and (5) other (unclassified institutional investors). However, some institutional investors are mistakenly classified into "other" groups since December 1998 and the distinction between the last three groups by Thomson Reuters is somewhat arbitrary (Gompers and Metrick (2001) and Lewellen (2011)). We circumvent these errors by employing the Koijen and Yogo (2019) corrected classifications provided for the period 2005-2017. This results in a regrouping of institutional investors into six types: banks, insurance companies, investment advisors (including brokerage firms and hedge funds), mutual funds, pension funds, and other (unclassified institutional investors, including endowments, foundations, and non-financial corporations).[8] For 2018 to 2021, for institutions founded before (after) 2017, we employ their pre-2017 (Thomson Reuters) classifications.

The calculation of CCPP (eq.(3)) requires that the market clears, i.e. for each stock and in each quarter, the number of outstanding shares equals the sum of shares held by all investors. Hence, for each stock and in each quarter, we define the shares held by the household sector as a "residual" of institutional holdings,

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[8] Data are available at https://www.koijen.net/code-and-data.html. They first regroup institutional investors who are misclassified into "other" groups. In addition, they compile "mutual fund" by extracting mutual funds from the "investment advisor" and "investment companies" groups. Furthermore, they classify "pension funds" separately by extracting them from the "other" group.

namely the difference between the outstanding shares and the sum of shares held by 13F institutional investors. Following Koijen and Yogo (2019), we also classify as "household", any institution with less than $10 million in assets under management, no stocks in the investment universe, or no outside assets.

3.2 Firms' climate change exposures and carbon emissions

We proxy firm-level total, opportunity, regulatory, and physical climate change exposures by Sautner et al. (2023a) respective textual measures, extracted from quarterly earnings conference call transcripts.[9] Opportunity exposures stem from the transition from polluting technologies to green technologies, yet there is uncertainty about the final outcome. Regulatory exposures arise from the costs associated with policy or regulatory changes to address climate change. Physical exposures arise from the adverse effects of physical climate changes.

Each measure captures the share of conversations between managers and analysts related to the respective climate change topics during the firm's earnings conference call. Earnings conference call is a key corporate event where there is exchange of information between firm's managers and analysts on material issues relevant to investing in the firm's stock. Management gives its view on the firm's past and future performance and responds to questions from call participants. Hence, in addition to dissecting total climate change exposures to their dimensions, these measures may convey information not contained in measures based on "hard" information, such as ESG ratings and carbon emissions. An increase (decrease) in a given measure's value signifies an increase (decrease) in the attention that financial analysts and management devote to the respective climate change topic during the earnings call. In sum, the employed measures are a natural choice for the purposes of our analysis. They identify the risks and opportunities of the firms, dissect climate change exposures in different dimensions, and have a rich informational content.

Sautner et al. (2023a), footnote 32, calls for caution when interpreting the zero values in their *quarterly* climate change exposure data. Zero values do not necessarily indicate zero climate change exposures because the same topics may not be covered by firms during subsequent earnings conference calls. Similarly, missing

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[9] Data are available on https://osf.io/fd6jq/. We use the updated on February 15, 2023 version.

observations due to the non-occurrence of an earnings conference call could lead to misreporting of climate change exposures. To address these issues, we follow Sautner et al. (2023a,b) and replace the zero and missing values by using an exponential weighted moving average (EWMA) model. Furthermore, in line with Sautner et al. (2023b), we set different sample starting points for total and topic-based climate change exposures, to ensure that at least 30% of the S&P 500 stocks have non-zero respective exposures at the beginning of the sample. After smoothing, our empirical analysis includes data on the total climate change exposure from Q1 2005 to Q4 2021, with topic-based exposure data from Q1 2008 to Q4 2021. Appendix B.1 provides more information on the processing of data.

We obtain annual data on carbon intensities (scope 1 and 2) from Trucost. Following Dyck et al. (2019) and Sautner et al. (2023a), we lag the carbon intensities data by one year when merging it with stock characteristics via CUSIP identifiers due to the one-year delay in the reporting of the data on the carbon emissions.

3.3 Option-implied firm-level cost of equity

We estimate the S&P 500 constituent firm's cost of equity (risk premium) by two alternative option-implied measures, namely the Martin and Wagner (2019) and Chabi-Yo et al. (2023) measures and for alternative horizons (1-month, 1-quarter, 2-quarter, 3-quarter, and 1-year) to explore any term structure effects. Option-implied cost of equity measures are real-time, forward-looking, market-based measures. Therefore, they properly update the cost of equity, avoid any noise in accounting reports which alternative cost of equity measures may employ, and circumvent the limitation that inferences about expected returns using realized returns may lack informativeness (Kim (2022), Pástor et al. (2022)). We obtain the Chabi-Yo et al. (2023) expected excess return data from the authors' website.[10]

Martin and Wagner (2019) measure is given by

$$\mathbb{E}_t R_{i,t+1} - R_{f,t+1} = \left[\mathrm{SVIX}_t^2 + \frac{1}{2}\left(\mathrm{SVIX}_{i,t}^2 - \overline{\mathrm{SVIX}}_t^2\right)\right] \cdot R_{f,t+1}, \tag{6}$$

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[10] Data are available on https://osf.io/7xcqw/. We use the version updated in September 2023.

where $R_{i,t+1}$ and $R_{f,t+1}$ are the simple return on the stock i and the risk-free rate from t to t+1, respectively, SVIX_t^2 represents the risk-neutral variance of the S&P 500 index at time t, $\overline{\text{SVIX}}_t^2 = \sum_i w_{i,t}\text{SVIX}_{i,t}^2$, is the value-weighted average of the individual stocks' risk-neutral variances $\text{SVIX}_{i,t}^2$ at time t, and $w_{i,t}$ is the ith stock's portfolio weight based on the market capitalization at time t.

$$\text{SVIX}_t^2 = \frac{2}{S_{m,t}^2 R_{f,t+1}} \left[\int_{S_{m,t}R_{f,t+1}}^{\infty} \text{call}_{m,t}(K)dK + \int_0^{S_{m,t}R_{f,t+1}} \text{put}_{m,t}(K)dK \right] \tag{7}$$

$$\text{SVIX}_{i,t}^2 = \frac{2}{S_{i,t}^2 R_{f,t+1}} \left[\int_{S_{i,t}R_{f,t+1}}^{\infty} \text{call}_{i,t}(K)dK + \int_0^{S_{i,t}R_{f,t+1}} \text{put}_{i,t}(K)dK \right], \tag{8}$$

where $S_{m,t}$ and $S_{i,t}$ denote the S&P 500 index price and S&P 500 index constituents' individual stock price, respectively, $\text{call}_{m,t}(K)$ and $\text{put}_{m,t}(K)$ denote the out-of-the-money S&P 500 index call and put option prices, and $\text{call}_{i,t}(K)$ and $\text{put}_{i,t}(K)$ denote the equity (constituents of the S&P 500 index) out-of-the-money call and put option prices, with strike price K and maturity t+1, measured at time t. Appendix B.3 provides details on how we calculate Martin and Wagner (2019) measure using daily implied volatility data on the S&P 500 constituent stocks' options and S&P 500 index options from the Volatility Surface of the OptionMetrics database.

3.4 Stock data and characteristics

We obtain monthly data on stock prices, returns, dividends, and shares outstanding from the CRSP Monthly Stock Database. We download accounting data from Compustat North America Fundamentals Quarterly and Annual Databases. Given that accounting data are often released with a delay, to merge CRSP data with Compustat, we lag Compustat data by at least 6 months and no more than 18 months to ensure that accounting data are available on the trading date.

For stock characteristics variables $\mathbf{x}_t(n)$ in equation (2), we follow Koijen and Yogo (2019) and choose market beta, log market equity, log book equity, profitability, investment, and dividends to book equity. The choice of these variables is motivated by the Fama and French (2015) five-factor model. Dividends-to-book equity is chosen because it is a traditional measure of fundamentals. We add firm-level climate change exposures to the model to address our research question. Sautner et al. (2023b) find that these measures cross-sectionally predict expected returns and risks. We obtain stock characteristics data on momentum, size (log of total assets), asset tangibility (ratio of property, plant, and equipment to total assets), leverage, Tobin's Q, capital expenditure, R&D expenses, cash ratio, and institutional ownership (IO). Appendix B.2 defines the stock characteristics variables.

The frequency of market beta and log market equity is monthly, whereas the frequency is quarterly for the rest of the stock characteristic data, and firm-level climate change exposures. We keep the quarter-end observations to merge the various stock characteristics data, consistent with Koijen and Yogo (2019). We merge the firm-level climate change exposure data with the stock characteristics data using GVKEY identifiers. We merge the option data with the stock characteristics via the Option Metrics CRSP Link Table, provided by WRDS. We match institutional stock holdings and characteristics data via the CUSIP identifiers. Following Koijen and Yogo (2019), at each quarter, we winsorize all stock characteristics but log market equity and log book equity, at the 2.5th and 97.5th percentiles.

3.5 Summary statistics

Table 1 reports summary statistics for the firm-level climate change exposures and the other stock characteristics (before cross-sectional standardization), option-implied cost of equity, and the institutional portfolio weights for the S&P 500 constituent stocks sample from Q1 2005 to Q4 2021. For the topic-based climate change exposures, we choose our sample to span Q1 2008 to Q4 2021 to minimize the number of missing observations, in line with Sautner et al. (2023b).

[Table 1 about here.]

The firm-level climate change exposures, *total*, *opp*, *reg*, and *phy* measure the frequency of bigrams related to the total, opportunity (e.g., wind power, solar energy, renewable resource), regulatory (e.g., gas emission, reducing carbon, carbon price), and physical (e.g., coastal area, global warm, snow ice) climate-related topics, discussed between firm managers and financial analysts over the quarterly transcripts of earnings conference calls, respectively. The pooled average values of these four measures scaled up by 1000 are 0.318, 0.092, 0.016, and 0.003, respectively. The average, pooled across investors and quarters, relative portfolio weight is 0.079, and the minimum value of portfolio weight is zero.

4 Empirical analysis

4.1 Stock-level CCPP: Estimation

We estimate the model-based stock-level CCPP (equation (3)) for each stock in the S&P 500 in any given quarter by using only information available in the respective quarter. This ensures that CCPP is a real-time measure and our subsequent analysis is not subject to a look-ahead bias. To this end, first, we estimate equation (2) by quarter and by investor, to get the required investor-specific time-varying coefficients (i.e., $\beta_{1,i,t}$ and $\beta_{0,i,t}$). On average, there are 3,356 investors (unreported summary statistics). We estimate equation (2) for the total and three topics-based climate change exposure separately, to avoid estimation biases from multicollinearity (see also Gibson et al. (2021), Sautner et al. (2023a,b), for an analogous approach in their formulated specifications). Then, we calculate CCPP at the stock level in each quarter, by inserting the estimated coefficients $\beta_{0,i,t}$ and $\beta_{1,i,t}$ and the individual investors' ownership data (including the household) in (3).

Note that even though we study the CCPP of the S&P 500 constituent stocks in our analysis, we estimate equation (2) using the full sample of U.S. common stocks. This enhances the sample size and enables the accurate estimation of the stock-level CCPP stemming from the precise estimation of the coefficients in equation (2).[11] Moreover, given that investors' asset universe does not contain only the S&P

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[11] Following Koijen and Yogo (2019), we estimate the model by quarter and by investor, if the specific investor holds over 1,000 different stocks in a quarter. There are on average 105 eligible such investors in each quarter. For the remaining investors with fewer cross-sectional stock holdings, we group similar investors based on their type and assets under management each quarter. We set the number of groups by ensuring that there are on average 2,000 stocks in each group in each quarter. On average, there are 180 groups per quarter which yields 17 investors on average per group.

500 stocks, their portfolio weights should be calculated with respect to the full sample of stocks; restricting the estimation of equation (2) only to the S&P 500 stocks investment universe, would use distorted rather than the actual portfolio weights. Following Koijen et al. (2023), we cross-sectionally standardize all but log market equity and log book equity stock characteristics, within each quarter and across sample U.S. common stocks so that CCPPs stemming from different types of climate change exposures can be compared.

Table 2 reports the pooled summary statistics (before cross-sectional standardization) for the estimated stock-level full sample CCPPs of the constituent S&P 500 stocks stemming from the total climate change exposure (Q1 2005 to Q4 2021) and the topic-based climate change exposures (Q1 2008 to Q4 2021).

[Table 2 about here.]

On average, CCPP is negative and stock prices decrease the most (least) with respect to the increase in the total (physical) climate change exposures. A one-standard-deviation increase in total (physical) climate change exposures, on average, decreases the stock price by 7.9% (2.7%). Furthermore, the variation in CCPP across the different climate change exposure measures and across stocks and quarters is significant; a one-standard-deviation increase in the total climate change exposures decreases (increases) the stock price by as much as 39% (16%); with the variation being greater (smaller) for the opportunity and regulatory (physical) CCPPS. Consistent with the properties of CCPP discussed in Section 2.2, CCPP takes both positive and negative values over the sample period with the vast majority of CCPP values being negative; for instance, unreported summary statistics show that only 15% of the CCPP observations are positive for the case of CCPP stemming from total climate change exposures.

Figure 1, Panels (a) to (d), plot the cross-sectional average of the CCPPs of the S&P 500 constituent stocks over time stemming from total, opportunity, regulatory, and physical exposures, respectively. We can see that this is negative for most of the sample period, regardless of the type of climate change exposure. Interestingly, there is a downward trend during 2008-2016 and the trend reverts from 2016 onward.

[Figure 1 about here.]

The sign and pattern of CCPP can be explained by investors' portfolio rebalancing activities. According to equation (3), the stock-level CCPP is more negative (positive) when the majority of investors in a firm decrease (increase) more their stock holdings when climate change exposures increase, i.e., when $\beta_{1,i,t}$ is more negative (positive) for most investors. We explore this theoretical prediction by examining the time-variation of the estimated $\beta_{1,i,t}$ coefficients in equation (2). Figure 2, Panels (a) to (d), plot the cross-sectional average of the individual investor's coefficients of the total, opportunity, regulatory, and physical exposures, respectively. We can see that, on average, these are negative most of the time and they are trending more negative over 2008-2016 with the trend reverting from 2016 onward. This explains the downward and upward trending patterns in CCPP. On average, investors underweight more stocks with higher climate change exposures over 2008-2016. These patterns are similar for all types of climate change exposure. The election of President Trump in November 2016, which signaled a relaxation in regulatory pressures, may have contributed to the post-2016 upward trend in CCPP by making investors underweighting less stocks with high climate change exposures. Ramelli et al. (2021) find that following Donald Trump's election, the U.S. stock market rewarded both the carbon-intensive and the climate-responsible companies.

[Figure 2 about here.]

Interestingly, the downward (upward) trends in CCPP are only partially offset by the dynamics of investors' demand elasticity. Figure 3, panel (a), plots the cross-sectional average of the individual investor's coefficients, $\beta_{0,i,t}$, estimated in equation (2). We can see that there has been a downward (upward) trend in the average $\beta_{0,i,t}$ coefficient pre (post)-2014, i.e. on average investors were relatively less price inelastic (more inelastic) pre (post)-2014, as also confirmed by Figure 3, panel (b), plotting the aggregate demand elasticity which is high (low) pre (post) 2014.

[Figure 3 about here.]

4.2 Effects to firms' cost of equity

We investigate whether investor portfolio rebalancing, triggered by climate change exposures, affects firms' cost of equity. We utilize a stock-level CCPP channel arising from this portfolio rebalancing. The proposed mechanism is simple: if the stock-level CCPP is significantly large, then investors' portfolio rebalancing may exert a significant effect to the firm's stock price, and possibly to its cost of equity. Previous evidence based on changes in institutional ownership and mutual fund flows, when investors take climate change risks into account, suggests that this may be the case (Pedersen et al. (2020), Pástor et al. (2021, 2022), Zerbib (2022), van der Beck (2023)). Notice that information on CCPP alone, does not inform us about the statistical and economic significance of its effect to the cost of equity, unless this is tested explicitly.

We test the proposed mechanism in a direct way by running contemporaneous panel regressions of firms' option-implied cost of equity on their CCPPs and controls.

$$CoE_{t,h}(n) = \alpha + \beta_1 \cdot CCPP_t(n) + \boldsymbol{\gamma}'\mathbf{X}_t(n) + \delta_t + \phi_j + \epsilon_{t,h}(n), \tag{9}$$

where $CoE_{t,h}(n)$, is either the MW or the GLB option-implied cost of equity for the nth stock estimated at time t corresponding to horizon $h=$ 1 month, 1 quarter, 2 quarters, 3 quarters, and 1 year. We consider the stock-level CCPP arising from institutional portfolio rebalancing triggered by total, opportunity, regulatory, and physical climate change exposures, separately. The vector $X_t(n)$ of control variables includes the log market equity, market beta, book-to-market ratio, profitability, investment, dividends-to-book equity, firm-level climate change exposure, momentum, and institutional ownership of the stock n at time t.[12] In this and subsequent regressions, we winsorize the raw values of all regressors at the 2.5th

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[12] The first seven controls are also used to estimate model (2). Model (2) can be equivalently reformulated by including the book-to-market ratio rather than log book equity; to estimate model (2), we had included log book equity rather than the book-to-market ratio to circumvent endogeneity concerns. We include momentum and institutional ownership as extra controls in the regression (9) since they are well-known predictors of stock returns (e.g., Gompers and Metrick (2001), and references therein); these are not included in the estimation of the model (2) to avoid endogeneity concerns. In addition, even after controlling for the reversal, which refers to the current month's stock return, unreported results show the significant effects of CCPP to the cost of equity still hold.

and 97.5th percentiles and we cross-sectionally standardize their values across the S&P 500 stocks within each quarter to facilitate the subsequent interpretation of the results. Furthermore, we include the year-quarter (δ_t) and industry (ϕ_j) fixed effects.[13] Standard errors are clustered at the firm level. We multiply the estimated coefficients by 100.

Table 3 reports the effects of stock-level CCPP on the firm-level cost of equity for different horizons ranging from one month to one year. The CCPP coefficient is negative and statistically significant, for all types of climate change exposures, over and above our set of controls. This suggests that a firm's cost of equity increases when its CCPP triggered by institutional rebalancing on the firm-level climate change exposures decreases, i.e., when it becomes more negative (less positive), if CCPP is negative (positive).[14] The economic effect of CCPP on the cost of equity is weaker for the long-term (one-year) horizon. Table 3, Column (1) shows that a one-standard-deviation decrease in the CCPP from total climate change exposure leads to a 0.22% increase in the MW annualized monthly cost of equity. Compared to the average value reported in summary statistics Table 1 (S&P 500 stocks sample), the percentage of increase is about 3% (= 0.220%/0.073). For the one-quarter and one-year horizons, the percentage of increase in the monthly MW CoE is 4% (= 0.258%/0.066) and 2% (= 0.153%/0.067), respectively.

[Table 3 about here.]

We find similar effects of CCPP from opportunity and physical exposures across the different horizons, yet the effects of CCPP from regulatory exposures are weaker and only significant for Chabi-Yo et al. (2023) alternative cost of equity measure

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[13] ϕ_j is a dummy variable that takes a value of 1, if the firm n belongs to industry j and zero otherwise. To control for industry effects, we assign each stock to a specific industry based on the first two digits of its four-digit Standard Industrial Classification (SIC) code, consistent with Hartzmark and Shue (2023) and Sautner et al. (2023a,b).

[14] To shed more light on this interpretation, we sort firms into two groups with negative and non-negative CCPPs, respectively. We run panel regressions of firms' option-implied cost of equity on CCPP interacted with the sign indicator of whether the CCPP is negative or non-negative and controls, including fixed-effects, as the ones in equation (9). Unreported results show that the negative relation between the cost of equity and CCPP stems from stocks with negative CCPPs only, i.e. firms' cost of equity increases as CCPP becomes more negative. The coefficient of the interaction of CCPP with the negative CCPP indicator is significantly negative, whereas the coefficient of the interaction of CCPP with the non-negative CCPP indicator is insignificant. These results confirm our proposed economic channel: an increase in a firm's climate change exposures increases its cost of equity because the majority of investors, underweight its stock, and thus they incur a negative CCPP, which decreases the stock price and increases the cost of equity.

which accounts for the higher-order moments of the risk-neutral distribution of the underlying asset returns. For instance, a one-standard-deviation decrease in CCPP from opportunity and physical (regulatory) exposures increases the monthly MW (quarterly GLB) cost of equity by 4% (1%) of the average CoE; the opportunity CCPP has a substantial impact, reaching as high as 6% of the average CoE for the one and two quarters.

Overall, we find that institutional rebalancing, triggered by firm-level climate change exposure, exerts CCPP on stocks, which significantly affects firms' cost of equity. The economic effect of institutional rebalancing on firms' cost of equity is about 1% to 6%, depending on the cost of equity's horizon and the type of climate change exposures. The significant effect of CCPP to the cost of equity extends the findings of Sautner et al. (2023b), who found a significant correlation between firm-level climate change exposure and option-implied cost of equity. CCPP affects the cost of equity, even after including the firm-level climate change exposure as a control. Our empirical findings confirm previous evidence that institutional portfolio underweighting based on ESG ratings, increases firms' cost of equity (e.g., Pedersen et al. (2020), Pástor et al. (2021), Zerbib (2022), van der Beck (2023)). Our results also support the Bolton and Kacperczyk (2021) divestment hypothesis, according to which divestment by institutional investors, due to considerations on firms' carbon emissions, affects firms' cost of equity.

On the other hand, our findings differ from Berk and van Binsbergen (2022) who find that divestment has a negligible effect to the firm's cost of equity. Once they calibrate a single period capital asset pricing model to a subset of stocks in the FTSE USA 4 Good Select Index over 2015-2020, they find that divestment from dirty to green stock increases the monthly cost of equity only by 0.44 basis points. The difference in results may be due to differences in the modeling setting, measures of climate change risks, stock samples, and cost of equity measures. For instance, Atta-Darkua et al. (2023) find that the effect of divestment to the monthly cost of equity is much greater (15 basis points) within the Berk and van Binsbergen (2022) formula, once they calibrate it to a different asset universe and a longer time period (MSCI ACWI index stocks over 2006-2019).

Our documented sizable effect of CCPP on the cost of equity (about 22 basis points) may also be attributed to the sizable CCPP (e.g., the pooled average CCPP is sizable up to -8%, reported in Table 2.). This is determined by the investors' rebalancing activities, as already evidenced in Section 4.1, and the aggregate demand elasticity as shown in the denominator of the formula (3). In each quarter and for each stock, we calculate the aggregate demand elasticity with the estimated individual investor-specific coefficients on log market equity in equation (2) and individual investor ownership. The pooled average of the estimated aggregate demand elasticity across S&P 500 stocks over 2005-2021 is 0.29. This is close to the pooled average of the aggregate demand elasticity in Koijen and Yogo (2019) (0.3), and the estimate of 0.2 in Gabaix and Koijen (2022). The inelastic demand elasticity contributes to the significant magnitude of the effects of institutional rebalancing on stock prices and the cost of equity.

4.3 Which investors contribute to CCPP?

In the previous section, we have documented that CCPP exerts a significant effect on firms' cost of equity. The model-based CCPP formula holds in equilibrium, incorporating information from all investors, and hence it cannot be computed separately for each type of investor. Nevertheless, we can explore whether the documented CCPP originates from all or certain types of investors by examining which types of investors react to climate change exposures. For instance, in the extreme case where none of the investors rebalances her portfolio when climate change exposures change (i.e. $\beta_{1,i,t} = 0$), CCPP would have been zero (eq. (3)).

We expect that certain types of investors like banks, pension funds, and insurance companies may be more sensitive to climate change exposures than others like investment advisors (brokerage firms) which are only executing orders from their clients. We estimate equation (2) for each type of investors separately. For each investor category, we pool the portfolio weight data on the S&P 500 stocks across quarters.

[Table 4 about here.]

Table 4 shows that there is a statistically significant negative relation between firm-level climate change exposures and portfolio holdings for all types of investors but investment advisors. The portfolio demand of banks (mutual funds) reacts the most (least) to changes in total climate change exposures. In terms of economic significance, a one-standard-deviation increase in the total climate change exposure decreases investors' portfolio holdings by 16.8% (banks), 12.9% (insurance companies), 5.6% (mutual funds), 12.1% (pension funds), and 6% (households). According to the Koijen and Yogo (2019) model's predictions, the evidence suggests that an increase in climate change exposure is perceived by the average investor as a signal of higher expected returns or lower risks, resulting in underweighting.

Once the dissected climate change exposures are considered, some interesting patterns arise. Among investors, banks rebalance the most their portfolio holdings with respect to changes in opportunity and regulatory climate change exposures, and so do insurance companies with respect to physical climate change exposures. On the other hand, mutual funds rebalance the least their portfolio holdings to any type of climate change exposure.

Our findings are consistent with the prior evidence that certain types of institutional investors, such as banks and insurance companies, care about climate change risks (e.g., Hong and Kacperczyk (2009), Bauer et al. (2021)). They also reveal that brokerage firms (part of the investment advisors group, see Gompers and Metrick (2001)) do not take into account firms' climate change exposures. These carry out securities transactions on behalf of their clients, and thus they are not directly exposed to climate change exposures. Our findings are also in line with previous evidence that hedge funds (part of the investment advisor group) do not engage in socially responsible investing through investments in high-CSR stocks (Hwang et al. (2021)), or in high-ESG stocks (Koijen et al. (2023)).

4.4 Effects to firms' future climate change exposures

It is not clear in advance whether CCPP would affect firms' future climate change exposures. Firms may change their future climate change exposures to mitigate the effect of CCPP on their cost of equity, only if the benefits outweigh the costs of such a reform (Heinkel et al. (2001), Edmans et al. (2023)). We explore this by running the following predictive panel regression,

$$\Delta CCE_{t+h}(n) = \alpha + \beta_1 \cdot CCPP_t(n) + \boldsymbol{\gamma}'\mathbf{X}_t(n) + \delta_t + \phi_j + \epsilon_{t+h}(n), \qquad (10)$$

where $\Delta CCE_{t+h}(n)$ is the change in firm n's climate change exposure from t to $t+h$, proxied by total, opportunity, regulatory and physical exposures, separately, and $CCPP_t(n)$ is the stock-level CCPP stemming from the respective type of climate change exposures. We consider alternative forecasting horizons h as in Section 4.2 and in further analysis, we extend h to be the next 2, 3, 4 and 5 years, separately. Following Sautner et al. (2023a), the vector $\mathbf{X}_t(n)$ of the control variables includes the size (log of total assets), asset tangibility (ratio of property, plant, and equipment to total assets), leverage, profitability, capital expenditure, R&D expenses, cash ratio, institutional ownership and the current level of climate change exposure.[15] δ_t and ϕ_j denote the year-quarter and industry fixed effects, respectively. Standard errors are clustered at the firm level. We multiply the estimated coefficients by 100,000.

[Table 5 about here.]

Table 5, Panels A, B, C, and D, report the results, for the pairs of total, opportunity, regulatory, and physical exposures and CCPP, respectively. We find that CCPP is insignificantly correlated with firms' future climate change exposure regardless of the type of climate change exposure and time horizon. In sum, our findings show that firms do not reduce their future climate change exposures, at least for horizons up to five years, despite the fact that the climate-triggered institutional price pressure increases their cost of equity. Note that we have controlled for firm's leverage, thus accounting for the fact that some firms rely less on equity than others. Our empirical findings echo Berg et al. (2022) and Heath et al. (2023) who find that the portfolio rebalancing of sustainable investment funds does not improve firms' future E&S characteristics. Our results also revisit the evidence by Noh et al. (2023) who find that investor pressure for sustainability predicts future improvements in firm sustainability, yet the magnitude is small. Our evidence of

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[15] The set of controls differs from the one used in Section 4.2 because the dependent variable differs. Nevertheless, we have checked that our results are not affected, even after controlling for the same controls.

not even statistical significance suggests that the use of "soft" information to proxy climate change exposures, captures features not contained in "hard" information (e.g. ESG ratings, carbon emissions) employed by Noh et al. (2023).

The lack of no relation between CCPP and future climate change exposures implies that there should be no relation between CCPP and future carbon emissions either. We test this prediction by regressing the changes in firms' future emission intensities on CCPP and the controls used in regression (10),

$$\Delta Emissions_{t+h}(n) = \alpha + \beta_1 \cdot CCPP_t(n) + \boldsymbol{\gamma}'\mathbf{X}_t(n) + \delta_t + \phi_j + \epsilon_{t+1}(n), \qquad (11)$$

where $\Delta Emissions_{t+h}(n)$ is the h-year ahead change in firm n's emission intensities (sum of Trucost scope 1 and scope 2 emissions per revenue) and $h =$ one year, two years, three years, four years, and five years ahead. We employ the carbon emission intensities rather than total emissions to account for the fact that bigger firms may emit more and thus they should not necessarily be considered to be less green. We do not consider scope 3 carbon emissions because their reporting is noisy and prone to double-counting (the supplier firm's scope 1 emissions could be the customer firm's scope 3 emissions, see also Hartzmark and Shue (2023)). Table 6 reports the results. In line with our conjecture, we find that CCPP stemming from any type of climate change exposure is not significantly correlated with the future total carbon emission intensities. Our findings suggest that firms do not become greener as a response to CCPP and they are consistent with the insignificant effects of CCPP to firms' future climate change exposures. Results suggest that the costs of reforms for a company to mitigate climate change exposures exceeds the 6% increase in its cost of equity relative to its average value, documented in Section 4.2.

[Table 6 about here.]

5 Further analysis

In this Section, we study whether the presence of any reverse causality between portfolio holdings and climate change exposures may be affecting the previously reported results. We also shed more light and provide an explanation for the insignificant relation between CCPP and firms' future climate change exposures.

5.1 On reverse causality

The relation between portfolio holdings and climate change exposures may be bi-directional given that previous literature has examined both directions. Hence, one may argue that the estimation of equation (2) may be subject to reverse causality concerns. Two remarks are in order at this point. The contemporaneous relation of portfolio weights with firm-level climate change exposures shown by equation (2) is not an ad-hoc choice. Instead, it is derived within the Koijen and Yogo (2019) theoretical setting. In addition, the results in Section 4.4 show that there is not a bi-directional relation in our setting; changes in portfolio holdings captured by CCPP do not affect future climate change exposures.

Nevertheless, we conduct an additional empirical test. Following Hartzmark and Shue (2023), we use 2-digit SIC codes to construct a stock-specific instrument for firm-level climate change exposures. For each firm and each quarter, we construct the instrument by calculating the industry average of climate change exposures, excluding the focal firm. The constructed instrument is not subject to the reverse causality concern as the portfolio weight of an individual stock can not affect the industry average (excluding the focal firm) of climate change exposures (see also Hartzmark and Shue (2023) for analogous reasoning). We use the constructed instrument to estimate the model (2). Once we estimate the coefficients $\beta_{0,i,t}$ and $\beta_{1,i,t}$, we calculate a new firm-level time-varying CCPP (termed instrumentalized CCPP) via (3), which captures how changes in the industry average climate change exposure affect the individual firm's stock prices. Figure C.1 in Appendix C plots the time evolution of the cross-sectional CCPP and instrumentalized CCPP averages, for CCPP stemming from total, opportunity, regulatory, and physical climate change exposures. We can see that their patterns are very similar.

Next, we run the same analysis as in Section 4.2 by regressing the option-implied cost of equity on the four measures of instrumentalized CCPP and the same controls as in regression (9). Table 7 reports the results which confirm the robustness of results provided in Section 4.2. The instrumentalized CCPP is significantly negatively correlated with the option-implied cost of equity.

[Table 7 about here.]

In a similar way, we re-run the regressions of firms' future climate change exposures and emission intensities on the instrumentalized CCPP and controls, following the specification of regressions (10) or (11), respectively. The coefficients on the instrumentalized CCPP are insignificant, confirming the robustness of findings in section 4.4, namely that CCPP does not affect firms' future environmental profiles.

5.2 CCPP and firms' future environmental profile: Does greenness matter?

Hartzmark and Shue (2023) find that there is a differential effect of changes in firms' cost of capital to their future environmental performance, depending on whether they are brown or green. An increase in their cost of capital, increases (does not affect) the future carbon emissions of brown (green) firms. Thus, the insignificant effect of CCPP to firms' future climate change exposures and emission intensities in Section 4.4 may be due to conflating effects from brown and green firms.

We explore this by examining the relation between CCPP and firms' future climate change exposures for brown, neutral and green firms, separately. We follow Hartzmark and Shue (2023) and divide firms into quintiles by their Trucost emission intensities reported in the previous year; quintiles 1 and 5 represent green and brown firms, respectively, and the middle three quintiles represent neutral firms. We regress future changes in climate change exposures or emission intensities on the interaction of CCPP and a type indicator which has three different values (Brown, Neutral, and Green), controls, and fixed effects as the ones in (10) and (11):

$$\begin{aligned}\Delta CCE_{t+h}(n)/\Delta Emissions_{t+h}(n) = \alpha + \beta_1 \cdot CCPP_t(n) \times Type_t(n) + \beta_2 \cdot Type_t(n) \\ + \boldsymbol{\gamma}'\mathbf{X}_t(n) + \delta_t + \phi_j + \epsilon_{t,h}(n),\end{aligned} \tag{12}$$

Table 8, Panels A and B, report the results on the coefficient of the interaction terms of CCPP with brown, neutral, and green firms for the cases where the dependent variable is the change in climate change exposures and emission intensities, respectively. We can see that CCPP is not significantly related to firms' future climate change exposures or emission intensities, even when firms are considered separately by their type, thus confirming the full-sample evidence in Section 4.4.

[Table 8 about here.]

A final remark is in order. Our findings differ from Hartzmark and Shue (2023) who find that brown firms increase their future carbon emission intensities following an increase in their cost of capital. The difference in results may be explained by the fact that in their setting, changes in firms' cost of capital are not tied exclusively to sustainable investing, and hence they may reflect the effect of other drivers, too. In contrast, in our case, changes in the cost of equity induced by CCPP are *directly* related to sustainable investing. Hence, our results should be interpreted as an increase in the cost of equity due to sustainable investing, rather than any other reason, does not make brown firms browner.

5.3 Do firms act against CCPP?

In Section 4.4, we document that CCPP does not affect firms' future climate change exposures for horizons up to five years. It may be the case that such effects may materialize over horizons beyond five years, yet we cannot explore this directly due to lack of data. Alternatively, this may imply that firms take no action to change their future environmental profile, despite the fact that they are confronted with a higher cost of equity due to a negative CCPP, because the costs of implementing them may outweigh the benefits from enjoying a lower cost of equity. We shed more light on this by examining the effects of CCPP to firms' future investment, innovation, and financing activities. If a firm decided to transform its operations, it would adjust property and plants and R&D expenses, and may increase its leverage to avoid borrowing at the higher cost of equity.

Following Berg et al. (2022), Choi et al. (2024), and Li et al. (2023), we measure these three outcomes by capital expenditure ratio (Capx), property, plant, and equipment ratio (Tangibility), R&D ratio, and leverage ratio (for variable definitions, see Appendix B.2). We regress firms' investment, innovation and financing measures on CCPP and controls and fixed effects as in Section 4.4, in analogy with

(10)

$$\Delta Y_{t+h}(n) = \alpha + \beta_1 \cdot CCPP_t(n) + \boldsymbol{\gamma}'\mathbf{X}_t(n) + \delta_t + \phi_j + \epsilon_{t+h}(n), \tag{13}$$

where $\Delta Y_{t+h}(n)$ is the h-period ahead change in firm n's capital expenditures, PPE, R&D and leverage ratio, separately. Table 9 reports the results for the case of CCPP stemming from total climate change exposures, and for forecasting horizon h to be the next one quarter, two quarters, three quarters, and one year, due to space constraints. We can see that firms do not significantly change their future capital expenditures, PPE, R&D and leverage ratios as a response to CCPP. Unreported results show that the insignificant effects are similar for the alternative CCPP measures and longer horizons. These findings confirm that CCPP does not affect firms' future climate change exposures because firms take no actions to reform.

[Table 9 about here.]

5.4 CCPP, media attention and future climate change exposures

We have documented that CCPP does not affect firms' future environmental profiles, despite the fact that they are faced with a higher cost of equity. However, such a relation may revive over periods of increased market-wide climate change attention. Firm managers may be more incentivized to take action over periods when media attention to climate change increases because this may trigger ESG tastes, the need to protect the company's reputation, and the introduction of compensation packages linked to ESG performance (e.g., Gantchev et al. (2022)).

To explore this, we proxy media's market-wide climate change attention by two alternative measures, namely Ardia et al. (2023) media climate change concerns Index (MCCC) and Faccini et al. (2023) climate change-related policy measure. MCCC is a textual measure constructed from major U.S. newspapers and newswires, capturing media's attention to any type of climate change risks. Faccini et al. (2023) measure is a textual measure constructed from Reuters news related to climate change, capturing the media's attention to U.S. climate policy change risks.[16] We regress firms' future changes in climate change exposures on the inter-

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[16] Data are obtained from https://sentometrics-research.com/download/mccc/ and

action of stock-level CCPP with market-level climate change attention, CCPP and controls and fixed effects as in Section 4.4, for each one of the four CCPP measures:

$$\begin{aligned}\Delta CCE_{t+h}(n) = \alpha + \beta_1 \cdot CCPP_t(n) \times \mathit{Attention}_t + \beta_2 \cdot CCPP_t(n) \\ + \beta_3 \cdot \mathit{Attention}_t + \boldsymbol{\gamma}'\mathbf{X}_t(n) + \delta_t + \phi_j + \epsilon_{t+h}(n)\end{aligned} \tag{14}$$

[Table 10 about here.]

Table 10 reports the results. The coefficient of the interaction term is statistically significant and positive for total, opportunity, and regulatory exposures at the 1% level, whereas it is weakly significant at 10% level or insignificant for physical exposures. The coefficient of the CCPP variable is statistically significant and negative in almost all cases across the various measures of climate change exposures. Taking these results together, firms with more negative CCPP decrease their future total, opportunity, and regulatory climate change exposures, as media climate change attention increases. Results are robust for both media climate change attention measures. Unreported results show that when media attention to climate change increases, firms decrease their future emission intensities under a more negative CCPP. Again, these results suggest that firms' managers may take actions to improve firms' future environmental profile when faced with a higher cost of equity due to a negative CCPP, when climate change risks are in the media's spotlight.

6 Conclusions and implications

We have taken a novel approach to address in a *direct* way the still open question whether the institutional portfolio rebalancing triggered by firm-level physical and transition climate change exposures affects S&P 500 firms' cost of equity. To this end, we have utilized a stock-level climate change price pressure (CCPP) channel arising from this portfolio rebalancing. The proposed mechanism is simple: if CCPP is significantly large, then investors' portfolio rebalancing may exert a significant effect to the firm's stock price, and possibly to its cost of equity. We test and confirm the above mechanism. We compute CCPP in closed-form within the Koijen and Yogo (2019) asset pricing setting by employing granular textual proxies for climate

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https://sites.google.com/view/george-skiadopoulos/research/selected-publications.

change exposures and real-time option-based measures to accurately estimate firms' cost of equity.

We find that on average investors underweight companies with high climate change exposures and this creates a large CCPP which may increase firms' cost of equity by up to 6% of its average value. The effect is greater (smaller) from CCPP originating from opportunity and physical (regulatory) firms' exposures. Among investors, banks and insurance companies contribute the most to the documented CCPP. However, despite facing a higher cost of equity, firms reduce their future climate change exposures and carbon emissions only after periods when climate change comes to media's spotlight.

Our findings imply that on average, institutional investors increase firms' cost of equity when underweighting stocks with higher climate change exposures, yet this is not an effective tool to make firms improve environmentally. From an average firm's perspective, this suggests that the costs of reforms that impact its environmental footprint, outweigh the benefits of enjoying a lower cost of equity in the future. Required reforms may relate not only to tangible assets but also to corporate culture and labor relations. Thus, a cost-benefit analysis is a non-trivial task and it worth be investigated by future research. More generally, the findings raise the question whether the climate transition for a company is more costly than a 6% increase in its cost of equity relative to its average value, or there are bigger governance, leadership, and internal dynamics issues at play. Engagement by investors may be proven to be more effective for firms to undertake reforms (Hoepner et al. (2024)). This underscores the importance of strong climate coalitions and raises concerns in light of the recent departures of leading institutional investors from some of them.[17] Media also play an important role in incentivising managers to act. Finally, policymakers could use the CCPP metrics to form targeted environmental regulations to foster corporate investments by identifying sectors where firms face a more negative CCPP, and thus a higher cost of equity.

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[17] In December 2022, Vanguard departed from the Net Zero Alliance. Over February-May 2024, State Street, PIMCO, Invesco, J.P. Morgan Asset Management and Swiss Re-exited Climate 100+, while BlackRock pulled out its U.S. business.

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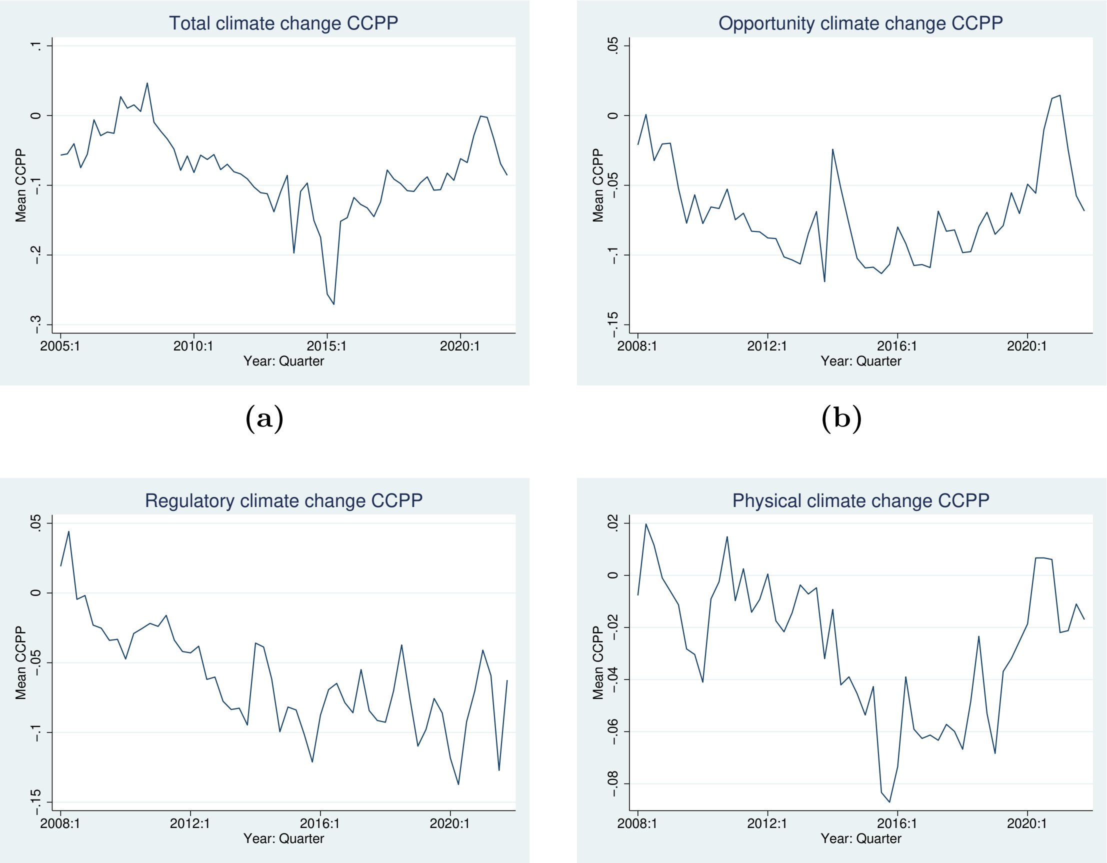
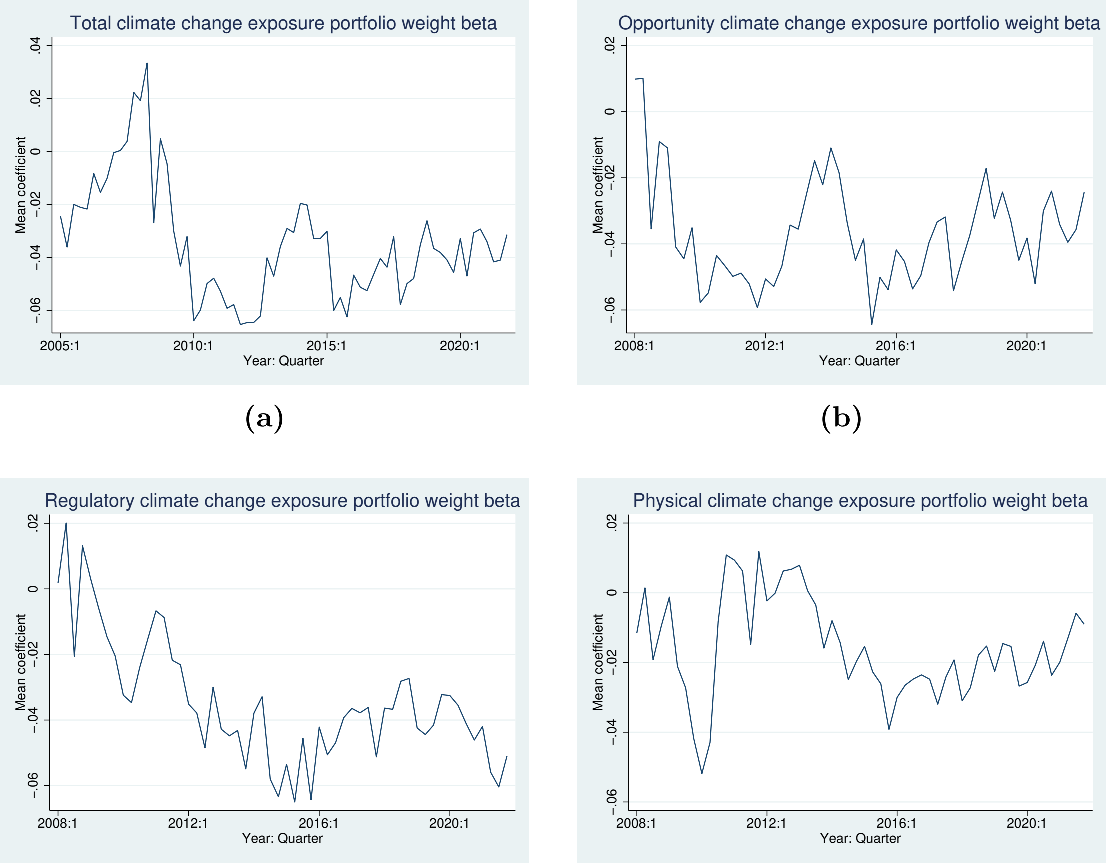


(a) **(b)**

(c) **(d)**

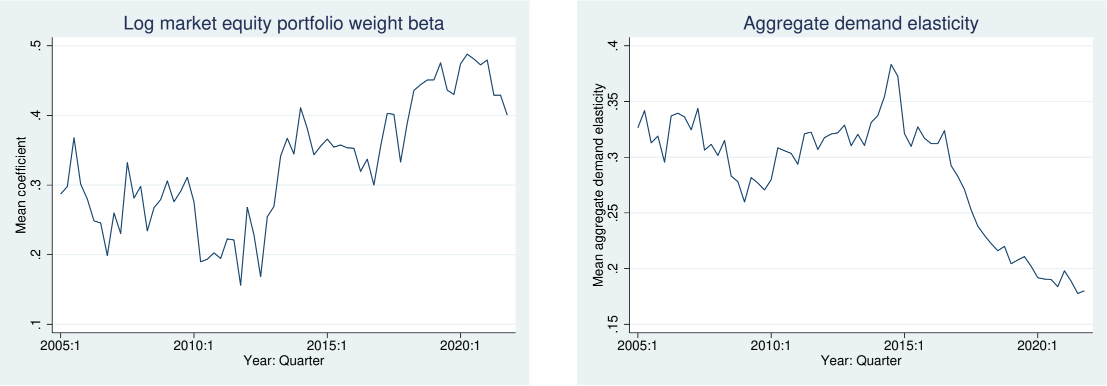
Figure 1. Panels (a) to (d) plot the cross-sectional average of the CCPPs of the S&P 500 constituent stocks (before cross-sectional standardization) arising from investors' portfolio rebalancing triggered by changes in stocks' total, opportunity, regulatory, and physical climate change exposures, respectively. CCPP is calculated by equation (3). For CCPPs stemming total climate change exposures, the sample period is from 2005:1 to 2021:4. For CCPP stemming from topic-based climate change exposures, the sample period is 2008:1 to 2021:4; this choice is dictated by the considerations on the climate change exposure data outlined in Sautner et al. (2023b).



(a) **(b)**

(c) **(d)**

Figure 2. Panels (a) to (d) plot the time series evolution of the sensitivity of the relative portfolio weights with respect to the total, opportunity, regulatory, and physical exposures, respectively (cross-sectional averages of the individual investors' coefficients $\beta_{1,i,t}$), estimated in equation (2). The coefficients are estimated using the full U.S. common stocks sample. The coefficients on the total climate change exposures are estimated over the period 2005:1 to 2021:4. The coefficients on the topic-based climate change exposures are estimated over 2008:1 to 2021:4; this choice is dictated by the considerations on the climate change exposures data outlined in Sautner et al. (2023b).



(a) **(b)**

Figure 3. Panel (a) plots the time series evolution of the sensitivity of the relative portfolio weights with respect to the log market equity (cross-sectional averages of the individual investors' coefficients $\beta_{0,i,t}$) estimated in equation (2). The coefficients are estimated from the U.S. common stocks full sample. Panel (b) plots the time series evolution of the cross-sectional average of the stock-level aggregate demand elasticity across S&P 500 stocks, estimated by the denominator of equation (2)). The quarterly sample period is 2005:1 to 2021:4.

Table 1. Summary statistics: S&P 500 stocks

Variable	Mean	SD	Min	Median	Max	Obs.
Panel A: Firm-level climate change exposures and carbon emissions						
Total ($\times 10^3$)	0.318	0.611	0.001	0.108	4.751	43707
Opp ($\times 10^3$)	0.092	0.242	0.000	0.015	2.214	35939
Reg ($\times 10^3$)	0.016	0.049	0.000	0.000	0.516	35939
Phy ($\times 10^3$)	0.003	0.008	0.000	0.000	0.052	35939
CI_Trucost	261.976	715.771	1.397	42.830	5362.251	9164
Panel B: Option-implied firm-level cost of equity						
MW30	0.073	0.097	-0.005	0.044	1.123	43707
MW91	0.066	0.082	-0.002	0.041	0.969	43703
MW182	0.064	0.073	0.001	0.042	0.859	43691
MW273	0.069	0.076	0.003	0.046	0.797	29655
MW365	0.067	0.070	0.005	0.046	0.709	28855
GLB30	0.100	0.110	0.003	0.064	1.073	43707
GLB91	0.085	0.092	0.002	0.056	0.894	43703
GLB182	0.080	0.082	0.002	0.053	0.764	43691
GLB273	0.081	0.081	0.003	0.053	0.673	29655
GLB365	0.078	0.075	0.003	0.054	0.618	28855
Panel C: Firm-level stock characteristics						
LNme	9.278	1.263	5.338	9.245	12.798	43707
LNbe	8.388	1.461	-0.105	8.367	13.206	43707
Beta	1.156	0.607	-0.112	1.081	3.484	43707
Profit	0.298	0.298	-0.449	0.234	3.177	43707
Gat	0.074	0.154	-0.467	0.051	0.823	43707
DivAbe	0.046	0.070	0.000	0.024	0.639	43707
BtM	0.613	0.555	0.017	0.442	6.202	43707
Momentum	0.084	0.328	-2.122	0.110	1.526	43705
Size	9.317	1.415	6.071	9.213	13.053	43707
Tangibility	0.254	0.238	0.004	0.162	0.876	41489
Leverage	0.265	0.175	0.000	0.252	0.808	43707
Capx	0.079	0.084	0.000	0.053	0.511	43579
R&D	0.019	0.039	0.000	0.000	0.201	43707
Cash	0.127	0.132	0.002	0.078	0.647	43704
IO	0.794	0.184	0.007	0.824	1.902	43163
Panel D: Investor-level portfolio relative weight						
Relative weight	0.079	52.470	0.000	0.001	264262.300	30516962

Notes: This table reports the mean (Mean), standard deviations (SD), minimum values (Min), median values (Median), maximum values (Max), and observations (Obs.) of our employed variables before cross-sectional standardization. *Total*, *Opp*, *Reg*, and *Phy* measure the relative frequency of bigrams related to overall climate change, opportunity, regulatory, and physical climate-related topics, in each firm's quarterly transcript of earnings conference calls scaled up by 10^3, respectively. *CI_Trucost* is the total carbon intensities reported by Trucost. *MW30*-*MW365* (*GLB30*-*GLB365*) is the Martin and Wagner (2019) (Chabi-Yo et al. (2023)) annualized option-implied cost of equity over the horizon of 1-month, 1-quarter, 2-quarter, 3-quarter, and 1-year, respectively. *LNme* and *LNbe* are the log market equity and log book equity, respectively. *Market Beta* is the sensitivity of stock excess returns to the market excess returns. *Profit* and *Gat* represent the profitability, and investment characteristics following Fama and French (2015). *DivAbe* is the dividends to book equity ratio. *BtM* is the ratio of book equity to market equity. *Momentum* is the cumulative return of the stock during the 11-month period covering months t-11 through t-1. *Size* is the natural logarithm of a firm's total assets. *Tangibility* is the ratio of property, plant, and equipment to total assets. *Leverage* is the ratio of the total debt to total assets. *Capx* is the ratio of capital expenditures to total assets. *R&D* is the ratio of research and development expenses to total assets. *Cash* is the ratio of cash and short-term investments to total assets. *IO* is the percentage ownership held by institutional investors. *Relative weight* represents portfolio weight on stock n relative to the outside asset, $\frac{w_{i,t}(n)}{w_{i,t}(0)}$ in equation (2). The quarterly sample period is from 2005:1 to 2021:4 and covers the S&P 500 constituent stocks. For topic-based climate change exposure, the sample is from 2008:1 to 2021:4; this choice is dictated by the considerations on the climate change exposure data outlined in Sautner et al. (2023b).

Table 2. Summary statistics for stock-level CCPPs: S&P 500 stocks

Variable	Mean	SD	Min	Median	Max	Obs.
CCPP_total	-0.079	0.082	-0.392	-0.072	0.158	39967
CCPP_opp	-0.070	0.063	-0.320	-0.070	0.158	32651
CCPP_reg	-0.060	0.062	-0.364	-0.057	0.094	32651
CCPP_phy	-0.027	0.041	-0.180	-0.027	0.091	32651

Notes: This table reports the mean (Mean), standard deviations (SD), minimum values (Min), median values (Median), maximum values (Max), and observations (Obs.) for the estimated stock-level CCPPs of the S&P 500 constituent stocks (before cross-sectional standardization) in equation (3). *CCPP_total*, *CCPP_opp*, *CCPP_reg*, and *CCPP_phy* measure the effects of investor rebalancing on stock prices stemming from total, opportunity, regulatory, and physical climate change exposures, respectively. For CCPP stemming from total climate change exposures, the sample period is 2005:1 to 2021:4. For CCPP stemming from topic-based climate change exposure, the sample period is 2008:1 to 2021:4; this choice is dictated by the considerations on the climate change exposure data outlined in Sautner et al. (2023b).

Table 3. Effects of CCPP to firms' cost of equity: S&P 500 stocks

	One-month (1)	One-quarter (2)	Two-quarter (3)	Three-quarter (4)	One-year (5)
Panel A: Effects to Martin and Wagner (2019) cost of equity					
CCPP_total	-0.220***	-0.258***	-0.248***	-0.189***	-0.153**
	(-3.49)	(-4.53)	(-4.54)	(-2.74)	(-2.30)
N	39743	39739	39730	27506	26787
Adj.R^2	0.644	0.630	0.610	0.621	0.629
Economic effect	3%	4%	4%	3%	2%
CCPP_opp	-0.325***	-0.372***	-0.352***	-0.258**	-0.208**
	(-3.64)	(-4.55)	(-4.50)	(-2.54)	(-2.13)
N	32428	32427	32423	22178	21483
Adj.R^2	0.647	0.633	0.613	0.625	0.634
Economic effect	4%	6%	6%	4%	3%
CCPP_reg	0.016	-0.095	-0.107	0.045	0.064
	(0.18)	(-1.19)	(-1.39)	(0.47)	(0.69)
N	32428	32427	32423	22178	21483
Adj.R^2	0.646	0.632	0.612	0.625	0.634
Economic effect	0.2%	1%	2%	0.7%	1%
CCPP_phy	-0.311***	-0.313***	-0.298***	-0.294***	-0.256***
	(-5.26)	(-5.86)	(-5.86)	(-4.79)	(-4.37)
N	32428	32427	32423	22178	21483
Adj.R^2	0.647	0.633	0.613	0.626	0.635
Economic effect	4%	5%	5%	4%	4%

Table continued

Table 3. continued

	One-month (1)	One-quarter (2)	Two-quarter (3)	Three-quarter (4)	One-year (5)
Panel B: Effects to Chabi-Yo et al. (2023) cost of equity					
CCPP_total	-0.106**	-0.184***	-0.184***	-0.179***	-0.151***
	(-2.32)	(-5.70)	(-6.36)	(-5.07)	(-4.41)
N	39743	39739	39730	27506	26787
Adj.R^2	0.812	0.850	0.858	0.859	0.863
Economic effect	1%	2%	2%	2%	2%
CCPP_opp	-0.132**	-0.231***	-0.224***	-0.229***	-0.191***
	(-2.05)	(-4.97)	(-5.36)	(-4.33)	(-3.70)
N	32428	32427	32423	22178	21483
Adj.R^2	0.806	0.846	0.854	0.855	0.859
Economic effect	1%	3%	3%	3%	2%
CCPP_reg	0.069	-0.075*	-0.094**	-0.090*	-0.076
	(1.10)	(-1.67)	(-2.32)	(-1.81)	(-1.57)
N	32428	32427	32423	22178	21483
Adj.R^2	0.806	0.846	0.854	0.855	0.859
Economic effect	0.7%	1%	1%	1%	1%
CCPP_phy	-0.194***	-0.203***	-0.194***	-0.213***	-0.186***
	(-4.81)	(-6.66)	(-7.01)	(-6.23)	(-5.56)
N	32428	32427	32423	22178	21483
Adj.R^2	0.806	0.847	0.854	0.856	0.859
Economic effect	2%	2%	2%	3%	2%
Controls	Yes	Yes	Yes	Yes	Yes
Time FE	Yes	Yes	Yes	Yes	Yes
Industry FE	Yes	Yes	Yes	Yes	Yes

Notes: This table reports results from a panel regression of firms' option-implied cost of equity on CCPP and controls

$$CoE_{t,h}(n) = \alpha + \beta_1 \cdot CCPP_t(n) + \boldsymbol{\gamma}'\mathbf{X}_t(n) + \delta_t + \phi_j + \epsilon_{t,h}(n),$$

where $CoE_{t,h}(n)$, is the nth stock Martin and Wagner (2019) (Panel A) and Chabi-Yo et al. (2023) (Panel B) option-implied cost of equity estimated at t for alternative horizons h=1 month, 1 quarter, 2 quarters, 3 quarters, and 1 year. We include CCPP arising from investor portfolio rebalancing triggered by changes in total ($CCPP_t(n)$), opportunity ($CCPPOpp_t(n)$), regulatory ($CCPPReg_t(n)$) and physical climate change exposures ($CCPPPhy_t(n)$), separately. The vector of control variables $X_t(n)$ for the nth stock includes the market beta, log market equity, book-to-market ratio, profitability, investment, dividends-to-book equity, firm-level climate change exposure, momentum, and institutional ownership. We cross-sectionally standardize each independent variable within each quarter and across the S&P 500 stocks. We include year/quarter and industry fixed effects. The economic effect is calculated as the effect of a one-standard-deviation change in the independent variable on the mean value of the dependent variable (reported in Table 1). Standard errors are clustered at the firm level, and the corresponding t-statistics are reported in brackets. One, two and three asterisks denote significance at the 10%, 5%, and 1% significance level, respectively. The S&P 500 sample period spans 2005:1 to 2021:4 (2008:1 to 2021:4) for the total (topics-based) climate change exposures. We multiply the estimated coefficients by 100 for display purposes.

Table 4. Estimated β coefficients on climate change exposure for each type of investors: S&P 500 stocks

	(1) Banks	(2) Insurances	(3) Investment advisors	(4) Mutual	(5) Pension	(6) Households
Panel A: Total climate change exposures						
Total	-0.168***	-0.129***	-0.039	-0.056*	-0.121***	-0.060***
	(-6.49)	(-5.78)	(-1.63)	(-1.78)	(-7.01)	(-5.07)
N	2,874,813	882,213	21,647,525	3,864,705	1,247,698	39,913
Panel B: Opportunity climate change exposures						
Opp	-0.149***	-0.097***	-0.029	-0.054*	-0.100***	-0.009
	(-6.61)	(-4.23)	(-1.33)	(-1.91)	(-5.89)	(-0.68)
N	2,403,826	713,163	1,9624,585	3,148,908	1,063,173	32,597
Panel C: Regulatory climate change exposures						
Reg	-0.133***	-0.106***	-0.032	-0.056*	-0.115***	-0.097***
	(-5.37)	(-5.29)	(-1.45)	(-1.94)	(-5.32)	(-4.36)
N	2,403,826	713,163	1,9624,585	3,148,908	1,063,173	32,597
Panel D: Physical climate change exposures						
Phy	-0.029*	-0.043***	0.012	-0.025**	-0.032***	-0.035**
	(-1.67)	(-5.03)	(0.90)	(-2.30)	(-3.42)	(-2.16)
N	2,403,826	713,163	19,624,585	3,148,908	1,063,173	32,597
Controls	Yes	Yes	Yes	Yes	Yes	Yes

Notes: This table reports the estimated coefficients by non-linear GMM in equation (2) for each type of investor. We proxy climate change exposures by the total climate change exposures (*Total*) (Panel A), opportunity (*Opp*), regulatory (*Reg*), and physical (*Phy*) climate change exposures (Panels B, C, and D, respectively). We employ the data on the S&P 500 stock portfolio holdings by 13F institutional investors. We use the same stock characteristics variables as in Koijen and Yogo (2019) (Market beta, log market equity, log book equity, profitability, investment, and dividend to book equity). Following Koijen et al. (2023), we cross-sectionally standardize all characteristics, except for log market equity and log book equity, within each quarter and across the S&P 500 stocks. Columns (1) to (6) report the results for banks, insurance companies, investment advisors, mutual funds, and pension funds, households defined in subsection 3.1, respectively. Standard errors are clustered at the investor level and the corresponding t-statistics are reported in brackets. One, two and three asterisks denote significance at the 10%, 5%, and 1% significance level, respectively. The quarterly S&P 500 sample period is 2005:1 to 2021:4 (2008:1 to 2021:4) for total (topics-based) climate change exposures.

Table 5. Effects of CCPP to firm's future climate change exposures: S&P 500 stocks

	1-quarter (1)	2-quarter (2)	3-quarter (3)	1-year (4)	2-year (5)	3-year (6)	4-year (7)	5-year (8)
Panel A: Effects to future total climate change exposures								
CCPP_total	0.070	0.101	0.147	0.164	0.163	0.314	0.645	0.419
	(1.46)	(1.12)	(1.10)	(0.93)	(0.65)	(0.94)	(0.91)	(0.96)
N	38840	38617	38396	38173	35250	32464	29779	27113
Adj.R^2	0.083	0.096	0.116	0.134	0.179	0.198	0.126	0.223
Panel B: Effects to future opportunity climate change exposures								
CCPP_opp	0.051	0.103	0.182	0.220	0.112	0.145	0.199	0.293
	(0.96)	(1.02)	(1.26)	(1.22)	(0.71)	(0.66)	(0.76)	(0.99)
N	31717	31536	31357	31180	28436	25809	23264	20734
Adj.R^2	0.036	0.042	0.051	0.061	0.162	0.173	0.197	0.215
Panel C: Effects to future regulatory climate change exposures								
CCPP_reg	-0.001	-0.013	-0.020	-0.029	-0.081	-0.114	-0.105	-0.141
	(-0.09)	(-0.63)	(-0.65)	(-0.76)	(-0.94)	(-1.00)	(-0.84)	(-1.15)
N	31717	31536	31357	31180	28436	25809	23264	20734
Adj.R^2	0.057	0.078	0.104	0.126	0.104	0.125	0.145	0.167
Panel D: Effects to future physical climate change exposures								
CCPP_phy	-0.002	-0.004	-0.003	0.001	0.007	0.020	0.023	0.007
	(-1.24)	(-1.25)	(-0.65)	(0.15)	(0.59)	(1.37)	(1.55)	(0.48)
N	31717	31536	31357	31180	28436	25809	23264	20734
Adj.R^2	0.089	0.156	0.182	0.207	0.152	0.174	0.168	0.151
Controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Time FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Industry FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes

Notes: This table reports regressions of firms' future changes in climate change exposures on the CCPP and controls:

$$\Delta CCE_{t+h}(n) = \alpha + \beta_1 \cdot CCPP_t + \boldsymbol{\gamma}'\mathbf{X}_t(n) + \delta_t + \phi_j + \epsilon_{t+h}(n),$$

where $\Delta CCE_{t+h}(n)$ is the change in firm n's climate change exposure from t to $t+h$, proxied by the total (Panel A), opportunity (Panel B), regulatory (Panel C), and physical (Panel D) climate change exposures. h denotes the forecasting horizon, h = 1, 2, 3 quarters, and 1, 2, 3, 4, 5 years ahead (Columns (1) - (8), respectively). $CCPP_t(n)$ denotes the CCPP for stock n stemming from investors' rebalancing stocks with respect to total ($CCPP_t(n)$), opportunity ($CCPPOpp_t(n)$), regulatory ($CCPPReg_t(n)$) and physical ($CCPPPhy_t(n)$) climate change exposures. $X_t(n)$ is the vector of control variables: size, asset tangibility, leverage, profitability, cash ratio, capital expenditures, R&D expenses, and institutional ownership for stock n. We cross-sectionally standardize each independent variable within each quarter and across the S&P 500 stocks. We include year/quarter and industry fixed effects. Standard errors are clustered at the firm level, and the corresponding t-statistics are reported in parentheses. One, two and three asterisks denote significance at the 10%, 5%, and 1% significance level, respectively. The quarterly S&P 500 stocks sample period is from 2005:1 to 2021:4 (2008:1 to 2021:4) for the total (topics-based) climate change exposures. We multiply the estimated coefficients by 100,000 for display purposes.

Table 6. Effects of CCPP to firms' emission intensities: S&P 500 stocks

	One-year (1)	Two-year (2)	Three-year (3)	Four-year (4)	Five-year (5)
	Effects to Trucost total carbon emission intensities				
CCPP_total	-3.666	-6.603	-11.041	-13.373	-13.794
	(-0.68)	(-0.90)	(-1.40)	(-1.47)	(-1.46)
N	7108	6582	6062	5536	5030
Adj.R^2	0.052	0.110	0.175	0.237	0.280
CCPP_opp	2.730	-0.464	-3.417	-6.054	-7.481
	(0.91)	(-0.10)	(-0.53)	(-0.73)	(-0.79)
N	5939	5424	4911	4391	3888
Adj.R^2	0.069	0.134	0.201	0.250	0.293
CCPP_reg	1.054	-3.690	-7.305	-10.471	-12.909
	(0.26)	(-0.59)	(-0.96)	(-1.00)	(-1.14)
N	5939	5424	4911	4391	3888
Adj.R^2	0.069	0.134	0.201	0.251	0.294
CCPP_phy	-0.639	0.423	-1.549	-4.364	0.820
	(-0.25)	(0.09)	(-0.29)	(-0.76)	(0.14)
N	5939	5424	4911	4391	3888
Adj.R^2	0.069	0.134	0.201	0.250	0.293
Controls	Yes	Yes	Yes	Yes	Yes
Time FE	Yes	Yes	Yes	Yes	Yes
Industry FE	Yes	Yes	Yes	Yes	Yes

Notes: This table reports results from regressions of firms' future changes in carbon emission intensities on the CCPP and controls for S&P 500 stocks:

$$\Delta Emissions_{t+h}(n) = \alpha + \beta_1 \cdot CCPP_t(n) + \boldsymbol{\gamma}'\mathbf{X}_t(n) + \delta_t + \phi_j + \epsilon_{t+1}(n)$$

The dependent variable, $\Delta Emissions_{t+h}(n)$, is next h-years' change in firm n's total carbon emission intensities (sum of scope 1 and scope 2 emission intensities). h denotes the forecasting horizon, where $h =$ one year, two years, three years, four years, and five years ahead (Columns (1) - (5), respectively). We examine the effects of CCPP from institutional stock rebalancing triggered by total ($CCPP_t(n)$), opportunity ($CCPPOpp_t(n)$), regulatory ($CCPPReg_t(n)$) and physical exposures ($CCPPPhy_t(n)$), respectively. The vector $X_t(n)$ of control variables includes size, asset tangibility, leverage, profitability, cash ratio, capital expenditures, R&D expenses, institutional ownership and the current level of total carbon emission intensity of the nth firm. We cross-sectionally standardize all independent variables within each quarter and across the S&P 500 stocks. In addition, we include the year and industry fixed effects. Standard errors are clustered at the firm level and the corresponding t-statistics are reported in brackets. One, two, and three stars represent the 10%, 5%, and 1% significance levels, respectively. The annual S&P 500 sample period is from 2005 to 2021 (2008 to 2021) for the total (topics-based) climate change exposures.

Table 7. Effects of instrumentalized CCPP to firms' cost of equity: S&P 500 stocks

	One-month (1)	One-quarter (2)	Two-quarter (3)	Three-quarter (4)	One-year (5)
Panel A: Effects to Martin and Wagner (2019) cost of equity					
InstrumentCCPP_total	-0.291***	-0.330***	-0.323***	-0.309***	-0.288***
	(-4.64)	(-5.82)	(-5.97)	(-4.66)	(-4.54)
N	39739	39735	39726	27506	26787
Adj.R^2	0.644	0.630	0.611	0.622	0.630
InstrumentCCPP_opp	-0.414***	-0.446***	-0.431***	-0.412***	-0.387***
	(-5.76)	(-6.85)	(-6.98)	(-5.37)	(-5.27)
N	32424	32423	32419	22178	21483
Adj.R^2	0.648	0.634	0.614	0.627	0.636
InstrumentCCPP_reg	-0.189**	-0.275***	-0.281***	-0.239***	-0.223***
	(-2.36)	(-3.76)	(-4.01)	(-2.70)	(-2.63)
N	32424	32423	32419	22178	21483
Adj.R^2	0.647	0.633	0.613	0.626	0.635
InstrumentCCPP_phy	-0.216***	-0.279***	-0.283***	-0.243***	-0.222***
	(-3.17)	(-4.57)	(-4.91)	(-3.67)	(-3.57)
N	32424	32423	32419	22178	21483
Adj.R^2	0.647	0.633	0.613	0.626	0.635

Table continued

Table 7. continued

	One-month (1)	One-quarter (2)	Two-quarter (3)	Three-quarter (4)	One-year (5)
Panel B: Effects to Chabi-Yo et al. (2023) cost of equity					
InstrumentCCPP_total	-0.156***	-0.217***	-0.220***	-0.224***	-0.206***
	(-3.49)	(-6.87)	(-7.78)	(-6.46)	(-6.24)
N	39739	39735	39726	27506	26787
Adj.R^2	0.812	0.850	0.858	0.859	0.863
InstrumentCCPP_opp	-0.211***	-0.277***	-0.277***	-0.284***	-0.262***
	(-4.02)	(-7.56)	(-8.50)	(-7.07)	(-6.80)
N	32424	32423	32419	22178	21483
Adj.R^2	0.806	0.847	0.855	0.856	0.860
InstrumentCCPP_reg	-0.118**	-0.220***	-0.234***	-0.253***	-0.240***
	(-2.06)	(-5.54)	(-6.62)	(-5.85)	(-5.81)
N	32424	32423	32419	22178	21483
Adj.R^2	0.806	0.847	0.854	0.856	0.859
InstrumentCCPP_phy	-0.123**	-0.203***	-0.216***	-0.227***	-0.222***
	(-2.53)	(-5.87)	(-7.07)	(-6.48)	(-6.62)
N	32424	32423	32419	22178	21483
Adj.R^2	0.806	0.847	0.855	0.856	0.859
Controls	Yes	Yes	Yes	Yes	Yes
Time FE	Yes	Yes	Yes	Yes	Yes
Industry FE	Yes	Yes	Yes	Yes	Yes

Notes: This table reports results from a panel regression of firms' option-implied cost of equity on the instrumentalized CCPP and controls

$$CoE_{t,h}(n) = \alpha + \beta_1 \cdot InstrumentCCPP_t(n) + \boldsymbol{\gamma}'\mathbf{X}_t(n) + \delta_t + \phi_j + \epsilon_{t,h}(n),$$

where $CoE_{t,h}(n)$, is the nth stock Martin and Wagner (2019) (Panel A) and Chabi-Yo et al. (2023) (Panel B) option-implied cost of equity estimated at t for alternative horizons h=1 month, 1 quarter, 2 quarters, 3 quarters, and 1 year. We include the instrumentalized CCPP arising from investor portfolio rebalancing triggered by increases in industry average excluding the focal company of total ($InstrumentCCPP_t(n)$), opportunity ($InstrumentCCPPOpp_t(n)$), regulatory ($InstrumentCCPPReg_t(n)$) and physical climate change exposures ($InstrumentCCPPPhy_t(n)$), separately. The vector of control variables $X_t(n)$ for the nth stock includes the market beta, log market equity, book-to-market ratio, profitability, investment, dividends-to-book equity, firm-level climate change exposure, momentum, and institutional ownership. We cross-sectionally standardize the independent variables within each quarter and across the S&P 500 stocks. We include year/quarter and industry fixed effects. Standard errors are clustered at the firm level and the corresponding t-statistics are reported in brackets. One, two and three asterisks denote significance at the 10%, 5%, and 1% significance levels, respectively. The S&P 500 sample period spans 2005:1 to 2021:4 (2008:1 to 2021:4) for the total (topics-based) climate change exposures. We multiply the estimated coefficients by 100 for display purposes.

Table 8. Brown firms, Green firms, CCPP, and future climate change exposures and emissions: S&P 500 stocks

	One-quarter (1)	Two-quarter (2)	Three-quarter (3)	One-year (4)	Five year (5)
Panel A: Effects to future climate change exposures					
CCPP_total × Brown	0.287	0.543	0.720	0.894	0.334
	(1.33)	(1.26)	(1.07)	(0.97)	(1.47)
CCPP_total × Neutral	0.052	0.091	0.176	0.209	-0.009
	(0.80)	(0.72)	(0.95)	(0.85)	(-0.15)
CCPP_total × Green	0.044	0.036	0.010	-0.042	-0.084
	(0.48)	(0.21)	(0.04)	(-0.14)	(-0.95)
N	29452	29435	29419	29400	21158
Adj.R^2	0.096	0.110	0.131	0.151	0.246
CCPP_opp × Brown	0.243	0.595	1.027	1.310	0.314
	(0.94)	(1.18)	(1.43)	(1.44)	(1.06)
CCPP_opp × Neutral	0.027	0.037	0.077	0.098	0.009
	(0.46)	(0.33)	(0.48)	(0.48)	(0.14)
CCPP_opp × Green	0.064	0.104	0.161	0.199	0.026
	(1.06)	(0.89)	(0.95)	(0.94)	(0.34)
N	25091	25077	25064	25048	16852
Adj.R^2	0.041	0.048	0.059	0.070	0.166
CCPP_reg × Brown	0.054	0.070	0.087	0.077	-0.006
	(1.18)	(0.79)	(0.67)	(0.47)	(-0.10)
CCPP_reg × Neutral	-0.008	-0.025	-0.037	-0.054	-0.015
	(-0.60)	(-0.97)	(-1.03)	(-1.17)	(-0.72)
CCPP_reg × Green	-0.014	-0.037	-0.058	-0.080	-0.023
	(-0.91)	(-1.36)	(-1.44)	(-1.53)	(-0.88)
N	25091	25077	25064	25048	16852
Adj.R^2	0.063	0.085	0.112	0.135	0.175
CCPP_phy × Brown	-0.012	-0.026*	-0.033	-0.027	-0.001
	(-1.40)	(-1.69)	(-1.59)	(-1.14)	(-0.26)
CCPP_phy × Neutral	-0.000	-0.001	0.003	0.007	0.001
	(-0.10)	(-0.18)	(0.47)	(1.02)	(1.34)
CCPP_phy × Green	0.002	0.008	0.012	0.014	-0.001
	(0.77)	(1.42)	(1.38)	(1.41)	(-0.59)
N	25091	25077	25064	25048	16852
Adj.R^2	0.081	0.147	0.170	0.195	0.424

Continued

Table 8. continued

	One-year (1)	Two-year (2)	Three-year (3)	Four-year (4)	Five year (5)
Panel B: Effects to future Trucost total emission intensities					
CCPP_total × Brown	-12.831	-20.850	-42.809	-52.593	-62.291
	(-0.45)	(-0.52)	(-1.07)	(-1.25)	(-1.35)
CCPP_total × Neutral	-2.148	-3.346	-4.190	-4.968	-3.610
	(-1.30)	(-1.09)	(-0.94)	(-0.85)	(-0.60)
CCPP_total × Green	-0.255	-2.101	-3.516	-1.445	1.679
	(-0.15)	(-0.70)	(-0.73)	(-0.21)	(0.22)
N	6963	6442	5924	5401	4917
Adj.R^2	0.052	0.108	0.176	0.239	0.284
CCPP_opp × Brown	12.226	2.879	-17.051	-29.530	-50.750
	(0.68)	(0.10)	(-0.48)	(-0.62)	(-0.89)
CCPP_opp × Neutral	0.641	-2.205	-2.483	-3.584	-1.583
	(0.38)	(-0.63)	(-0.55)	(-0.60)	(-0.24)
CCPP_opp × Green	2.011	0.085	1.048	3.070	6.450
	(1.33)	(0.03)	(0.24)	(0.50)	(0.86)
N	5865	5352	4840	4323	3842
Adj.R^2	0.070	0.138	0.206	0.256	0.300
CCPP_reg × Brown	5.169	-11.947	-34.628	-51.144	-69.797
	(0.25)	(-0.39)	(-0.92)	(-0.99)	(-1.19)
CCPP_reg × Neutral	-0.423	-3.094	-3.188	-4.235	-4.023
	(-0.21)	(-0.70)	(-0.61)	(-0.62)	(-0.53)
CCPP_reg × Green	1.265	-1.303	-0.826	1.033	4.275
	(0.76)	(-0.36)	(-0.17)	(0.15)	(0.52)
N	5865	5352	4840	4323	3842
Adj.R^2	0.070	0.138	0.208	0.257	0.302
CCPP_phy × Brown	-3.196	3.124	-12.060	-30.944	-9.150
	(-0.23)	(0.13)	(-0.42)	(-0.97)	(-0.25)
CCPP_phy × Neutral	-0.877	-1.203	-0.220	-0.530	-0.282
	(-1.30)	(-1.03)	(-0.15)	(-0.26)	(-0.12)
CCPP_phy × Green	0.436	-0.447	-0.300	0.592	2.417
	(0.67)	(-0.45)	(-0.22)	(0.28)	(0.92)
N	5865	5352	4840	4323	3842
Adj.R^2	0.070	0.138	0.206	0.256	0.299
Controls	Yes	Yes	Yes	Yes	Yes
Time FE	Yes	Yes	Yes	Yes	Yes
Industry FE	Yes	Yes	Yes	Yes	Yes

Notes: This table reports regressions of firms' future changes in the climate change exposures (total carbon emission intensities) on the interaction terms of stock-level CCPP and a type variable (an indicator of brown, neutral, and green firms), and controls:

$$\Delta CCE_{t+h}(n)/\Delta Emissions_{t+h}(n) = \alpha + \beta_1 \cdot CCPP_t(n) \times Type_t(n) + \beta_2 \cdot Type_t(n) + \boldsymbol{\gamma}'\mathbf{X}_t(n) + \delta_t + \phi_j + \epsilon_{t,h}(n),$$

$\Delta CCE_{t+h}(n)$, is h-period head change in firm n's total, opportunity, regulatory, and physical exposures, respectively (Panel A). $\Delta Emissions_{t+h}(n)$, is h-period head change in firm n's total carbon emission intensities (Panel B). h denotes the forecasting horizon. We include the interaction term of stock-level CCPP (stemming from total ($CCPP_t(n)$), opportunity ($CCPPOpp_t(n)$), regulatory ($CCPPReg_t(n)$) and physical exposures ($CCPPPhy_t(n)$), separately) and the type of brown, neutral and green firms. We include the controls: size, asset tangibility, leverage, profitability, cash ratio, capital expenditures, R&D expenses, institutional ownership, and the current level of climate change exposure/total carbon emission intensity. We cross-sectionally standardize the independent variables within each quarter and across the S&P 500 stocks. We include time and industry fixed effects. Standard errors are clustered at the firm level and the corresponding t-statistics are reported in brackets. One, two and three asterisks denote significance at the 10%, 5%, and 1% significance level, respectively. The data frequency of climate change exposures (total carbon emission intensities) is quarterly (annual). The S&P 500 sample period is from 2005 to 2021 (2008 to 2021) for the total (topics-based) climate change exposures. For panel A, we multiply the estimated coefficients by 100,000 for display purposes.

Table 9. Effects of CCPP to firm's alternative activities: S&P 500 stocks

	One-quarter (1)	Two-quarter (2)	Three-quarter (3)	One-year (4)
Panel A: Effects to future capital expenditures/assets				
CCPP_total	-0.047*	-0.002	-0.008	0.047*
	(-1.86)	(-0.06)	(-0.24)	(1.78)
N	38800	38562	38337	38113
Adj.R^2	0.375	0.365	0.358	0.152
Panel B: Effects to future PPE/assets				
CCPP_total	-0.005	-0.001	0.008	0.020
	(-0.60)	(-0.07)	(0.42)	(0.79)
N	38725	38489	38263	38120
Adj.R^2	0.060	0.090	0.113	0.124
Panel C: Effects to future R&D expenses/assets				
CCPP_total	-0.001	-0.001	-0.002	-0.002
	(-0.48)	(-0.21)	(-0.46)	(-0.36)
N	38820	38592	38373	38152
Adj.R^2	0.065	0.055	0.058	0.039
Panel D: Effects to future total debt/assets				
CCPP_total	0.028*	0.026	0.027	0.046
	(1.85)	(0.87)	(0.63)	(0.84)
N	38820	38592	38373	38152
Adj.R^2	0.051	0.069	0.083	0.097
Controls	Yes	Yes	Yes	Yes
Time FE	Yes	Yes	Yes	Yes
Industry FE	Yes	Yes	Yes	Yes

Notes: This table reports regressions of firms' future changes in alternative activities on the CCPP and controls:

$$\Delta Y_{t+h}(n) = \alpha + \beta_1 \cdot CCPP_t + \boldsymbol{\gamma}'\mathbf{X}_t(n) + \delta_t + \phi_j + \epsilon_{t+h}(n),$$

where $\Delta Y_{t+h}(n)$ is the h-period ahead changes in firm n's capital expenditures, PPE, R&D and leverage ratio, separately. h denotes the forecasting horizon, where $h =$ one quarter, two quarters, three quarters, and one year ahead (Columns (1) - (4), respectively). $CCPP_t(n)$ denotes the CCPP for stock n stemming from investors' rebalancing stocks with respect to total ($CCPP_t(n)$) climate change exposures. $X_t(n)$ is the vector of control variables: size, asset tangibility, leverage, profitability, cash ratio, capital expenditures, R&D expenses, and institutional ownership for stock n. We cross-sectionally standardize all independent variables within each quarter and across the S&P 500 stocks. We include year/quarter and industry fixed effects. Standard errors are clustered at the firm level, and the corresponding t-statistics are reported in parentheses. One, two and three asterisks denote significance at the 10%, 5%, and 1% significance level, respectively. The quarterly S&P 500 stocks sample period is from 2005:1 to 2021:4 (2008:1 to 2021:4) for the total (topics-based) climate change exposures. We multiply the estimated coefficients by 100 for display purposes.

Table 10. Media climate change attention, CCPP, and future climate change exposures: S&P 500 stocks

	One-quarter (1)	Two-quarter (2)	Three-quarter (3)	One-year (4)
Panel A: Ardia et al. (2023) MCCC measure				
CCPP_total × MCCC	1.704***	2.691***	3.282***	3.720***
	(4.90)	(4.73)	(4.64)	(4.33)
CCPP_total	-0.993***	-1.576***	-1.898***	-2.154***
	(-4.92)	(-4.90)	(-4.79)	(-4.52)
N	38840	38617	38396	38173
Adj.R^2	0.086	0.099	0.118	0.136
CCPP_opp × MCCC	0.858***	1.305***	1.595***	1.902***
	(4.08)	(3.87)	(3.64)	(3.71)
CCPP_opp	-0.496***	-0.742***	-0.891***	-1.076***
	(-3.88)	(-3.68)	(-3.44)	(-3.55)
N	31717	31536	31357	31180
Adj.R^2	0.074	0.087	0.102	0.120
CCPP_reg × MCCC	0.242***	0.425***	0.563***	0.693***
	(3.73)	(3.83)	(3.73)	(3.69)
CCPP_reg	-0.147***	-0.256***	-0.330***	-0.402***
	(-3.69)	(-3.84)	(-3.69)	(-3.63)
N	31717	31536	31357	31180
Adj.R^2	0.059	0.081	0.106	0.128
CCPP_phy × MCCC	0.013*	0.018	0.019	0.027
	(1.80)	(1.34)	(1.04)	(1.33)
CCPP_phy	-0.010**	-0.016*	-0.016	-0.017
	(-2.20)	(-1.75)	(-1.24)	(-1.20)
N	31717	31536	31357	31180
Adj.R^2	0.089	0.156	0.182	0.208

Continued

Table 10. continued

	One-quarter (1)	Two-quarter (2)	Three-quarter (3)	One-year (4)
Panel B: Faccini et al. (2023) U.S. policy measure				
CCPP_total × Policy	0.629***	0.990***	1.110***	1.109***
	(4.91)	(4.64)	(4.11)	(3.48)
CCPP_total	-0.483***	-0.769***	-0.828***	-0.810***
	(-4.80)	(-4.68)	(-4.00)	(-3.32)
N	38840	38617	38396	38173
Adj.R^2	0.087	0.100	0.118	0.136
CCPP_opp × Policy	0.315***	0.469***	0.500***	0.521***
	(4.39)	(4.16)	(3.54)	(3.24)
CCPP_opp	-0.242***	-0.346***	-0.335***	-0.337**
	(-3.88)	(-3.58)	(-2.75)	(-2.40)
N	31717	31536	31357	31180
Adj.R^2	0.076	0.088	0.102	0.120
CCPP_reg × Policy	0.069***	0.115***	0.162***	0.193***
	(3.28)	(3.17)	(3.16)	(3.08)
CCPP_reg	-0.054***	-0.088***	-0.116***	-0.133***
	(-3.10)	(-2.97)	(-2.79)	(-2.58)
N	31717	31536	31357	31180
Adj.R^2	0.059	0.080	0.106	0.128
CCPP_phy × Policy	0.003	0.007*	0.009*	0.013**
	(1.62)	(1.78)	(1.76)	(2.05)
CCPP_phy	-0.005**	-0.010**	-0.012*	-0.012
	(-2.06)	(-2.20)	(-1.79)	(-1.49)
N	31717	31536	31357	31180
Adj.R^2	0.089	0.156	0.182	0.208

Notes: This table reports regressions of firms' future changes in climate change exposures on the interaction terms of stock-level CCPP and market-level climate change attention, and controls:

$$\begin{aligned}\Delta CCE_{t+h}(n) &= \alpha + \beta_1 \cdot CCPP_t(n) \times Attention_t + \beta_2 \cdot CCPP_t(n) \\ &\quad + \beta_3 \cdot Attention_t + \boldsymbol{\gamma}'\mathbf{X}_t(n) + \delta_t + \phi_j + \epsilon_{t+h}(n),\end{aligned}$$

$\Delta CCE_{t+h}(n)$, is the h-period ahead change in firm n's total, opportunity, regulatory, and physical exposures, respectively. h denotes the forecasting horizon, where h=1, 2, 3 quarters, and 1 year ahead (Columns (1) - (4), respectively). MCCC is the Ardia et al. (2023) Media Climate Change Concerns Index (Panel A). Policy is the Faccini et al. (2023) U.S. climate change-policy measure (Panel B). We include the interaction term of institutional stock-level CCPP (stemming from total ($CCPP_t(n)$), opportunity ($CCPPOpp_t(n)$), regulatory ($CCPPReg_t(n)$) and physical exposures ($CCPPPhy_t(n)$), separately) with market-level climate change attention. We include the control variables: size, asset tangibility, leverage, profitability, cash ratio, capital expenditures, R&D expenses, institutional ownership and current level of climate change exposures. We cross-sectionally standardize the independent variables within each quarter and across the S&P 500 stocks. We include the year/quarter and industry fixed effects. Standard errors are clustered at the firm level and the corresponding t-statistics are reported in brackets. One, two and three asterisks denote significance at the 10%, 5%, and 1% significance level, respectively. The quarterly S&P 500 sample period is from 2005:1 to 2021:4 (2008:1 to 2021:4) for the total (topics-based) climate change exposures. We multiply the estimated coefficients by 100,000 for display purposes.

A Model Appendix

A.1 Stock-level CCPP derivation (equation (3))

The market clearing condition for stock n at time t, $P_t(n)S_t(n) = \sum_{i=1}^{I} A_{i,t}w_{i,t}(n)$, implies that the log stock price vector for all stocks at time t equals,

$$\mathbf{p}_t = \log\left(\sum_{i=1}^{I} A_{i,t}\mathbf{w}_{i,t}(\mathbf{p}_t)\right) - \mathbf{s}_t, \tag{A.1}$$

where the vector $\mathbf{s}_t$ denotes the log of the outstanding shares. Taking the derivative of both sides in equation (A.1) with respect to $\mathbf{cc}_t'$:

$$\frac{\partial \mathbf{p}_t}{\partial \mathbf{cc}_t'} = \mathbf{H}_t^{-1}\left(\sum_{i=1}^{I} A_{i,t}\frac{\partial \mathbf{w}_{i,t}}{\partial \mathbf{p}_t'}\frac{\partial \mathbf{p}_t}{\partial \mathbf{cc}_t'} + \sum_{i=1}^{I} A_{i,t}\frac{\partial \mathbf{w}_{i,t}}{\partial \mathbf{cc}_t'}\right), \tag{A.2}$$

where $\mathbf{H}_t = \sum_i^I A_{i,t}\,\mathrm{diag}\left(\mathbf{w}_{i,t}\right)$.

We then calculate $\frac{\partial \mathbf{w}_{i,t}}{\partial \mathbf{p}_t'}$, and $\frac{\partial \mathbf{w}_{i,t}}{\partial \mathbf{cc}_t'}$. However, we cannot take the derivative of the equation (2) directly, because the portfolio weight on the outside asset, $w_{i,t}(0)$ contains the information of portfolio weight on other stock n (in investor i's investment universe), $w_{i,t}(n)$. We need to transform equation (2) first.

Denote the portfolio weight on stock n relative to the outside asset at time t as $\delta_{i,t}(n)$,

$$\frac{w_{i,t}(n)}{w_{i,t}(0)} = \delta_{i,t}(n) = \exp\left(\beta_{0,i,t}me_t(n) + \boldsymbol{\beta}_{1,i,t}'\mathbf{cc}_t(n) + \boldsymbol{\beta}_{2,i,t}'\mathbf{x}_t(n) + \beta_{3,i,t}\right)\epsilon_{i,t}(n), \tag{A.3}$$

We then rewrite the portfolio weight on stock n as,

$$w_{i,t}(n) = \delta_{i,t}(n)w_{i,t}(0), \tag{A.4}$$

We sum up the portfolio weights of all stocks in investor i's investment universe,

$$\sum_{m\in\mathcal{N}_{i,t}} w_{i,t}(m) = w_{i,t}(0)\sum_{m\in\mathcal{N}_{i,t}} \delta_{i,t}(m), \tag{A.5}$$

where m represents the stock in investor i's investment universe.

Additionally, considering the budget constraint, for each investor i, the total sum of portfolio weights for all stocks in her investment universe is

$$\sum_{m \in \mathcal{N}_{i,t}} w_{i,t}(m) = 1 - w_{i,t}(0), \tag{A.6}$$

From equations (A.5) and (A.6), we can rewrite the portfolio weight on the outside asset at time t as:

$$w_{i,t}(0) = \frac{1}{1 + \sum_{m \in \mathcal{N}_{i,t}} \delta_{i,t}(m)} \tag{A.7}$$

Substituting equation (A.7) in equation (A.4), yields investor i's portfolio weight on stock n at time t as:

$$w_{i,t}(n) = \frac{\delta_{i,t}(n)}{1 + \sum_{m \in \mathcal{N}_{i,t}} \delta_{i,t}(m)} \tag{A.8}$$

Then, we take the derivative of $w_{i,t}(n)$ in equation (A.8) with respect to each type of climate change exposure, $cc_t(n)$:

$$\begin{aligned} \frac{\partial w_{i,t}(n)}{\partial cc_t(n)} &= \frac{\delta'_{i,t}(n)}{1 + \sum_{m \in \mathcal{N}_{i,t}} \delta_{i,t}(m)} - \frac{\delta_{i,t}(n)}{(1 + \sum_{m \in \mathcal{N}_{i,t}} \delta_{i,t}(m))^2} \delta'_{i,t}(n) \\ &= \beta_{1,i,t} w_{i,t}(n) - \beta_{1,i,t} w_{i,t}(n) w_{i,t}(n) = \beta_{1,i,t} w_{i,t}(n) \left(1 - w_{i,t}(n)\right) \end{aligned} \tag{A.9}$$

Similarly, we take the derivative of $w_{i,t}(n)$ with respect to $cc_t(l)$ (l represents any other stock in investor i's investment universe) based on equation (A.8):

$$\frac{\partial w_{i,t}(n)}{\partial cc_t(l)} = -\frac{\delta_{i,t}(n)}{(1 + \sum_{m \in \mathcal{N}_{i,t}} \delta_{i,t}(m))^2} \delta'_{i,t}(l) = -\beta_{1,i,t} w_{i,t}(n) w_{i,t}(l) \tag{A.10}$$

Equations (A.9) and (A.10) yield

$$\frac{\partial \mathbf{w}_{i,t}}{\partial \mathbf{cc}'_t} = \beta_{1,i,t} \mathbf{G}_{i,t}, \tag{A.11}$$

where $\mathbf{G}_{i,t} = \operatorname{diag}\left(\mathbf{w}_{i,t}\right) - \mathbf{w}_{i,t}\mathbf{w}'_{i,t}$.

Through analogous steps, the derivative of optimal portfolio weights with respect to the stock prices equals

$$\frac{\partial \mathbf{w}_{i,t}}{\partial \mathbf{p}'_t} = \beta_{0,i,t} \mathbf{G}_{i,t} \tag{A.12}$$

By substituting equations (A.11) and (A.12) in equation (A.2), the derivative of the equilibrium price with respect to climate change exposures equals:

$$\frac{\partial \mathbf{p_t}}{\partial \mathbf{cc}_t'} = \left(\mathrm{I} - \sum_{i=1}^{I} \beta_{0,i,t} A_{i,t} \mathbf{H_t}^{-1} \mathbf{G}_{i,t} \right)^{-1} \left(\sum_{i=1}^{I} \beta_{1,i,t} A_{i,t} \mathbf{H_t}^{-1} \mathbf{G}_{i,t} \right), \tag{A.13}$$

where $\mathbf{G}_{i,t} = \mathrm{diag}\left(\mathbf{w}_{i,t}\right) - \mathbf{w}_{i,t}\mathbf{w}_{i,t}'$.

We measure the CCPP for stock n using the nth diagonal element of the matrix in expression (A.13):

$$\frac{\partial p_t(n)}{\partial cc_t(n)} = \frac{\sum_i s_{i,t}(n)\beta_{1,i,t}\left(1 - w_{i,t}(n)\right)}{1 - \sum_i s_{i,t}(n)\beta_{0,i,t}\left(1 - w_{i,t}(n)\right)}, \tag{A.14}$$

where $p_t(n) = \log(P_t(n))$, $s_{i,t}(n) = A_{i,t}w_{i,t}(n) / \sum_i^I A_{i,t}w_{i,t}(n)$ is the proportion of market capitalization held by investor i for stock n at time t (i.e., investor i's ownership of stock n at time t).[18]

B Data Appendix

B.1 Sautner et al. (2023a) measure: Dealing with missing and zero observations

We report the proportion of missing and zero values of Sautner et al. (2023a) *quarterly* climate change exposure data for S&P 500 stocks from Q1 2002 (the starting quarter of their data) to Q4 2021.[19] The proportion of missing values of climate change exposures is high (around 10%), as illustrated in Panel (a) of Figure B.1.

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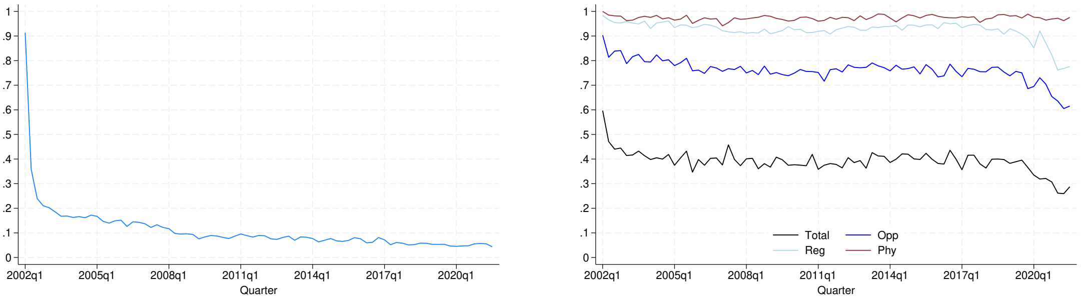
[18]

$$\frac{\partial \mathbf{p_t}}{\partial \mathbf{cc}_t'} = \begin{pmatrix} \frac{\partial p_t(1)}{\partial cc_t(1)} & \cdots & \frac{\partial p_t(1)}{\partial cc_t(n)} \\ \vdots & \cdots & \vdots \\ \frac{\partial p_t(n)}{\partial cc_t(1)} & \cdots & \frac{\partial p_t(n)}{\partial cc_t(n)} \end{pmatrix}$$

We focus on the diagonal rather than the off-diagonal elements to investigate how a firm's own climate change exposures affect its stock price.

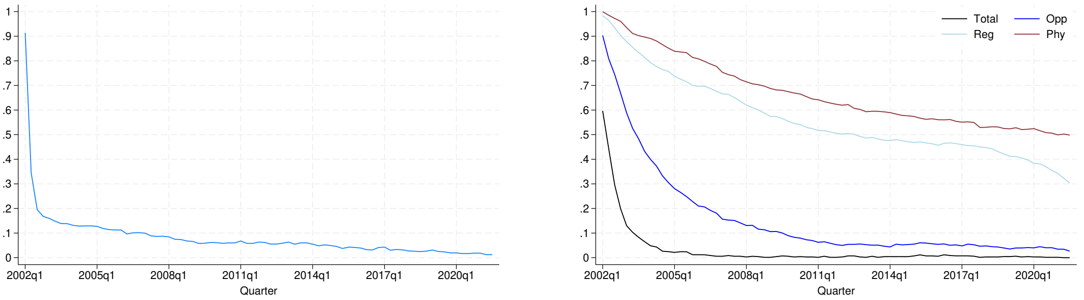
[19] We calculate the proportion of missing/zero climate exposure values in each quarter by counting the number of stocks with missing/zero exposure data and dividing it by the total number of S&P 500 stocks/S&P 500 stocks with non-missing climate change exposure. Proportions of missing observations are the same across different types of climate exposures. We use data on the total climate change exposure from Q1 2005 to Q4 2021 and data on topics-based climate change exposures from Q1 2008 to Q4 2021. Appendix B.1 elaborates on our rationale for selecting distinct sample starting points.

The reason for the missing values could be the unavailability of Refinitiv's downloadable conference call transcripts or the absence of conference calls. The total climate change exposure value is zero for nearly 40% of the non-missing observations. Opportunity exposures are mostly zero (80%) and regulatory/physical exposures are nearly always zero (close to 100%), as illustrated in Panel (b) of Figure B.1.



(a) Percentage of missing climate change exposure data for S&P 500 stocks

(b) Percentage of zero climate change exposure data for S&P 500 stocks



(c) Percentage of zero climate change exposure data for S&P 500 stocks after exponential smoothing

(d) Percentage of zero climate change exposure data for S&P 500 stocks after exponential smoothing

Figure B.1. This figure plots the percentage of missing observations of Sautner et al. (2023a) quarterly climate change exposure data for S&P 500 stocks in Panel (a) and the percentage of zero observations for different types of climate change exposures in Panel (b) from Q1 2002 to Q4 2021. The proportion of missing climate exposure values in each quarter is calculated by counting the number of stocks with missing data and dividing it by the total number of S&P 500 stocks. The proportion of zero climate exposure values in each quarter is calculated by counting the number of stocks with zero exposure data and dividing it by the total number of S&P 500 stocks with non-missing climate change exposure. Panels (c) and (d) report the percentage of missing values and zero exposure values for S&P 500 stocks after applying the exponential weighted moving average smoothing as in Sautner et al. (2023b). *Total*, *Opp*, *Reg*, and *Phy* measure the relative frequency of bigrams related to overall climate change, opportunity, regulatory, and physical climate-related topics, occurring in the transcripts of earnings conference calls, respectively.

Sautner et al. (2023a,b) recommend using the exponential weighted moving average (EWMA) method to fill in the zero and missing observations to smooth their quarterly climate change exposure data. The EWMA value $y_{i,t}$ for firm i at time t is calculated from firm i's climate change exposure observations from time 0 to t

$$y_{i,t} = \frac{\sum_{z=0}^{t} x_{i,t-z}(1-\alpha)^z}{\sum_{z=0}^{t}(1-\alpha)^z}, \tag{B.15}$$

where z denotes the time span between the time when firm i's first non-missing exposure is observed and the current time t. The decay parameter α is given by $1 - \exp(-\ln(2)/\tau)$, with the half-life parameter of six months denoted as τ, which is the decay time for the weight value to reach half its original value.[20]

Once we apply exponential smoothing, S&P 500 stocks have around 8% missing climate change exposure after 2005, as shown in Panel (c) of Figure B.1. The percentage of missing observations of climate change exposure data decreases slightly after exponential smoothing, in comparison to the missing percentage before smoothing (around 10%).

On the other hand, the percentage of zero observations of climate change exposure decreases significantly after exponential smoothing. Most S&P 500 stocks have non-zero total climate change exposure values (close to 100% after 2005). However, the percentage of zero observations for topics-based climate change exposures remains high. To ensure that at least 30% of S&P 500 stocks have non-zero topics-based exposure values, Sautner et al. (2023b)'s sample on the topics-based climate change exposure spans 2008 to 2021. In 2008, approximately 85% of S&P 500 stocks have non-zero opportunity exposure values, while regulatory and physical exposures had only about 35% and 30% non-zero values, respectively, as illustrated in Panel (d) of Figure B.1. In accordance with them, we use data on total climate change exposure from Q1 2005 to Q4 2021 and data on topics-based climate change exposures from Q1 2008 to Q4 2021 after exponential smoothing.

B.2 Variable definitions

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[20] Sautner et al. (2023b) find that the empirical results are insensitive to the choice of the half-life parameter; results are similar, when assigning values of τ between 3 to 12 months. We follow them and let τ equal a value of 6 months.

Table B.1. Variable Definition

Variable	Definition
Total/Opp/Reg/Phy	Total/Opportunity/Regulatory/Physical climate change exposure measures the frequency of climate change-related broadly-defined opportunity/regulatory/physical bigrams in quarterly earnings conference call transcripts. Source: Sautner et al. (2023a).
CI_Trucost	The sum of scope 1 and 2 carbon emissions normalized by the company's revenues in million US dollar units. Source: Trucost.
MW (30,91,182,273,365)	Option-implied annualized cost of equity measure over the horizon of 1-month, 1-quarter, 2-quarter, 3-quarter and 1-year, by Martin and Wagner (2019). Source: OptionMetrics database.
GLB (30,91,182,273,365)	Option-implied annualized cost of equity measure over the horizon of 1-month, 1-quarter, 2-quarter, 3-quarter and 1-year, by Chabi-Yo et al. (2023). Source: https://osf.io/7xcqw/.
LNme	At the end of each month, we calculate log market equity as the log of the product of the stock prices (PRC) with the number of outstanding shares (SHROUT). Source: CRSP Monthly Stock.
LNbe	At the end of each quarter, we calculate log book equity as the log of the sum of shareholder equity (SEQ), deferred taxes, and investment tax credit (TXDITC), minus the book values of preferred stock (PSTK). Quarterly deferred taxes and investment tax credits are aggregated for four quarters. Source: Compustat North America Fundamentals Quarterly and Annual.
Beta	At the end of each month, we regress monthly stock excess returns over the risk-free rate, on monthly market excess returns, using a 60-month moving window from 2000 to 2021. We require that there are at least 24 months of non-missing returns. Stock returns data are obtained from the CRSP Monthly Stock database. The risk-free rate and excess market returns data are obtained from Kenneth R. French Data Library.
Profit	At the end of each quarter, we calculate profitability as the ratio of operating profits to book equity, where the operating profits are annual revenues (REVT) minus the sum of cost of goods sold (COGS), selling, general, and administrative expenses (XSGA), and interest and related expenses (XINT), following Fama and French (2015). Quarterly accounting flow variables are aggregated for four quarters. Source: Compustat North America Fundamentals Quarterly and Annual database.

Table continued

Table B.1. continued

Variable	Definition
Gat	At the end of each quarter, we calculate investment as the annual log growth rate of the total assets (AT) following Fama and French (2015). Source: Compustat North America Fundamentals Quarterly and Annual.
DivAbe	At the end of each quarter, we calculate annual dividends (DIV) per split-adjusted share times shares outstanding divided by book equity. Source: CRSP Monthly Stock database, Compustat North America Fundamentals Quarterly and Annual.
BtM	At the end of each quarter, we calculate the ratio of book equity to market equity. Source: CRSP Monthly Stock database, Compustat North America Fundamentals Quarterly and Annual.
Momentum	The momentum of the stock n measured at the end of the month t is the cumulative return of the stock during the 11-month period covering months t-11 through t-1. Source: CRSP Monthly.
Size	At the end of each quarter, we calculate size as the natural logarithm of a firm's total assets (AT). Source: Compustat North America Fundamentals Quarterly and Annual.
Tangibility	Tangibility is the ratio of property, plant, and equipment (PPENT) to total assets (AT). Data are obtained from Compustat North America Fundamentals Quarterly and Annual.
Leverage	Leverage is total debt (DLTT+DLC) to total assets (AT). Source: Compustat North America Fundamentals Quarterly and Annual.
Capx	Capital expenditures (CAPX) divided by total assets (AT). Source: Compustat North America Fundamentals Quarterly and Annual.
R&D	Research and development expenses (XRD) divided by total assets (AT). Missing XRD values set to zero. Source: Compustat North America Fundamentals Quarterly and Annual.
Cash	Cash and short-term investments (CHE) divided by total assets (AT). Source: Compustat North America Fundamentals Quarterly and Annual.
IO	Institutional ownership is the percentage ownership held by the institutional investors (INSTOWN PERC) at the end of the quarter. Source: Thomson Reuters.

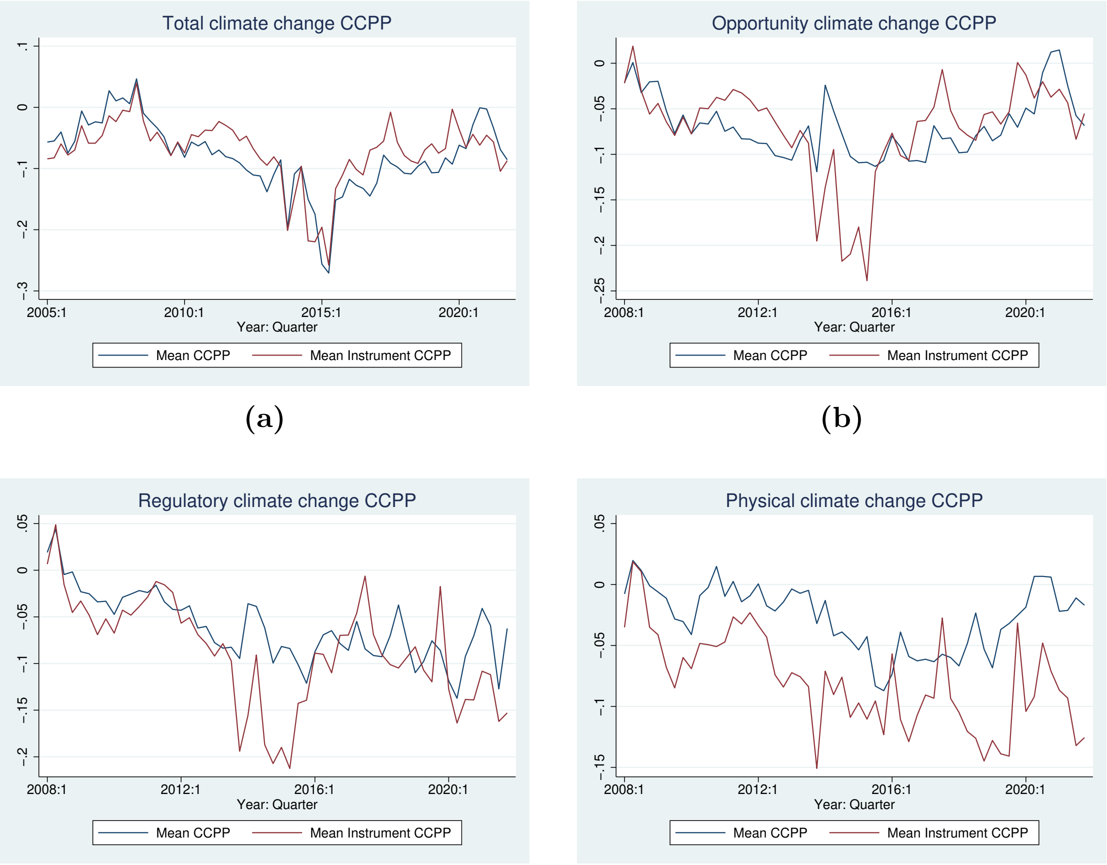
B.3 Option implied expected returns

To calculate Martin and Wagner (2019) option-implied expected excess return, we obtain the time-varying daily list of S&P 500 constituent stocks from the Center for Research in Security Prices (CRSP) from 2005 to 2021 using the Python code shared by WRDS. We download the daily implied volatility data on the S&P 500 constituent stocks' options and S&P 500 index options from the Volatility Surface of the OptionMetrics database. For each underlying stock, we select the out-of-the-money call and put options with absolute delta values smaller than 0.5 for the standardized maturities of 30, 91, 182, 273, and 365 days. We obtain the daily forward prices and daily zero-coupon rates with corresponding maturities from the Forward Price and the Zero Coupon Yield Curve of OptionMetrics, respectively, and the daily spot prices from the Security Prices of OptionMetrics.

To approximate the integrals in equations (7) and (8), for each underlying stock, maturity, and time, we interpolate the available implied volatilities as a function of moneyness (K/S), following Chabi-Yo et al. (2023). Specifically, we first define a moneyness grid of 1000 equally-spaced points within the [1/3, 3] range. Then, we apply a piecewise cubic Hermite polynomial to interpolate the implied volatility. Outside the moneyness range [1/3, 3], we extrapolate horizontally. Next, we convert implied volatilities to the corresponding call and put prices by employing the Black and Scholes (1973) formula, and we compute the risk-neutral variances. We calculate the option-implied cost of equity on a daily basis and then we take its average over each quarter, in line with Sautner et al. (2023a). We calculate the option-implied cost of equity for alternative horizons (1 month, 1 quarter, 2 quarters, 3 quarters, and 1 year) corresponding to the index and equity options' standardized maturities of 30, 91, 182, 273, and 365 days.

C Instrumentalized CCPP: Patterns of cross-sectional average

Figure C.1, Panels (a) to (d), plot the cross-sectional average of the CCPPs (instrumentalized CCPPs) of the S&P 500 constituent stocks over time stemming from investors' portfolio rebalancing triggered by changes in stocks' (industry average excluding the focal company) total, opportunity, regulatory, and physical exposures, respectively. The patterns of CCPPs and instrumentalized CCPPs are similar.



(a) **(b)**

(c) **(d)**

Figure C.1. Panels (a) to (d) plot the cross-sectional average of the CCPPs (instrumentalized CCPPs) of the S&P 500 constituent stocks (before cross-sectional standardization) arising from investors' portfolio rebalancing triggered by changes in stocks' (industry average of) total, opportunity, regulatory, and physical climate change exposures, respectively. CCPP is calculated by equation (3). For CCPPs stemming total climate change exposures, the sample period is from 2005:1 to 2021:4. For CCPP stemming from topic-based climate change exposures, the sample period is 2008:1 to 2021:4; this choice is dictated by the considerations on the climate change exposure data outlined in Sautner et al. (2023b).