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CEO Exposure to Abnormally Hot Temperature and Corporate Carbon Emissions

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Abstract

This paper examines whether CEOs react to personal experience with global warming. Using a difference-in-differences setting, we find that CEOs' exposure to abnormally hot temperature leads to a decrease in corporate carbon emissions intensity. Our results shed light on the role played by CEOs' perception of the reality of climate change in reducing corporate carbon emissions.

Keywords: Carbon emissions, Climate change, CEO behavior, Personal experience

JEL: G30, Q54

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1. Introduction

Survey evidence indicates that many investors are now considering environmental issues, and climate change, in their investment decisions (Krueger et al. 2020). Related studies show that investors react to environmental disasters (Capelle-Blancard and Laguna 2010). Leading institutional investors also increasingly engage with individual companies on environmental issues (e.g., Azar et al. 2021; Flammer et al. 2021). This shareholder pressure on companies is best illustrated by the 2020 letter to CEOs by the head of BlackRock, referring to climate change as a defining factor in companies' long-term prospect and encouraging CEOs to tackle it at their company level.

In response to increased shareholder pressure, many companies have committed to a “net-zero” emissions target.¹ Carbon emissions is one of the main drivers of global warming (IPCC, 2021) and companies can take actions to reduce them. Despite these voluntarily commitments, it is not clear whether corporate leaders are indeed willing to take drastic actions to reduce carbon emissions.² For example, Bolton and Kacperczyk (2021) show that the effect of commitment initiatives on overall emissions of publicly traded companies has been small and that the companies that make the most ambitious commitments tend have low carbon emissions. Research is thus needed to understand the factors that may encourage corporate leaders to significantly reduce carbon emissions.

In this study, we explore the role played by CEO personal experience with global warming. Specifically, we posit that CEOs, who have been exposed to abnormally hot temperatures, revise their perception of the reality of global warming, and, as a result, reduce carbon emissions. Our conjecture rests on two bodies of the literature showing respectively that CEOs' life experiences affect corporate policies and outcomes (e.g., Benmelech and Frydman 2015; Bernile et al. 2017;

¹ Source: <https://hbr.org/2021/06/your-company-pledged-to-reduce-its-carbon-footprint-now-what>

² Source: <https://www.marketplace.org/2019/10/18/more-companies-are-taking-on-climate-change-are-they-doing-enough/>

Cronqvist and Yu 2017; Dittmar and Duchin 2016) and that personal exposure to abnormally hot temperature increases people's awareness about global warming and its consequences (e.g., Akerlof et al. 2013; Myers et al. 2013; Zaval et al. 2014).³

We empirically test whether CEOs' exposure to abnormally hot temperature affects corporate carbon emissions using a sample of large U.S listed companies over the period 2002-2018. We conduct a staggered difference-in-differences analysis following Baker et al. (2021)'s recommendations. We find that CEOs respond to an exposure to abnormally hot temperature by reducing carbon emissions intensity. In the two years following the CEOs' exposure, on average, treated firms reduce their carbon emissions by 27 tons per million dollars of assets relative to control firms. This effect accounts for more than 10% of a standard deviation and corresponds to a decrease in emissions of 378,000 tons. While we cannot unequivocally eliminate endogeneity concerns⁴, increased CEO awareness of climate change is the most likely mechanism driving the decrease in carbon emissions we observe.

Our paper contributes to the literature studying the determinants of firm's environmental behaviors, and corporate emissions in particular. Prior studies highlight the role played by stock market listing (Shive and Foster 2020), financial constraints and resources (Cohn and Deryugina 2018; Xu and Kim 2020), shareholder activism (Akey and Appel 2019; Azar et al. 2021), legal liability protections (Akey and Appel 2021), and hometown favoritism (Li et al. 2021). It also adds to the literature examining how managerial and investor decisions and actions relate to personal life experiences such as early-life disasters (e.g., Bernile et al. 2017), family-related experiences (e.g., Cronqvist and Yu 2017; Roussanov and Savor 2014), macroeconomic shocks (e.g., Malmendier

³ Even though extreme local temperature provides negligible information about global warming, it represents a noticeable and salient event for people living in the area. Choi et al. (2020) show that extreme local temperatures serve as wake-up calls that alert people and investors to climate change. Howe et al. (2013) document that public perceptions correspond with patterns of observed temperature change from climate records: individuals who live in places with rising average temperatures are more likely than others to perceive local warming.

⁴ Temperature shocks may have direct effects on carbon emissions through a decrease in the energy used (heaters, air conditioning) in the firm's buildings or by affecting more generally the firm's activity. However, in these cases, the decrease in carbon emissions would be temporary and only observed during the year of the temperature shock. By contrast, we document that the decrease in carbon emissions is relatively long-lasting (up to two years after the shock).

and Nagel 2011; Schoar and Zuo 2017), or professional experiences (e.g., Benmelech and Frydman 2015; Dittmar and Duchin 2016).

2. Data, Measures, and Sample

2.1. Data

We obtain accounting data from Compustat, data on carbon emissions from Asset 4, and temperature data from the National Climatic Data Center (NCDC). The data are constructed based on weather records from about 5,900 stations covering the U.S. between 1973 and today.⁵

2.2. Abnormally Hot Temperature Shock

Our empirical analysis exploits the occurrence of an abnormally hot temperature in the close vicinity of the CEO's location. Following common approach in the literature (e.g., Dai et al. 2020; Deng and Gao 2013; Levine et al. 2018), we approximate the CEO's location by the city of the firm's headquarters. Managers are likely to live close to the city of the firm's headquarters is located and spend considerable time at the firm's headquarters. We measure the temperature in a city by matching it to its nearest station based on their respective coordinates.⁶ Following Choi et al. (2020), we decompose local temperature in three components, which account for predictable, seasonal, and abnormal patterns:

$$Temperature_{it} = Aver_{Temp_{it}} + Mon_{Temp_{it}} + Ab_{Temp_{it}} \quad (1)$$

where $Temperature_{it}$ is the actual temperature measured in city i in month t ; $Aver_{Temp_{it}}$ is the average monthly local temperature in city i over the 120 months prior to t ; $Mon_{Temp_{it}}$ is the average deviation of this month's temperature from the average, i.e., the average temperature in city i in the

⁵ The NCDC is a standard source for temperature data and is increasingly used in the finance literature to assess the effect of temperature on different outcomes (e.g., Choi et al. 2020).

⁶ For each city, we retrieve the coordinates (latitude and longitude) from Google Map. To match a city to its nearest station based on their respective coordinates, we use the Stata command *gnear*. We require the station to have at least 10 years of historical data prior to the year of matching to be able to compute our monthly measure of abnormal temperature. *Gnear* provides us with the number of kilometers between the city coordinates and the nearest matched station. In the robustness section, we show that our results hold when we use more stringent thresholds (i.e., 10 kilometers).

same calendar month over the last 10 years minus $Aver_Temp_{it}$. Figure 1 shows the mean abnormal temperature per year over 2001-2018. Consistent with our construct capturing periods of abnormally hot temperature, we observe an important spike in 2012 that coincides with an important heatwave in the US.

Our focus is on the abnormal temperature experienced by a CEO over the year. To obtain it, we average the monthly abnormal temperature over the last twelve months. Then, we capture a CEO's exposure to abnormally hot temperature using a dummy that takes the value 1 if the abnormal temperature in a city over the last twelve months is greater than 2 Fahrenheit degrees. The 2°F cutoff roughly corresponds to a one-standard deviation above the mean in the distribution of abnormal temperature in our sample and is motivated by the fact that the highest abnormal local temperatures are the most salient.⁷ Prior evidence suggests that individuals pay more attention to infrequent dramatic changes than to frequent gradual changes (Da et al. 2014). An abnormal temperature of at least 2°F likely represents an experience with global warming that is salient and noticeable for CEOs.

2.3. Carbon Emissions

Scope 1 emissions are direct emissions from owned or controlled sources. *Scope 2* emissions are indirect emissions from the generation of energy consumed and purchased by the company.⁸ Consistent with prior studies (e.g., Ilhan et al. 2020), we use a measure of carbon emission intensity (i.e., emissions scaled by company size) to account for the fact that large firms have high carbon emission levels. Our main variable of interest is therefore the sum of Scope 1 and Scope 2 carbon emissions scaled by total assets to capture changes in carbon emissions per unit of assets.⁹

⁷ In robustness tests, we check that our results hold with alternative thresholds and alternative ways to capture the exposure of CEOs to abnormally hot temperature.

⁸ Scope 1 and Scope 2 emissions are easier to measure and subject to stricter disclosure requirements than Scope 3 emissions, which consists in indirect emissions (not included in Scope 2) that occur in the value chain of the reporting company, including both upstream and downstream emissions. As such, data on scope 1 and scope 2 emissions have been more systematically reported and accurately estimated (Bolton and Kacperczyk 2020). Consistent with prior studies (e.g., Ilhan et al. 2020), we therefore focus on Scope 1 emissions and Scope 2 emissions. Moreover, Scope 3 emissions are to a larger extent beyond the control of CEOs.

⁹ Moreover, firm commitments are generally based and influenced by carbon emission intensity (Bolton and Kacperczyk 2021).

2.4. Sample

Our starting point are US listed companies for which carbon emissions data are available and for which we can compute our independent and control variables. As explained in Section 3, for the difference-in-differences analysis, we require 5 consecutive years of data around each temperature shock. It results in a final sample of 5,757 firm-year observations for the period 2002-2018.

3. Empirical Strategy

In our sample, shocks are staggered over time, i.e., temperature shocks affect CEOs located in cities at different points in time and a given CEO may be shocked several times. Baker et al. (2021) show that two-way fixed effects difference-in-differences analyses are likely to be biased in presence of such a treatment heterogeneity. We follow Baker et al. (2021) and Cenzgi et al. (2019) and implement a stacked regression estimator correcting for this bias. By stacking and aligning events in event-time, this approach is equivalent to settings where the events happen contemporaneously, and it prevents using past treated units as effective comparison units, which may occur with a staggered design.

More specifically, we create event-specific datasets (cohorts) and then stack them in relative time to calculate an average effect across all the events using a single set of treatment indicators. We consider a window of two years before and after each temperature shock ($[-2; +2]$), which allows for enough time to observe a change in carbon emissions. Each year, we single out the treated firms and require them not to have been treated in the previous two years. For the same year, we define control firms as those for which CEOs are not shocked over the entire time window $[-2, +2]$. Hence, we obtain a cohort of treated and control firms for each year and stack them into a new dataset.

We then estimate the following stacked difference-in-differences regression:

$$CO2\ Emissions_{itg} = \alpha_{ig} + \gamma_{tg} + Treated_{ig} \times Post_{tg} + X_{itg} + \epsilon_{itg} \quad (2)$$

We saturate the firm and year fixed effects with indicators g for the specific cohort the observations belong to.¹⁰ That is α_{ig} and γ_{tg} are unit and time fixed effects specific to each cohort. $Treated_{ig}$ and $Post_{tg}$ are subsumed by the fixed effects. X_{itg} is a set of time-varying firm control variables. In line with prior literature exploring the determinants of firms' environmental behavior (e.g., Akey and Appel 2019; Cohn and Deryugina 2018; Shive and Foster 2020), we control for size, return on assets, market-to-book, leverage, cash, and asset tangibility. Appendix A provides the variable definitions. The main variable of interest is $Treated_{ig} \times Post_{tg}$. Its coefficient captures the difference in carbon emissions intensity for treated firms before and after the temperature shocks, relative to control firms.

4. Results

Table 1 reports the summary statistics for the main variables. The carbon emissions of a company are expressed in tons of CO2 equivalent divided by the company's total assets in million U.S. dollar units. The average carbon emissions in our sample equals 153 tons/millions. The percentage of treated firms (i.e., firm-year observations with a CEO exposed to abnormally hot temperature) is 18%.

Table 2 presents the results of the estimation of Eq. (2) without and with firm-level control variables. It reports the estimation results including the year of the treatment year 0 (Columns 1 and 2) or excluding it (Columns 3 and 4). The coefficient on $Treated \times Post$ is negative and statistically significant, suggesting that CEOs respond to abnormally hot local temperature by reducing carbon emissions. Based on Column 2, carbon emissions decrease by 27.2 tons/millions relative to control firms. The effect is economically sizeable. It represents more than 10% of the standard deviation. On average, 1 million dollars of a firm's assets produce 27 tons of carbon emission less. Given that the average total asset in our sample is 14 billion dollars, it amounts to an average reduction of 378,000 tons ($14,000 \times 27$).

¹⁰ There are 12 different cohorts in total, one for each year in our sample period 2004-2016.

The difference-in-differences design assumes parallel trends. Specifically, identification relies on the assumption that absent the treatment (i.e., CEO's exposure to abnormally hot temperature), the outcome variable (i.e., carbon emissions) would have behaved in a similar way across treated and control firms. We therefore assess the dynamics of the treatment effect. Specifically, we re-estimate the baseline specification in Eq. (2) by replacing *Post* with indicator variables indicating years relative to the treatment. The results show that the coefficients on *-2 Year X Treated* and *-1 Year X Treated* are not statistically different from zero, indicating that there is no difference in carbon emissions between treated and control groups before the treatment. The decrease in carbon emissions is only observed in the years following the CEO's exposure to abnormally hot temperature.

As reported in Table 4, our results are robust to alternative definitions of abnormally hot temperature shocks: top quintile or top quartile of the yearly abnormal temperatures, or at least one standard deviation above the mean (cutoff point at 1.78 instead of 2 in that case).

5. Conclusion

Our results point to the reality of global warming, which becomes tangible through personal experience, pushing CEOs to act against climate change by reducing corporate emissions. With manifestations of global warming increasing in the recent years (IPCC, 2021), for instance during the recent megadrought episode in the US, one can expect more and more CEOs to be confronted to the reality of global warming, which, as our results suggest, should sustain a greater effort to reduce carbon emissions.

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Figure 1. Mean abnormal temperature over years

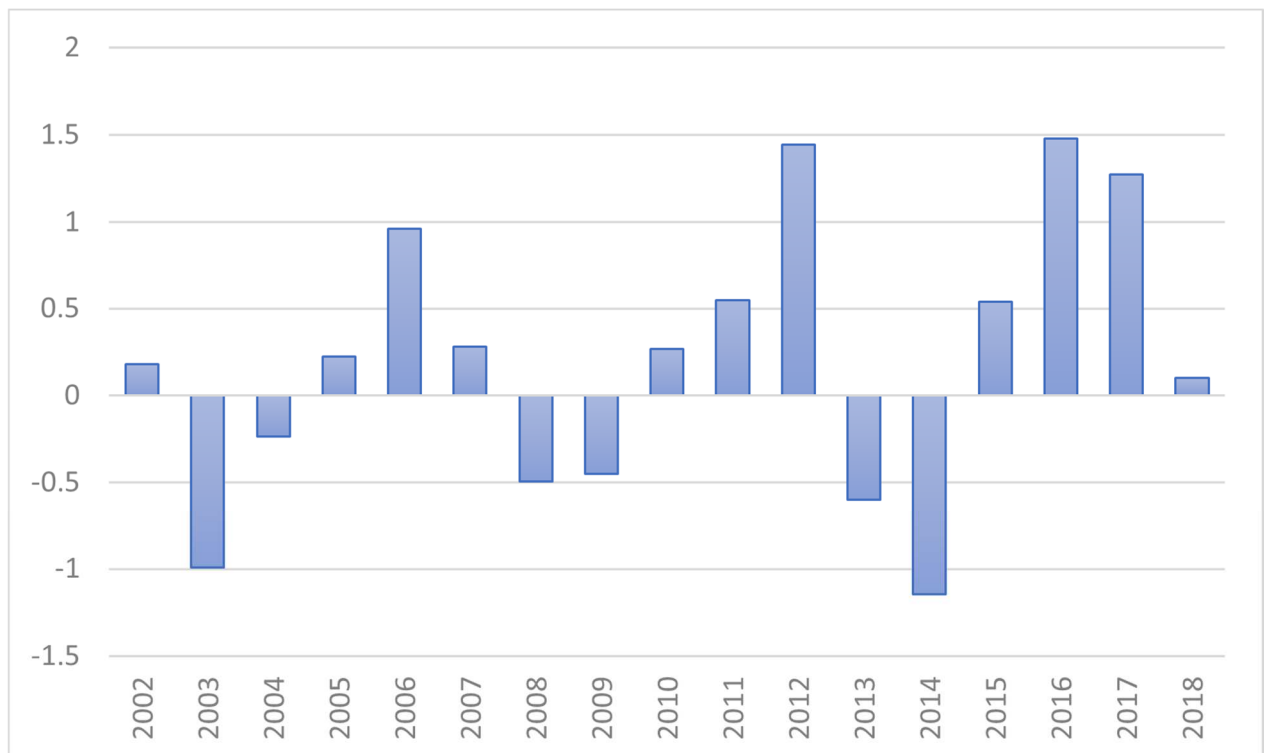


Table 1. Descriptive statistics

Appendix A provides the variable definitions.

Variables	#Obs.	Mean	S.D.	Min	0.25	Mdn	0.75	Max
Treated	5,757	0.18	0.38	0.00	0.00	0.00	0.00	1.00
Carbon Emission Intensity	5,757	153.94	430.70	0.02	14.73	42.73	149.89	7906.24
Size	5,757	9.48	1.00	6.64	8.66	9.50	10.47	10.72
Return on Asset	5,757	0.07	0.09	-1.23	0.04	0.07	0.11	0.43
Market-to-Book	5,757	3.53	10.59	-86.67	1.88	2.93	4.53	72.67
Debt Ratio	5,757	0.26	0.16	0.00	0.15	0.23	0.34	2.44
Cash	5,757	0.15	0.14	0.00	0.05	0.11	0.21	0.80
Tangibility	5,757	0..28	0.23	0.02	0.10	0.19	0.39	0.93

Table 2. DiD estimation results

This table reports the estimation results of Eq. (2). It reports the results with and without controls, and with or without including the year 0 in the sample. The main dependent variable is *Carbon Emission Intensity*, i.e., Scope 1 & 2 carbon emissions scaled by total assets. The main independent variable is $Treated \times Post$, whereby *Post* takes the value 1 in the two years (or three years when in include $t=0$) following the exposure, and 0 otherwise. *Treated* is equal to one if the firm's CEO has been exposed to an abnormally hot temperature in year 0. All regressions include both year-cohort and firm-cohort fixed effects. Robust standard errors, clustered by firm, are reported in parentheses. *, **, and *** denote significance at the 10%, 5% and 1% level, respectively. Constants are not reported. Appendix A provides the variable definitions.

	(1)	(2)	(3)	(4)
Carbon Emission Intensity	[-2,+2] window & omitting $t=0$	[-2,+2] window & omitting $t=0$	[-2,+2] window & including $t=0$	[-2,+2] window & including $t=0$
<i>Treated</i> × <i>Post</i>	-24.116** (10.443)	-27.182** (10.875)	-18.151** (8.921)	-20.563** (9.273)
<i>Size</i>		-79.343*** (22.685)		-77.391*** (19.707)
<i>Return on Asset</i>		5.367 (29.874)		9.793 (24.752)
<i>Market-to-Book</i>		0.057 (0.057)		0.049 (0.045)
<i>Debt Ratio</i>		-70.610* (41.882)		-55.992 (36.152)
<i>Cash</i>		-40.526 (31.655)		-41.674* (25.171)
<i>Tangibility</i>		-58.516 (96.706)		-23.892 (82.992)
Observations	4,325	4,301	5,524	5,492
Time × Cohort Fixed Effects	Yes	Yes	Yes	Yes
Firm × Cohort Fixed Effects	Yes	Yes	Yes	Yes
Adjusted R-squared	0.971	0.973	0.975	0.978

Table 3. Dynamic treatment effect estimation

This table reports the estimation results of Eq. (2) but replacing the *Post* dummy by yearly dummies. It reports the results with and without controls. The main dependent variable is *Carbon Emission Intensity*, i.e., Scope 1 & 2 carbon emissions scaled by total assets. All regressions include both year-cohort and firm-cohort fixed effects. Robust standard errors, clustered by firm, are reported in parentheses. *, **, and *** denote significance at the 10%, 5% and 1% level, respectively. Constants are not reported. Appendix A provides the variable definitions.

Carbon Emission Intensity	(1) [-2,+2] window & omitting t=0	(2) [-2,+2] window & including t=0
<i>-2 Year × Treated</i>		15.151 (12.000)
<i>-1 Year × Treated</i>	-5.117 (8.974)	9.815 (6.245)
<i>1 Year × Treated</i>	-27.193** (12.364)	-10.533* (5.554)
<i>2 Year × Treated</i>	-32.970** (16.340)	-16.097** (7.213)
Observations	4,301	5,492
Controls as in Table 2	Yes	Yes
Time × Cohort Fixed Effects	Yes	Yes
Firm × Cohort Fixed Effects	Yes	Yes
Adjusted R-squared	0.973	0.978

Table 4. Alternative definitions of hot temperature shocks

This table reports the estimation results of Eq. (2) but using alternative definitions of hot temperature shocks. Robust standard errors, clustered by firm, are reported in parentheses. *, **, and *** denote significance at the 10%, 5% and 1% level, respectively. Constants are not reported. Appendix A provides the variable definitions.

Carbon Emission Intensity	(1) Top Quintile	(2) Top Quartile	(3) One std. above (>1.78)
<i>Treated × Post</i>	-29.469*** (10.553)	-24.583** (10.969)	-22.960** (9.999)
Observations	2,921	2,559	3,448
Controls as in Table 2	Yes	Yes	Yes
Time × Cohort Fixed Effects	Yes	Yes	Yes
Firm × Cohort Fixed Effects	Yes	Yes	Yes
Adjusted R-squared	0.975	0.968	0.975

Appendix A. Variable definitions

Variables	Definitions	Sources
Size	Natural logarithm of total assets.	Compustat
Return on Asset	Net income scaled by total assets.	Compustat
Market-to-Book	Market value of equity dividend by book value of equity.	Compustat
Debt Ratio	Short-term plus long-term debt scaled divided by total assets.	Compustat
Cash	Cash and short-term investment scaled by total assets.	Compustat
Tangibility	Net property, plant, and equipment scaled by total assets.	Compustat