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CEO age and corporate environmental policies

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ABSTRACT

This study examines the link between CEO age and firm environmental performance. Building on the upper echelons theory, we predict that a firm is more environmentally friendly if CEOs are younger. Using hand-collected data of a total 12,512 plant-year observations for 1,074 individual firms in the period from 2010 to 2022, we document evidence that younger CEOs release significantly less greenhouse gas emissions, consistent with our conjecture. Additionally, we note that younger CEOs outperform older CEOs in terms of greenhouse gas emissions by investing more in abatement initiatives, increasing manufacturing efficiency, and increasing their use of ecologically friendly fuel. Our evidence of CEO age offers relevant implications for directors, shareholders, and financial regulators.

1. Introduction

The main contributor to global warming is carbon emissions produced by human activities.[1] There is a wide consensus that controlling carbon emissions is crucial to slowing the global warming trend. Abatement efforts are undertaken worldwide in order to reduce emissions, especially with the adoption of the Paris Agreement in 2015 by 196 parties. The corporate sector is mainly responsible for carbon emissions, but there is a lack of research concerning the drivers of corporate carbon emissions. The Chief Executive Officer (CEO) is one of the key players in a corporation (Altarawneh et al., 2022). Empirical research has shown evidence concerning the important effects of CEO traits on corporate performance and decision-making (Serfling, 2014; Tang et al., 2015). In terms of the influence of CEOs on corporate emission releases, previous studies have evaluated some of the CEO characteristics such as the CEO's gender (Nuber and Velte, 2021; Wang and Yu, 2019; Altunbas et al., 2022), CEO tenure (Chen et al., 2019) and CEO education (Amore et al., 2019). Among others, Wang and Yu (2019) assess the women's role in firm environmental policy. They argue that female CEOs are more concerned with the environment. Meanwhile, Altunbas et al. (2022) investigate CEO gender and firm-level carbon dioxide. Ren et al. (2021) examine the link between CEO ethical leadership and the environmental performance of firms. Nevertheless, there is a lack of evidence on the link between CEO age and the emissions releases of firms. This study aims to bridge this gap by investigating how CEO age affects corporate environmental policies at both the plant and the company levels.

According to the upper echelons hypothesis (Hambrick and Mason, 1984), the traits, experiences, and values of the CEO have a significant impact on the strategic decisions and corporate outcomes of the organization. In particular, the theory posits that based on their individual experiences, attitudes, and personalities, executives interpret their surroundings in a certain way, leading the

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[1] https://climate.ec.europa.eu/climate-change/causes-climate-change_en.

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differences on the organization actions. The upper echelons theory also suggests that it is possible to predict strategic decisions and organizational success using observable traits like age, education, and career routes. Since the introduction of this theory, there is a growing body of work that investigates how CEO qualities and life experiences influence corporate decision-making (Chin et al., 2013; Bernile et al., 2017; Sunder et al., 2017; Bandiera et al., 2020). Among others, O'Sullivan et al. (2021), provide evidence that the early life experience of trauma of a CEO has a positive association with corporate social performance. Related to this research, Malmendier and Nagel (2011) investigate the decision-making process of CEOs who had a military history or grew up during the Great Depression.

Meanwhile, recent studies state that CEO gender or gender diversity on the board of directors also has a significant effect on a firm's investment and risk preference (Ahern and Dittmar, 2012, Faccio et al., 2011). For example, Borghesi et al. (2014) argue that female CEOs, and younger CEOs are less likely to engage in Corporate Social Responsibility (CSR). Zhou et al. (2021) suggest that Chinese companies with well-educated CEOs tend to participate more in environmental innovation, especially if they operate in environmentally sensitive areas. Supporting this viewpoint, Wang et al. (2022) also find a considerable effect between the level of education and CEO's decisions that aim to protect the environment. Based on the above argument, we expect that CEO age, which is related to the life experience of a CEO has a fundamental role to play in the environmental policies of a corporation.

In order to test the above hypothesis, we use emission statistics from Greenhouse Gas Reporting Program (GHGRP), which is a unique database containing plant-level information. We match this data with hand-collected information on the age of CEOs'. This provides us with a unique dataset, that can empirically examine the association between the age of a CEO and carbon emissions. As predicted, we report that younger CEOs release significantly less greenhouse gas (GHG) emissions. The CEO-age effect has both economic meaning and statistical significance. Our findings remain intact when we conduct a set of extra checks, including analysis using different measures of GHG emissions and CEO age, as well as additional tests incorporating the CEO age range instead of CEO age.

We perform further empirical tests in order to provide robustness for our main findings. Firms with different characteristics may lead to differences in CO2 releases and this effect is not fully captured by using linear control variables in our model. Hence, we undertake a propensity score matching strategy to deal with this potential problem. Firms with fewer emissions releases may be more inclined to appoint a younger CEO, and/or there could be some omitted variables influencing both CEO age and emission release, which all drive our baseline model results on the link between CEO age and firms' emission releases. In order to encounter the impact of endogeneity, we use an instrumental variable approach to re-estimate our main regression. We also control for the implication of freshly appointed CEOs and CEOs reaching retirement.

We also investigate the possible channels that can explain the impact of CEO age on carbon release. We argue that there are two potential channels including the awareness about environmental and climate change issues, and the career concerns of young CEOs. Specifically, young CEOs are believed to have a better awareness of climate change and its impact. Thus, they are more likely to release less carbon emissions. Moreover, younger CEOs have a longer career horizon and thus have incentives to improve their image and reputation, by investing more in environmental investments and increasing corporate environmental performance. To test this argument, we employ changes in the enforceability of non-compete agreements (NCAs) as an exogenous shock to CEO career concerns following previous research (Ewens and Marx (2018); Ali et al., 2019). In our context, increased NCA enforceability translates to lower CEO mobility within the external labor market, limiting outside employment opportunities and intensifying career concerns. The coefficient estimates for the interaction term, Non-Compete*CEO Young, are negative and statistically significant at the 1 % level across all specifications.

Finally, we look into what actions a CEO takes to cut back on emissions. We find evidence that younger CEOs improve their GHG performance by increasing investment in abatement activities, improving production efficiency, and relying more on environmentally friendly fuel.

We believe that our research contributes to the following areas of the academic literature. First, our analysis enhances the well-established research studying various determinants of CSR and firms' environmental, social, and governance (ESG) performance (Li and Wu, 2020; Liu et al., 2021; Li et al., 2023; Gaganis et al., 2023) including recent evidence uncovering factors relating to the board of directors (Firoozi and Keddie, 2021; Jain and Zaman, 2020) and CEO characteristics (Arena et al., 2018; Cronqvist and Yu, 2017; Hegde and Mishra, 2019; Ortiz-de-Mandojana et al., 2019; Wang and Yu, 2019). In particular, we suggest that younger CEOs tend to release less emissions. Our paper also enriches the recent evidence of factors affecting firms' toxic releases and GHG (carbon) emissions, including executive compensation (Haque and Collins, 2020), limited liability (Akey and Appel, 2020), stock market listing (Shive and Forster, 2020), the role of institutional investors (Azar et al., 2021); the degree of financial constraint (Xu and Kim, 2022); managerial ability (Gaganis et al., 2023); CEOs' social network (Li et al., 2023); and CEO risk-aversion (Hossain et al., 2022). We expand this growing stream of literature by documenting that CEO's age significantly affects the company's carbon performance. Furthermore, we discuss and provide the test for potential channels that can explain the relationship between CEO's age and corporate carbon emissions. We suggest that due to the career concern, the young CEOs tend to release less emissions.

Second, we advance knowledge on the impact of CEOs' age connections on firm decisions, including trade credit (Kong et al., 2020), investment policies (Serfling, 2014); tax planning (James, 2020) and working capital management (Burney et al., 2021). Our research is one of the first papers that investigates the relationship between CEO age and environmental decisions of firms. We suggest that CEOs' age is relevant to the emission releases of firms. At a broader level, our discovery that younger CEOs help improve company GHG performance relates to a broader economics literature (Do et al., 2017).

Finally, we add to the body of research linking CEO traits to business performance and results. Existing studies show that corporate decisions are determined by CEO traits and preferences, including work experience (Custodio and Metzger, 2014), personal taste (Islam and Jason, 2020), (over)confidence (Koh et al., 2018), gender (Wang and Yu, 2019), age (Yim, 2013), reputation and superstar status (Ammann, Horsch and Oesch, 2016), ability and height (Adams et al., 2018), risk appetites (Ouyang et al., 2021); and risk-aversion (Hossain et al., 2022), among others. This study contributes to this literature by providing empirical evidence that CEO age shapes company decisions (e.g., Sefling, 2014; Andreou et al., 2017; James, 2020; Burney et al., 2021).

Our findings concerning CEO age and corporate environmental performance have important implications for the board of directors, shareholders, and financial regulators. First, our research may influence the age diversity of boards of directors, with a potential emphasis on appointing younger CEOs to improve environmental performance. This is because as younger CEO's tend to release less emissions, when assessing the CEO's performance and determining their tenure, directors may need to take their age into account. With respect to shareholders, our evidence offers relevant information for evaluating the environmental performance of companies and making investment choices. Shareholders may push for modifications to corporate governance procedures that support environmental sustainability by adopting stricter environmental regulations or selecting younger CEOs. Finally, our paper could also inform the development of regulatory policies related to environmental performance and corporate governance.

The remainder of the paper is constructed as follows. Section 2 reviews the research on CEO characteristics and corporate environmental performance. It also develops our testable hypothesis. Section 3 describes our dataset and sample. Section 4 reports our findings along with robustness tests. Finally, Section 5 concludes our paper.

2. Literature Review and hypothesis Development

Upper Echelons Theory primarily developed by Hambrick and Mason (1984) proposes that the characteristics of top management significantly influence an organization's strategies, decisions, and overall performance. In particular, the perceptions of top managers can shape organizational actions with their own experiences, values and personalities. Moreover, Managerial characteristics such as age, education, and career paths can be used to anticipate strategic choices and organizational performance. Later, Hambrick (2007) provides a discussion on subsequent refinements of the original Upper Echelons Theory and suggests several directions for future research. He states that fundamental dispositions and biases of top executives are significant determinants of a particular firm's performance. In particular, a manager's knowledge, skills, and value may affect the making-decision process. Based on this theory, considerable previous studies are addressing the role of CEO characteristics on CEO preference and their firm's behavior and corporate policy. Baker and Mueller (2002) provide evidence that the CEO characteristics can be a driver of firms' Research and Development (R&D) spending. They suggest that younger and science-related degree CEOs are more likely to engage in R&D. Several characteristics of a CEO have been considered such as age, gender, tenure and experience. For instance, Serfling (2014) provides evidence that CEO age is negatively related to risk-taking preference. As a result, younger CEOs prefer high risk investments and invest more in R&D projects. Following Li et al. (2017), companies with older CEOs tend to invest less in mergers and acquisitions. Recently, James (2020) provides evidence that younger CEOs significantly impact the tax planning of the firms, by associating with lower rates of taxation and larger permanent book-tax discrepancies.

Recently, there is a growing number of empirical studies examining the impact of CEO traits to corporate environmental behaviour, especially carbon emission release. For instance, Gaganis et al. (2023) investigate on the link between managerial ability and greenhouse gas emission of firms. They show that firms with more able managers tend to release less emission. Li et al. (2023) suggest that social network of CEOs also play an important role in affecting corporate carbon emission. Using a sample in China, they provide evidence that superior carbon performance is seen in firms with better network-CEOs. Meanwhile, focusing on risk tolerance of CEOs, Hossain et al. (2022) argue that firms with risk-aversion emit more greenhouse gas.

We argue that there are two key channels explaining the impact of CEO age on corporate emission release. First, younger CEO's have grown up with a heightened awareness of climate change and its impacts. They recognize that there are serious ramifications for climate change and that it is an urgent subject. As a result, they are more inclined to value environmental sustainability in both their personal and professional lives. Young CEOs therefore typically emit fewer carbon emissions.

Second, career concerns can be a contributing factor to lower emissions under younger CEOs. Previous studies focusing on CEO's characteristics suggest that CEOs have incentives to demonstrate their ability using not only financial performance but also non-financial signals (Chiu and Sharfman, 2016; Ali and Zhang, 2015). Following Hong et al. (2016), CSR performance is also considered when evaluating the CEOs performance. In particular, many public US companies incorporate CSR in CEO remuneration packages. CSR activities can lead to positive attention and thus improve the reputation of a CEO. As a result, a young CEO has more incentive to contribute to CSR investment (Borghesi et al., 2014). The increasing emphasis on corporate social responsibility means that younger CEOs are more likely to be held accountable for their company's environmental performance. Failure to address emissions could have negative consequences for their careers. In addition, younger CEOs have a long career horizon (Shahab et al. 2020) and thus they are under more pressure to demonstrate their social performance and convince the labor market of their value, which makes them more driven to reduce emissions and enhance their public image. The emission reduction plan involves risk due to the requirements of new technology, large financial investment and innovation. According to earlier research (Barker and Mueller, 2002; Cazier, 2011; E-Vahdati and Binesh, 2021) CEOs' career horizons decrease, and they are more inclined to cut back on R&D activities and adopt a more cautious investment strategy as they age. In comparison to their older counterparts, younger CEOs are more agile in adjusting to riskier projects and investments. Finally, environmental risks, such as climate change-related disasters and regulatory penalties, can significantly impact a company's financial performance (Pankratz, Bauer and Derwall, 2023). Younger CEOs may be more inclined to proactively address these risks to protect their careers.

Based on the above discussion, in our current study, we postulate that a CEO's age shapes her/his emission choices. Therefore, we present our hypothesis as follows:

Hypothesis: Younger CEOs tend to release less plant-emissions.

Table 1
Summary Statistics. This table shows summary statistics for the sample of plants and firm between 2010 and 2022 with non-missing variables in our main regression analyses. Continuous variables are winsorized at the 1st and 99th percentiles. Variable definitions are listed in the Appendix.

	No of Obs.	Mean	P25	Median	P75	Std. Dev.
Plant-level variables						
CO2 (thousands of metric tons)	12,512	569.273	17.008	46.841	227.945	1,414.819
CO2e (thousands of metric tons)	12,512	710.790	34.911	73.264	278.445	1,997.553
CO2_R	12,512	80.881	2.406	6.045	24.193	307.367
Abatement Costs ($m)	12,512	162.916	0.000	6.648	77.496	382.150
Production Efficiency	12,512	0.883	0.735	0.917	1.024	0.322
Using Environmentally Friendly Fuel (gas)	12,512	0.575	0.005	0.769	1.000	0.447
Generation (GWh)	12,512	2,358.519	69.262	751.130	3,455.632	3,424.445
#EPA actions	12,512	0.404	0.000	0.000	0.000	2.221
Penalty ($m)	12,512	2.057	0.000	0.000	0.000	12.88
Firm-level variables						
Size	1,035	23.711	3.395	15.597	36.355	24.561
Cash Holdings	1,035	0.326	0.218	0.313	0.419	0.169
PP&E	1,035	0.771	0.471	0.763	1.032	0.368
ROA	1,035	0.108	0.065	0.104	0.148	0.069
Tobin's Q	1,035	1.708	1.256	1.529	1.971	0.687
Investment	1,035	0.058	0.029	0.048	0.074	0.045
Cash Flow	1,035	0.076	0.051	0.076	0.113	0.073
Dividend	1,035	4.846	3.396	5.591	6.811	2.699
Sales Growth	1,035	0.063	−0.030	0.035	0.119	0.208

Table 2
Univariate test. This table presents the results of univariate tests on the level of emission releases, and control variables. Firms are classified as having Younger (Older) CEOs if CEO age is below (above) the sample median. The P-value is calculated using T-tests assuming unequal variance. Variable definitions are listed in the Appendix.

	Younger CEOs	Older CEOs	Difference	(P-value)
CO2 (thousands of metric tons)	537.050	597.737	−60.687	0.000
CO2e (thousands of metric tons)	670.557	746.330	−75.773	0.000
CO2_R	76.303	84.925	−8.622	0.000
Abatement Costs ($m)	171.062	153.694	17.367	0.000
Production Efficiency	0.927	0.833	0.094	0.000
Using Environmentally Friendly Fuel (gas)	0.604	0.542	0.061	0.000
Generation (GWh)	2,225.018	2,476.445	−251.427	0.000
#EPA actions	0.381	0.424	−0.043	0.000
Penalty ($m)	1.941	2.160	−0.219	0.000

3. Data and sample

Following Shive and Forster (2020), we first obtain emission statistics for the US enterprises from the GHGRP. In October 2009, The EPA (Environment Protection Agency) issued the GHGRP, which requires sources emitting 25,000 t or more of CO2e greenhouse gases (GHG) each year to report their emissions using the EPA's estimating techniques. After the EPA verifies the provided information, the data is made public via the Facility Level Information on GHGs Tool (FLIGHT). Using GHRP data, we collect data concerning the plant's geographic location, parent company ownership, North American Industry Classification System (NAICS) industry code, and annual GHG emissions. Our sample period spans from 2010 to 2022 because the data accessibility starts in 2010. The initial sample includes approximately 9,200 individual plants and 90,000 plant-year observations, for which GHG data are available.

To analyze how CEOs' age affects emission releases, we then manually match the data from GHGRP with annual financial and accounting data from Compustat for each firm, based on parent company names.[2] Next, following Lai et al. (2019) and Lim and Nguyen (2021), we hand collect data on the ages of the CEOs in the matched sample from a variety of sources. We first start finding CEO information using NNDB.com and Marquis Who's Who. When this strategy fails to yield the desired data, we turn to Wikipedia. Finally, we conduct comprehensive Google searches using the terms "[CEO full name] + native of" and/or "[CEO full name]." This method enables us to manually gather CEO birth information from different sources and we also can cross-check the information of each CEO when available. Then, our sample is matched with additional firm-level data from BoardEx on CEO attributes and data from the ISS database on corporate governance proxies.

Our final sample includes a total of 12,512 plant-year observations for 1,074 individual firms. Table 1 displays the summary

[2] We use the name of the parent company to match the GHGRP data with Compustat, using the Stata routine, *reclink2*. Then, we manually check all matches with a reclink2 score exceeding 0.90.

Table 3

CEO age and emission releases. This table reports the regression results of the effect of CEO age on emission releases. The main variable of interest is *Ln (CEO age)*, which is the natural logarithm of the age of the CEO. In columns (1) through (3), the dependent variable, *logCO2*, is defined as the natural logarithm of carbon dioxide (CO2) in millions of metric tons. In columns (4) through (6), the dependent variable, *logCO2e*, is defined as the natural logarithm of CO2-equivalent emissions of carbon dioxide, methane, nitrous oxide and fluorinated greenhouse gasses, in millions of metric tons. In columns (7) through (9), the dependent variable, *logCO2_R*, is defined as the natural logarithm of carbon dioxide (CO2) in millions of metric tons, scaled by total revenue. All specifications include year, state, and industry fixed effects, whose coefficients are suppressed. Standard errors, which are adjusted for heteroscedasticity and are clustered at facility level, are reported in parentheses below the coefficient estimates. Variable definitions are listed in the Appendix. The symbols ***, ** and * denote statistical significance at the 1%, 5% and 10% levels, respectively.

	logCO2			logCO2e			logCO2_R		
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Ln (CEO age)	0.237***	0.220***	0.219***	0.356***	0.422***	0.470***	0.416***	0.435***	0.474***
	(0.052)	(0.043)	(0.044)	(0.056)	(0.054)	(0.058)	(0.081)	(0.066)	(0.072)
Firm characteristics									
Size		−0.145	−0.236		−0.164*	−0.269		−0.572***	−0.601***
		(0.092)	(0.253)		(0.092)	(0.239)		(0.095)	(0.227)
Cash Holdings		0.239	0.944		0.253	0.893		0.190	0.921
		(0.392)	(0.713)		(0.367)	(0.703)		(0.388)	(0.717)
CAPX/PPE		0.064	0.078		0.088	0.109		0.178*	0.200*
		(0.124)	(0.128)		(0.116)	(0.123)		(0.101)	(0.109)
Tangible		−0.334	−0.666		−0.507**	−0.814*		−0.508*	−0.703
		(0.266)	(0.543)		(0.251)	(0.491)		(0.276)	(0.542)
Tobin's Q		0.021	0.016		−0.061***	−0.072***		−0.006	−0.007
		(0.021)	(0.022)		(0.018)	(0.019)		(0.022)	(0.023)
Firm Age		−0.296**	0.001		−0.246**	−0.228		−0.244**	−0.406
		(0.147)	(0.330)		(0.124)	(0.273)		(0.108)	(0.275)
CEO characteristics									
Duality			0.033			0.059			0.039
			(0.100)			(0.088)			(0.076)
CEO tenure			−0.029			−0.014			0.002
			(0.021)			(0.010)			(0.012)
Female			−0.270**			−0.071*			0.155
			(0.119)			(0.038)			(0.166)
Education			0.174			−0.228*			−0.331*
			(0.118)			(0.122)			(0.187)
Year Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
State Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Industry Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	12,512	12,512	12,512	12,512	12,512	12,512	12,512	12,512	12,512
R-squared	0.580	0.581	0.577	0.288	0.291	0.252	0.468	0.474	0.399

statistics of our main variables. Following prior empirical studies, all continuous variables are winsorized between 1 % and 99 % to lessen the effect of extreme values. We provide detailed variable definitions in the Appendix. As shown in Table 1, in terms of plant-level variables, the mean of our main variable CO2 is 569,273 thousand of metric tons. The means of CO2-equivalent emissions of carbon dioxide, methane, nitrous oxide and fluorinated greenhouse gasses (CO2e) and carbon dioxide (CO2) in millions of metric tons, scaled by total revenue (CO2_R) are 710.790 thousand of metric tons and 80.881, respectively. Regarding firm-level variables, our sample's mean and median values of firm's size in our sample are 23.711 and 15.597, respectively. Meanwhile, the figures for corporate cash holdings are 0.326 and 0.313, respectively.

Table 2 reports the results of univariate tests on the level of emission releases and control variables to analyze the difference between the younger and older CEO age group. Younger (older) CEOs are defined as the CEO age being below (above) the sample median. As shown in Table 2, younger CEOs release 60.687 thousand of metric tons of CO2 less than older CEOs and this spread is statistically significant with a p-value of 0.000. We see a similar result when conducting the univariate tests on other measures of emissions and other control variables. This observation suggests that the younger CEOs are more environmentally friendly.

4. Empirical results

4.1. CEO age and emission Releases: Baseline analysis

We first examine the *Hypothesis* that CEOs with less years generate fewer emissions. To this end, we follow recent research (e.g., Shive and Forster, 2020) and estimate the following regression model:

$$Log\left(Emissions_{p,i,t}\right) = \alpha + \beta^{*}Ln(CEOage)_{j,t} + \mu^{*}F_{i,t} + \lambda^{*}C_{j,t} + \delta_{t} + \varphi_{m} + \gamma_{k} + \varepsilon_{p,i,m,k,t} \quad (1)$$

Where *p*, *i*, *j*, *m*, *k*, and *t* denote plants, firms, CEOs, states, industries, and years, respectively. As in Chen, Zhou, and Zhu (2018) and Burney et al. (2021), our independent variable of interest is *Ln(CEO age),* calculated as the natural logarithm of the CEO's age. In equation (1), F and C represent a number of CEO- and firm-specific control variables that may have an impact on the emissions from plants. As in Shive and Forster (2020) and Xu and Kim (2020) throughout our analysis, we include the following firm-level controls: *Size*, *Cash holding, Tangible, Tobin's Q, and Firm age*. Several CEO traits and characteristics used in existing studies (e.g., Amore et al., 2019; Burney et al., 2021), namely *Duality*, *CEO tenure*, *Female*, *Education* are added to our analysis as CEO control variables. *Duality* is a dummy variable that equals one when CEO and board chair are the same person, and zero otherwise. *CEO tenure* is the number of years that a CEO has been in office. *Female* is a dummy variable that equals one if the CEO is female, and zero otherwise. *Education* measures the CEO education level, which is the number of years. γ, δ, and φ denote year, state, and industry fixed effects, respectively. ε is the error term.

Table 3 reports our results of the baseline regression, showing the impact of CEO age on firms' emission releases. Following Shive and Forster (2020), we show the results for three alternative proxies of emissions, including (i) the natural logarithm of carbon dioxide (CO2) emissions in millions of metric tons (columns (1)–(3)), (ii) the natural logarithm of CO2-equivalent emissions of carbon dioxide, methane, nitrous oxide, and fluorinated GHG, in millions of metric tons (columns (4)–(6)), and (iii) the natural logarithm of carbon dioxide (CO2) in millions of metric tons, scaled by total revenue (columns (7)–(9)).

Across all model specifications, the estimated coefficients on the *CEO age* variable are positive and statistically significant at the 1 % level, suggesting that plants of firms with younger CEOs' age release significantly less emissions. This finding holds for various types of GHG emissions (e.g., CO2 and CO2-equivalent emissions) across different emission intensities and persists after taking account for firm and CEO characteristics. For instance, the estimated coefficient of CEO age in column (3) is positive with a value of 0.219 and statistically significant at the 1 % level. Moreover, the estimated effect of CEO age on plant emissions is economically meaningful. As shown in column (3), the result suggests that for any 10 % increase in CEO age, the expected ratio of the emission releases is approximately (1.10)ˆ0.219 = 1.021. In other words, there is an increase of 2.1 % in emission releases when CEO age increases by 10 %. Using CO2e as an alternative measure of corporate emission releases, we indicate a similar impact of CEOs' age in emission releases of corporations. For further robustness we also employ the variable logCO2_R as a dependent variable. Similar results are seen in columns (7)-(9), but with greater magnitude. Overall, these results provide empirical support for our *Hypothesis*.

Regarding the independent variables, the estimated coefficient on firm size is negative and statistically significant at the 10 % level, implying that there are economies of scale for reductions in emissions release. We discover that CAPX/PPE is positively connected to plant emission releases of firms, although this impact is only significant in columns (5) and (8), when we ignore the CEO characteristics. Firms with more cash holding seem to release more emissions, although it is not statistically significant. Meanwhile, Tangible, Tobin's Q and firm age have a negative relationship with pollution. However, these relationships are not statistically significant. There is evidence that companies with female CEOs often have lower emissions (columns (3) and (6)); the latter finding is supporting by recent research (e.g., Wang and Yu, 2019). The effect of a CEO's educational level on its plants' emission releases is negative. Emission releases seem to be significantly lower when the CEO has greater educational qualifications. Taken together, while there is strong and consistent evidence of CEO age affecting plants' emissions, the results regarding other firm and CEO characteristics are generally weaker and more mixed.

4.2. CEO age range and corporate emission releases

In this section we run our baseline regression using the CEO age range as the replacement of the continuous CEO age variable, to

Table 4

CEO age range and emission releases. This table reports the regression results of the effect of CEO age on plants' emission reduction activities. The main variable of interest in columns (1), (3), and (5) is *Young CEO*, which is an indicator variable that is equal to one if the CEO age is less than the median value of our sample, and zero otherwise. The main variable of interest in columns (2), (4), and (6) is based on the quartile groupings of age (*Dummy for CEO age* $\leq$ *51*, *Dummy for 51* $<$ *CEO age* $\leq$ *55*, *Dummy for 55* $<$ *CEO age* $\leq$ *60*). In columns (1) and (2), the dependent variable, *logCO2*, is defined as the natural logarithm of carbon dioxide (CO2) in millions of metric tons. In columns (3) and (4), the dependent variable, *logCO2e*, is defined as the natural logarithm of CO2-equivalent emissions of carbon dioxide, methane, nitrous oxide and fluorinated greenhouse gasses, in millions of metric tons. In columns (5) and (6), the dependent variable, *logCO2_R*, is defined as the natural logarithm of carbon dioxide (CO2) in millions of metric tons, scaled by total revenue. All specifications include year, state, and industry fixed effects, whose coefficients are suppressed. Standard errors, which are adjusted for heteroscedasticity and are clustered at facility level, are reported in parentheses below the coefficient estimates. Variable definitions are listed in the Appendix. The symbols ***, ** and * denote statistical significance at the 1 %, 5 % and 10 % levels, respectively.

	logCO2		logCO2e		logCO2_R	
	(1)	(2)	(3)	(4)	(5)	(6)
Young CEO	−0.144***		−0.342***		−0.212***	
	(0.034)		(0.079)		(0.061)	
Dummy for CEO age ≤ 51		−0.128***		−0.231***		−0.193***
		(0.030)		(0.057)		(0.059)
Dummy for 51 < CEO age ≤ 55		−0.121*		−0.124*		−0.016
		(0.071)		(0.069)		(0.053)
Dummy for 55 < CEO age ≤ 60		0.078		0.109		0.042*
		(0.085)		(0.112)		(0.023)
Firm characteristics						
Size	−0.098	−0.173**	−0.135	−0.216**	−0.548***	−0.595***
	(0.089)	(0.082)	(0.088)	(0.085)	(0.084)	(0.088)
Cash Holdings	0.348	0.317	0.317	0.308	0.063	0.098
	(0.393)	(0.398)	(0.370)	(0.380)	(0.381)	(0.390)
CAPX/PPE	0.071	0.081	0.096	0.110	0.182*	0.195*
	(0.124)	(0.124)	(0.116)	(0.117)	(0.100)	(0.102)
Tangible	−0.271	−0.343	−0.462**	−0.530**	−0.372	−0.393
	(0.234)	(0.231)	(0.224)	(0.220)	(0.240)	(0.241)
Tobin's Q	0.040*	0.018	−0.020	−0.061***	0.044	−0.008
	(0.022)	(0.020)	(0.019)	(0.016)	(0.029)	(0.020)
Firm Age	−0.061	−0.147	−0.044	−0.135	−0.139	−0.189*
	(0.149)	(0.148)	(0.131)	(0.126)	(0.120)	(0.114)
CEO characteristics						
Duality	0.022*	0.022*	0.026**	0.026**	0.015	0.015
	(0.013)	(0.013)	(0.0132)	(0.0132)	(0.009)	(0.009)
CEO tenure	−0.029***	−0.028***	−0.020**	−0.016**	−0.007	−0.001
	(0.009)	(0.009)	(0.008)	(0.008)	(0.009)	(0.010)
Female	−0.383***	−0.376***	−0.245**	−0.203*	0.108	0.189
	(0.130)	(0.129)	(0.107)	(0.116)	(0.106)	(0.127)
Education	0.129	0.126	0.158	0.180	−0.418**	−0.363**
	(0.103)	(0.106)	(0.104)	(0.112)	(0.186)	(0.173)
Year Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes
State Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes
Industry Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes
Observations	12,512	12,512	12,512	12,512	12,512	12,512
R-squared	0.567	0.568	0.277	0.284	0.469	0.479

test if the association between CEO age and emission releases is linear (Burney et al., 2021; Andreou and Kellard, 2021). In particular, we first examine the impact of CEO age by employing a dummy variable that equals 1 if the CEO age is less than the sample median (Young_CEO). Dummy variables for each age group are also used to investigate the effects of CEO age on emission of a firm (CEO age $\leq$ 51; 51 $<$ CEO age $\leq$ 55; and 55 $<$ CEO age $\leq$ 60, omitted CEO age $>$ 60). The results of these tests are displayed in Table 4.

Following Table 4 columns (1) (3) and (5), the estimated coefficient of Young CEOs is negative and statistically significant at the 1 % level, suggesting that young CEO's release less emissions relative to older CEOs. For instance, the estimated coefficient of Young CEOs in column (1) is −0.144, suggesting that young CEOs tend to release approximately 14.4 % less CO2 than older CEOs. Columns (2) (4) (6) report the results using binary age groups. The estimated coefficient of the *CEO age* $\leq$ *51* group is negative and statistically significant at the 1 % level. Meanwhile, the estimated coefficients of *51* $<$ *CEO age* $\leq$ *55* and *55* $<$ *CEO age* $\leq$ *60* are still negative but insignificant. This finding suggests that firms with CEO's of 51 years old or younger tend to be more environmentally friendly. This result supports our above main findings shown in Table 3.

Table 5

CEO age and emission releases — Propensity score matching. This table reports the regression results of the effect of CEO age on plants' emission reduction activities, based on PSM analysis. We use one-to-one nearest neighbor propensity score matching without replacement to match firm-year observations with a CEO of 51 or younger (the treatment group) with firm-year observations with a CEO more than 60 years old (the control group). Panel A reports univariate comparisons between the treatment and control firms' characteristics and their corresponding t-statistics. Panel B reports regression results using the matched sample. The dependent variable in column (1) in Panel B, *logCO2*, is the natural logarithm of carbon dioxide (CO2) in millions of metric tons. The dependent variable in column (2) in Panel B, *logCO2e*, is defined as the natural logarithm of CO2-equivalent emissions of carbon dioxide, methane, nitrous oxide and fluorinated greenhouse gasses, in millions of metric tons. The dependent variable in column (3) in Panel B, *logCO2_R*, is defined as the natural logarithm of carbon dioxide (CO2) in millions of metric tons, scaled by total revenue. All specifications include year, state, and industry fixed effects, whose coefficients are suppressed. Standard errors, which are adjusted for heteroscedasticity and are clustered at facility level, are reported in parentheses below the coefficient estimates. Variable definitions are listed in the Appendix. The symbols ***, ** and * denote statistical significance at the 1 %, 5 % and 10 % levels, respectively.

Panel A: Differences in firm characteristics

Variables	Treatment	Control	Difference	p-value
logCO2	7.899	7.910	−0.011	0.865
logCO2e	0.227	0.222	0.005	0.516
logCO2_R	0.059	0.032	0.027	0.419
Size	7.899	7.910	−0.011	0.865
Cash Holdings	0.227	0.222	0.005	0.516
CAPX/PPE	0.059	0.032	0.027	0.419
Tangible	0.612	0.470	0.142	1.521
Tobin's Q	0.110	0.140	−0.030	1.023
Firm Age	2.076	2.191	−0.115	0.975

Panel B: Regressions using PSM matched sample

	logCO2	logCO2e	logCO2_R
	(1)	(2)	(3)
Ln (CEO age)	0.223***	0.289***	0.333***
	(0.072)	(0.078)	(0.082)
Firm characteristics			
Size	−0.160	−0.163	−0.718***
	(0.242)	(0.234)	(0.206)
Cash Holdings	1.764**	1.734**	1.217
	(0.782)	(0.758)	(0.797)
CAPX/PPE	0.231	0.265*	0.299**
	(0.155)	(0.149)	(0.133)
Tangible	−0.325	−0.332	−0.630
	(0.579)	(0.569)	(0.617)
Tobin's Q	0.015	0.014	0.034
	(0.025)	(0.025)	(0.021)
Firm Age	−0.154	−0.112	−0.546*
	(0.362)	(0.314)	(0.307)
CEO characteristics			
Duality	−0.108	−0.121	−0.111
	(0.145)	(0.143)	(0.121)
CEO tenure	0.005	0.004	0.041**
	(0.013)	(0.013)	(0.016)
Female	−0.294	−0.295	0.251
	(0.195)	(0.188)	(0.208)
Education	0.067	0.040	−0.697***
	(0.150)	(0.147)	(0.256)
Year Fixed Effects	Yes	Yes	Yes
State Fixed Effects	Yes	Yes	Yes
Industry Fixed Effects	Yes	Yes	Yes
Observations	5,718	5,718	5,718
R-squared	0.354	0.216	0.392

4.3. Robustness check

4.3.1. Propensity score matching (PSM)

Firms with different characteristics may lead to differences in CO2 releases and this effect is not fully captured by the linear control variables in our baseline model. Hence, we perform a propensity score matching approach to deal with this concern. In particular, we first create the treatment group that includes all firms with CEO age less than 51 years old. The control group includes firms with older CEO's, who share similar characteristics. Following Burney et al. (2021) we then match companies using one-to-one closest neighbour

Table 6
Two-Stage Instrumental Variable (IV) Analysis. This table presents the results of a two-stage instrumental variable (IV) regression analysis. In the first stage, we regress *Ln (CEO age)* on the set of control variables and an instrumental variable, *Ln (CPI at Birth)*. The instrumental variable, *Ln (CPI at Birth)*, is defined as the natural logarithm of the Consumer Price Index (CPI) in the year when the CEO was born. The instrumented Ln (CEO age) is then used in the second-stage regression. The dependent variable in column (2), *logCO2*, is the natural logarithm of carbon dioxide (CO2) in millions of metric tons. The dependent variable in column (3), *logCO2e*, is defined as the natural logarithm of CO2-equivalent emissions of carbon dioxide, methane, nitrous oxide and fluorinated greenhouse gasses, in millions of metric tons. The dependent variable in column (4), *logCO2_R*, is defined as the natural logarithm of carbon dioxide (CO2) in millions of metric tons, scaled by total revenue. All specifications include year, state, and industry fixed effects, whose coefficients are suppressed. Standard errors, which are adjusted for heteroscedasticity and are clustered at facility level, are reported in parentheses below the coefficient estimates. Variable definitions are listed in the Appendix. The symbols ***, ** and * denote statistical significance at the 1%, 5% and 10% levels, respectively.

	First Stage	Second Stage		
	CEO age	logCO2	logCO2e	logCO2_R
	(1)	(2)	(3)	(4)
Ln (CPI at Birth)	−0.314***			
	(0.098)			
Instrumented Ln (CEO age)		0.183***	0.437***	0.471***
		(0.042)	(0.058)	(0.072)
Firm characteristics				
Size	−0.235***	−0.096	−0.161	−0.575***
	(0.223)	(0.222)	(0.215)	(0.200)
Cash Holdings	1.081**	0.745	0.792	0.844
	(0.491)	(0.672)	(0.663)	(0.686)
CAPX/PPE	0.259	0.077	0.114	0.197*
	(0.214)	(0.130)	(0.127)	(0.109)
Tangible	−0.396	−0.251	−0.456	−0.452
	(0.544)	(0.454)	(0.432)	(0.483)
Tobin's Q	0.001	0.025	−0.062***	−0.002
	(0.023)	(0.021)	(0.017)	(0.022)
Firm Age	−0.179	−0.013	−0.152	−0.301
	(0.297)	(0.288)	(0.280)	(0.271)
CEO characteristics				
Duality	−0.098	0.058	0.080	0.051
	(0.113)	(0.100)	(0.089)	(0.077)
CEO tenure	0.010	−0.027***	−0.012	0.004
	(0.012)	(0.010)	(0.009)	(0.011)
Female	0.006	−0.180	−0.077	0.059
	(0.163)	(0.147)	(0.129)	(0.135)
Education	−0.413*	0.207*	0.256**	−0.392*
	(0.214)	(0.109)	(0.114)	(0.204)
Year Fixed Effects	Yes	Yes	Yes	Yes
State Fixed Effects	Yes	Yes	Yes	Yes
Industry Fixed Effects	Yes	Yes	Yes	Yes
Observations	12,512	12,512	12,512	12,512
R-squared	0.319	0.584	0.250	0.395
F-value	272.19			
Hausman test (p-value)	0.003			

propensity score matching, without replacement. All firm characteristics including *Size, Cash holdings, CAPX/PPE, tangible, Tobin's Q and Firm Age* are used as matching criteria. We then run the regression shown in Equation (1) employing the matched sample and present the PSM results in Table 5.

Table 5 Panel A compares the firm characteristics of the treatment and control groups. The p-value of all variables are more than 0.1, suggesting that the treatment and control groups have no variations in company characteristics at the 10 % level. Table 5 Panel B shows the results of regression model (1) using PSM matched sample. We use the same dependent variable as in the baseline models in Tables 3 and 4. The estimated coefficients of CEO age are negative and statistically significant at the 5 % level in column (1) and (2) and at the 10 % level in column (3). In summary, our results of the PSM test suggest that the changes in emission releases are arisen by CEO age, rather than by observable differences across firms.

4.3.2. Instrumental variable approach

In this section, we further address our other concern related to the endogeneity problems. Firms that emit more emissions may be less inclined to appoint a younger CEO, and/or there are some omitted factors which influence both CEO age and emission release. These all drive our results on the association between CEO age and firm's emission releases. In an effort to eliminate the impact of the endogeneity problems, we re-run our baseline regression employing an Instrumental variable approach. We adopt Ln(CPI at Birth) as an instrumental variable, following Burney et al. (2021). This variable captures the natural logarithm of the Consumer Price Index (CPI) in the year a CEO was born. Since younger CEOs were born in periods with generally higher CPIs, Ln(CPI at Birth) exhibits a negative correlation with CEO age.

Table 7
Difference-in-Difference. This table presents the effect of CEO age on plants' emission reduction activities, using a difference-in-differences (DID) analysis. In columns (1) and (4), the dependent variable, logCO2, is defined as the natural logarithm of carbon dioxide (CO2) in millions of metric tons. In columns (2) and (5), the dependent variable, logCO2e, is defined as the natural logarithm of CO2-equivalent emissions of carbon dioxide, methane, nitrous oxide and fluorinated greenhouse gasses, in millions of metric tons. In columns (3) and (6), the dependent variable, logCO2_R, is defined as the natural logarithm of carbon dioxide (CO2) in millions of metric tons, scaled by total revenue. All specifications include firm and year fixed effects, whose coefficients are suppressed. Standard errors, which are adjusted for heteroscedasticity and are clustered at facility level, are reported in parentheses below the coefficient estimates. The symbols ***, ** and * denote statistical significance at the 1%, 5% and 10% levels, respectively.

	Replace an old CEO with a young CEO			Replace a young CEO with an old CEO		
	logCO2	logCO2e	logCO2_R	logCO2	logCO2e	logCO2_R
	(1)	(2)	(3)	(4)	(5)	(6)
CEO Replacement*Post	−0.083***	−0.139***	−0.074***	0.059***	0.116***	0.085***
	(0.025)	(0.042)	(0.022)	(0.018)	(0.036)	(0.027)
Post	0.054	0.076	0.023	−0.013	0.115	0.054
	(0.061)	(0.122)	(0.034)	(0.020)	(0.272)	(0.044)
Firm characteristics						
Size	−0.083	−0.142	−0.564***	−0.073	−0.136	−0.558***
	(0.222)	(0.216)	(0.201)	(0.222)	(0.217)	(0.202)
Cash Holdings	0.805	0.851	0.885	0.797	0.844	0.872
	(0.674)	(0.664)	(0.692)	(0.679)	(0.669)	(0.696)
CAPX/PPE	0.069	0.103	0.187*	0.070	0.106	0.188*
	(0.130)	(0.127)	(0.108)	(0.130)	(0.127)	(0.108)
Tangible	−0.250	−0.448	−0.453	−0.280	−0.476	−0.477
	(0.456)	(0.433)	(0.485)	(0.457)	(0.435)	(0.486)
Tobin's Q	0.027	−0.060***	0.000	0.027	−0.060***	0.000
	(0.021)	(0.017)	(0.022)	(0.021)	(0.017)	(0.022)
Firm Age	−0.022	−0.182	−0.316	−0.030	−0.183	−0.313
	(0.286)	(0.280)	(0.274)	(0.291)	(0.286)	(0.279)
CEO characteristics						
Duality	0.056	0.076	0.046	0.051	0.072	0.043
	(0.100)	(0.090)	(0.078)	(0.102)	(0.091)	(0.078)
CEO tenure	−0.026**	−0.011	0.005	−0.025**	−0.010	0.005
	(0.010)	(0.010)	(0.011)	(0.010)	(0.010)	(0.011)
Female	−0.184	−0.084	0.054	−0.180	−0.080	0.059
	(0.148)	(0.130)	(0.136)	(0.147)	(0.130)	(0.136)
Education	0.214**	0.263**	−0.386*	0.217**	0.265**	−0.384*
	(0.108)	(0.114)	(0.204)	(0.108)	(0.114)	(0.204)
Firm Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes
Year Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes
Observations	324	324	324	402	402	402
R-squared	0.586	0.248	0.394	0.586	0.248	0.395

In the first stage, we compute the regression of Ln (CEO age) on *Ln (CPI at Birth)* with the same control variables as our baseline regression. The results are presented in Table 6 column (1). In the second stage, we replace *Ln(CEO age)* by the instrumented Ln (CEO age), which is estimated from the first stage and then re-compute our baseline model. We display the results of this stage in Table 6 columns (2) (3) and (4). The estimated coefficients of our interested variable are positive and statistically significant at the 1 % level. Overall, our results support our causal relationship between CEO age and corporate emission releases.

4.3.3. Difference-in-differences (DID) analysis

To address potential endogeneity concerns, we employ a difference-in-differences (DID) analysis around CEO turnover events, following Huang and Kisgen (2013). This approach allows us to isolate the causal effect of CEO age transitions on firm environmental performance by comparing changes in performance for firms experiencing CEO turnover (treatment group) with changes in performance for firms that do not (control group). Specifically, we implement two distinct DID settings. In the first setting, we assume firms experiencing a transition from an older CEO to a younger CEO as the treatment group while firms with no CEO turnover during the period as the control group. In the second setting, we consider experiencing a transition from a younger CEO to an older CEO are designated as the treatment group while firms with no CEO turnover during the period as the control group.

In the DID analysis, we examine a sample covering six years with three years before and three years after a CEO transition event. In total, our DID sample encompasses 54 events where an older CEO was replaced by a younger one, and 67 events where a younger CEO was replaced by an older CEO. Table 7 reports the findings from our DID analysis. The coefficients for the interaction term CEO Replacement*Post are statistically significant at the 1 % level and negative in columns (1), (2), and (3). This indicates a significant decrease in emissions by firms following a CEO transition where an older CEO was replaced by a younger one. In contrast, the coefficients for the interaction term CEO Replacement*Post are statistically significant at the 1 % level and positive in columns (4), (5), and (6). This suggests an increase in emissions by firms after a younger CEO was replaced by an older one. These results strongly support our hypothesis regarding the influence of CEO age on emission levels and further solidify the robustness of our argument even

Table 8
Young CEO, career concerns, and emission releases. This table reports the regression results of the effect of CEO age on emission releases, using changes of the enforceability of the non-competition agreement. The main variable of interest is *Non-Compete*, which takes a value of + 1 for firms located in states strengthening the enforceability of noncompete laws; takes the value of −1 for firms located in states weakening the enforceability of noncompete laws; and equals to 0 otherwise. *Young CEO* is an indicator variable that is equal to one if the CEO age is less than the median value of our sample, and zero otherwise. The dependent variable in column (1) in Panel B, *logCO2*, is the natural logarithm of carbon dioxide (CO2) in millions of metric tons. The dependent variable in column (2) in Panel B, *logCO2e*, is defined as the natural logarithm of CO2-equivalent emissions of carbon dioxide, methane, nitrous oxide and fluorinated greenhouse gasses, in millions of metric tons. The dependent variable in column (3) in Panel B, *logCO2_R*, is defined as the natural logarithm of carbon dioxide (CO2) in millions of metric tons, scaled by total revenue. All specifications include year, state, and industry fixed effects, whose coefficients are suppressed. Standard errors, which are adjusted for heteroscedasticity and are clustered at facility level, are reported in parentheses below the coefficient estimates. Variable definitions are listed in the Appendix. The symbols ***, ** and * denote statistical significance at the 1 %, 5 % and 10 % levels, respectively.

	logCO2	logCO2e	logCO2_R
	(1)	(2)	(3)
Young CEO	−0.089***	−0.290***	−0.110**
	(0.028)	(0.088)	(0.048)
Young CEO*Non-Compete	−0.178***	−0.773***	−0.389***
	(0.038)	(0.135)	(0.111)
Non-Compete	0.089	0.190	0.050
	(0.059)	(0.152)	(0.048)
Firm characteristics			
Size	−0.055	−0.055	−0.515**
	(0.221)	(0.214)	(0.200)
Cash Holdings	0.730	0.731	0.807
	(0.680)	(0.669)	(0.701)
CAPX/PPE	0.926**	1.132***	1.067***
	(0.447)	(0.413)	(0.295)
Tangible	−0.326	−0.537	−0.532
	(0.460)	(0.436)	(0.490)
Tobin's Q	0.037*	0.015	0.039*
	(0.022)	(0.018)	(0.021)
Firm Age			
	0.029	−0.089	−0.254
CEO characteristics	(0.291)	(0.286)	(0.283)
Duality	−0.055	−0.146	−0.130*
	(0.103)	(0.089)	(0.077)
CEO tenure	−0.027***	−0.020**	0.000
	(0.010)	(0.009)	(0.011)
Female	−0.175	−0.080	0.060
	(0.150)	(0.132)	(0.125)
Education	0.218**	0.205**	−0.410**
	(0.106)	(0.102)	(0.199)
Year Fixed Effects	Yes	Yes	Yes
State Fixed Effects	Yes	Yes	Yes
Industry Fixed Effects	Yes	Yes	Yes
Observations	12,512	12,512	12,512
R-squared	0.583	0.267	0.402

after employing the DID approach.

5. CEO age, career concern, and emission releases

5.1. Changes in states' non-compete laws

In this section, we investigate the potential influence of career concerns on the association between CEO age and emission releases. Following previous research (Ewens and Marx (2018); Ali et al., 2019), we employ changes of the enforceability of non-compete agreements (NCAs) as an exogenous shock to CEO career concerns. NCAs aim to restrict top executives from joining competitors (Garmaise, 2011; Ali et al., 2019; Kini et al., 2021). Consequently, changes in NCA enforceability can also influence CEO career concerns. Chen et al. (2018) show a positive correlation between firm location in states with strong NCA enforcement and higher earnings management levels. In our context, increased NCA enforceability translates to lower CEO mobility within the external labor market, limiting outside employment opportunities and intensifying career concerns.

Building upon prior work by Garmaise (2011), Klasa et al. (2018), and Huang et al. (2019), we exploit state-level variations in NCA enforceability as an exogenous shock to CEO career concerns. To capture these changes, we utilize the recently updated NCA

Table 9

Emission releases, young CEO, and cross-border acquisitions. This table presents the relationship between emission releases, young CEOs, and cross-border acquisitions. Specifications (1), (2), and (3) present the estimates of logit models where the dependent variable takes the value of 1 for acquiring firms undertaking cross-border M&A deals, and 0 otherwise. The variable, Emission, is defined as the natural logarithm of carbon dioxide (CO2) in millions of metric tons. The variable Young CEO is an indicator variable that is equal to one if the CEO age is less than the median value of our sample, and zero otherwise. The variable Diversifying is an indicator variable that is equal to one if both acquirer and target are in the same industry sector as measured by 3–digit SIC, and zero otherwise (.

	The likelihood of acquiringforeign targets	Development of target countries		Governance oftarget countries	
	(1)	High GDP(2)	Low GDP(3)	High Gov(4)	Low Gov(5)
Emission	0.016**	0.026***	0.019***	0.036***	0.032**
	(0.006)	(0.008)	(0.006)	(0.011)	(0.013)
Emission*Young CEO	0.044**	0.036	0.072***	0.048	0.069***
	(0.019)	(0.047)	(0.016)	(0.046)	(0.019)
Young CEO	0.032	0.023	0.039	0.071	0.082
	(0.083)	(0.053)	(0.069)	(0.083)	(0.060)
Firm characteristics					
Size	0.019	0.053	0.053	0.048	0.033
	(0.259)	(0.257)	(0.262)	(0.263)	(0.263)
Cash Holdings	1.025	1.018	1.094	1.070	1.065
	(0.758)	(0.765)	(0.763)	(0.765)	(0.773)
CAPX/PPE	0.491	0.503	0.471	0.459	0.458
	(0.403)	(0.404)	(0.403)	(0.405)	(0.404)
Tangible	−0.267	−0.307	−0.310	−0.315	−0.300
	(0.547)	(0.547)	(0.549)	(0.549)	(0.551)
Tobin's Q	0.012	0.007	0.013	0.009	0.008
	(0.022)	(0.022)	(0.022)	(0.023)	(0.023)
Firm Age	−0.166	−0.120	−0.177	−0.169	−0.137
	(0.357)	(0.339)	(0.355)	(0.369)	(0.367)
CEO characteristics					
Duality	−0.090	−0.086	−0.088	−0.082	−0.089
	(0.137)	(0.136)	(0.138)	(0.138)	(0.138)
CEO tenure	−0.025*	−0.025**	−0.024*	−0.024*	−0.026*
	(0.012)	(0.012)	(0.012)	(0.013)	(0.013)
Female	−0.314*	−0.307*	−0.307*	−0.304	−0.311
	(0.185)	(0.185)	(0.184)	(0.187)	(0.189)
Education	0.211	0.197	0.171	0.144	0.138
	(0.147)	(0.147)	(0.145)	(0.146)	(0.149)
Deal Characteristics					
Diversifying	−0.041	−0.031	−0.045	−0.022	−0.027
	(0.027)	(0.034)	(0.032)	(0.025)	(0.031)
All Cash	0.135***	0.112*	0.103*	0.105**	0.102*
	(0.034)	(0.066)	(0.061)	(0.048)	(0.060)
Hostile	−0.105	−0.098	−0.094	−0.093	−0.091
	(0.160)	(0.132)	(0.129)	(0.130)	(0.125)
Tender Offer	0.187**	0.168*	0.166**	0.167*	0.165**
	(0.081)	(0.099)	(0.075)	(0.096)	(0.074)
Year Fixed Effects	Yes	Yes	Yes	Yes	Yes
Industry Fixed Effects	Yes	Yes	Yes	Yes	Yes
Observations	1,889	1,889	1,889	1,889	1,889
R-squared	0.114	0.121	0.121	0.123	0.122

Source: Thomson Financial SDC). The variable All Cash is an indicator variable that is equal one for deals where the method of payment is 100% cash, and zero otherwise. The variable Hostile is an indicator variable that is equal one for deals classified as hostile or unsolicited, and zero otherwise. The variable Tender Offer is an indicator variable that is equal one for deals defined as tender offers, and zero otherwise. All specifications include year and industry fixed effects, whose coefficients are suppressed. Standard errors, which are adjusted for heteroscedasticity and are clustered at firm level, are reported in parentheses below the coefficient estimates. Variable definitions are listed in the Appendix. The symbols ***, ** and * denote statistical significance at the 1%, 5% and 10% levels, respectively

enforcement index developed by Kini et al. (2021). Based on this index, we construct a dummy variable, Non-Compete, which takes a value of 1 for firms headquartered in states that have strengthened NCA enforceability, −1 for firms in states that have weakened enforceability, and 0 otherwise. We then interact Non-Compete with a dummy variable, CEO Young, which captures CEO age. We postulate that CEOs operating in environments with stricter NCA enforcement (higher Non-Compete values) will experience heightened career concerns due to limited external mobility opportunities (Ali et al., 2019). Consequently, we expect a negative coefficient on the interaction term (Non-Compete*CEO Young).

Table 8 presents the results for the analysis of the role of career concerns on the association between CEO age and emission releases.

Table 10
Emission Reduction Activities. This table reports the regression results of the effect of CEO age on plants' emission reduction activities. The main variable of interest in columns (1), (4), and (7) is *Ln (CEO age)*, which is the natural logarithm of the age of the CEO. The main variable of interest in columns (2), (5), and (8) is *Young CEO*, which is an indicator variable that is equal to one if the CEO age is less than the median value of our sample, zero otherwise. The main variable of interest in columns (3), (6), and (9) is based on the quartile groupings of age (*Dummy for CEO age* $\leq$ *51*, *Dummy for 51* $<$ *CEO age* $\leq$ *55*, *Dummy for 55* $<$ *CEO age* $\leq$ *60*). In columns (1) through (3), the dependent variable, *Abatement Costs*, which covers all material and labor costs including equipment operation and maintenance costs (such as particulate collectors, conveyers, hoppers, etc.) associated with the collection and disposal of the by-products, including fly and bottom ash collection, FGD collection, and other pollution collection. In columns (4) through (6), the dependent variable, *Production Efficiency*, which is defined as the total electricity generation (kWh) divided by fuel consumption in MMBtu. In columns (7) through (9), the dependent variable, *Using Environmentally Friendly Fuel (gas)*, is defined as the proportion of electricity generated by gas as a fuel for process heating. All specifications include year, state, and industry fixed effects, whose coefficients are suppressed. Standard errors, which are adjusted for heteroscedasticity and are clustered at facility level, are reported in parentheses below the coefficient estimates. The symbols ***, ** and * denote statistical significance at the 1 %, 5 % and 10 % levels, respectively.

	Abatement Costs			Production Efficiency			Using Environmentally Friendly Fuel (gas)/tech		
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Ln (CEO age)	−0.370***			−0.409***			−0.189**		
	(0.119)			(0.128)			(0.086)		
Young CEO		0.298***			0.254***			0.180***	
		(0.093)			(0.083)			(0.056)	
Dummy for CEO age ≤ 51			0.218**			0.181**			0.139**
			(0.099)			(0.089)			(0.060)
Dummy for 51 < CEO age ≤ 55			0.149*			0.175*			0.093
			(0.088)			(0.102)			(0.064)
Dummy for 55 < CEO age ≤ 60			−0.105			−0.024			−0.058
			(0.171)			(0.035)			(0.041)
Firm characteristics									
Size	0.625	0.661	0.814	0.286**	0.287**	0.288**	0.846***	0.941**	0.654**
	(0.705)	(0.648)	(0.794)	(0.114)	(0.120)	(0.131)	(0.281)	(0.285)	(0.262)
Cash Holdings	0.257	0.271	0.245	0.082	0.086	0.054	0.274	0.433	0.275
	(0.296)	(0.224)	(0.228)	(0.470)	(0.461)	(0.139)	(0.379)	(0.398)	(0.320)
CAPX/PPE	0.052	0.072	−0.022	−0.243*	−0.220*	−0.240*	−0.081	−0.095	−0.096
	(0.603)	(0.593)	(0.597)	(0.143)	(0.122)	(0.133)	(0.066)	(0.068)	(0.068)
Tangible	0.775	0.939	0.914	0.203***	0.654***	0.509***	0.056*	0.235*	0.239*
	(0.914)	(0.844)	(0.922)	(0.068)	(0.204)	(0.154)	(0.033)	(0.136)	(0.138)
Tobin's Q	−0.146	−0.134	−0.132	0.842	0.855	0.888	0.028	0.027	0.023
	(0.199)	(0.127)	(0.205)	(0.973)	(0.790)	(0.936)	(0.028)	(0.021)	(0.026)
Firm Age	0.616	1.247	0.168	−0.160	−0.199	−0.169	−0.149	−0.069	−0.099
	(0.443)	(0.988)	(0.213)	(0.358)	(0.562)	(0.433)	(0.420)	(0.559)	(0.355)
CEO characteristics									
Duality	0.022*	0.022*	0.022*	0.026**	0.026**	0.026**	0.021	0.021	0.021
	(0.013)	(0.013)	(0.013)	(0.0132)	(0.012)	(0.0132)	(0.023)	(0.023)	(0.023)
CEO tenure	0.014	0.053	−0.004	−0.034	−0.071	0.259	−0.017	−0.022	−0.011
	(0.087)	(0.095)	(0.096)	(0.517)	(0.569)	(0.492)	(0.012)	(0.017)	(0.011)
Female	0.014	0.053	−0.004	−0.034	−0.071	0.259	−0.017	−0.022	−0.011
	(0.087)	(0.095)	(0.096)	(0.517)	(0.569)	(0.492)	(0.012)	(0.017)	(0.011)
Education	0.519*	0.567*	0.574*	0.120**	0.124**	0.125**	0.191*	0.204*	0.193*
	(0.301)	(0.328)	(0.314)	(0.059)	(0.060)	(0.061)	(0.104)	(0.118)	(0.112)
Year Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
State Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Industry Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	12,512	12,512	12,512	12,512	12,512	12,512	12,512	12,512	12,512
R-squared	0.434	0.431	0.435	0.543	0.544	0.547	0.398	0.381	0.421

The coefficient estimates for the interaction term, Non-Compete*CEO Young, are negative and statistically significant at the 1 % level across all specifications. This statistically significant negative coefficient suggests that the association between younger CEOs (CEO Young = 1) and higher emission levels is accentuated in settings characterized by stronger career concerns. This result aligns with our hypothesis that heightened career concerns incentivize younger CEOs to reduce emissions.

5.2. Cross-border acquisitions

Building on the work of Bose et al. (2021), a promising avenue for future research would be to explore how emission risks influence a firm's propensity to engage in cross-border acquisitions. Their study suggests that firms with high carbon footprints may seek to acquire foreign targets, potentially for the purpose of offshoring emissions. In our context, we investigate whether CEOs of high-emitting firms, experiencing heightened career concerns due to potential regulatory or social pressures, are more likely to pursue cross-border mergers and acquisitions (M&A) as a strategic response to mitigate emission levels. To operationalize these concepts, we follow Bose et al. (2021) by constructing a dummy dependent variable that takes a value of one for acquiring firms involved in cross-border M&A deals, and 0 otherwise. We then measure emission risk using a continuous variable, Emission, defined as the natural logarithm of carbon dioxide (CO2) emissions in millions of metric tons. Finally, a dummy variable, Young CEO, is employed to capture CEO age relative to the sample median, indicating younger CEOs with a value of 1 and older CEOs with a value of 0. We then interact the variable Emission and the Young CEO in the regression. The column (1) in Table 9 presents the empirical result. The coefficient estimate for the interaction term, Emission*Young CEO, is positive and statistically significant at the 5 % level. This finding suggests that young CEOs of high-emitting firms are more likely to acquire foreign targets. This finding aligns with the notion that firms with high carbon risk may seek cross-border acquisitions as a potential strategy to address their environmental impact.

To delve deeper into the relationship between CEOs of high-emitting firms and cross-border acquisitions, we rerun a logistic regression on the decision to choose a foreign or domestic target with new dependent variables. In columns (2) and (4), the dependent variable takes a value of 1 if the target is a foreign firm in a high GDP or high governance index country, and 0 otherwise. In columns (3) and (5), the dependent variable takes a value of 1 if the target is a foreign firm in a low GDP or low governance index country, and 0 otherwise. The result is reported in Table 9. The interaction term, Emission*Young CEO, exhibits a positive and statistically significant coefficient at the 1 % level in columns (3) and (5). This suggests that young CEOs of high-emitting firms are significantly more likely to pursue cross-border M&As when the target is located in a country with lower GDP or governance index. These findings provide initial evidence that firms led by young CEOs with high emission levels may be more inclined to utilize cross-border acquisitions, as a potential strategy to mitigate domestic environmental pressures. Future research could explore the specific mechanisms underlying this behavior.

6. Additional analysis

6.1. Emission reduction activities

Having established the impact of CEO age on plant-level emission output, we turn to exploring possible "physical" mechanisms that can explain this result. As suggested by Akey and Appel (2020), several emission control measures can be considered. First, Management can devote more funds to air cleaning procedures, for example, by investing in technology that reduces pollutants and/or raising the amount spent on continuing personnel and material costs. Second, CEOs may enhance plant productivity and optimize current controls, which minimizes greenhouse gas emissions by lowering the total quantity of input needed for production. Moreover, in order to lower emission intensity and discharge a lesser fraction of emissions into the environment for the same amount of output (such as electricity), management may urge its aging plants to use environmentally friendly fuel.

In order to test the influence of CEO age on the (plant-level) implementation of the emission reduction activities discussed above, we use the granular Energy Information Administration (EIA) data for a subset of electric utilities. The U.S. EIA provides electricity generation data on all utilities in the U.S. at the generator level. Additionally, it gathers data on the capital investments made by establishments in pollution abatement and the amounts of each type of fuel (coal, natural gas, or petroleum, for example).

Table 10 presents the results for the analysis of plants' emission control measures. In columns (1), (2) and (3), we proxy for the intensities of emission reduction activities using abatement costs. This cost includes all material and labor costs related to the by-products collecting and disposal. In columns (4), (5) and (6), we measure plants' emission reduction method using *Production Efficiency*, defined as the total electricity generation (kWh) divided by fuel consumption in MMBtu. In columns (7), (8), and (9), we measure plants' emission control using *Environmentally Friendly Fuel (gas)*, which is the proportion of electricity generated by gas as a fuel for process heating.

Following Table 8, the estimated coefficients of CEO age are negative and statistically significant at the 1 % level, indicating that younger CEO's are indeed more likely to employ emission control measures. There is a considerable economic impact of the CEO age effect on these measures. Based on our preferred models in columns (1), (3), and (5), when CEO age decreases by 1 %, plants experience a 37 % increase in abatement costs, a 41.9 % improvement in production efficiency, and a 18.9 % increase in the use of environmentally friendly fuel. According to Table 10 columns (2) (5) and (8), the estimated coefficients of *Young CEO* are positive and statistically significant at the 1 % level, suggesting that plants with younger CEOs tend to have higher abatement costs, greater production efficiency, and use more environmentally friendly fuel. Similar results are seen when we use alternative measures for CEO's age. In summary, we document corroborating evidence that younger CEOs take appropriate actions to reduce GHG emissions, further supporting our main result.

Therefore, as a result of the company's overall reduction in carbon emissions, a CEO's age has favorable externalities for the environment. It is not just shifting emission from age plants to other plants within the same organization.

6.2. CEO ages and EPA actions and Fines

Finally, we investigate the relationship between CEOs' age, actions and penalties taken by the EPA against establishments. We

Table 11

EPA Actions and Fines. This table reports the regression results of the effect of CEO age on EPA Actions and Fines. The main variable of interest in columns (1) and (4) is *Ln (CEO age)*, which is the natural logarithm of the age of the CEO. The main variable of interest in columns (2) and (5) is *Young CEO*, which is an indicator variable that equal to one if the CEO age is less than the median value of our sample, zero otherwise. The main variable of interest in columns (3) and (6) is based on the quartile groupings of age (*Dummy for CEO age* ≤ 51, *Dummy for* $51 <$ *CEO age* ≤ 55, *Dummy for* $55 <$ *CEO age* ≤ 60). In columns (1)-(3), the dependent variable, *# EPA actions*, is defined as the number of formal and judicial actions. In columns (4)-(6), the dependent variable, *Ln (dollar penalty)*, is defined as the natural logarithm of one plus the total dollar penalty assigned. All specifications include year, state, and industry fixed effects, whose coefficients are suppressed. Standard errors, which are adjusted for heteroscedasticity and are clustered at facility level, are reported in parentheses below the coefficient estimates. Variable definitions are listed in the Appendix. The symbols ***, ** and * denote statistical significance at the 1 %, 5 % and 10 % levels, respectively.

	# EPA actions			Ln (dollar penalty)		
	(1)	(2)	(3)	(4)	(5)	(6)
Ln (CEO age)	1.804***			0.313***		
	(0.601)			(0.101)		
Young CEO		−0.025***			−0.052***	
		(0.008)			(0.017)	
Dummy for CEO age ≤ 51			−0.018**			−0.041***
			(0.009)			(0.013)
Dummy for 51 < CEO age ≤ 55			−0.012*			−0.029*
			(0.007)			(0.017)
Dummy for 55 < CEO age ≤ 60			0.014			0.033
			(0.098)			(0.036)
Firm characteristics						
Size	−0.070	−0.033	−0.157	−0.100	−0.062	−0.178
	(0.143)	(0.143)	(0.140)	(0.133)	(0.132)	(0.127)
Cash Holdings	1.018**	0.981*	0.987*	0.984**	0.947*	0.969*
	(0.513)	(0.513)	(0.517)	(0.488)	(0.487)	(0.493)
CAPX/PPE	0.160	0.150	0.161	0.195	0.184	0.195
	(0.141)	(0.140)	(0.142)	(0.135)	(0.135)	(0.138)
Tangible	−0.371	−0.353	−0.489	−0.380	−0.361	−0.482
	(0.328)	(0.329)	(0.338)	(0.304)	(0.304)	(0.311)
Tobin's Q	0.012	0.045*	0.016	−0.024	0.013	−0.020
	(0.022)	(0.023)	(0.021)	(0.022)	(0.021)	(0.022)
Firm Age	−0.209	−0.196	−0.242	−0.126	−0.112	−0.155
	(0.184)	(0.187)	(0.183)	(0.165)	(0.168)	(0.166)
CEO characteristics						
Duality	0.015	0.017	0.017	0.121	0.121	0.121
	(0.032)	(0.032)	(0.032)	(0.215)	(0.215)	(0.215)
CEO tenure	−0.020	−0.024*	−0.021*	−0.010	−0.015	−0.010
	(0.012)	(0.013)	(0.013)	(0.011)	(0.011)	(0.011)
Female	−0.048***	−0.054***	−0.048***	−0.037**	−0.044***	−0.038**
	(0.017)	(0.018)	(0.018)	(0.015)	(0.015)	(0.015)
Education	0.106	0.060	0.106	0.086	0.037	0.089
	(0.147)	(0.146)	(0.144)	(0.144)	(0.140)	(0.139)
Year Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes
State Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes
Industry Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes
Observations	12,512	12,512	12,512	12,512	12,512	12,512
R-squared	0.440	0.439	0.441	0.275	0.273	0.277

predict that facilities that are closer to the birthplaces of CEOs will be subject to less regulatory proceedings and penalties corresponding to their lower emissions of air pollution. In order to test this conjecture, we collect information on environmental regulatory activities from the EPA's Enforcement and Compliance History Online (ECHO) system.[3] Established in the 1970 s, the EPA has facilitated the control of environmental pollution: the EPA can launch an investigation and subsequently take regulatory actions when environmental violations occur. Plants that are the target of enforcement actions may be fined money or they might have to pay compliance charges to remedy the infraction.

In our analysis, we follow Shive and Forster (2020) by creating two outcome variables, namely, (i) *EPA Actions* to capture the annual number of formal and judicial actions taken against a plan and (ii) *Dollar Penalties* to measure the total dollar penalty assigned to a plant in a year. Table 11 suggests that EPA actions and penalties are significantly lower for plants with younger CEOs. Across all models, *CEO age* carries a positive and significant coefficient at the 5 % level. The estimated effect of *CEO age* is also economically

[3] The ECHO system incorporates Federal Enforcement and Compliance (FE&C) from the Integrated Compliance Information System (ICIS) and tracks civil, judicial, and administrative EPA enforcement cases since 1980.

meaningful. Under our preferred specification in columns (1) and (4), plants with younger CEOs face 1.8 % fewer EPA actions and 31.3 % lower penalties. Overall, younger CEOs reduce the number of environmental violations and fines facing plants and thus enhances their reputation.[4]

7. Conclusion

In this study, we investigate the association between CEO age and carbon emissions of firms at plant-level. We first run the regression on a sample of 12,512 plant-year observations for 1,074 individual firms over the period of 2010 to 2022. We show that a one standard deviation decrease in CEO age leads to approximately 19.1 percent lower in plant emissions, controlling for some firm and CEO characteristics. This effect is robust when we use alternative emission variables. At the same time, we suggest that young CEOs tend to be more environmentally friendly by releasing less emissions. The baseline findings are also robust when we apply propensity score matching and two-stage instrumental variable analysis.

Our research enhances the literature on CEO age and corporate emissions release by contributing to the determinants of CSR and firms' environmental, social, and governance (ESG) performance. We also enrich the recent strand of literature investigating the link between CEO age and firms' decision. Furthermore, our paper also contributes to the literature connecting CEO characteristics to firm behavior and outcomes.

Our research has several limitations. First, our study focuses on corporations in the US only. Due to the differences in national laws, policies, and social norms that affect their environmental and emission performance, companies' approaches to environmental and climate issues may vary between nations (Ortiz-de-Mandojana et al., 2021). Future studies can revisit the link between CEO age and carbon emissions using data from other countries, especially developing economies. Second, we discuss two possible channels that can explain for the impact of CEO age on corporate emission release related to awareness and career concerns of young CEOs. However, due to the data availability, we only provide tests for the latter channel. We employ changes in the enforceability of non-compete agreements as an exogenous shock to CEO career concerns and suggest that heightened career concerns incentivize younger CEOs to reduce emissions. Additional studies can look more closely at the other possible avenues for this relationship.

Our findings have important implications for the corporate board of directors, shareholders, and policymakers. We suggest that younger CEOs tend to release less emissions, thus firms may foster the inclusion of young managers in the top management team. Our empirical evidence can be used by shareholders to evaluate companies' environmental performance and make well-informed investment decisions. Finally, policymakers with more active engagement of young people in the decision making, may have impacts on achieving environmental objectives. For future research, it would be interesting to study the connection between CEO age and other types of firms' decision. In addition, it would create additional value if our empirical framework could be applied to other nations with different country characteristics.

CRediT authorship contribution statement

Huong Le: Visualization, Validation, Software, Resources, Project administration, Methodology, Investigation, Funding acquisition, Formal analysis, Data curation. **Tung Nguyen:** Visualization, Validation, Software, Resources, Project administration, Methodology, Investigation, Formal analysis, Data curation, Conceptualization. **Andros Gregoriou:** Writing – review & editing, Writing – original draft, Supervision, Conceptualization.

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Appendix

Variable Definition

Variable	Definition
Ln(CEO age)	Natural logarithm of the CEO age.
Young CEO	Indicator equal to one if the CEO age is less than the median value of our sample, zero otherwise.
Younger CEOs	CEO age is below the sample median.
Older CEOs	CEO age is above the sample median.
CO2	the natural logarithm of carbon dioxide (CO_2) emissions in millions of metric tons.
CO2e	The natural logarithm of CO2-equivalent emissions of carbon dioxide, methane, nitrous oxide, and fluorinated GHG, in millions of metric tons

(*continued on next page*)

[4] Further robustness tests are reported in Appendix B, including the correlation matrix of the main variables used in our econometric analysis, alternative fixed effects, alternative CEO age range, cross sectional analysis of CEO age and emission releases and controlling the impact of newly hired CEOs and those approaching retirement. Our empirical findings remain intact once we estimate all these additional tests.

Table B1
The correlation matrix. This table presents the correlation matrix for the main variables included in our econometric models. Variable definitions are listed in the Appendix. The symbols ***, ** and * denote statistical significance at the 1%, 5% and 10% levels, respectively.

Variables	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
Size	1.000									
Cash Holdings	−0.244***	1.000								
CAPX/PPE	0.052	−0.110	1.000							
Tangible	−0.279**	0.345***	−0.148	1.000						
Tobin's Q	0.218	0.293	0.069	0.045	1.000					
Firm Age	0.204	0.230	0.066	0.291*	−0.432	1.000				
Duality	0.451**	0.364*	−0.142	0.300	0.112	0.330	1.000			
CEO tenure	0.111	0.024**	0.214	0.314	0.178	0.180	1.000	1.000		
Female	0.042*	0.117*	0.213	0.146	−0.089	0.115**	0.123	0.063	1.000	
Education	0.189	0.225	0.132*	0.120	0.076**	0.217	−0.032	0.197	0.049	1.000

Table B2
Using alternative fixed-effects. This table reports the regression results of the effect of CEO age on plants' emission reduction activities. The main variable of interest is *Ln (CEO age)*, which is the natural logarithm of the age of the CEO. The dependent variable in column (1), logCO2, is defined as the natural logarithm of carbon dioxide (CO2) in millions of metric tons. The dependent variable in column (2), logCO2e, is defined as the natural logarithm of CO2-equivalent emissions of carbon dioxide, methane, nitrous oxide and fluorinated greenhouse gasses, in millions of metric tons. The dependent variable in column (3), logCO2_R, is defined as the natural logarithm of carbon dioxide (CO2) in millions of metric tons, scaled by total revenue. The dependent variable in column (4), Abatement Costs, which covers all material and labor costs including equipment operation and maintenance costs (such as particulate collectors, conveyers, hoppers, etc.) associated with the collection and disposal of the by-products, including fly and bottom ash collection, FGD collection, and other pollution collection. The dependent variable in column (5), Production Efficiency, which is defined as the total electricity generation (kWh) divided by fuel consumption in MMBtu. The dependent variable in column (6), the dependent variable, Using Environmentally Friendly Fuel (gas), is defined as the proportion of electricity generated by gas as a fuel for process heating. The dependent variable in column (7), # EPA actions, is defined as the number of formal and judicial actions. The dependent variable in column (8), the dependent variable, Ln (dollar penalty), is defined as the natural logarithm of one plus the total dollar penalty assigned. All specifications include state*year and industry*year fixed effects, whose coefficients are suppressed. Standard errors, which are adjusted for heteroscedasticity and are clustered at facility level, are reported in parentheses below the coefficient estimates. Variable definitions are listed in the Appendix. The symbols ***, ** and * denote statistical significance at the 1%, 5% and 10% levels, respectively.

	Emission releases			Emission Reduction Activities			EPA Actions and Fines	
	logCO2	logCO2e	logCO2_R	Abatement Costs	Production Efficiency	Using Environmentally Friendly Fuel (gas)/tech	# EPA actions	Ln (dollar penalty)
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Ln (CEO age)	0.183***	0.439***	0.474***	−0.379***	−0.436***	−0.270***	1.370***	0.370***
	(0.042)	(0.057)	(0.072)	(0.091)	(0.118)	(0.070)	(0.119)	(0.065)
Firm characteristics	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
CEO characteristics	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
State*Year Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Industry*Year Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	12,512	12,512	12,512	12,512	12,512	12,512	12,512	12,512
R-squared	0.434	0.431	0.435	0.543	0.544	0.547	0.398	0.381

(*continued*)

Variable	Definition
CO2_R	The natural logarithm of carbon dioxide (CO2) in millions of metric tons, scaled by total revenue
Abatement Costs	All material and labor costs, such as equipment operation and maintenance costs
Production Efficiency	The total electricity generation (kWh) divided by fuel consumption in MMBtu.
Using environmentally fuel	The proportion of electricity generated by gas as a fuel for process heating.
Electricity Generation	Electricity generation (kWh) divided by fuel consumption in MMBtu.
EPA Action	The number of formal and judicial actions.
Penalty	Natural logarithm of (1 + Total penalty amount). Total penalty amount includes both the federal penalty amount and the state\local penalty amount.
Firm characteristics variable	
Size	Natural log of annual sales turnover.
Leverage	Liabilities divided by total assets.

(*continued on next page*)

Table B3

Using alternative CEO age range. This table reports the regression results of the effect of CEO age on plants' emission reduction activities. The main variable of interest is based on the quartile groupings of age (Dummy for CEO age ≤ 34, Dummy for 35 < CEO age ≤ 40, Dummy for 41 < CEO age ≤ 46, Dummy for 47 < CEO age ≤ 53, Dummy for 54 < CEO age ≤ 59). The dependent variable in column (1), logCO2, is defined as the natural logarithm of carbon dioxide (CO2) in millions of metric tons. The dependent variable in column (2), logCO2e, is defined as the natural logarithm of CO2-equivalent emissions of carbon dioxide, methane, nitrous oxide and fluorinated greenhouse gasses, in millions of metric tons. The dependent variable in column (3), logCO2_R, is defined as the natural logarithm of carbon dioxide (CO2) in millions of metric tons, scaled by total revenue. The dependent variable in column (4), Abatement Costs, which covers all material and labor costs including equipment operation and maintenance costs (such as particulate collectors, conveyers, hoppers, etc.) associated with the collection and disposal of the by-products, including fly and bottom ash collection, FGD collection, and other pollution collection. The dependent variable in column (5), Production Efficiency, which is defined as the total electricity generation (kWh) divided by fuel consumption in MMBtu. The dependent variable in column (6), the dependent variable, Using Environmentally Friendly Fuel (gas), is defined as the proportion of electricity generated by gas as a fuel for process heating. The dependent variable in column (7), # EPA actions, is defined as the number of formal and judicial actions. The dependent variable in column (8), the dependent variable, Ln (dollar penalty), is defined as the natural logarithm of one plus the total dollar penalty assigned. All specifications include year, state, and industry fixed effects, whose coefficients are suppressed. Standard errors, which are adjusted for heteroscedasticity and are clustered at facility level, are reported in parentheses below the coefficient estimates. Variable definitions are listed in the Appendix. The symbols ***, ** and * denote statistical significance at the 1 %, 5 % and 10 % levels, respectively.

	Emission releases			Emission Reduction Activities			EPA Actions and Fines	
	logCO2	logCO2e	logCO2_R	Abatement Costs	Production Efficiency	Using Environmentally Friendly Fuel (gas)/ tech	# EPA actions	Ln (dollar penalty)
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Dummy for CEO age ≤ 34	−0.070***	−0.210*	0.270	0.213***	0.173***	0.117***	−0.017	−0.050***
	(0.029)	(0.116)	(0.219)	(0.065)	(0.053)	(0.039)	(0.019)	(0.015)
Dummy for 35 < CEO age ≤ 40	−0.132***	−0.279***	−0.198***	0.255***	0.183***	0.146***	−0.018**	−0.047***
	(0.093)	(0.083)	(0.063)	(0.067)	(0.054)	(0.043)	(0.009)	(0.013)
Dummy for 41 < CEO age ≤ 46	−0.138***	−0.265***	−0.199***	0.224**	0.175**	0.147**	−0.013*	−0.046***
	(0.030)	(0.061)	(0.053)	(0.098)	(0.054)	(0.072)	(0.007)	(0.012)
Dummy for 47 < CEO age ≤ 53	−0.131*	−0.105*	−0.016*	0.123	0.167*	0.093*	−0.008*	−0.032**
	(0.077)	(0.058)	(0.008)	(0.097)	(0.098)	(0.055)	(0.005)	(0.016)
Dummy for 54 < CEO age ≤ 59	0.065	0.109	0.049	−0.084	−0.043	0.032	−0.005	0.015
	(0.068)	(0.112)	(0.048)	(0.074)	(0.056)	(0.067)	(0.009)	(0.022)
Firm characteristics	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
CEO characteristics	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
State Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Industry Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	12,512	12,512	12,512	12,512	12,512	12,512	12,512	12,512
R-squared	0.456	0.457	0.438	0.556	0.556	0.557	0.389	0.389

Table B4

CEO age and emission releases — Cross-Sectional Analysis. This table reports the regression results of the effect of CEO age on plants' emission reduction activities. The main variable of interest is *Young CEO*, which is an indicator variable that is equal to one if the CEO age is less than the median value of our sample, and zero otherwise. The variable *High HHI* is an indicator variable that equals to one if the product market competition based on Hirsch-Herfindahl index score is higher than the median value of our sample, and zero otherwise. The variable *Polluted ind* is an indicator variable that equals to one if the industry is among the top ten most polluting in our data, and zero otherwise. The variable *High tech* is an indicator variable that equals to one if firm is from high tech industries defined by Loughran and Ritter (2004), and zero otherwise. In columns (1) through (3), the dependent variable, *logCO2*, is defined as the natural logarithm of carbon dioxide (CO2) in millions of metric tons. In columns (4) through (6), the dependent variable, *logCO2e*, is defined as the natural logarithm of CO2-equivalent emissions of carbon dioxide, methane, nitrous oxide and fluorinated greenhouse gasses, in millions of metric tons. In columns (7) through (9), the dependent variable, *logCO2_R*, is defined as the natural logarithm of carbon dioxide (CO2) in millions of metric tons, scaled by total revenue. All specifications include year, state, and industry fixed effects, whose coefficients are suppressed. Standard errors, which are adjusted for heteroscedasticity and are clustered at facility level, are reported in parentheses below the coefficient estimates. Variable definitions are listed in the Appendix. The symbols ***, ** and * denote statistical significance at the 1%, 5% and 10% levels, respectively.

	logCO2			logCO2e			logCO2_R		
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Young CEO	−0.298***	−0.315***	−0.218**	−0.283**	−0.275**	−0.481**	−0.189**	−0.180***	−0.139**
	(0.093)	(0.082)	(0.099)	(0.102)	(0.102)	(0.089)	(0.086)	(0.056)	(0.060)
Young CEO*High HHI	−0.423***			−0.409***			−0.369***		
	(0.121)			(0.128)			(0.102)		
High HHI	0.149			−0.024			0.069		
	(0.188)			(0.035)			(0.105)		
Young CEO*Polluted ind		−0.378***			−0.254***			−0.375***	
		(0.093)			(0.083)			(0.091)	
Polluted ind		0.049**			−0.024			0.085	
		(0.022)			(0.035)			(0.084)	
Young CEO* High tech			0.115			0.186			0.089
			(0.105)			(0.162)			(0.102)
High tech			−0.015			−0.024			0.053
			(0.071)			(0.035)			(0.058)
Firm characteristics	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
CEO characteristics	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
State Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Industry Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	12,512	12,512	12,512	12,512	12,512	12,512	12,512	12,512	12,512
R-squared	0.434	0.431	0.435	0.543	0.544	0.547	0.398	0.381	0.421

Table B5
Controlling the impact of newly hired CEOs and those approaching retirement. This table reports the regression results of the effect of CEO age on emission releases, controlling the impact of newly hired CEOs and those approaching retirement. *Last_year*, is an indicator variable that equals one if a CEO is in his/her last year in office and zero otherwise, while *Tenure3* is an indicator variable that equals one if a CEO has a tenure equal to or less than three years and zero otherwise. The main variable of interest is *Ln (CEO age)*, which is the natural logarithm of the age of the CEO. The dependent variable in columns (1), *logCO2*, is defined as the natural logarithm of carbon dioxide (CO2) in millions of metric tons. The dependent variable in columns (2), *logCO2e*, is defined as the natural logarithm of CO2-equivalent emissions of carbon dioxide, methane, nitrous oxide and fluorinated greenhouse gasses, in millions of metric tons. The dependent variable in columns (3), *logCO2_R*, is defined as the natural logarithm of carbon dioxide (CO2) in millions of metric tons, scaled by total revenue. All specifications include year, state, and industry fixed effects, whose coefficients are suppressed. Standard errors, which are adjusted for heteroscedasticity and are clustered at facility level, are reported in parentheses below the coefficient estimates. Variable definitions are listed in the Appendix. The symbols ***, ** and * denote statistical significance at the 1%, 5% and 10% levels, respectively.

	logCO2	logCO2e	logCO2_R
	(1)	(2)	(3)
Ln (CEO age)	0.230***	0.342***	0.426***
	(0.048)	(0.060)	(0.075)
Last_year	−0.085	−0.106	−0.042
	(0.082)	(0.074)	(0.071)
Tenure3	0.214	0.191	−0.053
	(0.369)	(0.345)	(0.311)
Firm characteristics			
Size	−0.096	−0.133	−0.619***
	(0.094)	(0.091)	(0.094)
Cash Holdings	0.586	0.430	0.240
	(0.402)	(0.393)	(0.430)
CAPX/PPE	0.041	0.075	0.165
	(0.127)	(0.123)	(0.104)
Tangible	−0.400	−0.509**	−0.522**
	(0.253)	(0.235)	(0.264)
Tobin's Q	0.025	−0.032*	0.011
	(0.019)	(0.017)	(0.021)
Firm Age	−0.112	−0.049	−0.117
	(0.135)	(0.137)	(0.129)
CEO characteristics	−0.020**	−0.011	0.004
Duality	0.021	0.009	0.021
	(0.027)	(0.015)	(0.023)
CEO tenure	(0.010)	(0.009)	(0.011)
	−0.289**	−0.138	0.235
Female	(0.125)	(0.117)	(0.143)
	0.178*	0.200*	−0.382**
Education	(0.107)	(0.110)	(0.187)
	(0.137)	(0.143)	(0.125)
Year Fixed Effects	Yes	Yes	Yes
State Fixed Effects	Yes	Yes	Yes
Industry Fixed Effects	Yes	Yes	Yes
Observations	12,512	12,512	12,512
R-squared	0.537	0.284	0.472

(*continued*)

Variable	Definition
PP&E	Property, plant, and equipment (PPEGT) scaled by total assets (AT).
ROA	Net Income/Total Assets.
Tobin's Q	Ratio of market value of assets to book value of assets.
Cash holdings	Capital expenditures (CAPX) scaled by total assets (AT).
Investment	Sum of net income before extraordinary depreciation and amortization scaled by total assets (AT).
Cash flow	Sum of net income before extraordinary depreciation and amortization scaled by total assets (AT).
Dividend	A dummy variable equal to one if the firm pays a dividend, and zero otherwise.
Sales Growth	The percentage change in sales (SALE) from the previous year.
CAPX/PPE	The ratio between capital expenditures and net property plant and equipment at the fiscal year-end.
Tangible	Net property, plant, and equipment scaled by total assets.
Firm's age	Natural log of the gap between the founding year and the current calendar year.
CEO characteristics	
CEO tenure	The number of years that a CEO is in office.

(*continued on next page*)

(*continued*)

Variable	Definition
Female	An indicator equal to one if the CEO is female, and zero otherwise.
Education	The CEO education level, which is the number of years.

Appendix B

- Table B1: The correlation matrix
- Table B2: Using alternative fixed-effects
- Table B3: Using alternative CEO age range
- Table B4: CEO age and emission releases − Cross-Sectional Analysis
- Table B5: Controlling the impact of newly hired CEOs and those approaching retirement

Data availability

Data will be made available on request.

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