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Toxic Emissions and Corporate Green Innovation

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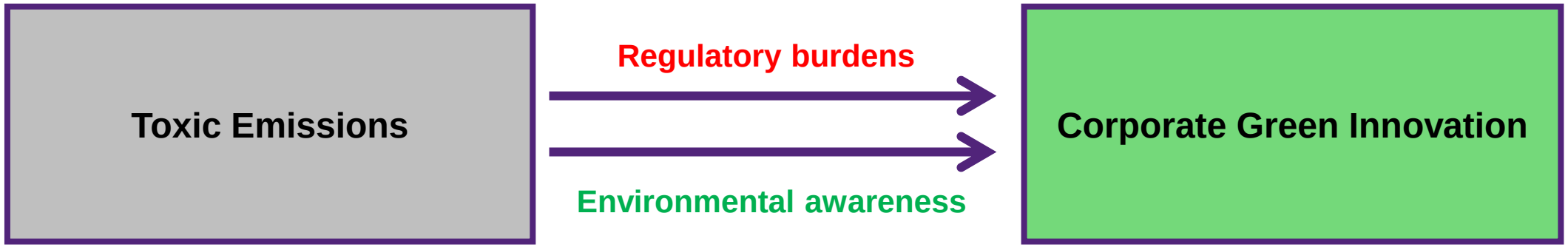
2023 AFA PhD Student Poster Session



Whether high-emission firms produce more green patents. **Yes!**
Why high-emission firms produce more green patents. **Motivations.**
How high-emission firms produce green patents.
When high-emission firms prioritize green patents.
The **implication** of green patents.

Cement Manufacturer Cemex to Reduce Harmful Air Pollution from Five Plants under Settlement with Environmental Protection Agency (EPA) and Justice Department

The Department of Justice and the U.S. Environmental Protection Agency (EPA) today (July 27, 2016) announced a settlement with Cemex Inc., under which the company will invest approximately $10 million to cut emissions of harmful air pollution at five of its cement manufacturing plants in Alabama, Kentucky, Tennessee and Texas to resolve alleged violations of the Clean Air Act.

"The cement sector is a significant source of air pollution posing real health risks to the communities where they reside … "

"This settlement requires Cemex to use state of the art technology to reduce harmful air pollution …"

EPA estimates this will result in NO_x emissions reductions of over 4,000 tons per year. Each facility will also be subject to strict SO_2 emission limits.

https://www.justice.gov/opa/pr/cement-manufacturer-cemex-reduce-harmful-air-pollution-five-plants-under-settlement-epa-and

Toxic Emissions and Corporate Green Innovation

MSCI

MSCI ESG KLD STATS: 1991-2018 DATA SETS | MARCH 2019

	Nano-technology	*Natural Gas Combined Heat & Power*	*Industrial Automation Optimization Tech & Syst*
Pollution Prevention & Control	*Environmental Rem. Waste Treatment*	*Reuse & Recycling Environmental IT*	*Conventional Poll. Control Carbon Capture & Storage*
Sustainable Water	*Water Infrastructure & Distribution Rainwater Harvesting*	*Smart Metering Devices Drought-Resistant Seed*	*Desalination Waste Water Treatment*
Green Building	*Green Certified Property LED Lighting Compact Fluorescent Lighting*	*Use of Recycled Mat. Blended Cement Specialty Cements / Low-temp Asphalt*	*Insulation Low Toxicity / VOC Mat. FSC-Certified Lumber*

ENV-STR-B: POLLUTION & WASTE – TOXIC EMISSIONS AND WASTE

This indicator is designed to assess how companies manage their risk of incurring liabilities associated with pollution, contamination, and the emission of toxic and carcinogenic substances. Companies that have a well-defined strategy, ambitious programs and targets to reduce toxic emissions, and disclosed performance metrics score higher.

JOURNAL ARTICLE

Climate Finance FREE

Harrison Hong, G Andrew Karolyi ✉, José A Scheinkman

The Review of Financial Studies, Volume 33, Issue 3, March 2020, Pages 1011–1023,
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Abstract

Climate finance is the study of local and global financing of public and private investment that seeks to support mitigation of and adaptation to climate change. In 2017, the *Review of Financial Studies* launched a competition among scholars to develop research proposals on the topic with the goal of publishing this special volume. We describe the competition, how the nine projects featured in this volume came to be published, and frame their findings within what we view as a broader climate finance research program.

JEL: E50 - General, G11 - Portfolio Choice; Investment Decisions, G40 - General

Issue Section: Articles

Motivation

Motivation: theoretical tension

- Positive impact of firms' toxic emissions on corporate green innovation

  - **1. Regulatory burdens and government investigations.**

    1) High emissions are a significant predictor of environment-related lawsuits (Hsu et al. (2022), Xu & Kim (2022)).

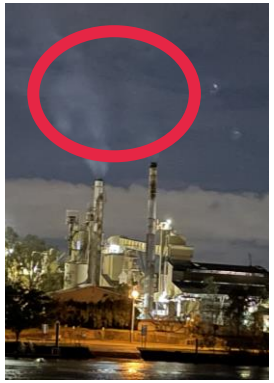
    2) High toxic-emission firms have lower firm value relative to low-emission firms (Xu & Kim (2022)),

    ➡ A reflection of the environmental policy uncertainty risk (Hsu et al. (2022)),

  - **2. Environmental awareness.**

    More aware of environmental issues (e.g., due to environmental disasters),

    ➡ The likelihood of greater investor activism (Akey & Appel (2019), Choi et al. (2021)), lower institutional ownership for firms with environmental concerns (Chava (2014)), and the development and adoption of stricter environment-related policies increases significantly (Ilhan et al. (2021)).



Hypothesis 1a. Firms with high toxic release levels produce more green patents than those with low toxic release levels.

Motivation: theoretical tension

State A

State B

- Impediments to generating green innovation for high-emission firms
  - **1. Regulatory arbitrage.**
    1) Financially constrained firms transfer their emissions activities from regulated to unregulated states to cope with environmental and climate-related policies (Bartram et al. (2022))
    2) Firms with low relocation costs facing high local regulatory pressures relocate their plants and facilities to regions with less stringent environmental policies (Dai et al. (2021))
  - **2. Managerial short-termism.**

    Managerial short-termism that is caused by external pressures and agency problems or generated by managers' personal styles, beliefs, or motivations (He & Tian (2013), Ladika & Sautner (2019)) can lead firm managers to ignore or make light of corporate green innovation.

Hypothesis 1b. The green patenting efforts of firms with high toxic release levels are indistinguishable from those with low toxic release levels.

Data and Sample

Data

- (1) The **Toxic Release Inventory (TRI)** program database administered by the **U.S. Environmental Protection Agency (EPA)**;

- (2) The **patent database** constructed by Kogan et al. (2017) containing the utility patent and citations data for all patents filed (and eventually granted) with the **United States Patents and Trademark Office (USPTO).**
  "**Green patents**" are identified based on the guidelines provided by the **Organization for Economic Cooperation and Development (OECD)** (Cohen, Gurun, & Nguyen, 2020; Haščič & Migotto, 2015);

- (3) Financial and accounting data are obtained from **Compustat**.

- (4) Text-based financial constraints (Hoberg and Maksimovic, 2015); asset redeployability (Kim and Kung, 2017).

Sample

- Our final sample includes 20,712 firm-year observations of 1,562 unique public firms over the 1987 to 2020 period.

Baseline Results

Table 2: Baseline Results - Firms' toxic emissions and corporate green innovation

$$Green\ Innovation_{i,t+1,2} = \alpha + \beta Toxic\ Emissions_{i,t} + \gamma Controls_{i,t} + FEs + \epsilon_{i,t} \quad (1)$$

VARIABLES	(1) Ln(Green Pat) (t+1)		(2) Ln(Green Pat) (t+2)	(3) Ln(Tot GPat Cites) (t+1)		(4) Ln(Tot GPat Cites) (t+2)
Ln(Total Release)	8.635***	Econ. Sign. 9.67%	10.154***	6.400**	Econ. Sign. 8.97%	9.212**
	(2.773)		(2.908)	(2.045)		(2.573)
Capex/assets	-181.110		-232.467*	-72.771		-116.085
	(-1.428)		(-1.783)	(-0.542)		(-0.827)
ROA	-176.946*		-189.653*	-240.111**		-252.349**
	(-1.865)		(-1.922)	(-2.447)		(-2.372)
PPE/assets	98.144		160.732**	39.445		84.964
	(1.259)		(2.026)	(0.530)		(1.105)
Profit margin	-9.079		-6.741	-4.196		12.631
	(-0.852)		(-0.739)	(-0.407)		(1.248)
Tobin's q	0.897		9.941	-5.943		1.751
	(0.078)		(0.842)	(-0.503)		(0.141)
Leverage	38.526		28.795	52.417		19.091
	(0.757)		(0.545)	(1.053)		(0.351)
Ln (market equity)	69.121***		73.371***	76.203***		78.159***
	(5.295)		(5.320)	(5.847)		(5.716)
Cash	-14.611		57.058	61.247		118.934
	(-0.163)		(0.604)	(0.618)		(1.171)
R&D/assets	-150.117		-185.721	435.756		512.612
	(-0.326)		(-0.380)	(0.994)		(1.060)
Observations	20,712		18,965	20,712		18,965
Adjusted R-squared	0.763		0.767	0.692		0.695
Firm FE	Yes		Yes	Yes		Yes
Industry-year FE	Yes		Yes	Yes		Yes

- Economically, a one-standard-deviation (4.05) increase in the natural logarithm of total toxic releases is associated with a 9.67% (8.97%) increase in *Ln(Green Pat)* (*Ln(Tot GPat Cites)*) from the mean level of 361.71 (288.87).

➢ All dependent variables (i.e., the innovation variables) are **multiplied by 1,000** to enhance the readability of coefficients in the regression analysis.

Tables A.4 and A.5
Baseline Results – Types of toxic emissions and corporate green innovation

VARIABLES	(1) Ln(Green Pat)	(2) Ln(Green Pat)	(3) Ln(Green Pat)	(4) Ln(Green Pat)	(5) Ln(Green Pat)
Ln(Health Effects Release)	7.544**			7.499**	
	(2.515)			(2.498)	
Ln(RSEI Hazard)		3.870**			3.842**
EPA's Risk-screening Environmental Indicators toxicity weight		(2.282)			(2.264)
Ln(No Health Effects Release)			0.906	0.646	0.616
			(0.399)	(0.284)	(0.271)
Observations	20,712	20,712	20,712	20,712	20,712
Adjusted R-squared	0.763	0.763	0.762	0.763	0.763
Controls	Yes	Yes	Yes	Yes	Yes
Firm FE	Yes	Yes	Yes	Yes	Yes
Industry-year FE	Yes	Yes	Yes	Yes	Yes

VARIABLES	(1) Ln(Green Pat)	(2) Ln(Green Pat)	(3) Ln(Green Pat)
Ln(Onsite Release)	9.193***		8.728***
	(3.009)		(2.970)
Ln(Offsite Release)		3.029	1.958
		(1.406)	(0.950)
Observations	20,712	20,712	20,712
Adjusted R-squared	0.763	0.763	0.763
Controls	Yes	Yes	Yes
Firm FE	Yes	Yes	Yes
Industry-year FE	Yes	Yes	Yes

- Emissions associated with **human health impacts** and **onsite toxic releases** are the main drivers of the relationship.
- A **double-sided** and **complicated** impact of highly polluting firms on society

Table A.6. Firms' toxic emissions and green innovation (excluding energy sector)

VARIABLES	(1) Ln(Green Pat) (t+1)	(2) Ln(Green Pat) (t+2)	(3) Ln(Tot GPat Cites) (t+1)	(4) Ln(Tot GPat Cites) (t+2)
Ln(Total Release)	7.473**	9.040**	6.483**	8.869**
	(2.229)	(2.419)	(1.981)	(2.370)
Capex/Assets	-267.287*	-292.329**	-177.762	-173.283
	(-1.946)	(-2.023)	(-1.221)	(-1.114)
ROA	-231.584**	-263.889**	-299.726***	-338.009***
	(-2.183)	(-2.315)	(-2.730)	(-2.731)
PPE/Assets	141.573	203.020**	77.650	124.879
	(1.539)	(2.177)	(0.922)	(1.438)
Profit Margin	0.804	3.890	6.545	12.506
	(0.113)	(0.474)	(1.095)	(1.430)
Tobin's q	1.652	10.203	-4.645	2.450
	(0.137)	(0.823)	(-0.374)	(0.186)
Leverage	38.179	25.834	46.541	17.154
	(0.715)	(0.466)	(0.891)	(0.302)
Ln(Market Equity)	76.248***	81.621***	79.576***	83.253***
	(5.367)	(5.419)	(5.610)	(5.628)
Cash	-12.437	62.212	50.108	129.069
	(-0.133)	(0.631)	(0.484)	(1.218)
R&D/Assets	-125.531	-156.521	434.139	475.899
	(-0.271)	(-0.318)	(0.986)	(0.983)
Observations	18,476	16,887	18,476	16,887
Adjusted R-squared	0.760	0.765	0.689	0.693
Firm FE	Yes	Yes	Yes	Yes
Industry-year FE	Yes	Yes	Yes	Yes

Cohen et al. (2020):
The energy sector includes the industries with the first two digits of SIC equal to

A. 10 (Metal, Mining),
B. 12 (Coal Mining),
C. 13 (Oil & Gas Extraction),
D. 14 (Nonmetallic Minerals, Except Fuels),
E. 29 (Petroleum & Coal Products), or
F. 49 (Electric, Gas, & Sanitary Services)

Loss of approx. 10% of our final sample

Table 3: Toxic Emission and Corporate Green Innovation **Value**

	Total (real and nominal) value		Average (real and nominal) value	
	(1)	(2)	(3)	(4)
VARIABLES	Ln(Tot GPat Real Value)	Ln(Tot GPat Nominal Value)	Ln(Avg GPat Real Value)	Ln(Avg GPat Nominal Value)
Ln(Total Release)	13.326**	15.477**	6.918*	8.718*
	(2.281)	(2.241)	(1.690)	(1.741)
Observations	20,712	20,712	20,712	20,712
Adjusted R-squared	0.720	0.706	0.598	0.598
Controls	Yes	Yes	Yes	Yes
Firm FE	Yes	Yes	Yes	Yes
Industry-year FE	Yes	Yes	Yes	Yes

- Green patents produced by high-emission firms have higher **total** and **average** values.
- Not merely a green washing activity.

Table 4 – Specific categories of green innovation

	Environmental (Env)		Climate change mitigation (CCM)						Total Env	Total CCM
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
Dependent Variables➔ *Ln(GPat(Var.))*	Env Mgt	Water Adapt	CCM Energy	CCM GH Gases	CCM Transport	CCM Build	CCM Waste	CCM Goods	Tot Env	Tot CCM
Ln(Total Release)	6.539***	0.302	3.584**	0.544*	1.980	-0.053	1.645**	5.546***	6.884***	6.697**
	(3.181)	(0.861)	(2.098)	(1.856)	(1.233)	(-0.032)	(2.146)	(2.650)	(3.229)	(2.286)
Observations	20,712	20,712	20,712	20,712	20,712	20,712	20,712	20,712	20,712	20,712
Adjusted R-squared	0.690	0.397	0.622	0.375	0.695	0.632	0.312	0.653	0.701	0.740
Controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Firm FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Industry-year FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes

- High-emission companies have better performance in both **environmental** (Column (9)) and **CCM** (Column (10)) categories than low-emission firms. See examples.

Table 5: Toxic emissions and green innovation strategy

VARIABLES	(1) Ln(Explorative GPat)	(2) Ln(Exploitative GPat)
Ln(Total Release)	6.080***	4.665**
	(2.814)	(2.118)
Observations	20,712	20,712
Adjusted R-squared	0.707	0.661
Controls	Yes	Yes
Firm FE	Yes	Yes
Industry-year FE	Yes	Yes

- High-pollution companies use both explorative and exploitative strategies in green innovation.
- High-emission firms push their boundaries and explore new technologies rather than relying only on developing expertise when producing green patents.

Identification: Two Experiments

Table 7: Identification - Experiment 1: The 2016 Nov election of President Trump

- Pre: 2015, 2016 vs.
- Post: 2017, 2018

$$Green\ Innovation_{i,t+1} = \alpha + \beta_1 Toxic\ Emissions_{i,t} + \beta_2 Toxic\ Emissions_{i,t} \times Post\ Election_{i,t} + \beta_3 Post\ Election_{i,t} + \gamma Controls_{i,t} + FEs + \epsilon_{i,t} \quad (2)$$

VARIABLES	(1)	(2)	(3)	(4)	(5)	(6)	(7)
	Green Patents			Env & CCM		Explorative & Exploitative	
	Ln(Green Pat)	Ln(Tot GPat Cites)	Ln(Tot GPat Real Value)	Ln(GPat(Tot Env))	Ln(GPat(Tot CCM))	Ln(Explorative GPat)	Ln(Exploitative GPat)
Ln(Total Release)	2.296	7.247	-8.852	3.111	3.589	-1.147	0.513
	(0.359)	(1.264)	(-0.638)	(0.711)	(0.614)	(-0.244)	(0.145)
Ln(Total Release) × Post Election	-15.714***	-19.591***	-29.996***	-8.590***	-17.295***	-8.627**	-9.143**
	(-3.119)	(-3.508)	(-2.876)	(-2.732)	(-3.112)	(-2.486)	(-2.489)
Post Election	-	-	-	-	-	-	-
Observations	2,079	2,079	2,079	2,079	2,079	2,079	2,079
Adjusted R-squared	0.791	0.496	0.727	0.792	0.719	0.705	0.685
Controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Firm FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Industry-year FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes

- High-emission firms largely reduced their efforts in green innovation after Trump's election, leading to a **decrease** in the **quantity**, **quality**, and **value** of green patents.

Identification - Experiment 1: The 2016 election of President Trump

PSM-DDD Analysis

VARIABLES	(1) DDD Ln(Green Pat)	(2) PSM-DDD Ln(Green Pat)	(3) DDD Ln(Tot GPat Cites)	(4) PSM-DDD Ln(Tot GPat Cites)
High Release	-155.624	-254.418	-291.926**	120.849
	(-1.063)	(-0.821)	(-2.050)	(0.617)
High Release × US HQ × Post Election	-170.720	-973.089*	-490.668***	-1,611.843***
	(-0.754)	(-1.723)	(-2.714)	(-3.675)
US HQ	-	-	-	-
Post Election	-	-	-	-
Observations	2,079	136	2,079	136
Adjusted R-squared	0.791	0.549	0.499	0.059
Other interactions	Yes	Yes	Yes	Yes
Controls	Yes	Yes	Yes	Yes
Firm FE	Yes	Yes	Yes	Yes
Industry-year FE	Yes	Yes	Yes	Yes

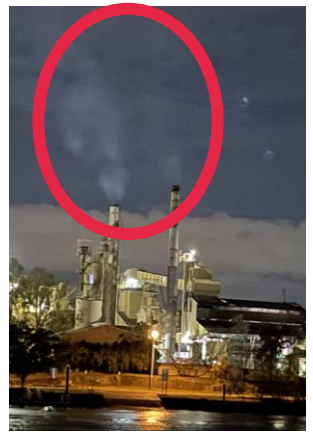
- **Local (US HQ)** high-emission firms significantly reduced green patenting, especially decreasing the **quality** of green innovation, compared with those headquartered **overseas** following Trump's election.

Table 8: Identification - Experiment 2: The BP Deepwater Horizon oil spill (Dyck et al., 2019)

VARIABLES	(1) Ln(Green Pat)	(2) Ln(Green Pat)	(3) Ln(Tot GPat Cites)	(4) Ln(Tot GPat Cites)
Ln(Total Release)	17.060**	16.706*	12.232*	12.834*
	(2.497)	(1.881)	(1.831)	(1.688)
Ln(Total Release) × Treated Firm (Extractive Industries) × Post-2010	**45.401****	**63.326*****	**35.548****	**50.862*****
	(2.519)	**(6.364)**	**(2.309)**	**(5.330)**
Treated Firm	603.606***	-	657.576***	-
	(3.918)		(4.592)	
Post-2010	7.627	-	-23.418	-
	(0.179)		(-0.549)	
Observations	1,198	1,194	1,198	1,194
Adjusted R-squared	0.276	0.347	0.233	0.302
Other interactions	Yes	Yes	Yes	Yes
Controls	Yes	Yes	Yes	Yes
Industry FE	No	Yes	No	Yes
Year FE	No	Yes	No	Yes

Event: April 20, 2010

Pre: 2008, 2009
vs.
Post: 2010, 2011



- For firms in **extractive industries**, this unexpected incident significantly **strengthened** the relation between firms' toxic emission levels and their green innovation.

Do Constraints Hinder High-Emission Firms' Green Patenting Efforts?

The effect of financial constraints

VARIABLES	(1) Total innovation Ln(All Pat)	(2) Total innovation Ln(Tot AllPat Cites)	(3) Nongreen innovation Ln(nonGPat)	(4) Nongreen innovation Ln(Tot NGPat Cites)	(5) Green innovation Ln(Green Pat)	(6) Green innovation Ln(Tot GPat Cites)	(7) Env & CCM Ln(GPat(Tot Env))	(8) Env & CCM Ln(GPat(Tot CCM))
Ln(Total Release)	11.834	17.247**	12.779*	16.818**	0.879	5.396	1.584	0.304
	(1.480)	(1.977)	(1.650)	(2.022)	(0.226)	(1.320)	(0.602)	(0.081)
Ln(Total Release) × **High HM Debt**	-7.137*	-8.344**	**-7.145***	**-8.088****	**-0.934**	**-2.556**	**-1.536**	**-0.623**
	(-1.901)	(-2.186)	**(-1.934)**	**(-2.155)**	**(-0.414)**	**(-1.019)**	**(-0.920)**	**(-0.294)**
High HM Debt	53.112	65.544	54.474	66.111	-2.296	11.285	4.884	-3.577
	(1.243)	(1.527)	(1.283)	(1.538)	(-0.095)	(0.423)	(0.307)	(-0.159)
Observations	7,573	7,573	7,573	7,573	7,573	7,573	7,573	7,573
Adjusted R-squared	0.918	0.901	0.918	0.901	0.825	0.741	0.773	0.812
Controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Firm FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Industry-year FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes

- In the presence of **financial constraints**, high-emission firms appear to **reduce** their **nongreen** patenting efforts more than their **green patenting efforts.**

The effect of asset redeployability

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	Total innovation		Nongreen innovation		Green innovation		Env & CCM	
VARIABLES	Ln(All Pat)	Ln(Tot AllPat Cites)	Ln(nonGPat)	Ln(Tot NGPat Cites)	Ln(Green Pat)	Ln(Tot GPat Cites)	Ln(GPat(Tot Env))	Ln(GPat(Tot CCM))
Ln(Total Release)	22.929***	27.328***	23.645***	27.386***	12.964***	10.960***	7.527***	10.413***
	(2.950)	(3.845)	(3.068)	(3.919)	(3.255)	(2.895)	(2.745)	(2.780)
Ln(Total Release) × **Low Redeployability**	-16.173*	-19.535**	-16.167*	-18.135**	-11.651**	-10.188**	**-2.816**	-10.062**
	(-1.829)	(-2.451)	(-1.824)	(-2.283)	(-2.494)	(-2.254)	**(-0.963)**	(-2.198)
Low Redeployability	151.104	216.475**	157.563	209.719**	89.157	90.943*	23.186	79.505
	(1.495)	(2.316)	(1.571)	(2.271)	(1.604)	(1.682)	(0.735)	(1.478)
Observations	17,968	17,968	17,968	17,968	17,968	17,968	17,968	17,968
Adjusted R-squared	0.894	0.885	0.894	0.885	0.801	0.750	0.733	0.785
Controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Firm FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Industry-year FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes

- In the presence of **limited asset redeployability,** high-emission firms maintain their **environmental-related green innovation.**

Implication of Green Innovation

Table 11 Implication of Corporate Green Innovation

$$\Delta Ln(Air\ Release)_{i,(t+1)} = \alpha + \beta Green\ Innovation_{i,t} + \gamma Controls_{i,t} + FEs + \epsilon_{i,t}.$$

i = firm; t = year; Δ = the changes from year *t-1* to year *t+1, 2, 3, 4, 5*, respectively.

Economically, one-standard-deviation increase in the log numbers of environment green patents are associated with **19.30%,** 19.06%, 15.94%, and **13.57%** decreases in *ΔLn(Air Release)* from the mean levels for year –1 to year 2 through year 5, respectively.

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
	Year −1 to Year 1		Year −1 to Year 2		Year −1 to Year 3		Year −1 to Year 4		Year −1 to Year 5	
VARIABLES	ΔLn(Air Release)	ΔLn(Air Release)	ΔLn(Air Release)	ΔLn(Air Release)	ΔLn(Air Release)	ΔLn(Air Release)	ΔLn(Air Release)	ΔLn(Air Release)	ΔLn(Air Release)	ΔLn(Air Release)
Ln(GPat(Tot Env))	-0.082		-0.148**		-0.197**		-0.207**		-0.210*	
	(-1.588)		(-2.136)		(-2.541)		(-2.299)		(-1.880)	
Ln(GPat(Tot CCM))		-0.068*		-0.084		-0.102		-0.077		-0.080
		(-1.758)		(-1.628)		(-1.628)		(-1.053)		(-0.950)
Observations	18,737	18,737	17,154	17,154	15,747	15,747	14,505	14,505	13,352	13,352
Adjusted R-squared	0.070	0.070	0.125	0.125	0.183	0.182	0.216	0.215	0.254	0.254
Controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Firm FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Industry-year FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes

Conclusion

Conclusion

- Firms with high toxic release levels produce more **high-quality**, **valuable** green patents than their counterparts with low toxic release levels. These results suggest a **double-edged impact** of highly polluting firms on society.

- Our results based on the **election of President Trump** and the **Deepwater Horizon** event support the **causal inferences** regarding how firms' toxic release levels affect their green patenting.

- High-emission firms' demand for green innovation can be affected by **local environmental and climate policies** as well as **environmental awareness**.

- **Financially constrained** high-emission firms **reduce nongreen innovation** rather than **green innovation** to address environmental concerns. Moreover, high-pollution firms facing **limited asset redeployability** appear to sacrifice other types of patenting for environmental-related green innovation.

- Corporate green innovation **mitigates toxic air emissions**.

Robustness Checks

- To avoid truncation bias, we delete last three years of sample and keep (1987-2017) – see IA Table 1
- Cohn, Liu and Wardlaw (2022)'s critique on Ln(1+#Count variable) - See IA Table 3 Poisson estimation
- Alternative key variable of interest using dummy variable (High release dummy instead of a continuous variable – Ln(Toxic Release) for Trump's 2016 election (DiD analysis) See IA Table 4
- Test of Parallel Trends for Trump's election – See IA Table 6

Contributions

- First study examining the impact of firms' toxic emissions on green innovation.
- Contributing to a growing stream of literature that examines environmental pollution (Hsu et al. (2022), Xu and Kim (2022)) by showing that firms' high levels of toxic releases act as a catalyst for pursuing green innovation.
- Our research extends the literature on firms' green innovation by showing a potential economic mechanism to the paradox in Cohen, Gurun and Nguyen (2020), who find that energy firms (with a low ESG score) produce more green patents.
- Our findings suggest a double-sided and complicated impact of highly polluting companies on society.
- Contributing to the studies focusing on the impacts of environmental and climate policies in financial areas. Using Trump's 2016 election as an unexpected event shock, we show that (local) climate and environmental policies indeed affect high-emission firms' green innovation.
- Prior studies show that constraints (e.g., financial constraints and limited asset redeployability) impede corporate innovation (Kim & Kung (2017), Moshirian et al. (2021)). Our paper extends the literature by showing that constrained firms may make structural decisions rather than simply reduce all innovation activities.

Thank you

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Backup slides

Table A.1 Variable Definitions

Variables	Definition
Dependent Variables:	
Ln(Green Pat)	Natural logarithm of one plus the number of green patents filed (and eventually granted).
Ln(Tot GPat Cites)	Natural logarithm of one plus the total number of forward adjusted citations received by the firm's green patents filed and eventually granted. Adjusted citations are the total number of citations divided by average number of citations in the same industry and year (Mudambi and Swift (2014)), where the industry is defined at the three-digit SIC code level.
Ln(GPat(Env Mgt))	Natural logarithm of one plus the number of green patents filed (and eventually granted) that are classified as environmental management technologies.
Ln(GPat(Water Adapt))	Natural logarithm of one plus the number of green patents filed (and eventually granted) that are classified as water-related adaptation technologies.
Ln(GPat(CCM Energy))	Natural logarithm of one plus the number of green patents filed (and eventually granted) that are classified as climate change mitigation technologies related to energy generation, transmission or distribution.
Ln(GPat(CCM GH Gases))	Natural logarithm of one plus the number of green patents filed (and eventually granted) that are classified as climate change mitigation technologies related to capture, storage, sequestration or disposal of greenhouse gases.
Ln(GPat(CCM Transport))	Natural logarithm of one plus the number of green patents filed (and eventually granted) that are classified as climate change mitigation technologies related to transportation.
Ln(GPat(CCM Build))	Natural logarithm of one plus the number of green patents filed (and eventually granted) that are classified as climate change mitigation technologies related to buildings.
Ln(GPat(CCM Waste))	Natural logarithm of one plus the number of green patents filed (and eventually granted) that are classified as climate change mitigation technologies related to wastewater treatment or waste management.
Ln(GPat(CCM Goods))	Natural logarithm of one plus the number of green patents filed (and eventually granted) that are classified as climate change mitigation technologies in the production or processing of goods.
Ln(GPat(Tot Env))	Natural logarithm of one plus the number of green patents filed (and eventually granted) that are classified as environmental technologies. It includes the green patents classified as environmental management and water-related adaptation technologies.
Ln(GPat(Tot CCM))	Natural logarithm of one plus the number of green patents filed (and eventually granted) that are classified as climate change mitigation technologies.
Ln(Explorative GPat)	Natural logarithm of one plus the number of explorative green patents filed (and eventually granted). A green patent is categorized as explorative if at least 60% of its citations do not refer to existing knowledge, which includes all the patents that the firm invented and all the patents that were cited by the firm's patents filed over the past five years.
Ln(Exploitative GPat)	Natural logarithm of one plus the number of exploitative green patents filed (and eventually granted). A green patent is categorized as exploitative if at least 60% of its citations are based on the firm's existing knowledge, which includes all the patents that the firm invented and all the patents that were cited by the firm's patents filed over the past five years.
Ln(Tot GPat Real Value)	Natural logarithm of one plus the total value of green innovation deflated to 1982 (million) dollars using the consumer price index (CPI). Value of innovation is constructed as the product of the estimate of the stock return due to the value of the patent and market capitalization of the firm divided by the number of patents granted to the same firm on the same day and multiplied by 2.27(1/(1-0.56)), where 0.56 is the unconditional probability of a successful patent application (Kogan et al. (2017)).
Ln(Tot GPat Nominal Value)	Natural logarithm of one plus the total value of green innovation in millions of nominal dollars. Value of innovation is constructed as above.
Ln(Avg GPat Real Value)	Natural logarithm of one plus [the total value of green innovation deflated to 1982 (million) dollars using the consumer price index (CPI) scaled by the total number of green patents filed].
Ln(Avg GPat Nominal Value)	Natural logarithm of one plus [the total value of green innovation in millions of nominal dollars scaled by the total number of green patents filed].
Key Independent Variables:	
Ln(Total Release)	Natural logarithm of one plus the pounds of total toxic releases administered under the TRI program.
Ln(CAA Release)	Natural logarithm of one plus the pounds of toxic releases administered under the Clean Air Act.
Ln(CWA Release)	Natural logarithm of one plus the pounds of toxic releases administered under the Clean Water Act.
Ln(CERCLA Release)	Natural logarithm of one plus the pounds of toxic releases administered under the Comprehensive Environmental Response, Compensation, and Liability Act.
Ln(OSHA Release)	Natural logarithm of one plus the pounds of toxic releases administered by the Occupational Safety and Health Administration.
Ln(Air Release)	Natural logarithm of one plus the pounds of toxic releases through air.
Ln(Water Release)	Natural logarithm of one plus the pounds of toxic releases through water.
Ln(Ground Release)	Natural logarithm of one plus the pounds of toxic releases through ground.
Ln(Health Effects Release)	Natural logarithm of one plus the pounds of toxic releases associated with health effects.
Ln(No Health Effects Release)	Natural logarithm of one plus the pounds of toxic releases not associated with health effects.
Ln(RSEI Hazard)	Natural logarithm of one plus the toxic releases multiplied by EPA's Risk-Screening Environmental Indicators (RSEI) toxicity weight.
Ln(Onsite Release)	Natural logarithm of one plus the pounds of total toxic releases to air, water and land onsite at the facility.
Ln(Offsite Release)	Natural logarithm of one plus the pounds of total toxic releases reported as transferred to offsite locations for release or disposal.
Control Variables:	
Capex/Assets	Ratio of capital expenditure to total assets.
Cash	Ratio of cash holdings to total assets.
Leverage	Sum of long-term and short-term debt divided by total assets.
Ln(Market Equity)	Natural logarithm of the market value of equity
PPE/Assets	Ratio of fixed assets to total assets.
Profit Margin	Ratio of operating income after depreciation to total sales.
R&D/Assets	Maximum (0, Research and development expense scaled by total assets)
ROA	Ratio of operating income after depreciation to total assets.
Tobin's q	Tobin's q is calculated as (total assets + market value of equity - book value of equity) divided by total assets.

Table A.2 Types of innovation

Table A.2. Firms' toxic emissions and nongreen/total innovation

This table presents regression estimates of firms' quantity and quality of nongreen and total patenting on total toxic emissions (measured by pounds in natural logarithm). The sample period is from 1987 to 2020. All dependent variables are calculated in year *t+1* and are multiplied by 1000. Firm-level controls include lagged *Capex/Assets*, *ROA*, *PPE/Assets*, *Profit Margin*, *Tobin's q*, *Leverage*, *Ln(Market Equity)*, *Cash*, and *R&D/Assets*. Continuous variables are winsorized at the 1st and 99th percentiles. All variable definitions are provided in Table A.1 in the appendix. Firm fixed effects and industry-year fixed effects are included in all regressions. Standard errors are clustered at the firm level (robust t-statistics are reported in parentheses). ***, **, and * denote significance at the 1%, 5%, and 10% levels, respectively.

	(1)	(2)	(3)	(4)
VARIABLES	Ln(All Pat)	Ln(Tot AllPat Cites)	Ln(nonGPat)	Ln(Tot NGPat Cites)
Ln(Total Release)	17.411***	20.416***	17.793***	20.787***
	(2.881)	(3.519)	(2.935)	(3.586)
Capex/Assets	-275.159	-20.548	-288.533	-60.218
	(-1.233)	(-0.086)	(-1.311)	(-0.257)
ROA	-502.395***	-583.315***	-492.539***	-554.581***
	(-3.481)	(-3.779)	(-3.464)	(-3.720)
PPE/Assets	426.642***	503.079***	420.144***	508.675***
	(2.599)	(3.077)	(2.613)	(3.148)
Profit Margin	6.767	2.855	8.566	3.403
	(0.536)	(0.158)	(0.730)	(0.201)
Tobin's q	-56.818***	-35.251**	-57.333***	-34.969**
	(-3.354)	(-2.040)	(-3.417)	(-2.082)
Leverage	143.858	160.588	138.452	160.398
	(1.480)	(1.585)	(1.452)	(1.605)
Ln(Market Equity)	230.836***	231.764***	227.864***	228.230***
	(8.876)	(9.054)	(8.941)	(9.027)
Cash	157.598	285.549*	141.674	282.227
	(1.024)	(1.651)	(0.934)	(1.634)
R&D/Assets	1,895.262**	2,658.038***	1,900.390**	2,602.536***
	(2.316)	(2.993)	(2.359)	(3.003)
Observations	20,712	20,712	20,712	20,712
Adjusted R-squared	0.873	0.848	0.873	0.848
Firm FE	Yes	Yes	Yes	Yes
Industry-year FE	Yes	Yes	Yes	Yes

Table A.3 Toxic Emissions Under Various EPA Acts

Table A.3. Toxic emissions under various EPA acts

This table shows the regression results of firms' green patenting on toxic emissions administered under various EPA acts. The toxic emissions measures include the log pounds of toxic releases regulated under the Clean Air Act (CAA), the Clean Water Act (CWA), the Comprehensive Environmental Response, Compensation and Liability Act (CERCLA), and the Occupational Safety and Health Act (OSHA) (Xu and Kim (2022)). Panel A presents the regression results, and Panel B reports the correlation matrix for releases under various acts. The sample period is from 1987 to 2020. All dependent variables are calculated in year *t+1* and are multiplied by 1000. Firm-level controls include lagged *Capex/Assets*, *ROA*, *PPE/Assets*, *Profit Margin*, *Tobin's q*, *Leverage*, *Ln(Market Equity)*, *Cash*, and *R&D/Assets*. Continuous variables are winsorized at the 1st and 99th percentiles. All variable definitions are provided in Table A.1 in the appendix. Firm fixed effects and industry-year fixed effects are included in all regressions. Standard errors are clustered at the firm level (robust t-statistics are reported in parentheses). ***, **, and * denote significance at the 1%, 5%, and 10% levels, respectively.

Panel A: Toxic emissions under various EPA regulations

VARIABLES	(1) Ln(Green Pat)	(2) Ln(Green Pat)	(3) Ln(Green Pat)	(4) Ln(Green Pat)
Ln(CAA Release)	5.820**			
	(1.998)			
Ln(CWA Release)		6.391**		
		(2.221)		
Ln(CERCLA Release)			7.904***	
			(2.606)	
Ln(OSHA Release)				6.534**
				(2.390)
Observations	20,712	20,712	20,712	20,712
Adjusted R-squared	0.763	0.763	0.763	0.763
Controls	Yes	Yes	Yes	Yes
Firm FE	Yes	Yes	Yes	Yes
Industry-year FE	Yes	Yes	Yes	Yes

Panel B: Correlation matrix for emissions under various acts

Variables	Total Release	CAA Release	CWA Release	CERCLA Release	OSHA Release
Total Release	1.00				
CAA Release	0.91***	1.00			
CWA Release	0.81***	0.74***	1.00		
CERCLA Release	0.96***	0.94***	0.82***	1.00	
OSHA Release	0.81***	0.83***	0.83***	0.83***	1.00

IA Table 1 Sample ends in 2017 (avoid truncation bias)

IA Table 1. Firms' toxic emissions and green innovation (sample ends in 2017)

This table presents OLS regression estimates of firms' quantity and quality of green patenting on total toxic emissions (measured by pounds in natural logarithm). For odd columns, the green innovation measures are calculated in year *t+1*, while for even columns, they are measured in year *t+2*. All dependent variables are multiplied by 1000. The sample period is from 1987 to 2017. Firm-level controls include lagged *Capex/Assets*, *ROA*, *PPE/Assets*, *Profit Margin*, *Tobin's q*, *Leverage*, *Ln(Market Equity)*, and *Cash*, while *R&D/Assets* is included in Columns (3) to (6). Continuous variables are winsorized at the 1st and 99th percentiles. All variable definitions are provided in Table A.1 in the appendix. Firm fixed effects and industry-year fixed effects are included in all regressions. Standard errors are clustered at the firm level (robust t-statistics are reported in parentheses). ***, **, and * denote significance at the 1%, 5%, and 10% levels, respectively.

VARIABLES	(1) RD/AT (t+1)	(2) RD/AT (t+2)	(3) Ln(Green Pat) (t+1)	(4) Ln(Green Pat) (t+2)	(5) Ln(Tot GPat Cites) (t+1)	(6) Ln(Tot GPat Cites) (t+2)
Ln(Total Release)	0.235	0.155	9.243***	10.802***	7.409**	9.958***
	(1.466)	(0.989)	(2.826)	(2.976)	(2.276)	(2.723)
Capex/Assets	18.074***	16.966***	-166.452	-239.194*	-86.147	-130.714
	(2.887)	(2.936)	(-1.309)	(-1.825)	(-0.656)	(-0.946)
ROA	-7.950	-7.901	-107.841	-137.014	-180.728**	-213.180**
	(-1.450)	(-1.279)	(-1.202)	(-1.470)	(-1.963)	(-2.116)
PPE/Assets	13.085***	10.918**	91.118	169.385**	44.919	94.726
	(2.857)	(2.342)	(1.083)	(2.071)	(0.595)	(1.236)
Profit Margin	-2.062**	6.087	-9.247	-8.324	-4.303	11.586
	(-2.157)	(1.636)	(-0.878)	(-0.939)	(-0.423)	(1.146)
Tobin's q	1.474**	0.807	7.418	13.359	0.088	4.542
	(2.214)	(1.225)	(0.619)	(1.114)	(0.008)	(0.371)
Leverage	3.146	3.751	39.994	32.434	53.496	21.490
	(1.303)	(1.566)	(0.774)	(0.613)	(1.111)	(0.402)
Ln(Market Equity)	-1.131*	-0.887	58.542***	67.988***	69.145***	74.868***
	(-1.878)	(-1.564)	(4.206)	(4.775)	(5.271)	(5.460)
Cash	13.706**	15.416*	-52.326	47.549	35.045	109.424
	(2.099)	(1.887)	(-0.561)	(0.499)	(0.353)	(1.084)
R&D/Assets			-256.700	-259.915	276.620	418.564
			(-0.538)	(-0.523)	(0.634)	(0.867)
Observations	19,701	18,469	19,701	18,469	19,701	18,469
Adjusted R-squared	0.836	0.839	0.785	0.782	0.719	0.709
Firm FE	Yes	Yes	Yes	Yes	Yes	Yes
Industry-year FE	Yes	Yes	Yes	Yes	Yes	Yes

IA Table 2 Subcategoris of green innovation

IA Table 2. Summary statistics - subcategories of green innovation

This table presents the summary statistics on subcategories of corporate green innovation. The final sample consists of 20,712 firm-year observations for 1,562 unique firms during 1987-2020. All variables in this table are winsorized at the 1st and 99th percentiles. All variable definitions are provided in Table A.1 in the appendix.

	N	Mean	Median	Std. Dev.	p25	p75
Ln(GPat(Env Mgt))	20712	0.16	0.00	0.50	0.00	0.00
Ln(GPat(Water Adapt))	20712	0.01	0.00	0.08	0.00	0.00
Ln(GPat(CCM Energy))	20712	0.10	0.00	0.40	0.00	0.00
Ln(GPat(CCM GH Gases))	20712	0.01	0.00	0.09	0.00	0.00
Ln(GPat(CCM Transport))	20712	0.08	0.00	0.38	0.00	0.00
Ln(GPat(CCM Build))	20712	0.08	0.00	0.35	0.00	0.00
Ln(GPat(CCM Waste))	20712	0.03	0.00	0.16	0.00	0.00
Ln(GPat(CCM Goods))	20712	0.14	0.00	0.46	0.00	0.00

IA Table 3 Poisson Estimation

IA Table 3. Firms' toxic emissions and green innovation (Poisson estimation)

This table presents Poisson regression estimates of firms' quantity and quality of green patenting on total toxic emissions (measured by pounds in natural logarithm). Columns (1) to (4) sh results from Poisson regression, while Columns (5) to (8) present results from estimating linear regressions of the log of one plus the outcome ("log1plus" regressions) where the sample restricted to the sample usable in Poisson regression (Cohn et al. (2022)). The regression coefficients reported in Columns (1) to (4) are incidence rate ratios (IRR). For odd columns, the gre innovation measures are calculated in year *t+1*, while for even columns, they are measured in year *t+2*. Columns (1), (2), (5), (6) show results for firms' quantity of green patenting, while Colum (3), (4), (7), (8) present results for firms' quality of green patenting. All dependent variables are multiplied by 1000. The sample period is from 1987 to 2020. Firm-level controls include lagg *Capex/Assets*, *ROA*, *PPE/Assets*, *Profit Margin*, *Tobin's q*, *Leverage*, *Ln(Market Equity)*, *Cash*, and *R&D/Assets*. Continuous variables are winsorized at the 1st and 99th percentiles. All varia definitions are provided in Table A.1 in the appendix. Firm fixed effects and industry-year fixed effects are included in all regressions. Standard errors are clustered at the firm level (robust statistics are reported in parentheses). ***, **, and * denote significance at the 1%, 5%, and 10% levels, respectively.

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	Poisson				Log1plus Poisson Sample			
VARIABLES	Green Pat (t+1)	Green Pat (t+2)	Tot GPat Cites (t+1)	Tot GPat Cites (t+2)	Ln(Green Pat) (t+1)	Ln(Green Pat) (t+2)	Ln(Tot GPat Cites) (t+1)	Ln(Tot GPat Cites) (t+2)
Ln(Total Release)	1.049**	1.059**	1.086**	1.106***	16.031**	19.779**	12.686*	19.337**
	(2.099)	(2.247)	(2.407)	(2.651)	(2.274)	(2.504)	(1.723)	(2.287)
Capex/Assets	0.335	0.270*	0.824	0.360	-362.350	-520.684	-122.053	-396.933
	(-1.222)	(-1.649)	(-0.163)	(-0.885)	(-1.118)	(-1.616)	(-0.325)	(-1.047)
ROA	0.937	0.999	0.885	1.310	66.808	-41.661	-57.914	-77.296
	(-0.082)	(-0.001)	(-0.129)	(0.348)	(0.219)	(-0.136)	(-0.180)	(-0.238)
PPE/Assets	0.818	1.091	0.859	1.094	232.112	341.278*	32.535	149.476
	(-0.352)	(0.160)	(-0.197)	(0.112)	(1.183)	(1.768)	(0.163)	(0.736)
Profit Margin	0.528	0.674	0.726	0.859	-398.605	-270.970	-344.045	-137.271
	(-0.922)	(-0.660)	(-0.370)	(-0.209)	(-1.493)	(-0.965)	(-1.246)	(-0.564)
Tobin's q	0.985	1.005	1.043	1.107**	8.443	21.155	-6.207	1.111
	(-0.287)	(0.109)	(0.762)	(2.090)	(0.401)	(0.996)	(-0.276)	(0.048)
Leverage	0.820	0.839	0.577	0.590	53.723	32.333	66.340	-40.304
	(-0.681)	(-0.625)	(-1.365)	(-1.411)	(0.490)	(0.288)	(0.617)	(-0.347)
Ln(Market Equity)	1.322***	1.280***	1.238***	1.195**	126.648***	126.339***	138.795***	135.200***
	(3.565)	(3.086)	(2.903)	(2.254)	(4.549)	(4.262)	(4.811)	(4.410)
Cash	0.821	1.196	1.826	0.582	-60.560	54.440	156.720	234.771
	(-0.436)	(0.364)	(0.737)	(-0.769)	(-0.300)	(0.262)	(0.659)	(0.987)
R&D/Assets	0.217	0.167	0.085	0.058**	-733.370	-723.677	293.051	302.678
	(-1.002)	(-1.299)	(-1.618)	(-2.361)	(-0.998)	(-0.961)	(0.398)	(0.390)
Observations	9,624	8,969	8,805	8,166	9,624	8,969	8,805	8,166
Adjusted R-squared					0.737	0.742	0.681	0.684
Firm FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Industry-year FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes

IA Table 4 Trump's Election: Alternative Measure

IA Table 4. Effect of President Trump's 2016 election (DiD analysis) – Alternative Measure

This table analyzes the effect of President Trump's election in 2016 based on the difference-in-differences (DiD) model. Columns (1) through (3) show the results for the quantity, quality, and value of green innovation, respectively. Columns (4) and (5) report the results for the quantity of environmental (Env) and climate change mitigation (CCM) patents. Finally, Columns (6) and (7) present the results for the quantity of explorative and exploitative green patents. To test whether the effect of toxic emissions on corporate green innovation weakened after Trump's election, we first generate an indicator variable, namely, *Post Election*, which equals one if the year is later than 2016 (including years 2017 and 2018); then, we replace a continuous interaction term (*Ln(Total Release)×Post Election*) in Table 6 with a dummy interaction term (*High Release×Post Election*) in our regressions. *High Release* is a dummy variable which equals one if a firm's toxic emissions are higher than the median level and zero otherwise. The sample period is from 2015 through 2018, which corresponds to the four years surrounding Trump's election on November 9, 2016. All dependent variables are calculated in year *t+1* and are multiplied by 1000. Firm-level controls include lagged *Capex/Assets*, *ROA*, *PPE/Assets*, *Profit Margin*, *Tobin's q*, *Leverage*, *Ln(Market Equity)*, *Cash*, and *R&D/Assets*. Continuous variables are winsorized at the 1st and 99th percentiles. All variable definitions are provided in Table A.1 in the appendix. Firm fixed effects and industry-year fixed effects are included in all regressions. Standard errors are clustered at the firm level (robust t-statistics are reported in parentheses). ***, **, and * denote significance at the 1%, 5%, and 10% levels, respectively.

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
		Green Patents		Env & CCM		Explorative & Exploitative	
VARIABLES	Ln(Green Pat)	Ln(Tot GPat Cites)	Ln(Tot GPat Real Value)	Ln(GPat(Tot Env))	Ln(GPat(Tot CCM))	Ln(Explorative GPat)	Ln(Exploitative GPat)
High Release	62.665*	100.603**	184.086**	25.545	70.457*	50.889	35.492
	(1.741)	(2.295)	(1.984)	(1.417)	(1.915)	(1.330)	(1.373)
High Release × Post Election	-96.083**	-125.299***	-211.834***	-71.623***	-99.736**	-45.649	-53.704*
	(-2.457)	(-2.743)	(-2.957)	(-2.736)	(-2.380)	(-1.546)	(-1.718)
Post Election	-	-	-	-	-	-	-
Observations	2,079	2,079	2,079	2,079	2,079	2,079	2,079
Adjusted R-squared	0.790	0.495	0.727	0.792	0.717	0.704	0.684
Controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Firm FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Industry-year FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes

IA Table 5
Country-level locations of firms' headquaters

IA Table 5. Country-level locations of firms' headquarters

This table describes the distributional properties of firms' headquarters for the years 2015 through 2018, which correspond to the four years surrounding Trump's election on November 9, 2016. Panel A shows the detailed country-level locations of firms' headquarters, and Panel B presents the locations of firms' headquarters based on areas.

Panel A: Detailed locations of firms' headquarters

Headquarters	Frequency	Percentage (%)
USA	1943	93.46
CAN	28	1.35
GBR	24	1.15
IRL	18	0.87
LUX	16	0.77
CHE	12	0.58
JPN	10	0.48
NLD	10	0.48
SGP	4	0.19
SWE	4	0.19
ZAF	4	0.19
DNK	3	0.14
ISR	3	0.14
Total	2079	100.00

Panel B: Firms' headquarters locations by area

Headquarters	Frequency	Percentage (%)
USA	1943	93.46
EU	87	4.18
OTHER	35	1.68
ASIA	14	0.67
Total	2079	100.00

IA Table 6 Test of parallel trends

IA Table 6. Test of parallel trends

This table compares the mean yearly growth rates for *Ln(Green Pat)* and *Ln(Tot GPat Cites)* between the *Treated* and *Control* (after matching) firms from 2015 to 2016 (two years before President Trump's election on November 9, 2016). The *Treated* firms consist of those with U.S. headquarters, and *Control* firms comprise those with overseas headquarters after matching. We conduct the test following Ilhan et al. (2021) and Lemmon and Roberts (2010). The fourth column presents the *p-value* of a difference-in-means test, which tests the null hypothesis that the mean values of the two groups of firms are the same. The last column reports the Wilcoxon *p-value* of the two-sample Wilcoxon–Mann–Whitney test, which tests the null hypothesis that the two groups are taken from populations with the same median.

	Treatment Firms	Control Firms	Difference	*p-value*	Wilcoxon *p-value*
Ln(Green Pat) Growth	-52.489	-106.199	53.710	0.559	0.630
Ln(Tot GPat Cites) Growth	-37.135	-46.347	9.212	0.930	0.972

IA Table 7 Sample Composition (Trump's Election)

IA Table 7. Sample composition

This table presents the composition of the sample for the years 2015 through 2018, which correspond to the fou years surrounding Trump's election on November 9, 2016. Panel A shows the sample composition based on toxi emissions levels and headquarters locations. Panel B reports the top 10 industries ranked by the number o observations for firms with non-U.S. headquarters.

Panel A: Sample composition based on toxic emissions level and headquarters locations

Groups	Low Toxic Emissions	High Toxic Emissions	Total
Non-U.S. Headquarters	66	70	136
U.S. Headquarters	966	977	1943
Total	1032	1047	2079

Panel B: Top 10 industries ranked by the number of observations for firms with non-U.S. headquarters

Industry	2-digit SIC	Frequency	Percentage (%)
Chemical & Allied Products	28	30	22.06
Electronic & Other Electric Equipment	36	22	16.18
Metal, Mining	10	12	8.82
Primary Metal Industries	33	12	8.82
Instruments & Related Products	38	12	8.82
Industrial Machinery & Equipment	35	8	5.88
Transportation Equipment	37	8	5.88
Electric, Gas, & Sanitary Services	49	8	5.88
Petroleum & Coal Products	29	7	5.15
Oil & Gas Extraction	13	6	4.41

IA Table 8 BP (DiD Analysis)

IA Table 8. BP Deepwater Horizon oil spill (DiD analysis)

This table presents difference-in-differences regression results for the effects of the BP Deepwater Horizon oil spill for the years 2008 through 2011, which correspond to the four years surrounding the spill that began on April 20, 2010. Different from Table 8, the two-year pre- and post-event periods are not each collapsed into one observation, and *Ln(Total Release)* is the actual total toxic emissions rather than those measured over the pre-event period. *Treated* firms are identified by the two-digit Standard Industrial Classification (SIC) code (i.e., SIC 13, Oil and Gas Extraction). Columns (1) and (2) show the results when the dependent variable is *Ln(Green Pat)*, while Columns (3) to (4) present the results when the dependent variable is *Ln(Tot GPat Cites)*. Columns (1) and (3) do not include fixed effects, while Columns (2) and (4) include industry and year fixed effects. Standard errors are clustered at the industry level. All dependent and independent variables are calculated in year *t*. All dependent variables are multiplied by 1000. Firm-level controls include lagged *Capex/Assets*, *ROA*, *PPE/Assets*, *Profit Margin*, *Tobin's q*, *Leverage*, *Ln(Market Equity)*, *Cash*, and *R&D/Assets*. Continuous variables are winsorized at the 1st and 99th percentiles. All variable definitions are provided in Table A.1 in the appendix. Robust t-statistics are reported in parentheses. ***, **, and * denote significance at the 1%, 5%, and 10% levels, respectively.

Difference-in-differences regressions

	(1)	(2)	(3)	(4)
VARIABLES	Ln(Green Pat)		Ln(Tot GPat Cites)	
Ln(Total Release)	17.155**	17.214**	12.398*	13.102*
	(2.618)	(2.286)	(1.839)	(1.927)
Treated Firm	566.450***		572.567***	
	(5.687)		(5.056)	
Post-2010	69.202		9.619	
	(1.448)		(0.291)	
Ln(Total Release) × Treated Firm × Post-2010	129.552***	155.424***	39.349***	60.708***
	(8.961)	(8.254)	(2.980)	(3.624)
Observations	2,481	2,480	2,481	2,480
Adjusted R-squared	0.259	0.334	0.211	0.283
Other Interactions	Yes	Yes	Yes	Yes
Controls	Yes	Yes	Yes	Yes
Industry FE	No	Yes	No	Yes
Year FE	No	Yes	No	Yes