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## Abstract

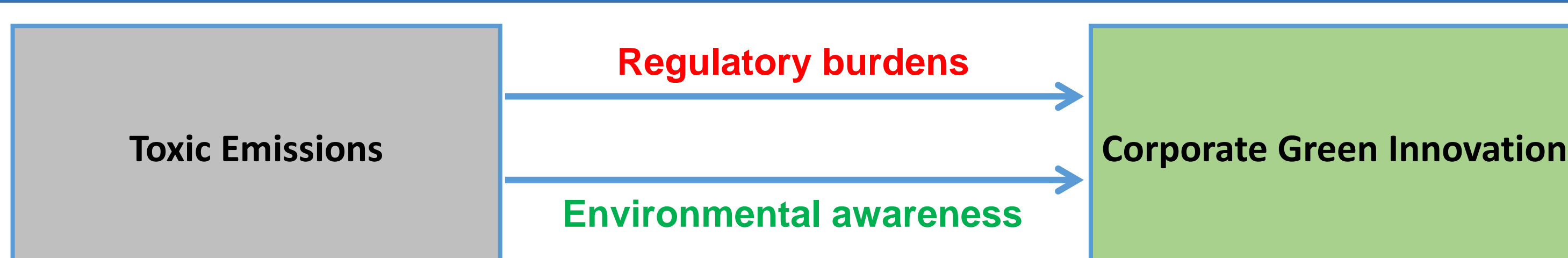
This paper examines the relationship between firms' toxic emissions and green innovation. Consistent with our main hypothesis, which hinges upon regulatory burden and environmental awareness, we show that high-emission companies produce more green patents of higher quality and value than low-emission firms. High-pollution firms appear to bring meaningful change in their green credentials by generating more environmental related green patents using explorative innovation strategies. We exploit the BP Deepwater Horizon oil spill and the election of President Trump as sources of quasi-exogenous variation to alleviate endogeneity concerns. We also find that environmental related green patents mitigate future toxic air releases.

## Background

- One of the negative consequences of industrialization has been the generation and release of toxic chemicals that have detrimental effects on the environment, climate, and public health.
  - Toxic emissions are an important component of Environmental, Social and Governance (ESG) scores (e.g., MSCI & Sustainalytics) used by investors and other market participants worldwide.
  - Investors demand a higher rate of return and banks charge a higher interest rate on loans for high-pollution firms (Chava (2014), Hsu et al. (2022)).
  - The U.S. Environmental Protection Agency (EPA) and the Department of Justice (DOJ) cooperated in federal environmental enforcement by establishing the Office of Environmental Justice (OEJ).
- Corporate green innovation has the potential to help address climate change and environmental concerns (Hong et al. (2020)).
- Anecdotal evidence - firms invest in technology to address regulatory concerns:
  - As part of their settlement with the DOJ and the EPA to resolve alleged violations of emissions, Cemex agreed to invest approximately \$10 million to use state-of-the-art technology to reduce harmful pollution.



## Research Questions



- **RQ1:** Whether high-emission firms produce more green patents. **Yes!**
- **RQ2:** Why high-emission firms produce more green patents. **Motivations.**
- **RQ3:** How high-emission firms produce green patents.
- **RQ4:** When high-emission firms prioritize green patents.
- **RQ5:** The **implication** of green patents.

## Empirical Approach

- Data Source: Toxic Release Inventory (TRI) Program Database; Patent Database Constructed by Kogan et al. (2017); Compustat; Text-based Financial Constraints (Hoberg and Maksimovic (2015)); Asset Redeployability (Kim and Kung (2017))

### Regression Model

- $Green\ Innovation_{i,t+1,2} = \alpha + \beta Toxic\ Emissions_{i,t} + \gamma Controls_{i,t} + FEs + \epsilon_{i,t}$  (1)
- $Green\ Innovation_{i,t+1,2}$  include the natural logarithm of one plus the number of green patents filed (and forward adjusted citations received by the firm's green patents filed) in years  $t+1$  and  $t+2$ .
- $Toxic\ Emissions_{i,t}$  is the natural logarithm of one plus the number of pounds of firm-level total toxic releases administered under the TRI program in year  $t$ .
- $Controls_{i,t}$  include *Capex/Assets, ROA, PPE/Assets, Profit Margin, Tobin's q, Leverage, Ln(Market Equity), Cash, and R&D/Assets*.
- $FEs$  include firm fixed effects and industry-year fixed effects.
- Standard errors are clustered at the firm level.

## Hypothesis

- **Positive impact of firms' toxic emissions on corporate green innovation**
  - High-pollution firms should produce more green patents to reduce their **regulatory burden and government investigations** (e.g., EPA penalties) because high toxic emissions are a significant predictor of **environment-related lawsuits** (Hsu et al. (2022), Xu and Kim (2022)).
  - The consequences of **environmental awareness** provide additional support for this positive relationship between the level of firms' toxic releases and green innovation, since environmental awareness is likely to increase investor activism, the cost of capital, and regulatory burdens (Chava (2014)).
- **Hypothesis 1a.** Firms with **high toxic release levels** produce **more green patents** than those with low toxic release levels.
- **Impediments to generating green innovation for high-emission firms**
  - Impediments such as **regulatory arbitrage** (Bartram et al. (2022)) and **managerial short-termism** could mean that the green patenting efforts of high-emission firms are **indistinguishable** from those of low-emission firms.
- **Hypothesis 1b.** The **green patenting efforts** of firms with high toxic release levels are **indistinguishable** from those with low toxic release levels.

## Baseline Results

VARIABLES	(1) Ln(Green Pat) <sub>t+1</sub>	(2) Ln(Green Pat) <sub>t+2</sub>	(3) Ln(Tot GPat Cites) <sub>t+1</sub>	(4) Ln(Tot GPat Cites) <sub>t+2</sub>
Ln(Total Release) <sub>t</sub>	8.635*** (2.773)	10.154*** (2.908)	6.400** (2.045)	9.212** (2.573)
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.

## Key Findings

- **RQ1:** High-emission firms produce more high-quality, valuable green patents than their low-emission counterparts, suggesting a **double-edged** impact of highly polluting firms on society. Results based on **the Trump election** and **the Deepwater Horizon event** support the **causal** inferences.
- **RQ2:** High-emission firms' demand for green innovation is driven by **local environmental and climate policies**, as well as **environmental awareness**.
- **RQ3:** High-emission firms use **explorative** innovation strategies and generate more **environmental and climate change mitigation (CCM)** green patents.
- **RQ4:** **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.
- **RQ5:** Corporate green innovation **mitigates toxic air emissions**.

## Contribution

- First study examining the impact of firms' toxic emissions on green innovation.
- Contributing to a growing stream of literature that examines **environmental pollution** (Akey and Appel (2021), Hsu et al. (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 et al. (2020), who find that energy firms (with a low ESG score) produce more green patents.
- Contributing to the studies focusing on the impacts of **environmental and climate policies** in financial areas.
- Prior studies show that constraints (e.g., financial constraints and limited asset redeployability) impede corporate innovation. Our paper extends the literature by showing that constrained firms may make **structural decisions** rather than **simply reduce all innovation activities**.

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