The Pollution Premium

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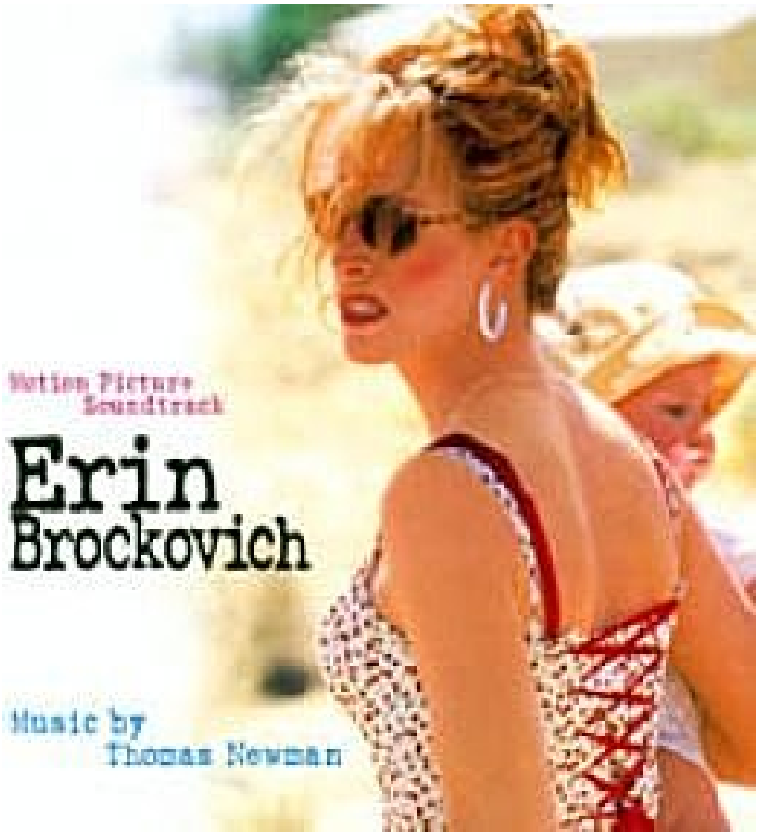
Research Question

- Research question: Effect of industrial pollution on firm valuation
- Key messages:
  - Firms with more toxic emissions carry higher expected returns.
  - Industrial pollution increases cost of equity.
- Main findings:
  - Construct empirical proxies for firm-level pollutants.
  - Examine the CS variation in stock returns driven by diff. emission intensity
  - Identify economic mechanism: environmental regulation uncertainty risks
  - Develop a model to formalize our intuition & quantify model predictions.

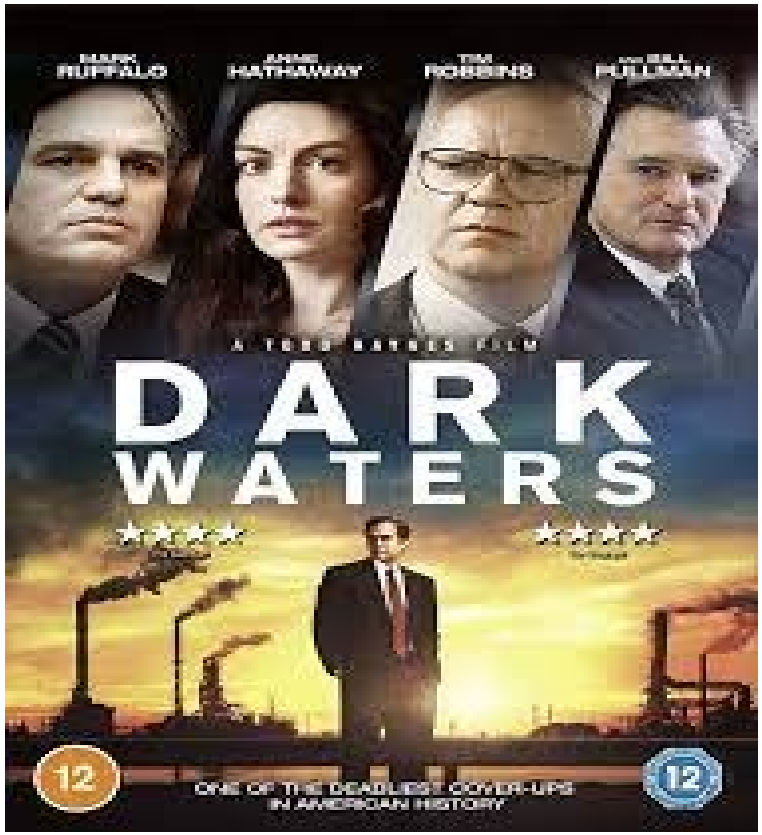
Motivating Example

Industrial Pollution and Litigations



Movie: Erin Brockovich (2000)

Pacific Gas & Electric



Movie: Dark Waters (2019)

DuPont

Motivating Example

Dow's Environmental Settlement

- Civil penalty: \$3m in 2002, \$77m in 2019

Summary of the Paper

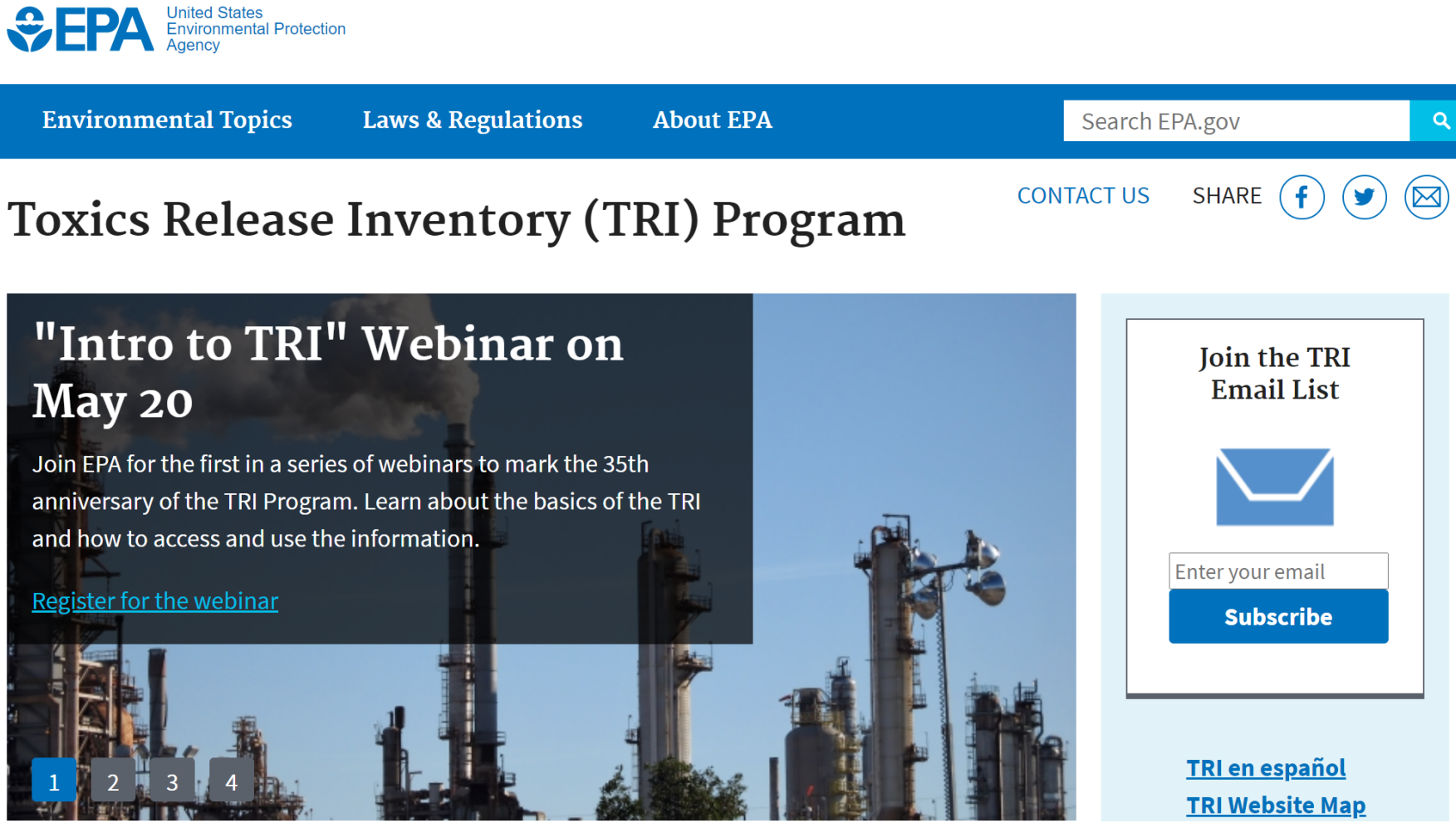
- Empirical evidence: higher emissions $\rightarrow$ higher cost of equity
  - Measure emission intensity and construct sorted portfolios
  - High-emission firms 4.42% p.a. higher average return than their industry counterparts
- Economic mechanism – environmental regulation uncertainty risk
  - Higher emission intensity predicts more future litigations
  - Higher emission intensity relates to a higher (lower) current (future) profitability
  - An event study: Trump's presidential victory in 2016
- Theory
  - A model with heterogenous firms and learning for regulation changes
  - Formalize the intuition and quantitatively account for the pollution premium

Related Literature

- Policy implications and environmental pollution:
  - Acemoglu (2002), Acemoglu, Aghion, Bursztyn, and Hermous (2012), Acemoglu, Akcigit, Hanley, and Kerr (2016), Aghion, Dechezlepretre, Hermous, Martin, and van Reenen (2015), Currie, Davis, Greenstone, and Walker (2015), and so on.
  - Our paper: firm-level pollution and gov.'s policies have AP implications.
- Investment strategies with social responsibility and climate change:
  - Bolton and Kacperczyk (2019, 2020), Pastor et al. (2019), Hong and Kacperczyk (2009), Chava (2014), Hong, Li, and Xu (2017), Choi, Gao, and Jiang (2018), Bansal and Ochoa (2016), and Giglio, Maggiori, Rao, Stroebel, and Weber (2018), and so on.
  - Our paper: a regulation uncertainty risk-based explanation.
- Investment/production-based models on the cross-sectional returns:
  - Berk, Green, and Naik (1999), Gomes, Kogan, and Zhang (2003), Zhang (2005), Papanikolaou (2011), Ai, Croce, and Li (2013), Eisfeldt and Papanikolaou (2013), Kogan and Papanikolaou (2012, 2013, 2014), and among others
  - Our paper: firms' pollution-profit relation and policy uncertainty leads to return predictability.

Data and Measurement

- Data Sources
  - Toxic release inventory (TRI), by U.S. EPA
  - Enforcement and Compliance History Online (ECHO) System
  - CRSP, Compustat, ASSET4, and Others
- Toxic Chemical Emissions in TRI
  - Chemical emissions under a facility (plant)
  - Coverage: 1987-2019; annual data
  - Emission intensity: sum of emissions at firm level scaled by total assets
- Enforcement cases in ECHO
  - Each case with the identified dependent (plant)
  - Settlements: civil penalty and related recovery cost
- Matched sample:
  - Match EPA with CRSP, Compustat, and Capital IQ.
  - U.S. public firms traded on NYSE, AMEX or NASDAQ.
  - Total 9989 firm-year observations with non-missing emissions.
  - Sample period: 1991-2016; On average, 670 companies per year.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Toxics Release Inventory (TRI) Program
"Intro to TRI" Webinar on May 20
Join EPA for the first in a series of webinars to mark the 35th anniversary of the TRI Program. Learn about the basics of the TRI and how to access and use the information.
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ICIS-FE&C Download Summary and Data Element Dictionary

The Enforcement and Compliance History Online (ECHO) system incorporates Federal enforcement and compliance (FE&C) data from the Integrated Compliance Information System (ICIS), used to track federal enforcement cases. ICIS contains information on federal administrative and federal judicial cases under the following environmental statutes: the Clean Air Act (CAA), the Clean Water Act (CWA), the Resource Conservation and Recovery Act (RCRA), the Emergency Planning and Community Right-to-Know Act (EPCRA) Section 313, the Toxic Substances Control Act (TSCA), the Federal Insecticide, Fungicide, and Rodenticide Act (FIFRA), the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA or Superfund), the Safe Drinking Water Act (SDWA), and the Marine Protection, Research, and Sanctuaries Act (MPRSA).

Empirical Facts

Summary Statistics

Table: **Emission Intensity across Industries**

Industry Name	**Obs**	**Mean**	**Median**	**Std**
Oil	260	35,470.13	605.17	207,681.14
Construction	899	12,456.96	2,671.39	24,423.21
Chemicals	1,083	11,010.58	1,711.43	30,400.66
Construction Materials	901	10,851.91	624.55	70,868.74
Electrical Equipment	357	8,019.68	542.39	23,308.29

- Unit of measure: emission (pounds) / total asset (million dollars)

Univariate Portfolio Sorting

Future Returns: October t to September $t+1$ based on Emission in $t-1$

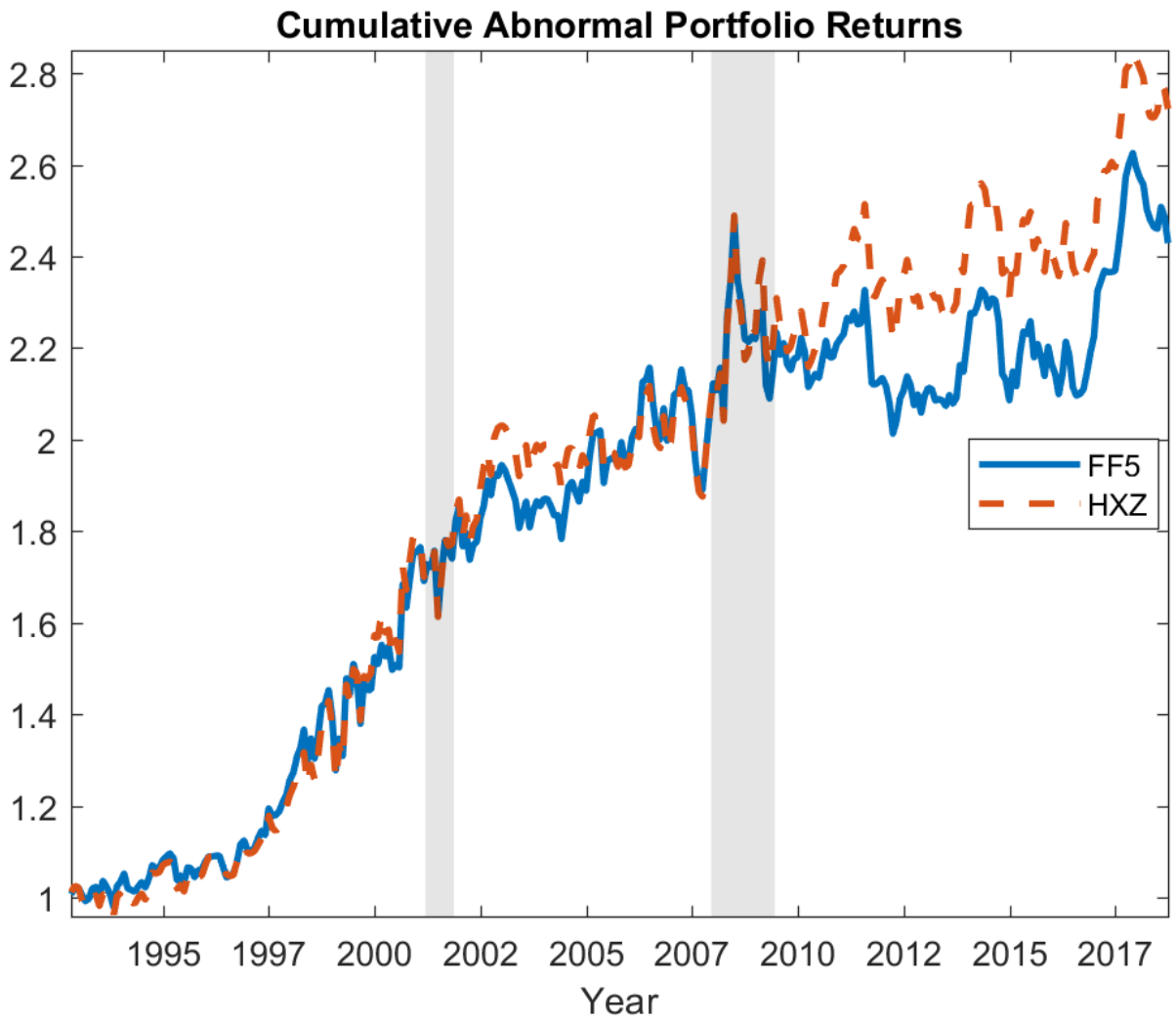
Table: **Univariate Portfolio Sorting within FF49 Industry**

	L	2	3	4	H	H-L
	Panel A: Emission Intensity by AT					
E[R]-R_f (%)	6.90	9.68	9.08	9.11	11.32	4.42
[t]	2.03	3.15	3.16	2.86	3.26	3.66
Std (%)	15.33	16.94	15.64	16.46	16.30	9.53
SR	0.45	0.57	0.58	0.55	0.69	0.46
	Panel B: Emission Intensity by ME					
E[R]-R_f (%)	6.87	8.35	9.56	8.06	12.68	5.81
[t]	2.23	2.52	3.16	2.04	3.94	2.56
Std (%)	14.71	16.96	16.01	17.53	16.73	10.06
SR	0.47	0.49	0.60	0.46	0.76	0.58

Empirical Facts

Cumulative Abnormal Returns of the High-minus-Low Portfolio

- Abnormal Return: Return adjusted for FF5 or HXZ factors



The Economic Mechanism

Future Litigations

- Higher emission intensity predicts more future litigations

$$N_{i,t+5} = a + b \times \log Emissions_{i,t} + c \times Controls_{i,t} + \varepsilon_{i,t},$$

	Probit	NB	Possion
Log Emissions	0.66	1.24	1.24
[t]	24.99	26.74	17.38

  - $N_{i,t+5}$ binary or count of environmental lawsuits $t+1$ to $t+5$.
  - Control for firm's fundamental and industry by year FE.
- Interpretations: one-std-increase in the logarithm of emission intensity
  - a 16.20% higher probability
  - 2.46 times higher litigation frequency
  - Mean penalties (real term): \$ 1.57 m, Std: \$ 8.93 m

- Unexpected surprise: Trump's presidential victory in 2016
  - An unexpected shock switching to a weak regulation regime
- Empirical Finding:
  - High-emission firms benefit more from such an exogenous shock.

Figure: Trump's Regulatory Rollback

The Economic Mechanism

An Event Study of Regulation Uncertainty Risk (Con'd)

- Cumulative abnormal return (CAR) w.r.t. CAPM: price reactions on a (0,10) ten-day event window
  - Construct emission-sorted portfolios

Table: **A Event Study**

	L	**2**	**3**	**4**	**H**	**H-L**
Daily Ret.	3.64	5.35	5.03	3.75	6.31	2.68
Annualized Ret.	90.89	133.87	125.82	93.85	157.86	66.97
[t]	4.55	5.62	5.14	3.84	5.11	1.98

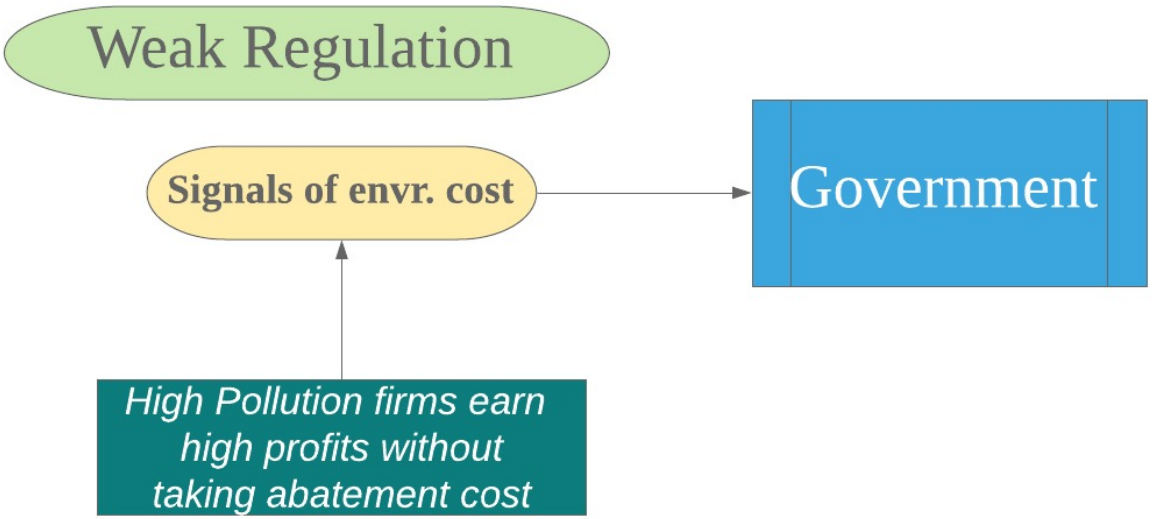
- Subsequently, Ramelli et al. (2021) shows supportive evidence that clean firms benefit from 2020 Joe Biden's presidential election victory.

An AP Model Formalize the Economic Mechanism

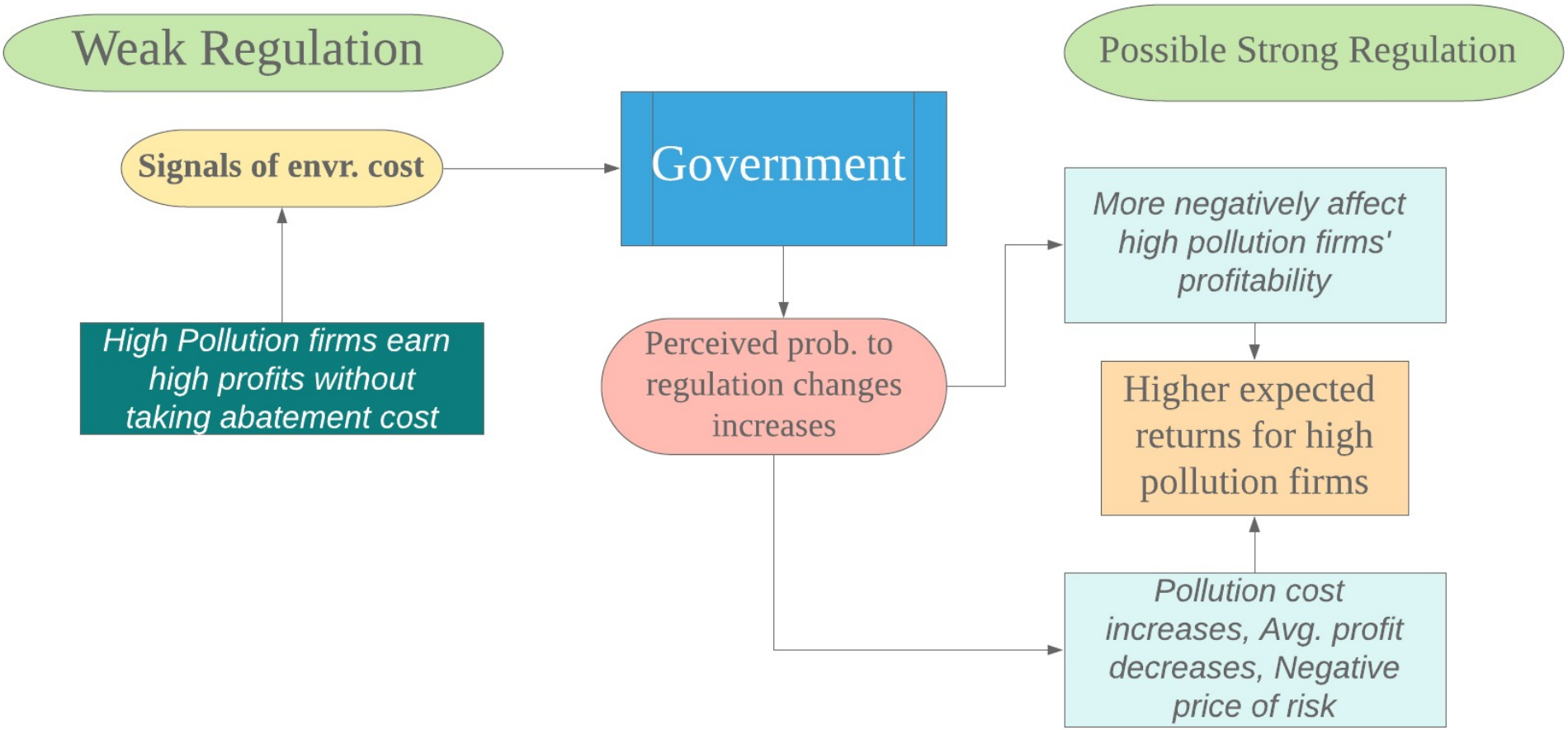
Model Overview

- A model with heterogenous firms and learning for regulation changes
- Key model features:
  - Dirty firms make more pollution and earn higher current profits than clean.
  - Govt learns about the agg pollution effect and decides whether to change its regulation policy.
  - Investors form expectation about gov't policy changes.
  - Dirty firms more adversely affected by regulation changes than clean firms, thus demand higher expected returns (i.e., "pollution premium").
  - Changes in investors' perceived probability of policy change is a source of priced risks.
- Coherent empirical evidence to support pollution premium & model implications.

Model Structure



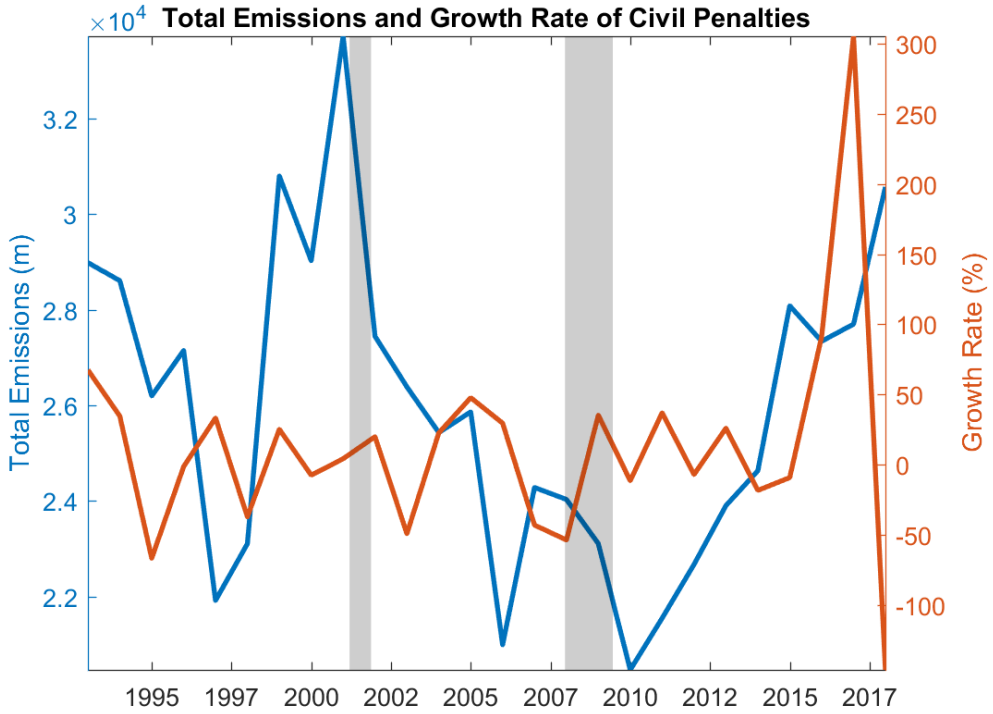
Model Structure



Testable Model Implications

Proxy for Regulation Regime Change Risk

- Growth in civil penalties: a proxy for regulation regime change risk
- A higher growth suggests increased perceived probability of a policy regime switch
  - a spike of growth followed by a sharp decline: Obama $\rightarrow$ Trump
- A weak regulation regime is associated with higher toxic emissions.



Testable Model Implications

- Testable implications w.r.t. a positive shock to regulation regime change risk
  1. Implication 1: future profitability drops more for high pollution firms
     - more negative cash flow beta
  2. Implication 2: realized returns drops more for high pollution firms
     - more negative return beta
  3. Implication 3: negative price of risk

Testable Model Implications

Implications 1 and 2

Table: **Risk Exposure**

	L	2	3	4	5	H-L
			Panel A: Risk Exposure			
β^i_{MKT}	15.77	17.2	17.49	17.81	16.55	0.78
[t]	9.63	11.95	8.61	7.07	11.13	0.90
$\beta^i_{\Delta n}$	1.45	2.69	-0.41	-0.85	-1.46	-2.91
[t]	1.39	3.05	-0.33	-0.65	-1.24	-3.45
$\alpha^i = \bar{R} - \beta^i \times \lambda$	-3.09	0.65	-1.57	-1.74	0.19	-3.48
[t]	-1.19	0.26	-0.60	-0.67	0.07	-1.37
			Panel B: Future Profitability			
Δn	-0.31	-0.44	-0.23	-0.44	-0.54	-0.35
[t]	-1.01	-1.26	-0.49	-2.97	-1.98	-2.18

Testable Model Implications

Implication 3: Price of Risk

- Moment conditions implied the Euler equation:

$$\mathrm{E}\left[MR_i^e\right] = 0$$

- Expected returns:

$$\mathrm{E}[R_i^e] = -\mathrm{Cov}(M, R_i^e),$$

- The empirical equivalent of the SDF:

$$M_t = 1 - \lambda \times dZ_t - \lambda_{c,t} \times d\hat{Z}_t^c$$

- Implications of the GMM test:
  1. Signal shocks are negatively priced, $\lambda_{c,t} < 0$
  2. Sargan–Hansen J Test: model is not misspecified

Testable Model Implications

Implication 3: Price of Risk (Con'd)

Table: **Price of Risk**

	(1)	(2)	(3)
MKT		0.69	0.67
[t]		10.57	8.60
Δn	-1.66		-0.99
[t]	-6.23		-4.37
SSQE (%)	21.78	2.16	1.54
MAPE (%)	30.12	8.47	6.63
J-Test	6.600	6.776	6.667
p	0.97	0.99	0.95
JT-Diff			2.725
p			0.099

A Summary of Model Intuition

- As the regulation tightens, high-emission firms are more adversely affected (Implication 1)
- High-emission firms face more negative exposures to regulation uncertainty risk (Implication 2)
- Environmental regulation uncertainty risk is negatively priced (Implication 3)
- To sum up, investors require higher risk premia (i.e., cost of equity) to hold these firms' stocks.

Alternative Explanations

- We empirically examine a wide set of potential explanations:
  - Behavioral explanations
    - Preference for greenness
    - Under-reaction to emission abatement
    - Retail investors' behavioral bias
  - Corporate policies and governance
    - Weak governance and monitoring
    - Political connections
  - Existing systematic risk factors
    - Technology obsolescence
    - Financial constraint
    - Economic and political uncertainty
    - Adjustment cost

Afterthoughts

- Recent evidence: green stocks outperform brown stocks, post 2013.
  - Based on Pastor, Stambaugh and Taylor (PST, 2023)
  - Greenness is based on MSCI ESG Ratings, different from our measure.
- **Does this evidence contradict with our theory?** NO.
- PST(2023) emphasize the difference between realized return v.s. expected return.
  - Recent outperformance of green stocks is "realized return".
    - Due to an unanticipated increase in environment concern. (i.e. a sequence of unexpected good news to green stocks).
    - Such outperformance may not expect to go forward.
  - PST confirm green stocks still have lower "expected return" than brown.
    - Expected return measured by ex-ante implied cost of capital.
    - Perfectly consistent with both our theory and evidence.

Afterthoughts

Figure: ICC spread of green-minus-brown portfolio has been negative!

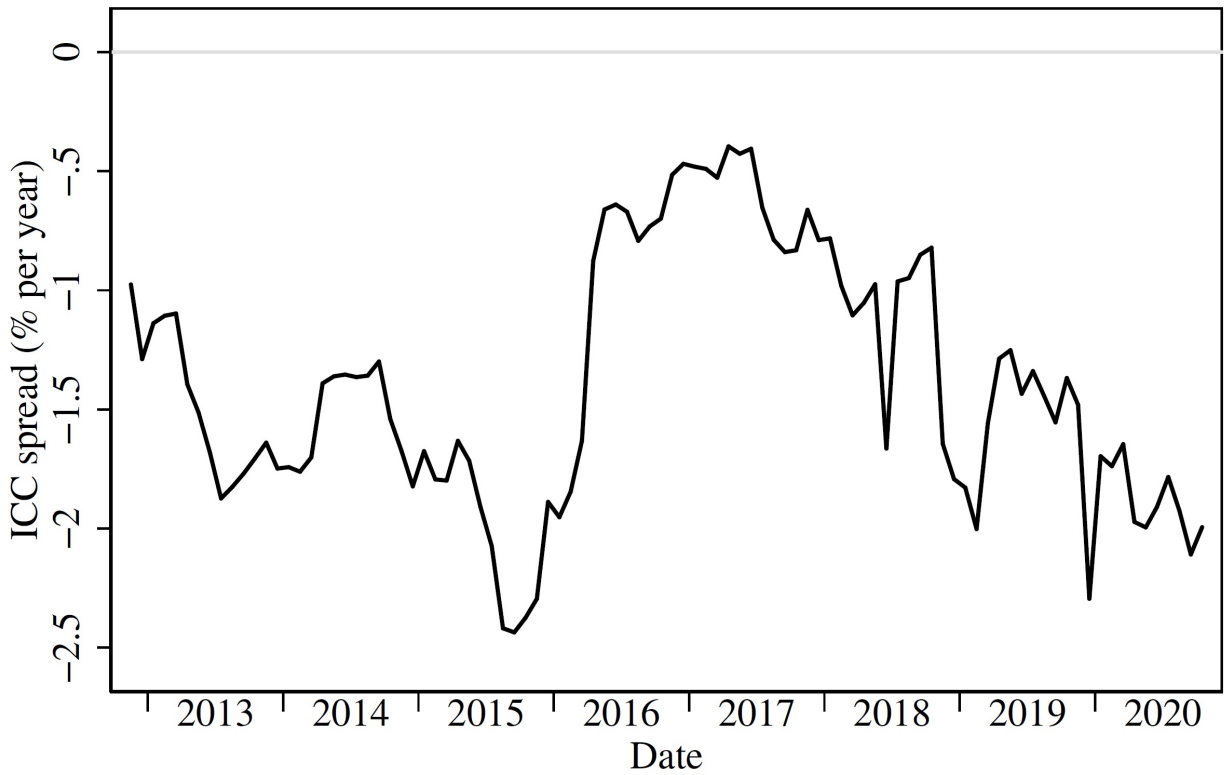


Figure 4 Panel B from Pastor, Stambaugh and Taylor (2023)

- Consistent with our paper: ICC spread of green-minus-brown – negative of the pollution premium

Conclusive Remarks

- We study the asset pricing implications of environmental pollution.
- Take-away:
  - Investors have demanded risk premium by holding pollution stocks.
  - High emission intensity increases the cost of equity.
  - Underlying economic mechanism: regulation uncertainty risk

The End