Pollution Abatement Investment under Financial Frictions and Policy Uncertainty

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Abstract

We examine how financial frictions and policy uncertainty jointly influence firms' investments in pollution abatement.

Our data analyses suggest that financially constrained firms are less likely to invest in pollution abatement and are more likely to release toxic pollutants, with this pattern intensified by policy uncertainty surrounding environmental regulations.

We develop a general equilibrium model with heterogeneous firms, including both financially constrained and unconstrained firms, in which financially constrained firms face increased marginal costs of finance from pollution abatement.

The aggregate effect of environmental policies depends on the distribution of financial frictions and policy uncertainty.

Mechanisms

Mechanism: Setup

Intuition Here:

- *1. Diminishing marginal benefit and increasing marginal cost of abatement investment*
- *2. Such asymmetry is further amplified by policy uncertainty*

A firm that solves a one-period problem of abatement:

- an abatement investment a; emission $e = \frac{\bar{e}}{\epsilon + a}$; pollution penalty τe
- External financing frictions: (1) an initial debt b
  (2) receives future financial cost -ϕ if binding $d \leqslant 0$
- Policy uncertainty: a pollution penalty $\tau \sim [0, \bar{\tau}]$ with pdf $\pi_\tau(\tau)$ and s.d. σ_τ

The firm's optimization: (define $\tilde{a} \equiv a$ as the direct cost of a)

$$\max_a \int_0^{\bar{\tau}} \left\{ \underbrace{[1 - b \overbrace{- \tilde{a}}^{\text{Cost}} \overbrace{- \tau e}^{\text{Benefit}}]}_{\text{Internal Fund: } d} + [\nu - \underbrace{\phi \cdot \mathbf{1}(d \leqslant 0)}_{\text{Costly External Financing}}] \right\} y \pi_\tau(\tau) d\tau \quad (1)$$

Mechanism: Constrained Firms

A constrained firm that has high initial debt b_c: $\rightarrow$ low cutoff $\hat{a}_c(\bar{\tau}, b_c)$

- an optimal abatement investment: $a_c^* > \hat{a}_c(\bar{\tau}, b_c)$
- there exists a cutoff $\hat{\tau} = \frac{1-b-\tilde{a}}{e}$ such that $d \leqslant 0$ if $\tau > \hat{\tau}$
- financial costs and benefits enter the MC and MB curves

$$MC = \underbrace{1}_{\text{direct cost}} + \underbrace{(-\phi)\frac{\pi_\tau(\hat{\tau})}{1 - \Pi_\tau(\hat{\tau})}\frac{d\hat{\tau}}{d\tilde{a}}\frac{d\tilde{a}}{da}}_{\text{financial cost}} = 1 + \phi \frac{\pi_\tau(\hat{\tau})}{1-\Pi_\tau(\hat{\tau})}\frac{(\epsilon + a)}{\bar{e}}$$

$$MB = \underbrace{-E[\tau]\frac{de}{da}}_{\text{direct benefit}} + \underbrace{(-\phi)\frac{\pi_\tau(\hat{\tau})}{1 - \Pi_\tau(\hat{\tau})}\frac{d\hat{\tau}}{de}\frac{de}{da}}_{\text{financial benefit}} = \frac{\bar{e}E[\tau]}{(\epsilon+a)^2} + \phi \frac{\pi_\tau(\hat{\tau})}{1-\Pi_\tau(\hat{\tau})}\frac{(1-b-a)}{\bar{e}}$$

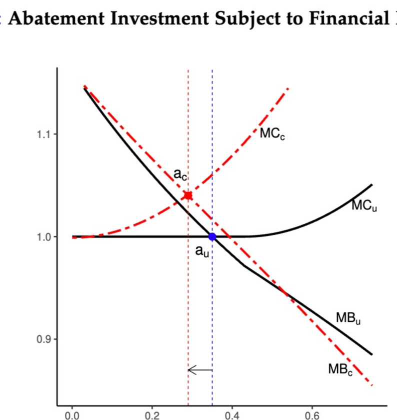
- where $\frac{\pi_\tau(\hat{\tau})}{1-\Pi_\tau(\hat{\tau})}$ is the hazard rate of incurring $d < 0$, external financing cost ϕ
- the marginal financial cost increases in a
- the marginal financial benefit decreases in a and b

Mechanism: the Implication of Financial Frictions

Takeaways:

1. Financial cost and benefit asymmetry in abatement $a \rightarrow$ constrained $a_c^* \downarrow$
2. Higher initial debt further decreases financial benefit $\rightarrow$ constrained $a_c^* \downarrow$

Figure: **Abatement Investment Subject to Financial Frictions**

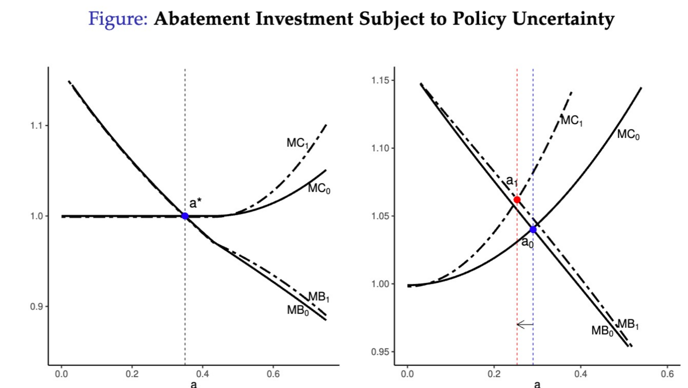


Mechanism: the Implication of Policy Uncertainty

The hazard rate $\frac{\pi_\tau(\hat{\tau})}{1-\Pi_\tau(\hat{\tau})}$ increases with σ_π (e.g., Arellano, Bai, Kehoe, 2019)

Takeaway: 3. Financial cost and benefit asymmetry in a enlarged $\rightarrow a_c^* \Downarrow$

Figure: **Abatement Investment Subject to Policy Uncertainty**



(a) Unconstrained Firm (b) Constrained Firm

Empirical Analysis

Data Sources I: (pollution, abatement, and production at facility-level)

- Toxic Release Inventory (TRI) Database by the US Env'tl Protection Agency (EPA)
- Pollution Prevention (P2) Database, also from EPA
- National Establishment Time-Series (NETS) Database

Data Sources II: (financial constraint and policy uncertainty)

- CRSP, Compustat, and Others (BEA, BLS, FRED)
- Stateline Database and the CQ Election Electronic Library
- Textual Analysis of Firm-level Uncertainty by Hassan et al. (2019, 2020a, 2020b)

Connecting Data Sources: (facility-firm-state, 1991-2017)

- Abatement activities and pollution emissions at facility-level
- Financial constraint measures at firm-level
- Policy uncertainty measures at state or firm-level

Regression Specification: (Poisson and OLS)

$$x_{p,i,s,t+h} = \beta_1\, \sigma_{\tau|s,t} + \beta_2\, \sigma_{\tau|s,t} \times \eta_{i,s,t} + \beta_3\, \eta_{i,s,t} + \beta_4\, \Gamma_{i,s,t} + \beta_5 X_{s,t} + \beta_6 \mathtt{RepRatio}_{s,t} + \psi_p + \pi_t + \varepsilon_{p,i,s,t}, \quad (2)$$

- $x_{p,i,s,t+1\rightarrow t+h}$: abatement by facility p in state s and belonging to parental firm i at from $t+1$ to next election $t+h$
- $\sigma_{\tau|s,t}$: " = 1" if the most recent state governor vote diff is within 5%; o/w " = 0"
- $\eta_{i,s,t}$: financial constraint of parental firm i in year t (WW and SA, standardized)
- $\Gamma_{i,s,t}$: firm-level controls (size, book-to-market, inv. rate, and ROA)
- $X_{s,t}$: state-level controls (local fundamentals)
- $\mathtt{RepRatio}_{s,t}$: number of Rep. wins over the past 4 gubernatorial elections
- ψ_p: facility fixed effects; π_t: time fixed effects; SE cluster at facility-level;

Table: **Abatement Investment under Financial Frictions and Policy Uncertainty**

	Election-Based Uncertainty							
	Poisson				OLS			
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
σ_τ	0.00	0.01	-0.00	0.01	-0.00	-0.00	-0.00	-0.00
[t]	0.21	0.61	-0.05	0.38	-0.17	-0.12	-0.27	-0.25
WW	-0.01	-0.03			-0.01	-0.01		
[t]	-0.21	-0.66			-0.74	-1.46		
WW × σ_τ	-0.06	-0.06			-0.01	-0.01		
[t]	-3.70	-3.73			-2.86	-2.63		
SA			-0.19	-0.21			-0.05	-0.06
[t]			-4.41	-4.57			-4.46	-4.51
SA × σ_τ			-0.04	-0.04			-0.01	-0.01
[t]			-2.52	-2.61			-1.92	-1.70
Observations	91,433	89,990	93,096	91,351	149,882	148,130	152,272	150,150
Controls	No	Yes	No	Yes	No	Yes	No	Yes
Facility FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Time FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Cluster SE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes

- With respect to the economic significance: take SA measure in OLS, for example
  If the SA index increases by one standard deviation:

1. Pollution abatement activities drop between 5% and 6%
2. With increased policy uncertainty, we find a further reduction of 1%

Table: **Toxic Emissions under Financial Frictions and Policy Uncertainty**

	Election-Based				Text-Based			
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
σ_τ	-0.03	-0.03	0.39	0.37	-0.01	-0.01	-0.01	-0.01
	(-0.95)	(-0.82)	(1.65)	(1.56)	(-1.06)	(-1.03)	(-1.39)	(-1.33)
WW	-0.06	-0.07			-0.01	-0.01		
	(-0.83)	(-0.73)			(-1.41)	(-1.04)		
WW × σ_τ	0.08	0.08			0.02	0.02		
	(2.46)	(2.46)			(2.56)	(2.62)		
SA			-0.13	-0.16			0.02	0.02
			(-1.57)	(-1.81)			(4.06)	(4.07)
SA × σ_τ			0.18	0.17			0.01	0.01
			(1.81)	(1.71)			(2.02)	(2.09)
Observations	112,894	111,893	114,746	113,649	64,280	64,142	65,028	64,853
R-squared	0.72	0.72	0.72	0.72	0.92	0.92	0.92	0.92
Controls	No	Yes	No	Yes	No	Yes	No	Yes
Facility FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Time FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Cluster SE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes

Quantitative Analysis

A Full-Blown GE Model

Heterogeneous Production w/ Pollution Firms:

- Produce and invest in both capital and abatement technology
- Face idiosyncratic productivity shocks and pollution penalty shocks
- Borrow subject to collateral constraints + non-negative dividend requirement

A General Equilibrium Block

- A family of representative households consumes and supplies labor
- Dis-utility of representative households from pollution emissions
- Aggregate capital and abatement technology producers

Policy Uncertainty Shocks

- MIT Shocks to the variance of the idiosyncratic pollution penalty shocks

Production and Finance: (Khan and Thomas, 2013)

- Production: $y_{jt} = z_{jt} k_{jt}^{\alpha}$, $\alpha < 1$ with $\log z_{jt+1} = \rho \log z_{jt} + \epsilon_{jt+1}$
- Finance: (1) collateral constraints $b' \leqslant \theta_k k$; (2) non-negative dividend $d_{jt} \geqslant 0$.

Pollution and Abatement:

- Emission: $e_{jt} = \frac{\bar{e}}{x_{jt}} z_{jt} k_{jt}^{\alpha}$, where $\bar{e}$ is the default level of emission intensity
- Abatement tech: $x_{jt+1} = (1 - \delta_x) x_{jt} + a_{jt+1}$, where δ_x is the depreciation
- Abatement investment: $a_{jt+1} \geqslant 0$

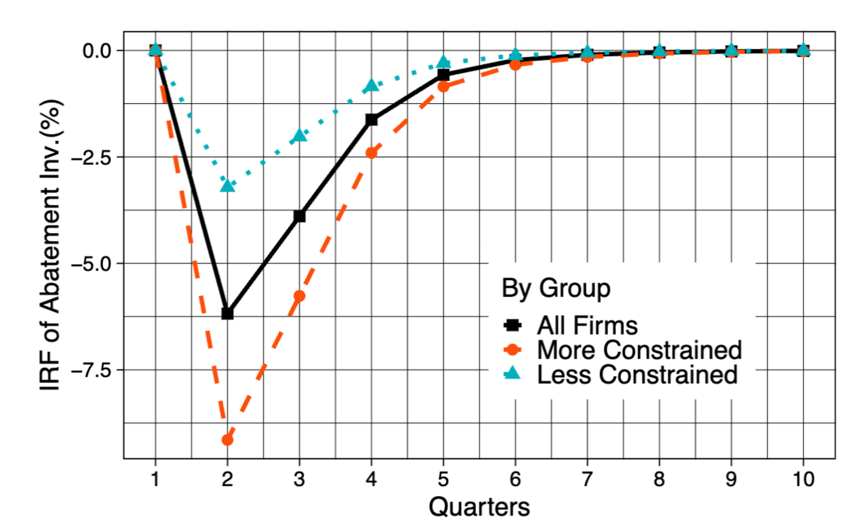
Environmental Policy Uncertainty:

- Pollution penalty: $\tau_{jt} e_{jt}$ (Shapiro and Walker, 2018)
- Idiosyncratic shock τ_{jt} i.i.d across firms following $\tau_{jt} \sim \mathtt{Lognormal}(\mu, \sigma)$
- Shocks to environmental policy uncertainty will be reflected in changes in σ_τ

Table: : **Targeted Moments: Model and Data**

Moments	Data	Model
Output and Finance		
1-year autocorrelation of output	0.89	0.90
3-year autocorrelation of output	0.69	0.71
5-year autocorrelation of output	0.53	0.56
Size ratio of entrant relative to average	0.28	0.28
Annual exit rate of firms	0.09	0.09
Mean of debt/asset ratio	0.34	0.34
Pollution and Abatement		
Mean of emission intensity	5.38	4.16
Median of emission intensity	5.66	4.45
Standard deviation of emission intensity	3.05	1.82
P75/P25 of emission intensity	1.98	1.56
Ratio of zero pollution penalty	0.40	0.40
Mean of pollution penalty	0.02	0.02
Standard deviation of pollution penalty (normal)	0.02	0.02
Standard deviation of pollution penalty (elevated)	0.04	0.04

Figure: **Impulse Responses of Abatement Investment**



Conclusions

Effectiveness of environmental policy depends on FCs and policy uncertainty.

Empirical evidence: higher FCs × policy uncertainty → lower abatement.

Preliminary intuition in a simple model shows the mechanism.

Preliminary macro-finance model for quantification.

What's Next?

Explore more heterogeneity in the data/model.

More rigorous model simulated regressions or SMM.

Optimal policy decision under financial frictions and policy uncertainty.

A combination of financial policy and environmental policy.

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