# Financial Frictions and Pollution Abatement Over the Life Cycle of Firms


Min Fang
University of Florida

Po-Hsuan Hsu
National Tsing Hua University

Chi-Yang Tsou
University of Manchester


September 14, 2024
IWFSAS 2024

# Motivation

- Known: Low inputs in pollution abatement in the aggregate
  - 2005 EPA: \$5.9b in capital investment, \$20.7b in operating cost
  - 2005 BEA: \$2,534.7b in physical investment, \$341.9b in R&D investment
  - Pollution abatement is mainly in operation costs, which is hard to finance

# Motivation

- Known: Low inputs in pollution abatement in the aggregate
  - 2005 EPA: $5.9b in capital investment, $20.7b in operating cost
  - 2005 BEA: $2,534.7b in physical investment, $341.9b in R&D investment
  - Pollution abatement is mainly in operation costs, which is hard to finance
- New Findings: Abatement activities over firms' life cycle
  - Strong sorting of abatement, investment, total emission, and emission intensity over size, age, and other financial friction indicators

# Motivation

- Known: Low inputs in pollution abatement in the aggregate
  - 2005 EPA: \$5.9b in capital investment, \$20.7b in operating cost
  - 2005 BEA: \$2,534.7b in physical investment, \$341.9b in R&D investment
  - Pollution abatement is mainly in operation costs, which is hard to finance
- New Findings: Abatement activities over firms' life cycle
  - Strong sorting of abatement, investment, total emission, and emission intensity over size, age, and other financial friction indicators
- Unknown: What drives insufficient pollution abatement investment?
  1. Research Question: The role of financial frictions over firms' life cycle
  2. Economic Implications:

     Aggregate outcomes and welfare + Design of environmental policies

# Summary of the Paper

Empirical Evidence: Pecking order of investment and abatement

- Financially constrained firms prefer physical investment to pollution abatement
- Lower abatement leads to higher emission intensity

# Summary of the Paper

Empirical Evidence: Pecking order of investment and abatement

- Financially constrained firms prefer physical investment to pollution abatement
- Lower abatement leads to higher emission intensity

Full-blown Quantitative Model:

- A GE model with heterogeneous firms and financial constraints
- Formalize the intuition for the joint link btw abatement, emission, inv, and debt
- Quantitatively accounts for a set of empirical evidence

# Summary of the Paper

Empirical Evidence: Pecking order of investment and abatement

- Financially constrained firms prefer physical investment to pollution abatement
- Lower abatement leads to higher emission intensity

Full-blown Quantitative Model:

- A GE model with heterogeneous firms and financial constraints
- Formalize the intuition for the joint link btw abatement, emission, inv, and debt
- Quantitatively accounts for a set of empirical evidence

Quantitative Implications:

- 1: The effect of financial frictions
- 2: The effect of regulatory penalty
- 3: Environmental policy implications

# Empirical Facts

# Data and Measurements

**Data Sources I: toxic emission, pollution abatement, and env. litigation**

- Toxic Release Inventory (TRI) Database Data: TRI
- Pollution Prevention (P2) Database Data: P2
- Enforcement and Compliance History Online (ECHO) system
- National Establishment Time-Series (NETS) Database

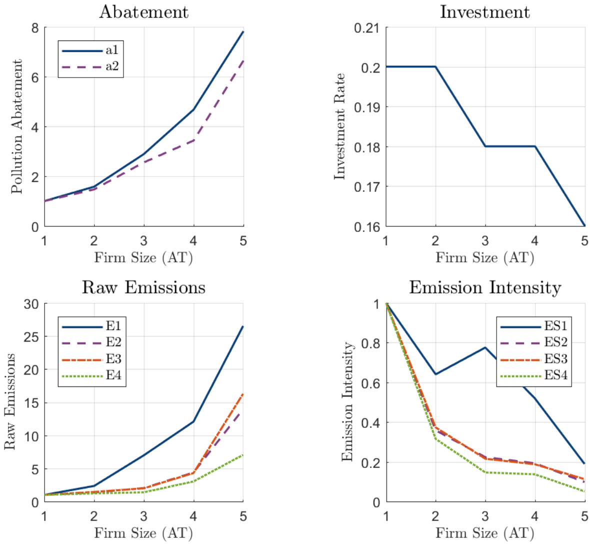
**Data Sources II: financial constraint and other firm characteristics**

- CRSP, Compustat, and others (BEA, BLS, FRED)

**Variables of Interests:**

- Pollution Abatement: sum up the number of new source reduction activities
- Emission Intensity: sum up raw emissions normalized by sales
- Financial Constraint: total assets, property plant and equipment, age, and SA
- Other Firm Characteristics

# Pecking Order: Firm Grouping based on Size



# Pecking Order: More Facts and Takeaway

Additional evidence of the pecking order

- Same strong sorting on different measures of Size, Age, FF indicators
- Significant regression coefficients with the same measures

## Pecking Order: More Facts and Takeaway

Additional evidence of the pecking order

- Same strong sorting on different measures of Size, Age, FF indicators
- Significant regression coefficients with the same measures

Takeaways:

- Observation: Small/young/constrained firms prefer investment to abatement
- Underlying: The interplay of FFs, firm growth (through inv.), and environment

# The Pecking Order of Investment and Abatement

# The Model in One Page

**Production and Pollution**

- Production: $y_{jt} = z_{jt} k_{jt}^{\alpha}$
- Pollution: $e_{jt} = y_{jt} \times \frac{\bar{e}}{1+\gamma a_{jt}}$
- Regulation: $\tau_{jt} e_{jt}$

**Financial Frictions and Decisions**

- Collateral constraint: $b_{jt+1} \leq \theta k_{jt+1}$ | Cannot issue equity: $d_{jt+1} \geq 0$
- Chooses: debt $b_{jt+1}$, capital $k_{jt+1}$, and abatement $a_{jt+1} \geq 0$

**Recursive Problem for Firms** ($\pi_d$ as exogenous exit risk)

$$v(z_{jt}, n_{jt}) = \max_{a_{jt+1}, k_{jt+1}, b_{jt+1}} d_{jt} + \mathbf{E_t} \left\{ \Lambda_{t+1} \left[ \pi_d n_{jt+1} + (1-\pi_d) v(z_{jt+1}, n_{jt+1}) \right] \right\} \tag{1}$$

$$d_{jt} \equiv n_{jt} - k_{jt+1} - a_{jt+1} + \frac{b_{jt+1}}{1+r_t} \geq 0, \tag{2}$$

$$n_{jt+1} \equiv z_{jt+1} k_{jt+1}^{\alpha} + (1-\delta) k_{jt+1} - \tau_{jt+1} e_{jt+1} - b_{jt+1}, \tag{3}$$

**Households Welfare**

- $W_t = logC_t - \zeta \, logE_t$, $\quad \zeta$ stands for disutility from pollution

# Key Trade-offs with Financial Frictions

- Def: $\mu_t(z,n)$: Lagrange multiplier on collateral constraints
- Def: $\lambda_t(z,n)$: Lagrange multiplier on nonnegative dividend
- FOC for Physical Capital:

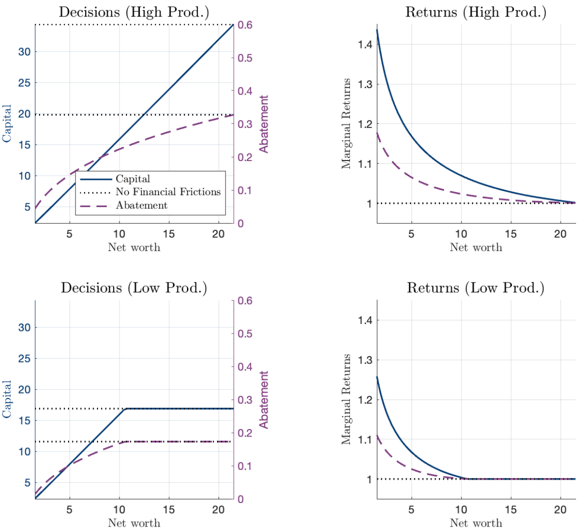
$$\underbrace{1+\lambda_t(z,n)}_{\text{marginal cost}} = \mathbf{E}_t\Bigg\{\Lambda'\Bigg[\Big(\pi_d+(1-\pi_d)(1+\lambda_{t+1}(z',n'))\Big) \times \underbrace{\left(\left(1-\frac{\tau'\bar{e}}{1+\gamma a'}\right)MPK(z',k')+(1-\delta)\right)}_{\text{marginal benefit from production}}\Bigg]\Bigg\} + \underbrace{\theta\mu_t(z,n)}_{\text{relax borrowing constraint}}$$

- FOC for Pollution Abatement:

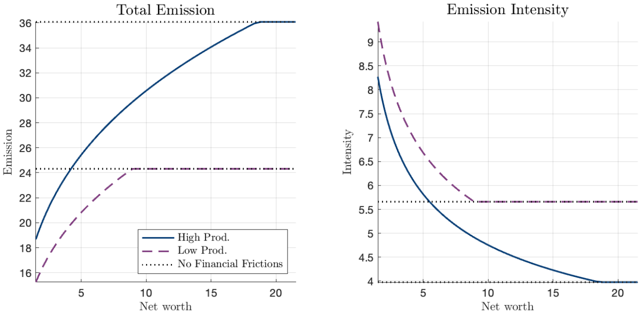
$$\underbrace{1+\lambda_t(z,n)}_{\text{marginal cost}} \geq \mathbf{E}_t\left\{\Lambda'\left[\Big(\pi_d+(1-\pi_d)(1+\lambda_{t+1}(z',n'))\Big) \underbrace{\frac{\gamma\tau'\bar{e}}{(1+\gamma a')^2}z'k'^{\alpha}}_{\text{marginal benefit of abatement}}\right]\right\}$$

- Investment generates an additional return by relaxing borrowing constraint

# Decision Rules: Investment vs Abatement



# Decision Rules: Total Emission vs Emission Intensity




## Quantitative Implications

- Raw emission increases in net worth
- Emission intensity decreases in net worth

# Quantitative Assessments

## Parameterization and Validation

Parameterization

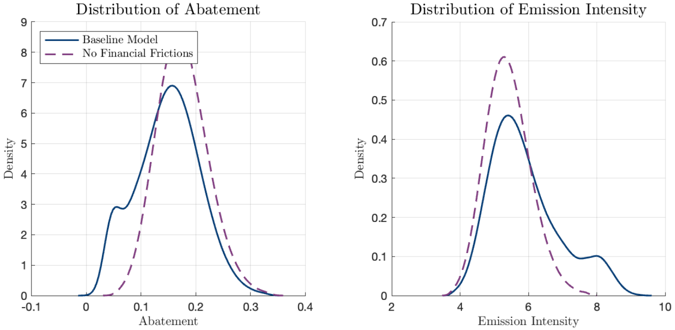
- We parameterize the model to carefully match firm distributions in the US
- We match penalties to the litigation costs across firms in the US

Empirical Validation

- Quasi-Natural Experiments of Anti-recharacterization Laws (Causal evidence)
- More pollution abatement from smaller firms when the constraint is relaxed

# Effects of Financial Frictions I: Distribution

Figure: **Environmental Distribution in Stationary Equilibrium**




Implication on Distribution:

- Financial frictions inhibit firms from growing ⇒ Lower abatement
- Lower abatement ⇒ Higher emission intensity ⇒ Therefore, stay dirtier

# Effects of Financial Frictions II: Aggregation

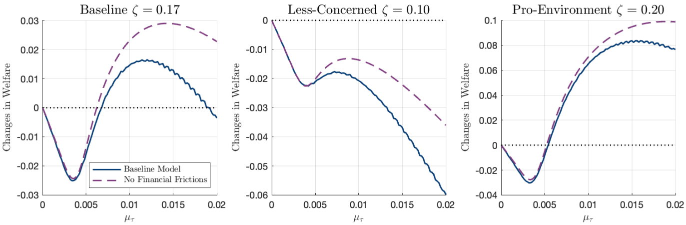
Table: : **The Aggregate Effects of Financial Frictions**

| Outcomes | Output | Capital | Consump. | Abatement | Emission | Intensity |
|---|---|---|---|---|---|---|
| Frictionless | 4.8 | 17.0 | 2.9 | 0.17 | 25.4 | 5.4 |
| Baseline | 4.0 | 13.2 | 2.6 | 0.14 | 23.1 | 6.2 |
| % Changes | -20% | -29% | -12% | -21% | -10% | +13% |

- Financial frictions inhibit firms from growing
  - => low abatement $\Rightarrow$ higher emission
  - => much lower output $\Rightarrow$ lower emission
  - => emission intensity is higher
    - ⋆ Quantitatively speaking, about 13% higher in the economy

# Effects of Financial Frictions III: Optimal Regulation

Figure: **Welfare Implications Decomposition Conditional on Penalty $\mu_\tau$**

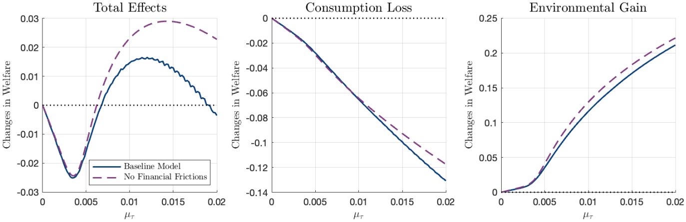



Preference matters:

- Baseline model generates 1.8% welfare gain from optimal regulation
- Completely different cases with other preferences

# Effects of Financial Frictions III: Optimal Regulation

Figure: **Welfare Implications Decomposition Conditional on Penalty $\mu_\tau$**




Optimal penalty implications:

- Off-setting between consumption loss and environmental gain
- A higher optimal penalty for the economy without financial frictions
- Aggregate gain of regulation policy is reduced by about 40% (3% vs 1.8%)

# Green Loan Policy: Implementation

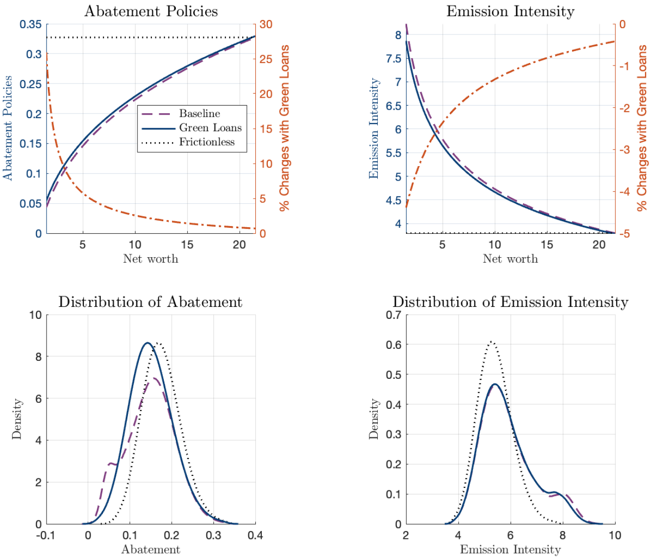
We implement the green loan interventions in an extension of our baseline model by modifying the collateral constraint.
Firms can now use certificates of their pollution abatement costs as additional collateral to apply for a green loan from the government up to $\theta_a$.
The new collateral constraint would be:

$$b_{jt+1} \leq \theta_k k_{jt+1} + \theta_a a_{jt+1}, \tag{4}$$

We take the case that $\theta_a = 1$

# Green Loan Policy: Decision

Figure: **Green Loan Effects on Decision Rules and Distributions**



# Green Loan Policy: Aggregate Effects

Table: : **The Allocation and Aggregate Effects of Green Loan Policies** $(\theta_a = 1)$

| *Panel A: Allocation of Green Loans* | | | | | | |
|---|---|---|---|---|---|---|
| Outcomes | Total $\sum b$ | Green $\sum b_g$ | Used $\frac{\sum \Delta a}{\sum b_g}$ | Washed $\frac{\sum \Delta k}{\sum b_g}$ | New $\sum \theta_k \Delta k$ | |
| Baseline | 5.30 | 0.00 | – | – | – | |
| Green Loan | 5.37 | 0.04 | 0.002 | 0.038 | 0.03 | |
| % to Total $\sum b$ | +1.32% | +0.75% | +0.04% | +0.71% | +0.56% | |
| % to Green $\sum b_g$ | – | – | 5% | 95% | 75% | |
| *Panel B: Aggregate Effects of Green Loan Policies* | | | | | | |
| Outcomes | Output | Capital | Consump. | Abatement | Emission | Emission Intensity |
| Baseline | 4.04 | 13.25 | 2.58 | 0.137 | 23.14 | 6.16 |
| Green Loan | 4.06 | 13.32 | 2.59 | 0.139 | 23.11 | 6.12 |
| % Changes | +0.5% | +0.5% | +0.4% | +1.5% | -0.1% | -0.6% |

# Conclusion

# Conclusion

- Theory guided empirical work on corporate environmental decisions
- Key Findings:
  - Financial constraints significantly affect abatement investment
  - Constrained firms prioritize physical capital over abatement
- General equilibrium model to quantitatively account for:
  - Firm life-cycle patterns, the trade-off between investment and abatement
  - Substantial less welfare gain from regulation due to financial frictions
- Policy suggestions
  - Credit intervention policies (works well even under imperfect monitoring)