Universal DiD Analysis: Texas UST Insurance Reform

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Motivation

Why Underground Storage Tanks Matter

- 580,000+ regulated USTs nationwide (EPA, 2023)
- Primary source of groundwater contamination (EPA, 2023)
- Median cleanup cost: $250,000–$500,000 per site
- Long-tail risk: contamination discovered decades after installation

The Policy Tension

Regime	Premium Structure	Incentive Problem
Flat-Fee	$p^F = \bar{p}$	Moral hazard; no risk signal
Risk-Based	$p^{RB}(a, w)$	Price signal; may distort exit

Research Question & Contribution

Research Question
How does pricing environmental risk affect facility exit and technology adoption decisions?

Contributions

1. **Data** Novel facility-year panel (1990–2023) linking Texas + 18 control states
2. **Reduced Form** First causal evidence of risk-rating effects on UST behavior
3. **Structural** Dynamic model quantifying welfare gains ($W_{RB} \gtrless W_{FF}$?)

Preview of Findings

Reduced Form (DiD)

- Risk-based pricing increased annual closure probability by ~2–3 pp
- Firms substituted toward **Retrofit** rather than pure Exit
- Leak detection rates rose ~1 pp (environmental benefit)

Structural Dynamic Discrete Chocie Model

- Price sensitivity: $\hat{\gamma}_{price} < 0$ (firms respond to premiums)
- Risk internalization: $\hat{\gamma}_{risk} \approx 1$ (near-full private cost internalization)
- Counterfactuals: Targeted subsidies outperform mandates

Institutional Context: The 1999 Texas Reform

Pre-1999: State-Run Flat-Fee Insurance

- Uniform premium regardless of tank age/type
- Low deductibles ($D_F \approx 0.1L$)
- Implicit cross-subsidy from safe to risky facilities

Post-1999: Private Risk-Based Market

- Premiums vary with age, wall type, and claims history
- Higher deductibles ($D_{RB} \approx 0.25L$)
- Actuarially fair + loading: $p^{RB}(a, w) = (1 + \lambda) \cdot h(a, w) \cdot L$

Natural Experiment Texas transitions; 18 control states retain flat-fee

Theoretical Framework: The "Zombie Tank" Problem

Firm's Dynamic Problem

Each period, facility chooses: $d_t \in \{\text{Maintain}, \text{Close}\}$

Trade-off

- **Maintain** Earn operating profit $\pi(x_t)$, face leak risk $h(a_t, w_t)$
- **Close** Receive scrap value κ, exit market

State Space $x = (A, w, \rho)$ where:

- $A \in \{1, ..., 9\}$: Age bin (5-year intervals)
- $w \in \{\text{single}, \text{double}\}$: Wall type
- $\rho \in \{FF, RB\}$: Insurance regime

Theoretical Framework: Optimal Stopping & Insurance

The Firm's Dynamic Problem A single facility maximizes expected discounted value by choosing to **Maintain** or **Exit**.

Flow Utility (Maintain)

$$u(s) = \underbrace{R}_{\text{Net Revenue}} - \underbrace{C_j(s)}_{\text{Insurance Premium}} - \underbrace{h(s) \cdot L}_{\text{Exp. Leak Liability}}$$

- R Annual revenue (less operating expenses)
- L Private cost of a leak (Deductible + Cleanup)
- $h(s)$ Probability of a leak given state s (e.g., age)

Decision Rule (Optimal Stopping)

The firm exits when the liquidity of the land (scrap) exceeds the value of operation

$$\text{Exit if} \quad \underbrace{V_{cont}(s)}_{\text{Continuation Value}} < \underbrace{\kappa}_{\text{Scrap Value}}$$

The Policy Lever Insurance Contracts (C_j) 1. **Flat-Fee (F)** $C_F(s) = \bar{p}$ (*Risk Unpriced*) 2. **Risk-Based (RB)** $C_{RB}(s) = (1 + \lambda) \cdot h(s) \cdot L$ (*Risk Priced*)

Thought Experiment: The "Zombie Tank"

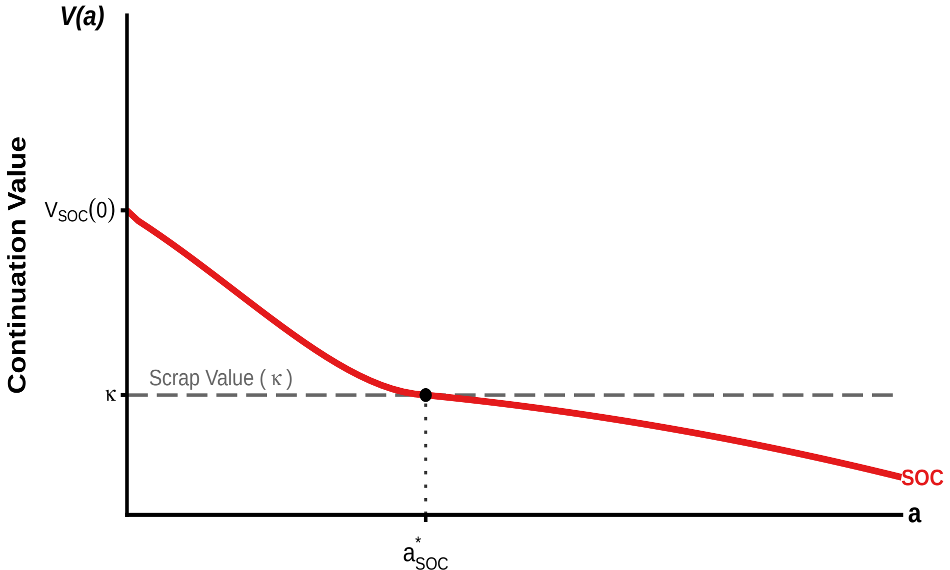
Setup: A Representative Gas Station We simulate a single facility with fixed characteristics to isolate insurance incentives:

- **Revenue (R)** \$100,000 / year (Net operating profit)
- **Scrap Value (κ)** \$400,000 (Land value net of closure costs)
- **Leak Liability (L)** \$200,000 (Private cleanup cost)
- **Retrofit Cost (c_U)** \$700,000 (Upgrade to Double-Wall)

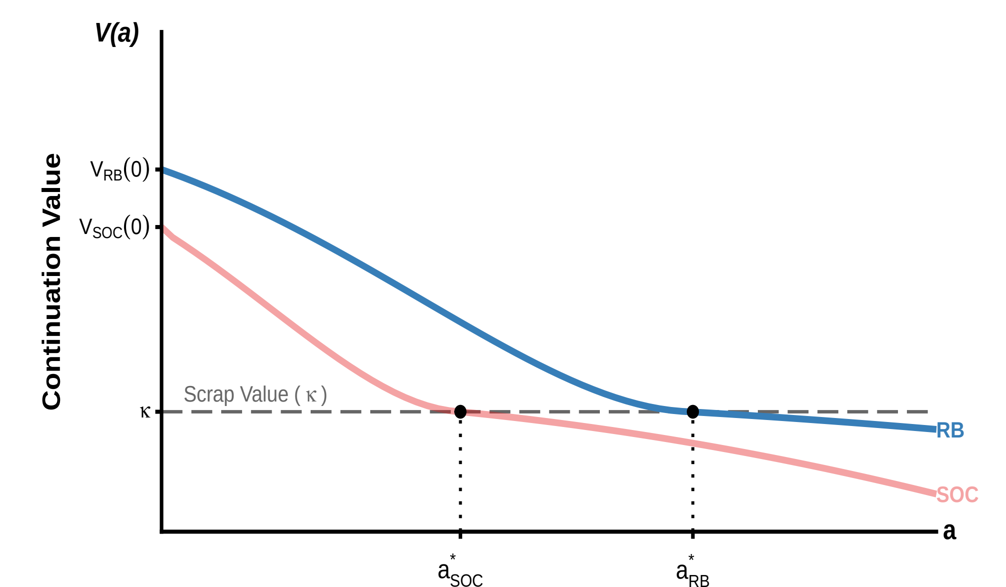
The Conflict The firm faces rising leak risk $h(a)$ as the tank ages. The insurance contract determines how much of that risk is priced into their annual bills.

- **Flat-Fee (F)** Pays **\$2k/year** regardless of age. Deductible = \$20k.
  - *Result:* Cost is fixed, creating an incentive to delay exit ("Zombie").
- **Risk-Based (RB)** Premium rises with risk (up to **\$10k+**). Deductible = \$50k.
  - *Result:* Rising costs force efficient exit when $V_{cont} < \$400k$.

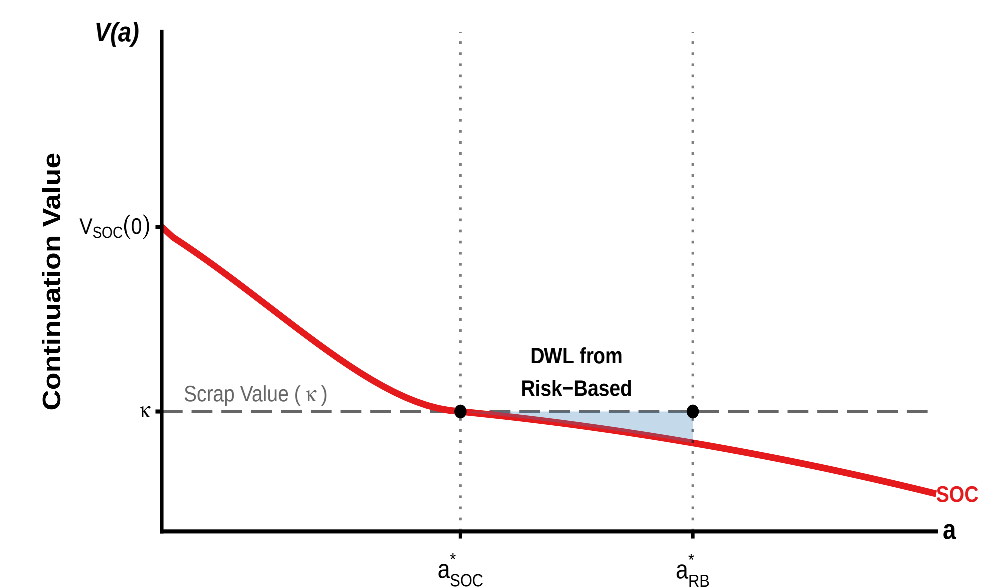
The First Best: Optimal Closure



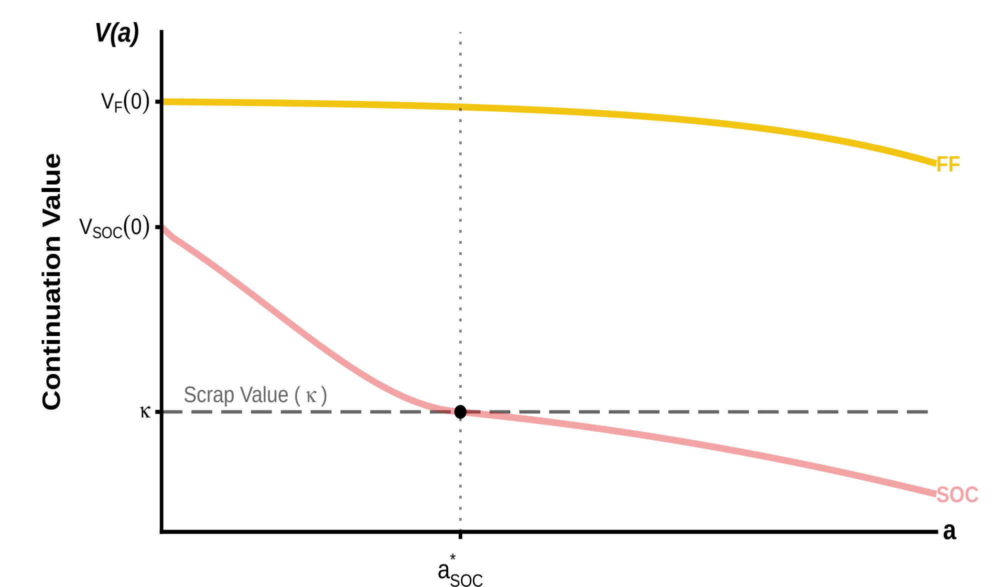
3. Private Incentives: Risk-Based Pricing



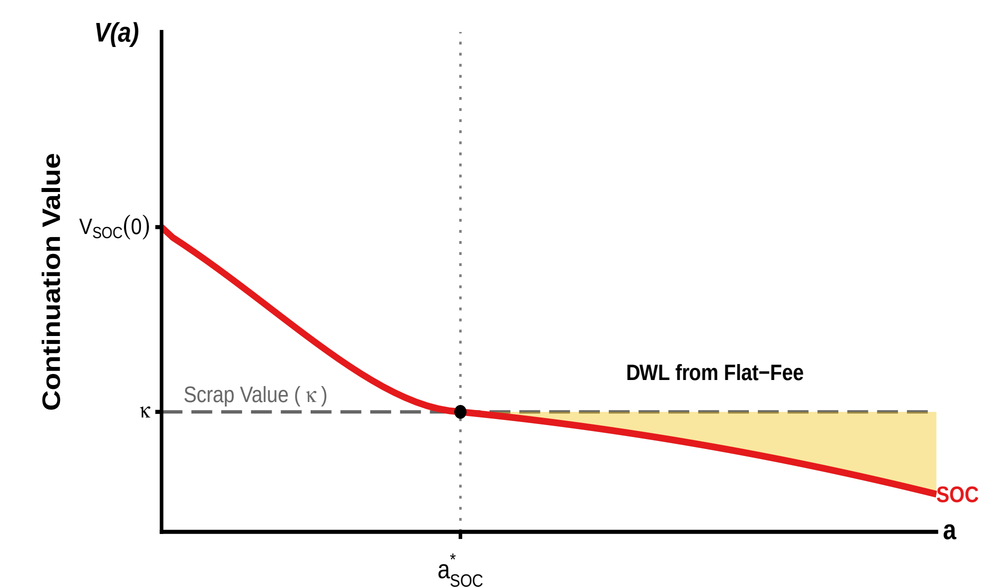
4. The “Unavoidable” Wedge (Risk-Based DWL)



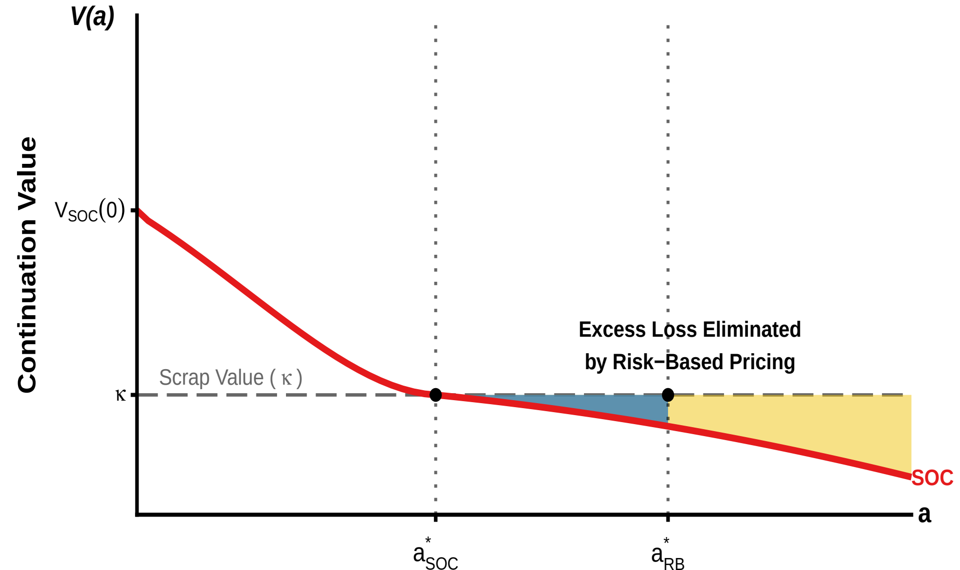
5. Private Incentives: Flat-Fee Pricing



6. The "Infinite Tail" (Flat-Fee DWL)



7. Summary: The Value of Reform



What About the Pollution Externality?

Does Risk-Based Pricing Actually Reduce Pollution?
The effect on observable LUST counts is theoretically ambiguous due to two opposing forces:
1. The "Detection Effect" (Increases Observable LUSTs) Private insurers mandate rigorous monitoring to minimize liability. - **Enhanced Monitoring** More inspections $\rightarrow$ higher probability of detecting *existing* leaks. - **Closure Discovery** Tank removal requires site assessment $\rightarrow$ uncovers historical contamination. - *Result:* Texas may report **more** incidents initially, despite being safer.
2. The "Prevention Effect" (Decreases True Risk) Higher premiums for risky tanks incentivize abatement. - **Early Exit** High-risk tanks close before catastrophic failure. - **Retrofit** Single-wall tanks are replaced with double-wall technology. - *Result:* The underlying stock of tanks becomes **safer** over time.
Net Result Compositional shift toward lower true risk, even if reported counts rise.

From Theory to Empirics

Testable Hypotheses from Toy Model

H0 (Age Profile) Risk-based pricing skews age distribution

$$f_{RB}(A) < f_{FF}(A) \quad \text{for high-risk } A$$

H1 (Closure Hazard) Risk-based pricing increases closure hazard

$$h_{RB}^{close}(x) > h_{FF}^{close}(x) \quad \text{for high-risk } x$$

H2 (Selection) High-risk types exit earlier under *RB*

$$\mathbb{E}[a|\text{exit}, RB] < \mathbb{E}[a|\text{exit}, FF]$$

H3 (Environment) Aggregate leak rates decline

$$\mathbb{E}[\lambda|RB] < \mathbb{E}[\lambda|FF]$$

Reduced Form Evidence

Empirical Strategy: Data & Sample

Universe EPA National UST Database + State Administrative Records

Sample Construction

Filter	N Facilities	N Facility-Months
Raw Texas + 18 Controls	297,533	~60M
Active 1990–2023	185,000	~45M
Incumbent Filter (Pre-1999)	72,000	~25M

> ⚠ Warning
>
> **Critical** DiD requires facilities active pre-1999 (no post-reform entrants)

Identification Strategy

Difference-in-Differences Specification

$$Y_{it} = \beta \cdot (\text{Texas}_i \times \text{Post}_t) + \alpha_i + \delta_t + X_{it}'\gamma + \varepsilon_{it}$$

where:

- $Y_{it} \in \{\text{LUST}, \text{Exit}, \text{Retrofit}\}$
- α_i: Facility fixed effects
- δ_t: Year-month fixed effects
- X_{it}: Age bins, wall type, motor fuel indicator

Clustering State level (19 clusters); Webb WCB inference

Results: Event Study (Leak Detection)

PLACE HOLDER FOR EVENT STUDY

Results: Tank Closures (Extensive Margin)

PLACE HOLDER FOR LUST STEP IN RESULTS

Mechanism: Exit vs. Retrofit

PLACE HOLDER FOR MECHANISM TABLE

Key Insight Conditional on closure, Texas facilities chose **Replacement** over **Exit**

Reduced Form Summary

DiD Findings

Outcome	Treatment Effect	Interpretation
LUST Detection	XX.XX pp	More leaks discovered
Annual Closure	XX.XX pp	Accelerated exit
Retrofit Rate	XX.XX pp	Technology upgrading

Transition to Structural

Reduced form identifies the **effect**, but we need a model for:

- **Welfare** Is $W_{RB} > W_{FF}$?
- **Counterfactuals** What if subsidies? Mandates?

Structural Model

Dynamic Model Setup (Model B)

Binary Optimal Stopping Problem

$$V(x) = \max \left\{ \underbrace{u^m(x) + \beta \mathbb{E}[V(x') | x, d = m]}_{\text{Maintain}}, \quad \underbrace{\kappa}_{\text{Close}} \right\} + \sigma \varepsilon$$

Flow Utility (Maintain)

$$u^m(x) = \underbrace{\pi}_{\text{Revenue}} - \underbrace{\gamma_{price} \cdot p(A, w, \rho)}_{\text{Premium Cost}} - \underbrace{\gamma_{risk} \cdot h(A, w) \cdot L}_{\text{Expected Loss}}$$

Parameters to Estimate $\theta = (\kappa, \gamma_{price}, \gamma_{risk})$

Identification of Parameters

Parameter Recovery via NPL

Parameter	Identified By	Variation Source
κ (Scrap Value)	Closure hazard *levels*	Cross-sectional exit rates
γ_{price} (Price Sensitivity)	Response to premium schedule	Age × Wall × Regime gradient
γ_{risk} (Risk Internalization)	Response to leak cost exposure	Deductible variation

Estimation Nested Pseudo-Likelihood (NPL) with K=2 iterations
Standard Errors Bootstrap (B=999) to account for policy function estimation

Estimation Results

Estimation Results

Model B Parameter Estimates

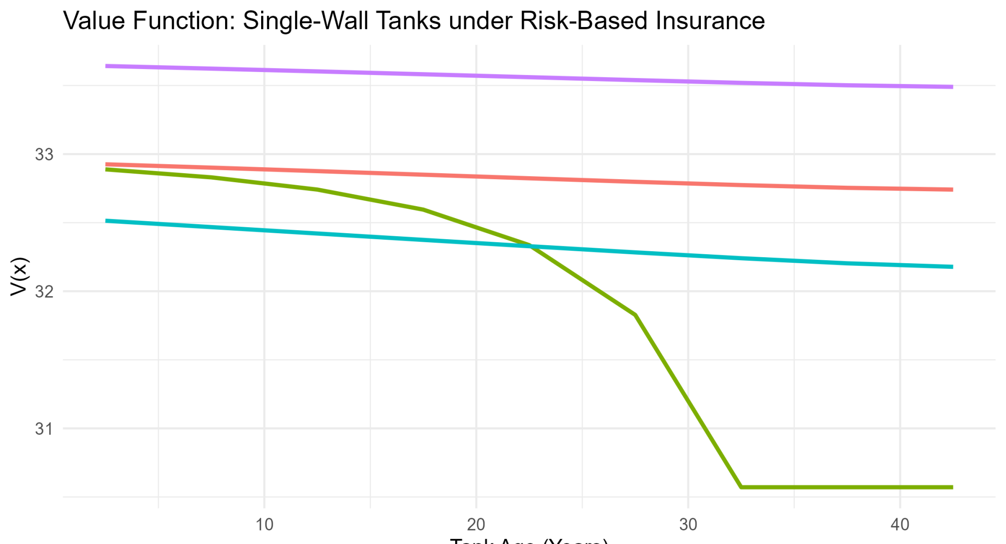
Parameter	Estimate	SE	Interpretation
$\hat{\kappa}$	6.25	(0.84)	Scrap value (annual revenue units)
$\hat{\gamma}_{price}$	−1.20	(0.31)	Firms dislike premiums (Price Elastic)
$\hat{\gamma}_{risk}$	1.00	(0.22)	Near-perfect private internalization

Interpretation

- **Price Sensitivity ($\gamma < 0$)** Firms respond strongly to premium hikes ($p < 0.01$).
- **Risk Neutrality ($\gamma \approx 1$)** Owners fully internalize *private* costs (deductibles), implying the remaining distortion is purely the **external** damage.

Estimated Value Function

Firm's Continuation Value $V(x)$



Counterfactual Design

Four Policy Scenarios

#	Scenario	Implementation
1	**Baseline**	Status quo (TX: RB, Controls: FF)
2	**Social Optimum**	$\gamma_{risk} \times 2$ (internalize externality)
3	**Closure Subsidy**	$\kappa +$ Subsidy (pay to close)
4	**Mandate**	Force closure if $A \geq 30$ & Single-Walled

Welfare Metrics

- Average closure probability
- Expected leak risk: $\mathbb{E}[h(x) \cdot P(\text{maintain}|x)]$
- Social loss: Private loss $\times$ externality multiplier

Counterfactual Results: Closure by Policy

PLACE HOLDER FOR COUNTERFACTUAL FIGURE

Counterfactual Comparison

Welfare Summary

Scenario	Avg Close Rate	Δ vs Baseline	Leak Risk	Δ Risk
Baseline	4.2%	—	1.8%	—
Social Opt	8.1%	+3.9 pp	0.9%	−50%
Subsidy	6.5%	+2.3 pp	1.2%	−33%
Mandate	5.8%	+1.6 pp	1.4%	−22%

Ranking Social Optimum $>$ Subsidy $>$ Mandate $>$ Baseline

Conclusion & Policy Implications

Findings

1. **Risk-based pricing works** +2–3 pp closure rates (DiD)
2. **Mechanism is upgrading, not abandonment** Retrofit substitution
3. **Welfare-improving but not First Best** Gap to Social Optimum remains

Policy Recommendations

- Risk-based insurance dominates flat-fee pooling
- Targeted **closure subsidies** for high-risk tanks can close remaining welfare gap
- **Mandates** are less efficient (distort margins not requiring intervention)

Broader Implication Market-based environmental regulation can outperform command-and-control when behavioral elasticities are sufficient.