Ryan (2012)
“The costs of environmental regulation in a concentrated industry”

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Outline

Introduction

The costs of environmental regulation are different for markets with differing competitiveness.

- In competitive market, environmental regulation is a Pigouvian tax
  - no structural change in supply
  - mild welfare loss
- In Oligopoly market, environmental regulation induces
  - less competition due to higher entry costs
  - less investment due to high expansion costs
  - more severe welfare loss

$\Rightarrow$ To quantify welfare costs of the 1990 CAA on the cement industry, accounting for dynamic firm entry and investment

The CAA

- The 1970 CAA was the first national response to environmental concerns.
  - EPA has authority to set and change regulations and to enforce compliance.
- The 1990 CAA is a major amendment, mainly to deal with SO_2 emissions.
  1. SO_2 cap-and-trade program
  2. regulation of a number of aspects of motor vehicle fuels
  3. authority for EPA to ensure the Montreal Protocol compliance
  4. instructions to EPA to issue technology standards for each of 189 listed air toxics: operating permits, environmental certification, and testing procedure
- After 1988, climate change becomes major legislation issue.
  - The 2009 Waxman-Markey bill: CO_2 cap-and-trade program

The CAA

	Policy instrument used			
	Technology standards	*Performance standards*	*Emissions trading*	*Taxes*
A: Pollutant categories				
Criteria pollutants	*	*	*	
Toxic/hazardous pollutants	*	*		
Stratospheric ozone depletion			*	*
Acid rain			*	
Greenhouse gases		Proposed	Proposed	
B: Regulated sectors				
Electricity generation	*	*	*	
Other stationary sources	*	*	*	*
Mobile sources	*	*		

Source: Schmalensee and Stavins (2019)

The US Portland cement industry

- This industry plays large role in emissions to environment.
  - high energy requirements
  - emitting large amount of CO_2 in production
- This industry is highly concentrated.
  - 116 plants in 37 states, operated by 1 government and 40 firms in 2000
  - exporter competition is low due to difficulty to store and transport
- Cement are homogeneous good
  - Quantity competition

Data

Portland cement industry, 1980 – 1999

- Market-level data
  - US Geological Survey: the number of plants in each market, the quantity and prices of shipped cement
  - other market data such as prices of electricity, coal and natural gas, population and housing permits
- Plant-level data
  - Portland Cement Association's annual Plant Information Summary (PIS): capacity and production quantity by each plant

Model

- J markets: $j = 1, ..., J$
- $\bar{N}$ cement firms: $i = 1, ..., \bar{N}$
- Firm capacity $\{s_{it} : i \in \bar{N}\}$: $s_{1t}, s_{2t}, ...$
- Firm with $s_{it} = 0$ is considered as potential entrant.

Timeline

1. Firms receive private information
    - Incumbent firms receive private info on exit cost, decide whether exit or not; if not exit, they receive private info on investment/divestment costs
    - Potential entrants receive private info on entry cost
2. All firms decide on entry/exit and investment/divestment simultaneously
3. Incumbent firms compete over quantity
4. Firms enter/exit, and investments mature

Model

1. Demand: $\ln Q_{jt} = \alpha_0 + \alpha_1 \ln P_{jt} + \alpha_{2j} + \alpha_{3t} X_{jt} + \epsilon_{jt}$
   - Instrument P_{jt} by coal prices, gas prices, electricity rates, and wage rates.
2. Production cost: $C_i(q) = \delta_1 q_i + \delta_2 1(q_i > \nu s_i)(q_i - \nu s_i)^2$
   - Cournot quantity competition $\Rightarrow$ Profit $\bar{\pi}_{it}(s_{it}; \alpha, \delta)$
3. Investment adjustment cost:
   $\Gamma(x_i) = 1(x_i > 0)(\gamma_{i1} + \gamma_2 x_i + \gamma_3 x_i^2) + 1(x_i < 0)(\gamma_{i4} + \gamma_5 x_i + \gamma_6 x_i^2)$
   - Private info γ_{i1} and γ_{i4}: normal distribution $\mathcal{N}(\mu_\gamma^+, \sigma_\gamma^{+2})$ and $\mathcal{N}(\mu_\gamma^-, \sigma_\gamma^{-2})$
4. Entry/exit cost: $\Phi(a_i) = \begin{cases} -\kappa_i, & \text{if the firm is a new entrant} \\ \phi_i, & \text{if the firm exits} \end{cases}$
   - Private info κ_i and ϕ_i: normal distribution $\mathcal{N}(\mu_\kappa, \sigma_\kappa^2)$ and $\mathcal{N}(\mu_\phi, \sigma_\phi^2)$

Firm's period payoff

$$\pi_{it}(s_{it}, a_{it}) = \bar{\pi}_{it}(s_{it}; \alpha, \delta) - \Gamma(x_{it}; \gamma) + \Phi(a_{it}; \kappa, \phi) \quad (1)$$

Model

Markov-perfect Nash Equilibrium (MPNE)

Given the setting above, there exists a pure strategy $\sigma_i : (s, \epsilon_i) \to a_i$ in equilibrium.

Incumbent's value function is

$$V_i(s;\sigma(s),\theta,\varepsilon_i) = \bar{\pi}_i(s;\theta) + \max\left\{\phi_i, E_{\varepsilon_i}\left\{\max_{x_i^*\geq 0}\left[-\gamma_{i1} - \gamma_2 x_i^* - \gamma_3 x_i^{*2} \quad +\beta\int E_{\varepsilon_i} V_i\left(s';\sigma\left(s'\right),\theta,\varepsilon_i\right) dP\left(s_i + x^*, s'_{-i}; s, \sigma(s)\right)\right],\right.\right.$$
$$\left.\left.\max_{x_i^*<0}\left[-\gamma_{i4} - \gamma_5 x_i^* - \gamma_6 x_i^{*2} \quad +\beta\int E_{\varepsilon_i} V_i\left(s';\sigma\left(s'\right),\theta,\varepsilon_i\right) dP\left(s_i + x^*, s'_{-i}; s, \sigma(s)\right)\right]\right\}\right\} \quad (2)$$

Potential entrant's value function is

$$V_i^e\left(s;\sigma(s),\theta,\varepsilon_i\right) \quad = \max\left\{0, \max_{x_i^*>0}\left[-\gamma_{1i} - \gamma_2 x_i^* - \gamma_3 x_i^{*2} \quad +\beta\int E_{\varepsilon_i} V_i\left(s';\sigma\left(s'\right),\theta,\varepsilon_i\right) dP\left(s_i + x^*, s'_{-i}; s, \sigma(s)\right)\right] - \kappa_i\right\}. \quad (3)$$

MPNE means

$$V_i\left(s;\sigma_i^*(s),\sigma_{-i}(s),\theta,\varepsilon_i\right) \geq V_i\left(s;\tilde{\sigma}_i(s),\sigma_{-i}(s),\theta,\varepsilon_i\right) \quad (4)$$

Estimation: Bajari, Benkard, and Levin (2007)'s two steps

Step 1: Generate Markov chains by agents

- $s_{it} \rightarrow (x_{it}, a_{it}) \rightarrow s_{it+1} \rightarrow (x_{it+1}, a_{it+1}) \rightarrow ...$
- $s_{it} \rightarrow (x_{it} + \epsilon_{\gamma}, a_{it} + \epsilon_{\kappa,\phi}) \rightarrow s'_{it+1} \rightarrow (x_{it+1} + \epsilon_{\gamma}, a_{it+1} + \epsilon_{\kappa,\phi}) \rightarrow ...$
- ...

Step 2: Recover parameters

$$\min_{\theta} \frac{1}{n_k} \sum_{n=1}^{n_k} 1(V^* > \tilde{V})[V_i\left(s; \sigma_i^*(s), \sigma_{-i}(s), \theta, \varepsilon_i\right) - V_i\left(s; \tilde{\sigma}_i(s), \sigma_{-i}(s), \theta, \varepsilon_i\right)]^2 \tag{5}$$

Demand

	I	II	III	IV	V	VI
Price	–3.21	–1.99	–2.96	–0.294	–2.26	–0.146
	(0.361)	(0.285)	(0.378)	(0.176)	(0.393)	(0.127)
Intercept	21.3	10.30	20.38	–3.41	11.6	–6.43
	(1.52)	(1.51)	(1.56)	(1.09)	(2.04)	(0.741)
Log population		0.368		0.840	0.213	0.789
		(0.0347)		(0.036)	(0.074)	(0.033)
Log permits					0.218	0.332
					(0.072)	(0.035)
Market fixed effects	No	No	Yes	Yes	No	Yes

Production

Production Function Estimates		
Parameter	Coefficient	Standard Error
Marginal cost (δ_1)	31.58	1.91
Capacity cost (δ_2)	1.239	0.455
Capacity cost threshold ($\tilde{\nu}$)	1.916	0.010
Marginal cost post-1990 shifter	2.41	3.33
Capacity cost post-1990 shifter	−0.0299	0.22
Capacity cost threshold post-1990 shifter	0.0917	0.0801

Prices, Revenues, and Profits		
Variable	Value	Standard Deviation
Price	57.81	16.83
Revenues	39,040	19,523
Costs	22,525	11,051
Profit	16,515	12,244
Margin	39.29 percent	18.21 percent

Production and Capacity

Specification	I	II	III	IV	V
Capacity	0.8617	0.8600	0.860	0.860	0.860
	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)
Rivals' capacity	−0.007	−0.005	−0.002	−0.003	0.0003
	(0.001)	(0.001)	(0.001)	(0.001)	(0.0006)
Firm entered * capacity		0.0009	0.0002	0.0112	0.0103
		(0.0027)	(0.0027)	(0.0064)	(0.007)
Firm exited * capacity		−0.0154	−0.0128	−0.0173	−0.0135
		(0.0035)	(0.0036)	(0.0078)	(0.008)
Time trend			0.671	0.681	
			(0.130)	(0.131)	
Entry dummy				−11.66	−11.49
				(6.141)	(6.678)
Exit dummy				3.041	0.492
				(4.810)	(5.107)
Market fixed effects	Yes	Yes	Yes	Yes	No
Market-time fixed effects	No	No	No	No	Yes
R^2	0.9925	0.9925	0.9926	0.9926	0.9933

Exit

Specification	I	II	III	IV
Exit Policy				
Own capacity	−0.0015661	−0.0015795		
	(0.000268)	(0.0002712)		
Competitors' capacity	0.0000456	0.0000379		
	(0.0000173)	(0.0000249)		
Population		0.0590591		
		(0.1371835)		
After 1990	−0.5952687	−0.606719	−0.6328867	−0.4623664
	(0.1616594)	(0.1639955)	(0.157673)	(0.1910193)
Own capacity per capita			−0.0005645	−0.0010199
			(0.0001255)	(0.0002164)
Competitors' capacity per capita			0.0000744	0.0002379
			(0.00000286)	(0.0001023)
Constant	−1.000619	−1.019208	−1.664808	−1.529715
	(0.1712286)	(0.176476)	(0.1475588)	(0.3526938)
Region fixed effects	No	No	No	Yes
Log-likelihood	−227.21	−227.12	−238.54	−217.38

- The probability of exit decreases after the 1990 CAA.

Entry

Entry Policy				
Competitors' capacity	0.0000448	−0.0003727		
	(0.0000365)	(0.0002351)		
After 1990	−0.6089773	−0.8781589	−0.602279	−1.003239
	(0.2639545)	(0.3229502)	(0.2651052)	(0.337589)
Constant	−1.714599	−0.454613	−1.665322	−0.3434765
	(0.2152315)	(0.7086509)	(0.2642566)	(0.6624767)
Competitors' capacity per capita			0.000026	−0.0003633
			(0.000038)	(0.0001766)
Region fixed effects	No	Yes	No	Yes
Log-likelihood	−70.01	−56.47	−70.491	−55.53
Prob > χ^2	0.0177	0.4516	0.0287	0.3328

- The probability of entry decreases after the 1990 CAA.

Costs of CAA 1990

	Before 1990		After 1990		Difference	
	Mean	SE	Mean	SE	Mean	SE
Parameter						
Investment cost	230	85	238	51	−8	19
Investment cost squared	0	0	0	0	0	0
Divestment cost	−123	34	−282	56	−155	35
Divestment cost squared	3932	1166	5282	1130	1294	591
Investment Fixed Costs						
Mean (μ_γ^+)	621	345	1253	722	653	477
Standard deviation (σ_γ^+)	113	72	234	145	120	97
Divestment Fixed Costs						
Mean (μ_γ^-)	297,609	84,155	307,385	62,351	12,665	34,694
Standard deviation (σ_γ^-)	144,303	41,360	142,547	29,036	109	17,494
Scrap Values						
Mean (μ_ϕ)	−62,554	33,773	−53,344	28,093	9833	21,788
Standard deviation (σ_ϕ)	75,603	26,773	69,778	27,186	−6054	11,702
Entry Costs						
Mean (μ_κ)	182,585	36,888	223,326	45,910	43,654	21,243
Standard deviation (σ_κ)	101,867	22,845	97,395	14,102	−6401	12,916

- Investment adjustment and exit cost are increasing, but not significantly different post the 1990 CAA.
- Entry costs significantly go up.

Welfare Costs of CAA 1990

	Low Entry Costs (Pre-1990)		High Entry Costs (Post-1990)		Difference	
	Mean	Standard Error	Mean	Standard Error	Mean	Standard Error
De Novo Market						
Total producer profit ($ in NPV[b])	43,936.11	(7796.98)	33,356.87	(7767.22)	−11,182.04	(7885.20)
Profit firm 1 ($ in NPV)	45,126.30	(10,304.87)	34,321.61	(9520.93)	−11,965.22	(11,684.96)
Total net consumer surplus ($ in NPV)	1,928,985.09	(62,750.34)	1,848,872.52	(75,729.17)	−66,337.44	(58,404.32)
Total welfare ($ in NPV)	2,116,810.12	(74,265.74)	1,992,937.65	(96,634.83)	−119,771.39	(49,423.06)

- In a market with more potential entrants, welfare loss is 140k due to the 1990 CAA.

Welfare Costs of CAA 1990

	Low Entry Costs (Pre-1990)		High Entry Costs (Post-1990)		Difference	
	Mean	Standard Error	Mean	Standard Error	Mean	Standard Error
Mature Market						
Total producer profit ($ in NPV)	223,292.75	(4831.95)	231,568.23	(5830.42)	9551.01	(5465.77)
Profit firm 1 ($ in NPV)	549,179.30	(14,138.37)	579,742.32	(20,446.75)	32,968.00	(19,161.33)
Total net consumer surplus ($ in NPV)	2,281,584.08	(52,663.88)	2,208,573.20	(62,906.14)	−62,974.37	(32,662.05)
Total welfare ($ in NPV)	3,178,504.60	(60,267.34)	3,141,916.43	(62,618.02)	−30,099.56	(18,078.21)

- In a market with less potential entrants and more incumbents, welfare loss is milder and 30k due to the 1990 CAA.

Conclusion

- Environment regulation has huge cost in the concentrated industry since
  - Less new entry by potential entrants, thus less competition
- The 1990 CAA significantly increases the sunk cost of entry, at least $\$810$ million.
- The 1990 CAA has caused more welfare loss in the concentrated industry.

References

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