Introduction
○○○

Model
○○○○○○○

Estimation Strategy
○○

Empirical Results
○○○○○○○

When Does Regulation Distort Costs? Lessons from Fuel Procurement in US Electricity Generation

Cicala (2015), AER

Enviromental Reading Group session 16

Dec 8, 2023

Context

- **Cost of Service:** Producers submit their cost information. The regulator audits these cost, determines price for variable cost, and pays capital cost + fair rate of return.

- **Distortions:**
  - Averch-Johnson effect: pure profit incents over-investment.
  - Moral Hazard Problem: less incentive to exert effort to reduce production cost.
  - Lobbying: special interest groups influence the regulator's decision.

Introduction
○●○

Model
○○○○○○○

Estimation Strategy
○○

Empirical Results
○○○○○○○

Context

Electricity Deregulation: price is determined by centralized auction.

- Transmission line is controlled by independent system operator.
- integrated utilities divest their generation units.

Introduction
○○●

Model
○○○○○○○

Estimation Strategy
○○

Empirical Results
○○○○○○○

Research Question

- How does divestiture reduce coal procurement cost in electricity market?
  - Generation costs
  - Trade gains
- DID, Treatment: Deregulation.
  - Fuel procurement cost between Regulated vs. unregulated firms.
  - Close **geographical proximity**.

Introduction
000

Model
●000000

Estimation Strategy
00

Empirical Results
0000000

Setup

- Production function: $G(F, K)$; F: fuel, K: capital
- inverse demand function: $p = p[G(F, K)]$. constant elesticicity of demand: $\eta = -\frac{G(F,K)}{p[G(F,K)]} \frac{dp}{dG} < 1$
- Firms can exert effort to reduce input cost. $c = \beta - e$, with convex cost function $\psi(e)$.
- $\theta(c)$ is the probability that cost pasts audit.
- s is rate of return on capital investment, r is the cost of capital. $s > r$.

Introduction
○○○

Model
○●○○○○○

Estimation Strategy
○○

Empirical Results
○○○○○○○

Maximization Problem

$$\max_{e,F,K} R(F,K) - (\beta - e)F - rK - \psi(e) \tag{1}$$

$$s.t. R(F,K) \leq \theta(\beta - e)[\beta - e]F + sK \tag{2}$$

Introduction
ooo

Model
oooeooo

Estimation Strategy
oo

Empirical Results
ooooooo

First Order Conditions

$$[e] : \psi'(e) = F\{1 - \lambda[\theta(\beta - e) + [\beta - e]\theta'(\beta - e)]\} \tag{3}$$

- Shirk because of non-observable effort;
- Shirk because of market power

Introduction
○○○

Model
○○○●○○○

Estimation Strategy
○○

Empirical Results
○○○○○○○

First Order Conditions

$$[F] : (1-\eta)pG_F = \frac{1-\lambda\,\theta(\beta-e)}{1-\lambda}(\beta-e) \tag{4}$$

$$[K] : (1-\eta)pG_K = r - \frac{\lambda}{1-\lambda}(s-r) \tag{5}$$

$$\frac{G_K}{G_F} = \frac{r}{\beta-e}\left[1 - \frac{\lambda}{1-\lambda}\frac{s-r}{r}\right] / \left[\frac{1-\lambda\,\theta(\beta-e)}{1-\lambda}\right] < \frac{r}{\beta-e} \tag{6}$$

- Capital-bias because of excess rate of return $s > r$.
- Capital-bias because of non-observability.
- Capital-bias because of binding revenue constraint. (yardstick competition)

Introduction
000

Model
0000●00

Estimation Strategy
00

Empirical Results
0000000

Regulator's Problem

$$[e] : \psi'(e) = F\{1 - \lambda[\theta(\beta - e) + [\beta - e]\theta'(\beta - e)]\} \tag{7}$$

- If β is public information, to design θ such that
  $\theta(\beta - e^*) + [\beta - e^*]\theta'(\beta - e^*) = 0$
- Otherwise, if $\beta \in [\underline{\beta}, \bar{\beta}], \theta(c) + c\theta'(c) = 0. \Rightarrow$ Screening $+$ no information rent.
- However, pooling might happen if $\bar{\beta}$-$\underline{\beta}$ is too large. $\Rightarrow$ information rent.

Introduction
ooo

Model
oooooo●o

Estimation Strategy
oo

Empirical Results
ooooooo

Lobbying

probability of being approved is a function of influence $\theta(c, b)$,

$$\frac{de^*}{db} = -\frac{F\lambda \left[\frac{\partial \theta}{\partial b} + (\beta - e^*)\frac{\partial^2 \theta}{\partial c \partial b}\right]}{\psi''(e^*) + \frac{\partial F}{\partial c}} < 0 \tag{8}$$

Introduction
ooo

Model
ooooooo●

Estimation Strategy
oo

Empirical Results
ooooooo

Testable Implications

Regulation leads to

- asymmetric information
- political influence
- capital over-investment

While deregulation can induce inefficiency by:

- market power

Introduction
ooo

Model
ooooooo

Estimation Strategy
●o

Empirical Results
ooooooo

Close Proximity

To find the m closest facilities of treatment firm i by:

$$\sum_{j|D_j \neq D_i} \{||X_j - X_i|| \leq ||X_l - X_i||\} = m \tag{9}$$

$m = 10$.

Introduction
000

Model
0000000

Estimation Strategy
0●

Empirical Results
0000000

Regression Equation

$$Y_{it} = \gamma_i + \delta_t + \tau_t(X_i)D_{it} + \varepsilon_{it} \tag{10}$$

ATE: $\tau = E[\tau_t(X_i)|D = 1]$.

Introduction
000

Model
0000000

Estimation Strategy
00

Empirical Results
●000000

Data

1990-2019, plant level

- Coal sources
- Fuel costs
- Generating unit configurations
- Plant operations
- Regulatory Status

Introduction
○○○

Model
○○○○○○○

Estimation Strategy
○○

Empirical Results
○●○○○○○

Deregulation on coal purchase cost: weighted matched DID

TABLE 2—COAL: MATCHED DID ESTIMATES OF $\log(Price)$ AND DIVESTITURE

	(1)	(2)	(3)	(4)	(5)	(6)
Post-divest	−0.124***	−0.188***	−0.152*	−0.124***	−0.128***	−0.136**
	(0.044)	(0.058)	(0.077)	(0.045)	(0.046)	(0.064)
m nearest neighbors				10	5	1
Proximity threshold (mi.)	200	100	50			
Year-month FE	Yes	Yes	Yes	Yes	Yes	Yes
Facility FE	Yes	Yes	Yes	Yes	Yes	Yes
R^2	0.721	0.712	0.668	0.723	0.726	0.738
Facilities	230	146	69	198	166	121
Divested facilities	87	74	39	87	87	87
Observations	47,024	28,449	12,682	37,495	32,958	23,336

Introduction
○○○

Model
○○○○○○○

Estimation Strategy
○○

Empirical Results
○○●○○○○

Deregulation on coal purchase cost: unweighted standard DID

TABLE 3—COAL: DID ESTIMATES OF log(*Price*) AND DIVESTITURE

	(1)	(2)	(3)	(4)	(5)	(6)
Post-divest	−0.051	−0.054	−0.131***	−0.055	−0.069*	−0.137**
	(0.035)	(0.035)	(0.041)	(0.036)	(0.040)	(0.055)
Divest	0.145***					
Facilities	(0.030)					
Proximity threshold (mi)				200	100	50
Year-month FE	Yes	Yes	Yes	Yes	Yes	Yes
Facility FE		Yes	Yes	Yes	Yes	Yes
Division-year FE			Yes			
R^2	0.252	0.772	0.803	0.733	0.700	0.712
Facilities	397	397	397 333	221	123	
Divested facilities	88	88	88	88	78	47
Observations	86,225	86,225	86,225	71,569	47,324	26,483

Introduction
○○○

Model
○○○○○○○

Estimation Strategy
○○

Empirical Results
○○○●○○○

Deregulation on gas purchase cost: weighted matched DID

TABLE 4—GAS: MATCHED DID ESTIMATES OF LOG($Price$) AND DIVESTITURE

	(1)	(2)	(3)	(4)	(5)	(6)
Post-divest	0.012	0.027	0.010	0.012	0.005	0.038
	(0.026)	(0.029)	(0.036)	(0.027)	(0.027)	(0.038)
m nearest neighbors				10	5	1
Proximity threshold (mi.)	200	100	50			
Year-month FE	Yes	Yes	Yes	Yes	Yes	Yes
Facility FE	Yes	Yes	Yes	Yes	Yes	Yes
R^2	0.853	0.852	0.861	0.855	0.857	0.854
Facilities	276	198	111	254	224	165
Divested facilities	109	99	59	109	109	109
Observations	46,828	33,465	17,631	41,089	36,727	26,510

Gas procurement is more transparent compared to coal procurement. ⇒ **No asymmetric information**, so less effect of deregulation.

Introduction
○○○

Model
○○○○○○○

Estimation Strategy
○○

Empirical Results
○○○○●○○

Capital Investment

TABLE 5—MATCHED DID ESTIMATES OF SULFUR COMPLIANCE STRATEGY

	Scrubber	Low sulfur	Uncontrolled
Post-divest	−0.072***	0.100***	−0.032
	(0.024)	(0.031)	(0.038)
Divested unit	0.014	0.010	−0.023
	(0.040)	(0.034)	(0.047)
m nearest neighbors	10	10	10
R^2	0.017	0.049	0.056
Units	384	384	384
Divested units	197	197	197
Observations	7,145	7,145	7,145

Introduction
○○○

Model
○○○○○○○

Estimation Strategy
○○

Empirical Results
○○○○○●○

Lobbying

TABLE 7—MATCHED DID ESTIMATES OF PERCENT OF IN-STATE COAL
AMONG PLANTS BURNING IN-STATE COAL IN 1997

	(1)	(2)	(3)	(4)	(5)	(6)
Post-divest	−0.093	−0.114	−0.111	−0.102	−0.107	−0.160***
	(0.058)	(0.073)	(0.072)	(0.065)	(0.065)	(0.055)
Post-divest x	−0.374***	−0.351***	−0.342***	−0.374***	−0.373***	−0.377***
Switching plant	(0.059)	(0.057)	(0.092)	(0.059)	(0.059)	(0.059)
m nearest neighbors				10	5	1
Proximity threshold (mi.)	200	100	50			
Year-month FE	Yes	Yes	Yes	Yes	Yes	Yes
Facility FE	Yes	Yes	Yes	Yes	Yes	Yes
R^2	0.687	0.667	0.689	0.682	0.679	0.718
Facilities	82	68	30	81	74	57
Divested facilities	40	33	15	40	40	40
Observations	17,433	13,745	5,858	16,802	14,707	10,820

Introduction
○○○

Model
○○○○○○○

Estimation Strategy
○○

Empirical Results
○○○○○○●

Reference

Cicala, S. (2015). When Does Regulation Distort Costs? Lessons from Fuel Procurement in US Electricity Generation. American Economic Review, 105(1), 411-444.