The Costs of Environmental Regulation in a Concentrated Industry
(Ryan, ECMA 2012)

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Context

Clean Air Act in 1990 = regulation in polluting ind.

- Increased costs of investment
- Increased costs of entry

$\Rightarrow$ Potential issue in concentrated industries

Dynamic oligopoly analysis (vs. typical engineering estimates)

- Recover sunk costs, scrap values, investment costs
- Consider dynamic effects ($\uparrow$ concentration)

Methodology

Bajari, Benkard and Levin (2007) two-step estimator:

1. Estimate policy functions (equilibrium behavior)
2. Recover parameters that “justify” policy functions

In this paper:

- Product market profits (Cournot)
- Policy functions (state var. = capacity)
  - Investment/Divestment
  - Entry/Exit
- “Dynamic part”

Data and Summary Statistics

Paper dataset vs. Shared dataset

Two datasets in use:

1. Market-level demand/supply data
2. Plant-level production/investment data

First problems arise: by simple grouping, only 22 mkts (vs. 27)

- Some markets within a state are not “separated”

  (ex. PA represents WPA and EPA)

  $\Rightarrow$ + 3 markets
- Some combinations of states are “shuffled”

  (ex. MDVAWV while MD should be alone)

  $\Rightarrow$ + 2 markets (but impossible to do)

Bottomline: not identical dataset

Main Results

Plan

1. Product market game:
   1.1 Cement demand estimation
   1.2 Cost function estimation
2. Policy function estimation:
   2.1 Investment/Divestment policy function
   2.2 Entry/exit policy function
3. Dynamic part:
   3.1 Incumbents' problem estimation
   3.2 Entrants' problem estimation

Cement Demand Estimation

$$\ln Q_{jt} = \alpha_0 + \alpha_1 \ln P_{jt} + \alpha_{2j} + \alpha_{3t}' X_{jt} + \epsilon_{jt}$$

Different specifications are tested:

- Market size controls: population, construction permits
- Market Fixed Effects

$\Rightarrow$ Choose no controls but fixed effects.

Production Costs Estimation

$$C(q_i, s_i; \delta) = \delta_1 \cdot q_i + \delta_2 \cdot 1[q_i > \nu \cdot s_i] \cdot (q_i - \nu \cdot s_i)^2$$

Estimation using NLLS:

- For a given guess of parameters:
  - Solve the Cournot game in each market-year
  - Compare simulated quantities with actual (MSE)
  - Update parameters

- BUT objective function is highly nonlinear and takes time:
  - $\Rightarrow$ Global methods $>$ gradient-based
  - $\Rightarrow$ Less function eval. $>$ More function eval.

Solving the NLLS Problem

Intuition: Brute force until I figure out the optimal “area”, then Powell algorithm.

Pre-1990 period:

- Five rounds of brute force on a $7 \times 7 \times 7$ grid

  (Not a lot but already $\sim$ 2 hrs...)
- Then Powell multiple times (w/ different starting values)

Post-1990 period:

- Brute force is not very effective...

  (Because obj. fun. is very flat)

  $\Rightarrow$ Only three rounds of BF
- Then Powell multiple times (w/ different starting values)

Investment Policy Function

(S, s) rule of investment!

Each firm has (1) a target capacity and (2) adjustment bands.

- If current cap. is within bands = no investment
- If current cap. is outside bands = investment to target

$=$ Captures lumpy investment behavior

Based on two assumptions:

1. Firms adjust as soon as they hit bands = id. bands
2. Firms always adjust to target cap. = id. target

$\Rightarrow$ Any observed non-zero investment tells us about both!

Investment Policy Function: Estimation

$$\textit{(Target):}\ \ln(s_{it}^*) = \text{Bs}\left(s_{it}, \sum_{j \neq i} s_{jt}\right)$$

$$\textit{(Bands):}\ \ln(s_{it}^* - s_{it}) = \text{Bs}\left(s_{it}, \sum_{j \neq i} s_{jt}\right)$$

where $\text{Bs}(\cdot)$ is a cubic bivariate B-spline.

Entry/Exit Policy Functions

Simple probit regression: entry/exit probability on state variables.

$$\Pr\left[entry|s_i = 0, s\right] = \Phi\left(\psi_1 + \psi_2 \cdot \left(\sum_{j\neq i} s_{jt}\right) + \psi_3 \cdot 1[t \geq 1990]\right)$$

$$\Pr\left[exit|s_{it}, s\right] = \Phi\left(\psi_1 + \psi_2 \cdot s_{it} + \psi_3 \cdot \left(\sum_{j\neq i} s_{jt}\right) + \psi_4 \cdot 1[t \geq 1990]\right)$$

Incumbents' dynamic payoffs

Most difficult part to understand...

Equilibrium per-period payoff function:

$$
\begin{aligned}
\mathrm{E}\left[\pi_i(s, \sigma(s); \theta)\right] = \bar{\pi}_i(s) & - p_i(s) \cdot \left(\tilde{\gamma}_{1i} + \gamma_2 x_i + \gamma_3 x_i^2\right) \\
& + p_d(s) \cdot \left(\tilde{\gamma}_{4i} + \gamma_5 x_i + \gamma_6 x_i^2\right) \\
& + p_e(s) \cdot \tilde{\phi}_i
\end{aligned}
$$

Normally, this function is linear in uncoditional distribution parameters! Here, where are they?

What I would have done

Consider the exit decision:

- $\tilde{\phi}_i$ is the expected scrap value conditional on exiting:

$$\tilde{\phi}_i = \mathrm{E}\left[\phi_i | \phi > \mathrm{E}\left[\max\{V_i^+(s) - \gamma_{1i}, V_i^-(s) - \gamma_{4i}, V_i^0(s)\}\right]\right]$$

- So given that $\phi \sim N(\mu_\phi, \sigma_\phi^2)$, then:

$$\tilde{\phi}_i = \mu_\phi + \sigma_\phi \cdot \lambda(\mathrm{E}\left[\max\{...\}\right])$$

where $\lambda(\cdot)$ is the inverse Mills ratio.

$\Rightarrow$ If we had $\mathrm{E}\left[\max\{...\}\right]$ = linear in distribution parameters!

Then, do typical BBL!

Entrants' dynamic payoffs

Could be done if previous step was done!

Value function:

$$V_i^e(s;\sigma(s),\theta) = \max\{0, \max_{x_i \geq 0} -\kappa_i - \gamma_{1i} - \gamma_2 x_i - \gamma_3 x_i^2 + W_i(\sigma(s))\}$$

where κ_i is entry cost draw.

Firm will enter iff:

$$\Pr\left[\kappa_i + \gamma_{1i} \leq EV^e(s)\right] = \Phi\left(EV^e(s)\right)$$

where $\Phi = N(\mu_\kappa + \mu_\gamma^+, \sigma_\kappa^2 + \sigma_\gamma^2) \Rightarrow$ solve by NLLS!

Discussion