ECON-L1350 - Empirical Industrial Organization PhD II – Topics

Lecture 1

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Helsinki GSE Empirical IO PhD cycle

1. ECON-L1300 - Empirical Industrial Organization I: Static models
    - Demand and supply estimation, BLP, identification, mergers, applications
2. ECON-L1350 - Empirical Industrial Organization II: Topics
    - This course: more of the standard toolkit, and applications

Schedule

- Week 1
    - Structural estimation, electricity markets, Iivo Vehviläinen
    - Exercise #1 (electricity market supply estimation)
- Week 2
    - Guest lectures / seminars: Gautam Gowrisankaran
    - Electricity markets, health markets
    - No exercise
- Week 3
    - Productivity (Nelli Valmari)
    - Exercise #2

Schedule

- Week 4
  - Health markets (Tanja Saxell)
  - Exercise #3
- Week 5
  - Auctions (Janne Tukiainen)
  - Exercise #4
- Week 6
  - Entry (Otto Toivanen)
  - Exercise #5

About the course

- This is a PhD level course. That means the following things:
  - We take the prerequisites as given.
  - The work load of the course is substantially higher than in MSc courses.
  - The exercises will be more difficult than in the MSc courses.
  - You are expected to prepare for the lectures by reading the compulsory material in advance.
- Otto's $3 + 2 + 3$ rule: a lecture necessitates
  - 3 hours of preparation
  - 2 hours of paying attention during the lecture
  - 3 hours of post-lecture work trying to understand what it all really was about.

Materials for the course

- Lectures and lecture notes.
- Reading list.
- Exercises.

About today's lecture

- Today's lecture is a warm-up lecture
- Agenda
  1. IO in applications
  2. How to cook up a structural model
  3. Example: an standard application in electricity markets

When can we trust market outcomes?

- IO considerations
    1. Incentives in the presence of asymmetric information
    2. The determinants of strategic interaction
    3. The impact of market design and market structure on the intensity of competition

First week application: Electricity markets

- Key policy considerations in energy now:
    1. Resilience against shocks
    2. Response to climate change

Electricity markets

- Electricity markets inherently imperfectly competitive
    1. Supply must meet demand at all times
    2. Not viable to store in large scales (yet)
    3. Inelastic demand: technologies, contracts
    4. Concentrated supply
    5. Constrained entry

See Wilson (2002)

Electricity markets

- A lot of institutional details
- Yet, empirical work is aided by
  - Electricity is a single homogeneous good
  - Demand is (has been) inelastic
  - Clearly defined market rules
  - Lots of data
- Empirical work usually speaks to short-term efficiency
  1. Can be informative of the long-term pressures as well
  2. Guide regulatory responses needed

Electricity markets

- Rich structure for study, issues include

  1. Market design: Double-sided auction day-ahead, real-time mechanisms, long-term contracting (e.g. Cramton, 2017; Wolak 2021)
  2. Auction theory: uniform price vs. discriminatory (Fabra et al. 2006)
  3. Wholesale competitiveness (Borenstein et al. 2002; Puller 2007; Bushnell et al. 2008)
  4. Forward contracting (Liski & Montero, 2006, Ito & Reguant, 2016)
  5. Bidding behavior (Hortaçsu & Puller, 2008, Hortaçsu et al. 2019)
  6. Transmission, reliability (Joskow & Tirole, 2005, 2007)
  7. Retail markets (Borenstein & Holland, 2005; Joskow & Tirole, 2006)
  8. Environmental policies (Kaffine 2013; Cullen 2013; Novan, 2015; Liski & Vehviläinen, 2020; Fabra 2021)
  9. Pass-through (Fabra & Reguant, 2014)
  10. Efficiency improvements (Ryan, 2021; Butters, Dorsey & Gowrisankaran, 2021; Liski & Vehviläinen, 2023)

Start with basics: Structural models a la Reiss & Wolak

- Typical ingredients for a structural economic model in IO:
  1. Economic environment
  2. Market primitives
  3. Exogenous parameters
  4. Decisions
  5. Equilibrium

RW1. Economic environment

- Market institutions
- Economic actors
- Information sets

Example: Puller, 2007

Chapter II. Institutional Structure of the California Electricity Market

- Written about the California electricity crisis in 2000
  - Enron scandal: fraud and the biggest bankruptcy at the time
- Starts with restructuring: generation, transmission, distribution
- Key institution: Power exchange
  - Day-ahead market, supply = demand for all hours
  - Geographical locations (largely ignored here)
  - Price caps
- Real time markets (not discussed much)

Example: Puller, 2007

Chapter II. Institutional Structure of the California Electricity Market

- Available information
  - Operative characteristics of plants known
  - Output by plant observed
  - Repeated interaction in the day-ahead market (not used)

RW2. Market primitives

- Production possibilities
- Preferences
- Endowments

Example: Puller, 2007

Chapter II. Institutional Structure of the California Electricity Market

- Restructuring left fossil fuel capacities to 5 large firms

TABLE 1.—POSTDIVESTITURE MARKET STRUCTURE OF FOSSIL-FUELED GENERATING UNITS (54% OF TOTAL CALIFORNIA CAPACITY)

Firm	Capacity (MW)	Percentage of Capacity
AES	3921	22
Reliant	3698	21
Duke	3343	19
Southern	3130	18
Dynegy	2871	16
PG&E	570	3
Thermo Ecotek	274	2

PG&E reached an agreement by which it would retain ownership of two old plants until they could be retired. The 46% of capacity that is not included in this table includes nuclear, hydroelectric, and renewable resources owned largely by PG&E and Southern California Edison.

- Entry constrained

Example: Puller, 2007

Chapter II. Institutional Structure of the California Electricity Market

- Supply = strategic actors & competitive fringe
  - 5 large utilities
  - 2 small firms
  - Two nuclear plants, jointly owned
  - Many hydro plants owned by one firm
  - Many independent plants
  - Imports from other states
- Demand = inelastic $\rightarrow$ residual demand
  - 3 incumbent utilities buy for their customers

RW3. Exogenous parameters

- Constraints
- Exogenous variables

- 5 large firms strategic, control fossil fuel technologies
- Other supply = competitive fringe that optimizes based on
    1. hourly electricity prices
    2. input prices
    3. weather
    4. seasonal variation
- Assume constant-price-elasticity for the shape of the fringe supply

- Interested in how fringe quantities change as prices change:

$$\ln Q^{S}_{fringe,t} = \beta_0 + \beta_1 \ln P_t + \beta_2 \ln P_t^{input} + \beta_3 T_t + \beta_4 \mu_t + \beta_5 \delta_t + \nu_t$$

  - P_t is the electricity price for the hour 5–6p.m.
  - P_t^{input} are the daily gas prices, separate for North vs. South
  - T_t is temperature from neighboring states
  - μ_t is a month-year dummy that captures hydro reservoirs and nuclear outages (and seasonal elements)
  - δ_t is day-of-week dummy

RW4. Decisions

- Decision variables
- Time horizons
- Objective functions

- Strategic firms make production decisions against the residual demand:
$$Q^D_{strat,t}(P_t) = Q^D_t - Q^S_{fringe,t}(P_t)$$
- Competitive fringe acts as price taker
- Strategic firms optimize against marginal revenues
- Short-term only: independent decisions for each hour (day)

RW5. Equilibrium

- Equilibrium concept
    1. Monopoly
    2. Walrasian
    3. Bertrand
    4. Cournot
    5. Electricity markets: supply function equilibrium (Klemperer and Meyer, 1989; Green and Newbery, 1992)
    6. ...

- Costs assumed to be known from engineering data
- Enables test of different behaviors
    1. Competitive benchmark, marginal cost pricing
    2. Monopoly
    3. Cournot competition

Example: Puller, 2007

Chapter IV. Data

- Summary statistics:

TABLE 2.—HOUR 18 PRICE-COST MARGINS WHEN FIRMS ARE NOT AT CAPACITY

Firm	% hours not at capacity	Price-Cost Margin ($/MWh) Mean	Median	St. Dev.	Min	Max	Median Lerner
DukeSouth	88	61.43	13.97	100.98	−29.67	443.19	.23
Southern	98	37.71	11.55	81.97	−22.60	1045.94	.26
Reliant	94	31.70	7.31	76.71	−26.05	686.36	.21
Dynegy	100	25.20	2.60	73.61	−32.43	688.68	.08
AES	99	22.42	2.96	78.51	−524.76	684.50	.09
Duke	87	19.75	3.69	45.67	−20.80	475.79	.11

This table contains summary statistics of hours when firms are not operating at capacity and can increase output. The price-cost margin is the difference between price and the marginal cost of the highest-marginal-cost unit that is operating and has excess capacity.

Notes:

1. The Lerner index $\equiv (price - MC)/price$ is presented as a general measure of market power.
2. The "firm" DukeSouth represents the generating units owned by Duke in the southern part of the state when transmission capacity constraints are binding. Transmission constraints tend to bind when demand (and perhaps the potential to exercise market power) are high.
3. The large negative margin for AES represents a single day in which a unit was operating but in the process of starting up so that the emission costs were high.

- Simulating Cournot equilibrium
    1. Start with some price between competitive price and monopoly prices, and say equal allocation of output
    2. Calculate best-responses for each of the firms assuming other quantities stay fixed
    3. Iterate until hopefully converge to an equlibrium (When is this a contraction mapping?)
- Places strong assumptions on all firms behaving equally

- Assume that firm's choose quantities to optimize

$$\max_{q_{it}} P(q_{it} + q_{-it})q_{it} - C_{it}(q_{it}) \quad s.t. \quad q_{it} \leq k_{it}$$

- First order condition gives

$$P(q^*_{it} + q_{-it}) - C'_{it}(q^*_{it}) + \theta_{it} P'_t q^*_{it} - \lambda^*_{it} = 0$$

from which one can tease out an estimation strategy for the conduct parameter θ that involves joint estimation of the fringe and the θs

Example: Puller, 2007

Chapter V. Results

- Results from joint estimation of fringe and firm-level conduct:

TABLE 4.—CONDUCT PARAMETER ESTIMATES BY FIRM FOR HOUR 18

	4-Firm Market†		5-Firm Market‡	
Firm	Estimate	Std. Error	Estimate	Std. Error
Southern	—	—	1.21	0.11
Reliant	1.48	0.32	1.01	0.09
Duke	1.02	0.18	0.81*	0.08
AES	0.99	0.20	0.82	0.12
Dynegy	5.15*	1.14	1.75*	0.19

	June–November 2000	
Firm	Estimate	Std. Error
Southern	1.46*	0.17
Reliant	1.19	0.14
Duke	1.15	0.15
AES	0.96	0.17
Dynegy	2.39*	0.29

Estimates of θ_i from estimation of system of equations (1) and (3) where each strategic firm supply relation contains a firm-specific parameter for conduct θ_i and shadow value of capacity λ_i. The instruments and estimation techniques are described in the note to table 3.

*Reject H_0:$\theta_i = 1$ at 5% level.

†July 1, 1998 to April 15, 1999.

‡April 16, 1999 to November 30, 2000.

- How credible these estimates are?

Example: Puller, 2007

Issues

- Robustness w.r.t. functional form
- Measurement errors in costs
- Constraints on production, transmission links
- Real-time markets and ancillary service provision
- What else?

A bit more on the theory

In general:

- Characterize the best response of bidders to their beliefs about the distribution of the residual demand curve
- Find mutual best responses consistent with the beliefs

Best responses in multiunit auctions are tricky:

- We'll only scratch the surface, for more:
  - Wolak 2003, electricity markets
  - Athey & Hailey 2007, nonparametric
  - Krishna, Auction theory, 2009
  - Hortaçsu & Perrigne 2021, recent survey

A bit more on the theory

- Assume:
  - Firm i supplies a schedule $S_i(p, QC_i)$, having contracted a fixed quantity QC_i at fixed price PC_i
  - Demand $\tilde{D}(p)$ is uncertain, costs $C_i(p)$ known, QC_i not
- Market clearing:

$$\sum_i S_i(p^c, QC_i) = \tilde{D}(p^c)$$

- Firm's profit is then

$$\pi_i = S_i(p^c, QC_i)p^c - C_i(S_i(p^c)) - (p - PC_i)QC_i$$

Hortaçsu & Puller 2005

A bit more on the theory

- Assume that the strategies take the form $\alpha_i(p) + \beta_i(QC_i)$
- Define $H_i(p, S_i^*(p); QC_i) = \Pr(p^c \leq p | QC_i, S_i^*(p))$
- Then optimal supply schedule fulfills:

$$\underbrace{p - C_i'(S_i^*(p^c))}_{\text{markup}} = \underbrace{(S_i^*(p^c) - QC_i)}_{\text{net position}} \frac{H_S(p, S_i^*(p^c); QC_i)}{H_p(p, S_i^*(p^c); QC_i)},$$

where the last ratio depends on the impact of supply change to the market price distribution and the density of market price

Hortaçsu & Puller 2005

Forward contracting: Liski & Montero (2006)

- Standard argument
  - Forward market forces firms to compete in forward contracts, reducing their market power in spot (Allaz & Vila 1993)
- Repeated interaction argument
  - Pro-competitive: Forward contracting reduces non-contracted sales
  - Pro-collusion: Forward contracting reduces benefits of deviation and allows for potentially harsher punishments

Sequential markets: Ito & Reguant (2016)

Static use of market power:

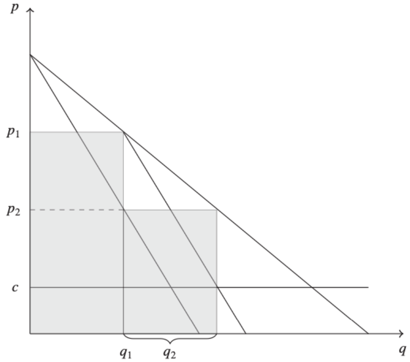

FIGURE 1. A PRICE-DISCRIMINATING RESIDUAL MONOPOLIST

Notes: This figure shows the intuition behind the declining price result (Result 1). A residual monopolist with marginal cost c has an interest in more expensive power plants setting a high price in the first market (p_1). In the second market, the monopolist can regain some of the withheld quantity by lowering the price (p_2).

Sequential markets: Ito & Reguant (2016)

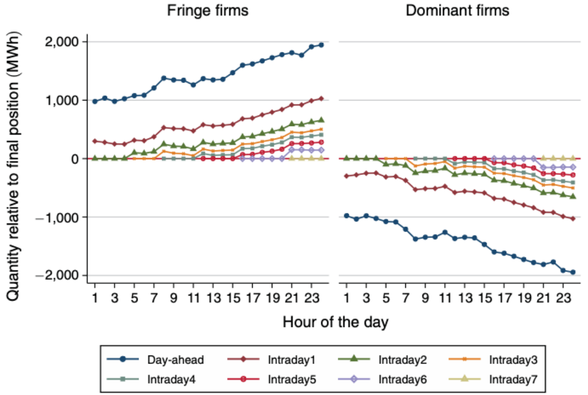

FIGURE 4. SYSTEMATIC OVERSELLING AND UNDERSELLING IN FORWARD MARKETS

- Theory prediction: Large firms oversell in forward markets, small firms arbitrage the differences
- Seems to hold with data from the Iberian market

Recap

A structural model combines theory with

- Market and institutions
- Economic actors
  - what they know
  - what they can do
- How actions map to outcomes
- Equilibrium concept

Exercise #1

- Replicate Puller's competitive fringe model with Nord Pool data
- Compare the resulting supply curve to the actual bid data
- Improvements: functional forms and endogeneity

Next time

- To do more with data
- Topics