ECON-L1350 - Empirical Industrial Organization PhD II – Topics

Lecture 2

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Today

- Solving uniform price equilibrium
- Identification of a more serious model
- Topics

Example: Demand

bid.id	date.time	type	P	Q
1	2015-01-15 11:00:00	D	0.011	144.215
2	2015-01-15 11:00:00	D	0.029	79.928
3	2015-01-15 11:00:00	D	0.042	63.523
...	...	...	...	...
79	2015-01-15 11:00:00	D	25	0.035
80	2015-01-15 11:00:00	D	25.010	0.464
81	2015-01-15 11:00:00	D	25.145	0.881
...	...	...	...	...
165	2015-01-15 11:00:00	D	120.900	30
166	2015-01-15 11:00:00	D	123.203	25.400
167	2015-01-15 11:00:00	D	126.257	45

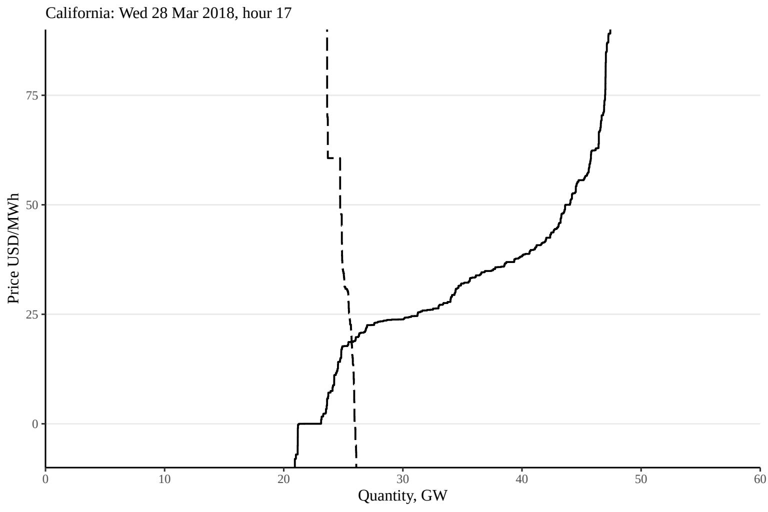
Table 1: Demand bids in the Nordic electricity market.

Example: Supply

bid.id	date.time	type	P	Q
1	2015-01-15 11:00:00	S	0.011	146.371
2	2015-01-15 11:00:00	S	0.029	272.917
3	2015-01-15 11:00:00	S	0.042	205.597
...	...	...	...	...
116	2015-01-15 11:00:00	S	20.007	4.999
117	2015-01-15 11:00:00	S	20.100	64.486
118	2015-01-15 11:00:00	S	20.200	32.611
...	...	...	...	...
583	2015-01-15 11:00:00	S	100.100	5.107
584	2015-01-15 11:00:00	S	108	0.569
585	2015-01-15 11:00:00	S	110	4.689

Table 2: Supply bids in the Nordic electricity market.

Market equilibrium given bids



Structural model: The same as the market operators use

Useful trick: reformulate as an optimization problem

Given demand bids $(p_i, q_i)_{i\in\mathcal{D}_t}$ and supply bids $(p_j, q_j)_{j\in\mathcal{S}_t}$ exchange solves:

$$\max_{d^i,s^i} \sum_i p^i d^i - \sum_j p^j s^j$$

$$\text{s.t.} \quad d_t = \sum_i d_i, \quad 0 \leq d_i \leq q_i,\ i \in \mathcal{D}_t$$

$$s_t = \sum_j s_j, \quad 0 \leq s_j \leq q_j,\ j \in \mathcal{S}_t,$$

$$d_t - s_t = 0$$

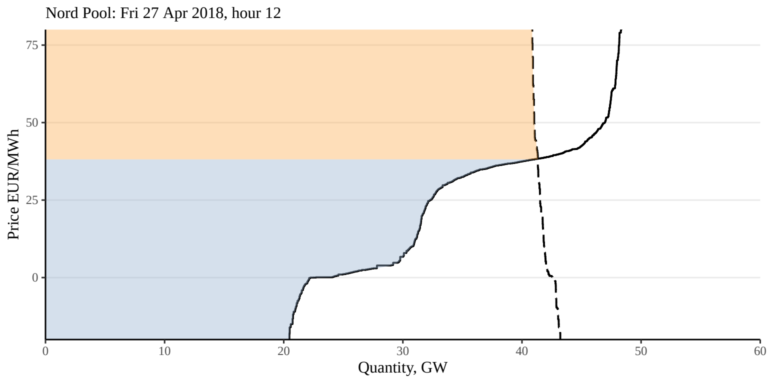
Or, because $d_t = s_t$ at market price p^*,

$$\Leftrightarrow \max_{d_i,s_j} \sum_i (p_i - p^*) d_i + \sum_j (p^* - p_j) s_j$$

Samuelson, 1952.

Structural model: The same as the market operators use

Maximizing the consumer and producer surplus from bids.



The shadow prices of the market clearing constraint $d_t = s_t$ are market prices.

Ryan 2021: Extension across space

I. The Indian Electricity Sector

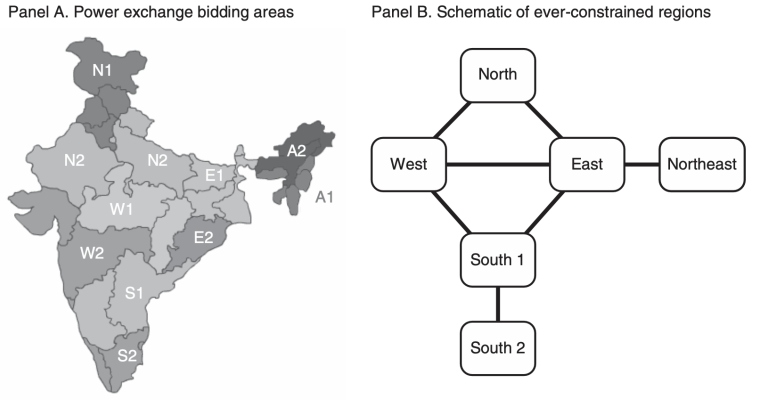


FIGURE 1. INDIAN POWER GRID

Notes: The figure shows geographic and schematic representations of the bidding areas in the Indian day-ahead power market. Panel A represents the ten subregions in which bids are submitted, formed from five regions with two subregions apiece. Panel B represents the six functionally distinct regions that are ever separated by constrained transmission links and the structure of interregional transmission links among them.

Market equilibrium: Incorporating trade

Surplus maximization, across regions

Solve the equilibria for all bidding areas simultaneously:

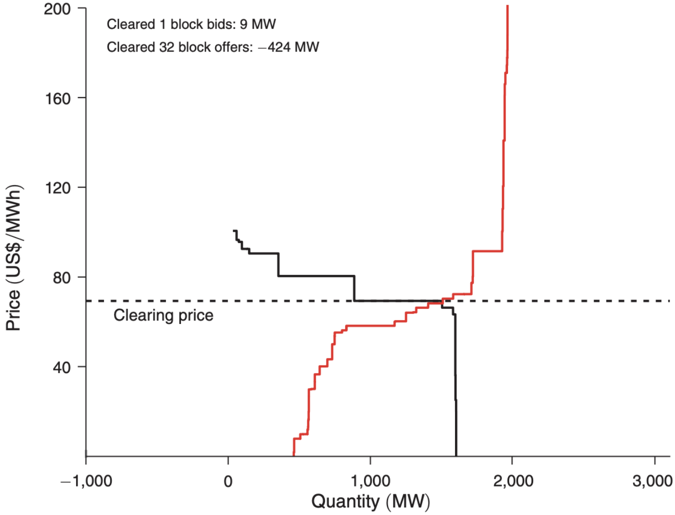
$$\max_{d_i, s_j} \sum_{g \in \mathcal{G}} \left[\sum_{i \in \mathcal{D}_g} p_i d_i - \sum_{j \in \mathcal{S}_g} p_j s_j \right]$$

and relax the autarky supply–demand balance constraints with a possibility to trade at most a net quantity y from each market:

$$\begin{aligned} d_g - s_g &= x_g, \quad \forall g, \\ -y \leq x_g &\leq y, \quad \forall g, \\ \sum_{g \in \mathcal{G}} x_g &= 0. \end{aligned}$$

Ryan 2021: Even better bid data

I. The Indian Electricity Sector



Note on complex bids

- Dynamic costs limit the ability of the firm to adjust output
- Market clearing allows for complex bids
  - e.g. revenue requirement over the day, or block bids
  - ties bids together, and breaks the convexity of market clearing
- Reguant (2014) imposes structure to identify costs, including start-up costs, and contract positions
  - separation of single bids and complex bids
  - parametrized cost function
  - simulated data used in identification

Example: Complex bids – market power

- Consider e.g. inverse demand $P = 16 - 2Q$ and supply bids

	p_j	q_j
A	1	4
B	2	2
C	3	1

- Then outcomes depend on how bids are handled

		Q	P	equlibrium
Normal bids	A+B+C/2	6.5	3	*
All-or-nothing	A+B	6	4	*
	A+C	5	6	*
	A+B+C	7	2	

IID. Descriptive Evidence: Effect of Congestion on Bid Prices

TABLE 4—BID PRICES AND CONGESTION

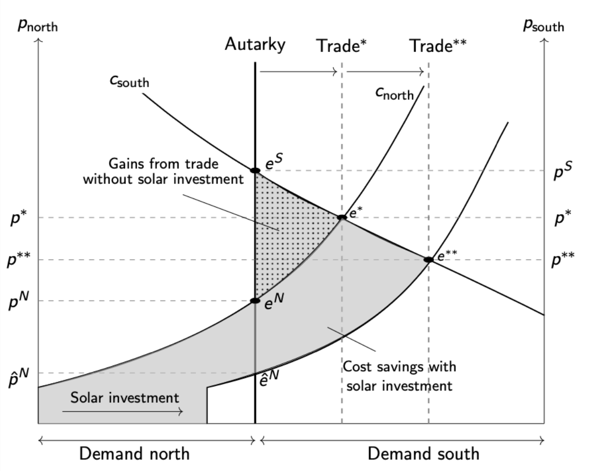
Sample:	All firms		Public firms		Nonstrategic	
	Dependent variable: Price bid					
	OLS (1)	2SLS (2)	OLS (3)	2SLS (4)	OLS (5)	2SLS (6)
North region congested (=1)	6.47	8.63	7.28	7.65	0.18	2.65
	(0.63)	(2.18)	(0.77)	(2.43)	(0.25)	(1.44)
Mean in uncongested hours	106.37	106.37	105.82	105.82	111.63	111.63
Observations	141,455	141,455	43,011	43,011	101,868	101,868

- Reduced form on how congestion affects bids of the firms

Efficiency improvements

- Lower cost of trade affects efficiency of the market
  - true even in the competitive case
  - additional motivation: reduction of market power
- Additional structure needed

Efficiency improvement: competitive case



- Gains from trade, including dynamic impacts to entry

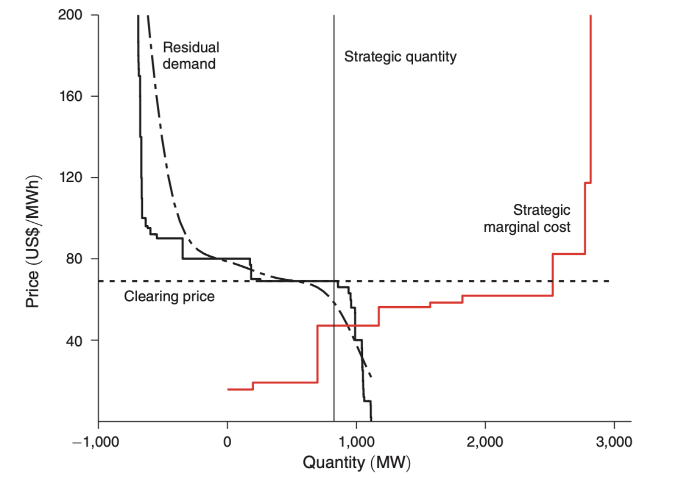
Gonzales, Ito & Reguant (2021)

Steps towards identification:

1. Market clearing demand
   - Residual demand = actual - competitive fringe
2. Objective of the firms
   - First order condition for profit maximization
   - Assumption: Firms optimize against the residual demand in the congested price area, but do not try to cause congestion

1. Contract positions ignored
2. Costs unknown, to be estimated
   - Constant marginal cost assumption
3. Dealing with uncertainty in bidding
   - Bootstrap demand and bids $\rightarrow$ sample of residual demands
   - GMM with the bootstrapped data
   - Capacity constraints require optimization
4. Online appendix and codes tell the detail

Ryan 2021: Simulated Cournot



Strategic firms optimize against smoothed residual demand

Efficiency improvements – other dimensions

- Source of demand inelasticity
  - Contractual commitments, fixed price contract vs. real-time pricing (Borenstein & Holland, 2005; Joskow & Tirole, 2006)
  - Technology commitments: heating technology choices (Sahari, 2019), industrial processes, etc.
- New technologies: Improved allocative efficiency
  - Storage, ITC, cryptocurrency mining, data centers
- Efficiency over time instead of space

Surplus maximization, across time

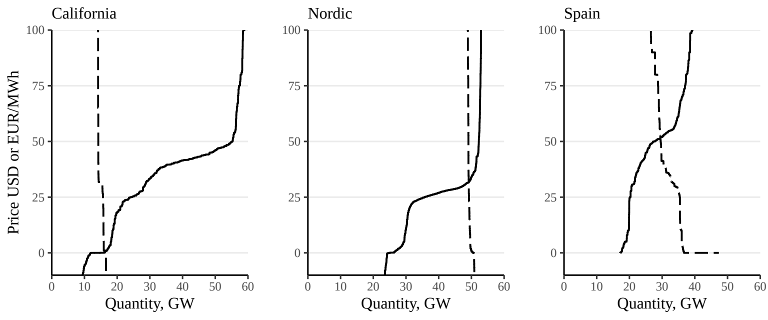
Solve the equilibria for all bidding areas simultaneously:

$$\max_{d_i, s_j} \sum_{t \in \mathcal{T}} \left[\sum_{i \in \mathcal{D}_t} p_i d_i - \sum_{j \in \mathcal{S}_t} p_j s_j \right]$$

and relax the autarky supply–demand balance constraints with a possibility to "trade" at most a net quantity y from each hour:

$$\begin{aligned} d_t - s_t = x_t, \quad \forall t, \\ -y \leq x_t \leq y, \quad \forall t, \\ \sum_{t \in \mathcal{T}} x_t = 0. \end{aligned}$$

Data set: Bid curves



- Three markets with structural differences in existing generation
  - California: biggest in solar
  - Nordics: most hydro
  - Spain: largest share of wind
- 160+ million bids from the years 2011–2020

Taming the duck in California

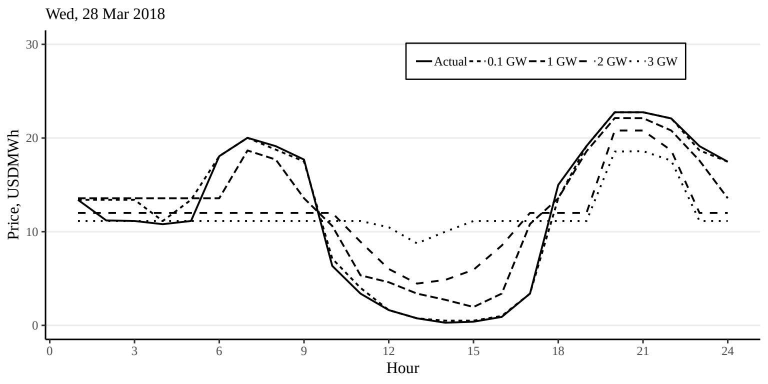
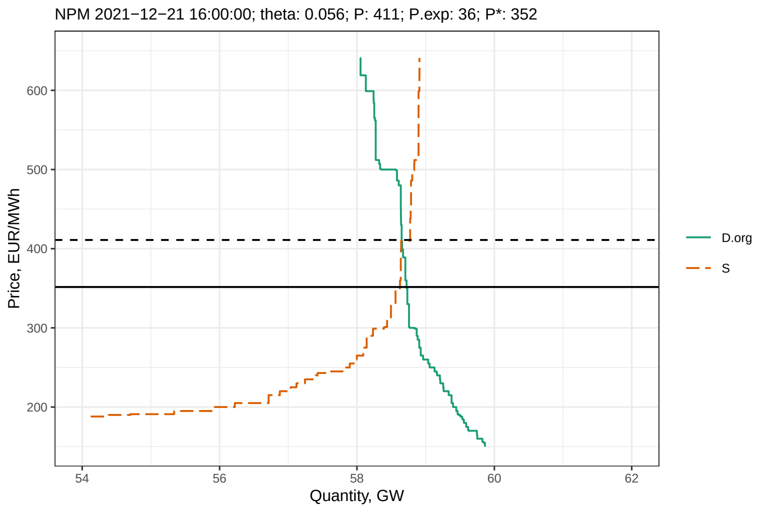


Illustration of how hourly prices in California converge as new efficiency improving technology is added to the market equilibrium calculation.

Liski & Vehviläinen (2023)

Price caps



Optimal to implement price caps to correct for market misallocation.

Gerlagh, Liski & Vehviläinen (2022)

Recap: Identification in electricity markets

- Inelastic demand of homogenous good and competitive fringe
- Strategic firms optimize profits in multi-unit auctions
- Identifying assumptions
  - Wolak (2000): identification of marginal costs possible if contract positions are known
  - Hortaçsu & Puller (2008): identification of forward contract positions possible if marginal costs are known
- Additional structural assumptions on the primitives, nature of competition and availability of information

Final remarks: Policy implications

- Industry where demand is inelastic, supply is concentrated and entry constrained
- Externality through common network
  - Overconsumption of one consumer risks blackout for everyone
  - Below efficient capacity levels by firms with market power
- Less than optimal market institutions
  - Price caps to limit market power and correct for the inelastic demand, but lead to further distortion in investment incentives
  - Non-convexities and complexity reduce transparency
- Current discussions: long-term contracting