Strategic Bidding in Multi-unit Auctions with Capacity Constrained Bidders: The New York Capacity Market

Sebastian Schwenen, DIW Berlin

Belec, DIW Berlin, May 2015
Motivation

- Looking inside capacity markets: Offer a model-based analysis of bidding behavior.

- Applying the model to data from the NY capacity market, show that strategic firm behavior in capacity markets can lead to high rent extraction from generating firms.

- Offer novel empirical support for a class of models for multi-unit uniform price auctions (Fabra and von der Fehr, 2006).
• Regulatory tool to stimulate investment in power markets.

• Some academics, policymakers, industry claim investment not sufficient, for many reasons.

• Capacity markets new in UK, FR, IT; discussed in German coalition treaty; in US since the early 2000’s.

• The product traded is availability of power plants, for a specified time-horizon.

• In NY, capacity products procured by system operator (SO), on behalf of consumers (costs are passed on).
NYISO Market

- Nodal (zonal) energy market
- Automated market power mitigation
- Three (four since 2014) regional capacity markets
- Bid caps on capacity markets (summer / winter)
- Capacity forwards have to be notified to the ISO

Figure 1: NYISO Market.
Demand for capacity is constructed by ISO

Example demand curve:

Figure 2: Capacity demand curve (ICAP) in NYC, winter 2006/07.

- Demand curve is applied for six month
- Spot auctions are conducted monthly
- 55 monthly multi-unit uniform price procurement auctions
- June 2003 until February 2008
- 1085 bids
- Bidder ID, functional form of demand, bid caps
- Data available at [www.nyiso.com](http://www.nyiso.com)

<table>
<thead>
<tr>
<th></th>
<th>Mean</th>
<th>Min</th>
<th>Max</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of bidders</td>
<td>15.3</td>
<td>3</td>
<td>35</td>
</tr>
<tr>
<td>Number of bids</td>
<td>19.7</td>
<td>4</td>
<td>63</td>
</tr>
<tr>
<td>Offer share largest firm</td>
<td>66.5%</td>
<td>35.8%</td>
<td>85.3%</td>
</tr>
<tr>
<td>Offer share two largest firms</td>
<td>88.0%</td>
<td>66.3%</td>
<td>99.8%</td>
</tr>
<tr>
<td>Offer share three largest firms</td>
<td>93.7%</td>
<td>83.7%</td>
<td>100%</td>
</tr>
</tbody>
</table>

*Table 1: Auction statistics.*
The model

- Firms offer their capacity $k$ at price-bids $b_j$.

- SO sorts bids $b_j$ in increasing order...

- and finds clearing bid $b_p$ (pivotal bid needed for $\sum k \geq D$).

- Marginal costs normalized to zero (we observe zero bids).

- Framework relies on Fabra et al (2006), with capacity constraints
  a. one large firm clears the auction, setting $b_p$, earning some $\pi_p$
  b. competing firms bid low enough (below $\overline{b}_j$) such that for firm $p$ undercutting is not profitable.
Results: example auction outcome

Figure 3: Auction April 2007 with bounds for inframarginal bids.
Results: The pivotal bidder

- The pivotal bid equals the bid cap in all auctions.
- In all auctions the largest bidder is the pivotal bidder.
- The pivotal bidder bids all its capacity at $b_p$.
- Sales and unsold capacity vary across auctions.
Results: Infra-marginal bidders

- Roughly 95% of all low bids are explained by the model.
- Much violations happened in the first five auctions: learning?
- Low bids were mainly submitted either at zero or just below the bound.

Figure 4: Histogram bid-bound ratio.
Best-response function regressions

OLS regressions for best response functions of low bids:

- The pivotal bidder earns $\pi_p$.
- When undercutting, this bidder sells either all capacity, $k_p$,
- or serves residual demand at a lower price, $D(b_j) - K_{j-1}$.

Coming from the model, estimate:

$$\ln(b_j) = \beta_0 + \beta_1 \ln(\pi_p) + \beta_2 \ln(D(b_j) - K_{j-1}) + \ldots$$

$$\ln(b_j) = \beta_0 + \beta_1 \ln(\pi_p) + \beta_2 \ln(k_p) + \ldots$$
Results: Best-response function regressions

Low bids react to the pivotal bidder’s capacity:

<table>
<thead>
<tr>
<th></th>
<th>(1)</th>
<th>(2)</th>
<th>(3)</th>
<th>(4)</th>
</tr>
</thead>
<tbody>
<tr>
<td>(\ln(\pi_p))</td>
<td>1.751***</td>
<td>1.094***</td>
<td>0.862***</td>
<td>1.583***</td>
</tr>
<tr>
<td></td>
<td>(0.0945)</td>
<td>(0.0582)</td>
<td>(0.0333)</td>
<td>(0.0524)</td>
</tr>
<tr>
<td>(\ln(\bar{k}_p))</td>
<td>-2.761***</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>(0.0750)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(\ln(a))</td>
<td>0.793***</td>
<td>0.0855</td>
<td>0.0865**</td>
<td>0.154***</td>
</tr>
<tr>
<td></td>
<td>(0.0916)</td>
<td>(0.0569)</td>
<td>(0.0289)</td>
<td>(0.0445)</td>
</tr>
<tr>
<td>(D_s)</td>
<td>-0.453***</td>
<td>-0.140*</td>
<td>-0.0320</td>
<td>-0.375***</td>
</tr>
<tr>
<td></td>
<td>(0.0698)</td>
<td>(0.0616)</td>
<td>(0.0224)</td>
<td>(0.0495)</td>
</tr>
<tr>
<td>(\ln(D(b_j) - K_{j-1}))</td>
<td></td>
<td>-1.724***</td>
<td>-0.927***</td>
<td>-2.497***</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(0.0460)</td>
<td>(0.0495)</td>
<td>(0.0579)</td>
</tr>
<tr>
<td>(\beta_0)</td>
<td>-0.168</td>
<td>3.877***</td>
<td>0.224</td>
<td>4.660***</td>
</tr>
<tr>
<td></td>
<td>(1.191)</td>
<td>(0.672)</td>
<td>(0.202)</td>
<td>(0.526)</td>
</tr>
<tr>
<td>(N)</td>
<td>85</td>
<td>336</td>
<td>80</td>
<td>239</td>
</tr>
<tr>
<td>(\text{adj. } R^2)</td>
<td>0.961</td>
<td>0.906</td>
<td>0.983</td>
<td>0.924</td>
</tr>
</tbody>
</table>

Standard errors in parentheses
* \(p < 0.05\), ** \(p < 0.01\), *** \(p < 0.001\)
Conclusion

- When firms are capacity constrained, coordination on pivotal bidder seems simple.

- Inframarginal firms can react with their bids to maintain this equilibrium over different auctions.

- From a consumer/antitrust perspective, capacity markets cannot be recommended to enhance security of supply.

- Remedies are difficult to implement: DCA? Bid floors? Price Caps?
Thank you for your attention.

sschwenen@diw.de
Appendix: The model

The pivotal bidder finds

\[ b^*_p = \min\{\arg \max_b (D(b) - K_{p-1}), b^{\text{cap}}\}, \]

while the low bidders have to bid lower than

\[ \bar{b}_j := \begin{cases} 
    b_j (D(b_j) - K_{j-1}) = \pi_p & \text{if } \bar{k}_p > D(b_j) - K_{j-1} \\
    b_j \bar{k}_p = \pi_p & \text{if } D(b_j) - K_{j-1} > \bar{k}_p.
\]  

to not be underbid by the pivotal bidder.
Appendix: Low bid profit equivalence

- There is no significant relation between amount of capacity bid and distance to its bound.

**Figure 5:** Bid-bound ratio over submitted capacity.
Appendix: Results pivotal bids

- The bid cap is binding in nearly all auctions.

Figure 6: Unconstrained optimal and observed high bids.
• With truth-telling (or no withholding), the auctioneer could have saved around 40% of procurement costs while at the same time procuring more capacity.

• With properly adjusted bid floors, the observed equilibria can be destroyed and auction prices lowered.