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

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IAEE NY, June 2014
Motivation

- Offer empirical support for a simple model of bidding behavior in multi-unit uniform price auctions (capacity markets).
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- Show that in the NY capacity market, observed bid patterns from 2003 to 2008 result from strategic firm behavior.
Capacity Markets

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• The product is the availability of power plants, which commit to offer electricity for a specified time-horizon.

• The regulator/ISO finances these auctions by passing the procurement costs on to end-users.
NYISO Energy Markets

- Energy market with LBMP

- Three NYISO administered capacity markets, including forward markets for ICAP (this paper looks at the NYC ICAP market)
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Figure 1: ICAP Demand Curve winter 2010, taken from NYISO.com.
The NYISO Energy Market: Forward & Spot ICAP Markets

- Market participants can engage in bilateral or institutional forward markets for ICAP, must notify their position to the NYISO, who procures the missing ICAP in its monthly ICAP spot auction.
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Figure 2: Forward and spot sales example, taken from NYISO.com.
Data

The data stems from the New York City capacity market:
- 55 monthly multi-unit uniform price procurement auctions
- June 2003 until March 2008
- 1093 bids
- Bidder ID, functional form of demand, bid caps

<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>19.9</td>
<td>4</td>
<td>63</td>
</tr>
<tr>
<td>offer share largest firm</td>
<td>66.6%</td>
<td>30.4%</td>
<td>85.3%</td>
</tr>
<tr>
<td>offer share two largest firms</td>
<td>81.8%</td>
<td>51.0%</td>
<td>99.8%</td>
</tr>
<tr>
<td>offer share three largest firms</td>
<td>89.0%</td>
<td>65.0%</td>
<td>100%</td>
</tr>
</tbody>
</table>

Table 1: Auction statistics.
Example: Auction Outcome

Figure 3: Auction August 2006.
Green and Newbery (1992), Hortacsu and Puller (2008) show how firms compete in SFE.
Modelling

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- Model relies on Fabra et al. (2006), perfect information with marginal costs being normalized to zero.
The Model
...calculates bounds for infra-marginal bids.

Figure 4: Auction August 2006, with bounds for low bids.
The Model

...calculates bounds for infra-marginal bids.
...and derives an asymmetry condition for the largest firm to be pivotal.

Figure 4: Auction August 2006, with bounds for low bids.
Results: The Pivotal Bidder

- The pivotal bid equals the bid cap in all auctions.
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- In all auctions the largest bidder is the pivotal bidder.
- In all auctions the condition for sufficiently asymmetric firm sizes holds.
Results: The Infra-marginal Bidders

- Roughly 95% of all low bids are explained by the model.
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- Much violations happened in the first five auctions: learning?
Results: The Infra-marginal Bidders

- Low bids were mainly submitted either at zero or just below the bound.

Figure 5: Histogram bid-bound ratio.
Results: The Infra-marginal Bidders

OLS regressions for best response functions of low bids:

- The pivotal bidder earns $\pi_p$.
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- The pivotal bidder earns $\pi_p$.
- When undercutting, this bidder sells either all capacity, $k_p$, or serves residual demand at a lower price, $D(b_j) - K_j - 1$. 
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Coming from the model, estimate:

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

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\]
Results: The Infra-marginal Bidders

- Low bids react to the pivotal bidder’s capacity.

<table>
<thead>
<tr>
<th></th>
<th>(1) ln(b_{in}^j)</th>
<th>(2) ln(b_{out}^j)</th>
<th>(3) ln(b_{out}^j)</th>
<th>(4) ln(b_{out}^j)</th>
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<tbody>
<tr>
<td>ln(\pi_p)</td>
<td>2.169***</td>
<td>1.182***</td>
<td>1.024***</td>
<td>1.670***</td>
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<tr>
<td></td>
<td>(21.33)</td>
<td>(22.60)</td>
<td>(18.76)</td>
<td>(29.91)</td>
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<tr>
<td>ln(k_p)</td>
<td>-2.304***</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td></td>
<td>(-32.54)</td>
<td></td>
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<td></td>
</tr>
<tr>
<td>ln(D(b_j) - K_{j-1})</td>
<td>-1.555***</td>
<td>-1.000***</td>
<td>-2.224***</td>
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</tr>
<tr>
<td></td>
<td>(-35.40)</td>
<td>(-12.91)</td>
<td>(-34.95)</td>
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<tr>
<td>ln(p(0))</td>
<td>0.744***</td>
<td>0.061</td>
<td>0.008</td>
<td>0.132***</td>
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<tr>
<td></td>
<td>(6.72)</td>
<td>(1.12)</td>
<td>(0.23)</td>
<td>(2.75)</td>
</tr>
<tr>
<td>D_w</td>
<td>0.870***</td>
<td>0.300***</td>
<td>0.194***</td>
<td>0.581***</td>
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<td></td>
<td>(12.53)</td>
<td>(5.51)</td>
<td>(5.39)</td>
<td>(11.41)</td>
</tr>
<tr>
<td>cons</td>
<td>-4.337***</td>
<td>2.130***</td>
<td>-0.171</td>
<td>1.966***</td>
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<td>(-6.17)</td>
<td>(3.96)</td>
<td>(-0.66)</td>
<td>(3.93)</td>
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<tr>
<td>R^2</td>
<td>0.93</td>
<td>0.89</td>
<td>0.93</td>
<td>0.89</td>
</tr>
<tr>
<td>N</td>
<td>80</td>
<td>346</td>
<td>133</td>
<td>246</td>
</tr>
</tbody>
</table>

t statistics in parentheses
* p < 0.05, ** p < 0.01, *** p < 0.001
Conclusion

• When firms are capacity constrained, simple models are sufficient to predict bidding behavior in multi-unit auctions.
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- Capacity markets, when organized in this form, are a costly tool to enhance security of supply.

- In the market studied, without strategic bidding, the auctioneer could have saved around 40% procurement costs.
THANK YOU!
Appendix: The Model

The pivotal bidder finds

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

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 6: Bid-bound ratio over submitted capacity.](image)
Appendix: Results Pivotal Bids

- The bid cap is binding in nearly all auctions.

Figure 7: Unconstrained optimal and observed high bids.
Appendix: Counterfactuals

• 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.
Appendix: Bid Floors

- As capacity constrains are relaxed, bid floors become more effective.

Figure 8: Auction prices with bid floors.