Jump Bidding as a Signaling Game

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What is Jump Bidding?

In May 2019, Claude Monet’s *Meules* auctioned for over $110m.

The auctioneer started increasing the price by $1m at a time from $77m.

After the price reached $92m, instead of offering $93m, a bidder offered $94m.
Motivation

▶ What is jump bidding in an English auction?
  ▶ Placing a bid in excess of what the auctioneer is asking for in a particular round
  ▶ A common phenomenon in art auctions, spectrum auctions and takeover bids

▶ Incompatible with the well-known “open exit” model
  ▶ No scope for jump bidding
  ▶ Jump bidding, when allowed, is “irrational”

▶ Rationalization of jump bidding
  ▶ Reducing transaction costs
  ▶ Anecdotal evidence of using jump bidding to intimidate competitors - “signaling”
This Paper

The first paper to carry out an empirical analysis of jump bidding using a structural approach

▶ Rationalizes jump bidding using a signaling model extended from Avery (1998)

▶ Using data from spectrum auctions,
  ▶ structurally estimates bidders’ value distribution using the signaling model
  ▶ compares estimation results with those estimated using the open exit model
  ▶ demonstrates that ignoring jump bidding leads to underestimation of bidders’ valuation

▶ Quantifies revenue loss to the government due to bidders’ ability to signal
Preview of Results

- Based on the signaling model, the mean valuation of a spectrum license is significantly higher than that based on the open exit model.

- If bidders were forbidden from placing jump bids, the government could have had an 8% increase in total revenues from a past spectrum license auction.
Literature Review and Contribution

- **Auction theory on jump bidding**
  - **This paper**: extends Avery (1998) to a more general and empirically estimable form

- **Empirical research on jump bidding**
  - **Descriptive** McAfee and McMillan (1996), Cramton (1997)
  - **Reduced form** Hungria-Gunnelin (2018), Sommervoll (2020), Khazal et al. (2020)
  - **This paper**: the first structural analysis on jump bidding
Structural estimation of auctions

- **Parametric** Paarsch (1992), Laffont et al. (1995), Hong and Shum (2003)
- **Nonparametric** Guerre et al. (2000), Li et al. (2002), Athey and Haile (2002)
- This paper: parametric estimation of a first-price auction using simulation and numerical approximations

Structural estimation of a spectrum auction Hong and Shum (2003), Fox and Bajari (2013)
Auction Format

- Modified version of an open exit auction
- Each round, bidders simultaneously submit bids
- At the end each round,
  - all bidding information is made public
  - each bidder publicly announces whether to drop out
  - the auction ends if only 1 bidder remains, who then wins and pays her bid
- If more than 1 bidder remains, the auctioneer sets the minimum required price for the next round
Theoretical Model Assumptions

- **Affiliated value auction** Milgrom and Weber (1982)
- \( n \geq 2 \) risk neutral bidders, each values the object at \( U_i \) but does not observe the valuation directly
- Each bidder receives a private observation \( X_i \). \( X_i \)'s are
  - strictly affiliated
    - identically and continuously distributed over the support \((0, \bar{X})\), \( \bar{X} > 0 \)
- Bidder valuations are affiliated, i.e.
  \[
  V_i = v(x_i, x_{-i}) = E[U_i \mid x_i, x_{-i}]
  \]
  \( v \) is continuous and increasing in each argument
How can jump bids serve as signals?

- What are the bidders trying to signal?
  - Bidders are trying to signal their private observations X’s

- What are the necessary conditions for a separating equilibrium?
  - Signals must be costly
  - Further, cost of signaling must differ across different “types” of players
Costs and Benefits of a Jump Bid

▶ A bidder faces 2 choices:
   a regular bid of $50 vs. a jump bid of $100

▶ By jump bidding to $100, the bidder forgoes the possibility of winning at $50

▶ \( \text{Ex ante cost of jump bidding} = \text{Probability of winning at }$50 \times (100 - 50) \)

▶ The probability of winning at $50, thus the \textit{ex ante} cost, is lower for a bidder with higher private observation

▶ What are the benefits of jump bidding?
  ⇒ Competitors drop out at lower prices than without jump bidding
Game 1: Single-Round Signaling

Set up

- Stage 1 (round 1): Bidders simultaneously choose an ordinary bid 0 or a jump bid of any size

- Stage 2 (round 2 and onwards):
  - Bidders commit to a drop out price given by either $S^*(x) = v(x, x)$ or $S_a = 0$
  - No jump bidding; bidders always place the minimum required amount set by the auctioneer
Game 1: Single-Round Signaling

Highlights of Results

- There exists a unique signaling equilibrium in Game 1
- In this equilibrium, the auction ends after the first round
- In round 1, each bidder places a jump bid using the first-price auction strategy
- The expected price in the signaling equilibrium is weakly lower than that in an open-exit auction without jump bidding
Game 2: Multi-round Signaling

- In real life, bidders can signal in unlimited number of rounds; the decision to stop is endogenous
- Multiple equilibria
- Make prediction on common characteristics (i.e., necessary conditions) shared by all the equilibria
Game 2: Inferences with Multi-round Signaling

For any symmetric equilibrium with multi-round signaling, the following holds:

- If a jump bid is placed, then it does not exceed the single-round jump bid strategy.

- If a non-jump bid is placed, then the bidder single-round jump bid strategy is below the minimum required amount for a jump bid, and the bid does not exceed the open exit strategy.
Data

- Federal Communications Commission ("FCC") Broadband PCS auction (C Block), or "Auction 5", between Dec 1995 and May 1996
  - Divided the US into 493 regional markets, offered 1 license per market
  - Simultaneous multiple round format; the auction went for 184 rounds
  - Auction only open to small businesses (annual revenue less than $40m); 255 firms took part, of which 89 won at least one license

- Auxiliary data
  - Area of each market approximated using QGIS
  - County-level income per capita in 1995 from the Bureau of Economic Analysis
Jump Bidding by Round

Number of new bids and jump bids

Number of bids vs Round

- No. of new bids
- No. of jump bids
- No. of jump bids (> $1000)
- No. of jump bids (> 2.5%)

Legend:
- Blue: No. of new bids
- Red: No. of jump bids
- Green: No. of jump bids (> $1000)
- Orange: No. of jump bids (> 2.5%)
Jump Bidding after Round 100
Empirical Model

- A parametric approach Hong and Shum (2003)

- $U_i$, the value of the object to bidder $i$, takes a multiplicative form

\[ U_i = A_i V \]

- $A_i$: bidder-specific private value for $i$
- $V$: common value component unknown to all bidders
- $V$ and $A_i$ are independently log normally distributed
Empirical Model (Cont’d)

- Each bidder receives private observation $X_i$,

$$X_i = U_i \cdot \exp(s_i\xi_i)$$

where $\xi_i$ is an unobserved error term with a standard normal distribution, and $s_i$ is a parameter

- The joint distribution of $(U_i, X_i, i = 1, \ldots, N)$ is fully characterized by parameters $\{m, r_0, \bar{a}, t, s\}$
Simulated Nonlinear Least-Squares Estimation

- The objective function is

$$\tilde{Q}_{S,T}(\theta) = \frac{1}{T} \sum_{t=1}^{T} \sum_{i=2}^{N_t} (p^t_i - \tilde{m}^t_i(\theta))^2$$

where

$$\tilde{m}^t_i(\theta) = \frac{1}{S} \sum_{s=1}^{S} (b^t_i(\bar{x}_s; \theta))$$

- $p^t_i$: observed log dropout bid for bidder $i$ in auction $t$
- $\tilde{m}^t_i(\theta)$: simulated estimator of the model predicted log dropout bid for bidder $i$ in auction $t$
Simulated Nonlinear Least-Squares Estimation

- The objective function is

\[
\tilde{Q}_{S,T}(\theta) = \frac{1}{T} \sum_{t=1}^{T} \sum_{i=2}^{N_t} (p_i^t - \tilde{m}_i^t(\theta))^2
\]

where

\[
\tilde{m}_i^t(\theta) = \frac{1}{S} \sum_{s=1}^{S} (b_i^t(\tilde{x}_s; \theta))
\]

- \(b_i^t(\cdot)\): model predicted log bid for each draw of private observation \(x_i^s\)
## SNLS Estimation Results

<table>
<thead>
<tr>
<th>Coefficient</th>
<th>Open Exit</th>
<th>Signaling</th>
</tr>
</thead>
<tbody>
<tr>
<td>Components of mean</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Constant(^b)</td>
<td>6.25</td>
<td>7.29</td>
</tr>
<tr>
<td></td>
<td>(0.001)</td>
<td>(0.000)</td>
</tr>
<tr>
<td>POP (mils)</td>
<td>0.53</td>
<td>0.54</td>
</tr>
<tr>
<td></td>
<td>(0.000)</td>
<td>(0.000)</td>
</tr>
<tr>
<td>POP density (’000/km(^2))</td>
<td>2.74</td>
<td>1.27</td>
</tr>
<tr>
<td></td>
<td>(0.003)</td>
<td>(0.002)</td>
</tr>
<tr>
<td>Inc/cap ($’000)</td>
<td>0.28</td>
<td>0.32</td>
</tr>
<tr>
<td></td>
<td>(0.009)</td>
<td>(0.008)</td>
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<tr>
<td>Standard deviations</td>
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<td></td>
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<tr>
<td>r0 (common value comp.)</td>
<td>6.20</td>
<td>5.11</td>
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<tr>
<td></td>
<td>(0.002)</td>
<td>(0.024)</td>
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<tr>
<td>t (private value comp.)</td>
<td>2.73</td>
<td>2.82</td>
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<tr>
<td></td>
<td>(0.002)</td>
<td>(0.013)</td>
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<tr>
<td>s (unobserved error)</td>
<td>4.28</td>
<td>0.53</td>
</tr>
<tr>
<td></td>
<td>(0.002)</td>
<td>(0.001)</td>
</tr>
<tr>
<td># obs</td>
<td>5614</td>
<td>5614</td>
</tr>
</tbody>
</table>

**Note:**

\(^a\) Bootstrapped standard errors in brackets, computed from empirical distribution of parameter estimates from 100 parametric bootstrap resamples

\(^b\) Not separately identified from $\bar{a}$
Mean Valuation Comparison

**Figure**: Mean Valuation - Signaling Model vs. Open Exit Model
## Counterfactual Analysis

<table>
<thead>
<tr>
<th></th>
<th>“Jump bid” auctions</th>
<th>All auctions</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean log actual prices ($)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Highest/winning bid</td>
<td>15.95</td>
<td></td>
</tr>
<tr>
<td><strong>Second highest bid</strong></td>
<td><strong>15.90</strong></td>
<td></td>
</tr>
<tr>
<td>Mean log predicted price ($)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Multi-round signaling</td>
<td><strong>16.58</strong></td>
<td></td>
</tr>
<tr>
<td>Single-round signaling</td>
<td>16.90</td>
<td></td>
</tr>
<tr>
<td>Open exit auction (no signaling)</td>
<td>17.18</td>
<td></td>
</tr>
<tr>
<td>Predicted total revenues ($bn)</td>
<td>% Δ</td>
<td>% Δ</td>
</tr>
<tr>
<td>Multi-round signaling</td>
<td>17</td>
<td>170</td>
</tr>
<tr>
<td>Single-round signaling</td>
<td>23 33%</td>
<td>176 3%</td>
</tr>
<tr>
<td>Open exit auction (no signaling)</td>
<td>31 76%</td>
<td>183 8%</td>
</tr>
<tr>
<td># auctions</td>
<td>81</td>
<td>491</td>
</tr>
</tbody>
</table>
Conclusions

▶ With strict affiliation, jump bidding can be rationalized using a signaling model.

▶ Using data from spectrum auctions, the signaling model implies a higher mean valuation compared to the open exit model.

▶ By prohibiting jump bidding, the government could have had 8% higher revenues from the C block spectrum license auction.
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