Jump Bidding as a Signaling Game

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What is Jump Bidding?

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- 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
  - Transaction costs Fishman (1988) Daniel and Hirshleifer (1997), Isaac et al. (2007), Kwasnica and Katok (2009)
  - Information Avery (1998), Easley and Tenorio (2004), Ettinger and Michelucci (2015)
  - 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

Literature Review and Contribution (Cont'd)

- 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

Strict Affiliation

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

- *Ex ante* cost of jump bidding =
  Probability of winning at \$50 × (\$100-\$50)

- The probability of winning at \$50, thus the *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

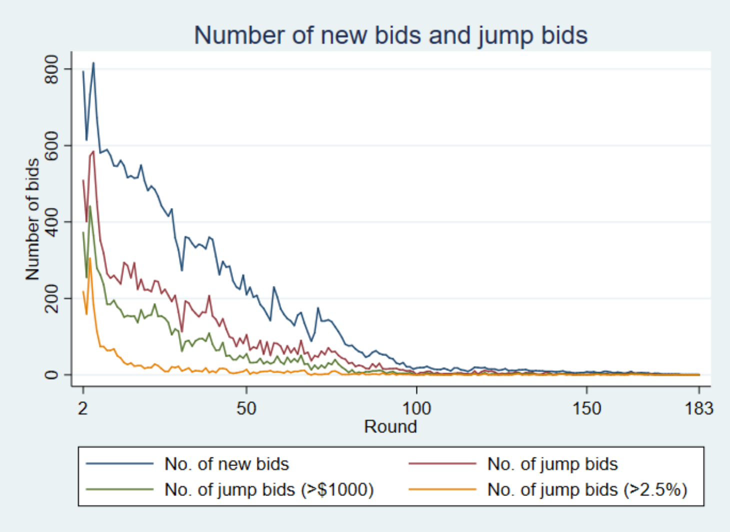
For any symmetric equilibrium with multi-round signaling, the following holds:

- 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

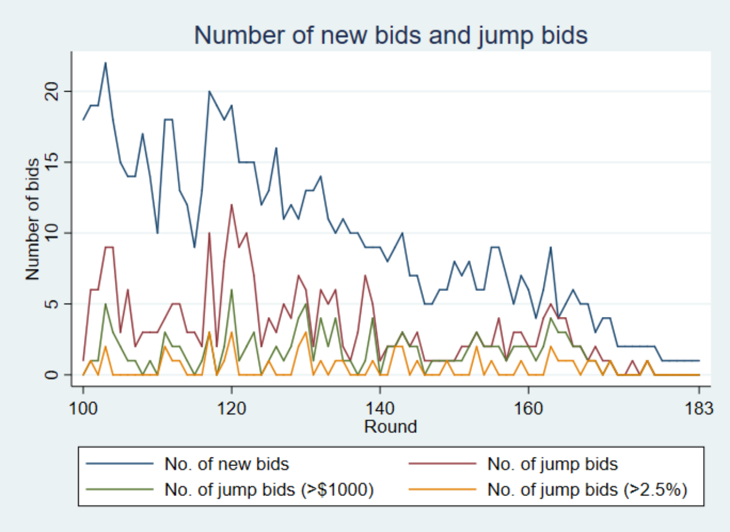
Data

- 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



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 ξ_i is an unobserved error term with a standard normal distribution, and s_i is a parameter

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

Simulated Nonlinear Least-Squares Estimation

- The objective function is

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

  where

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

- p_i^t: observed log dropout bid for bidder i in auction t
- $\tilde{m}_i^t(\theta)$: simulated estimator of the model predicted log dropout bid for bidder i in auction t

Simulated Nonlinear Least-Squares Estimation

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

where

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

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

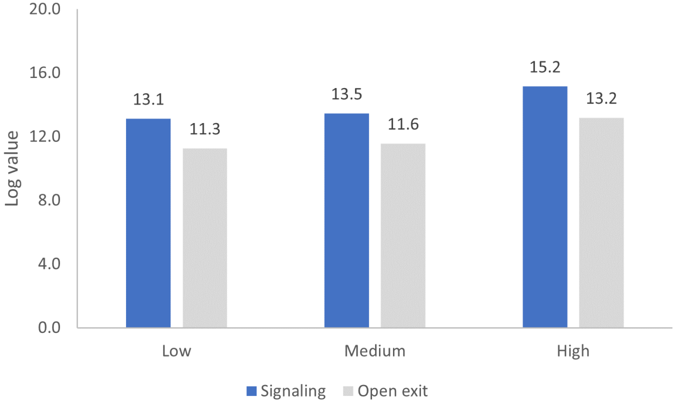
SNLS Estimation Results

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

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

	"Jump bid" auctions		All auctions	
Mean log actual prices ($)				
Highest/winning bid	15.95			
Second highest bid	**15.90**			
Mean log predicted price ($)				
Multi-round signaling	**16.58**			
Single-round signaling	16.90			
Open exit auction (no signaling)	17.18			
Predicted total revenues ($bn)		% Δ		% Δ
Multi-round signaling	17		170	
Single-round signaling	23	33%	176	3%
Open exit auction (no signaling)	31	76%	183	8%
# auctions	81		491	

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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