Contract, Commitment, Auction in Petroleum Industry

Mohammad H. Rahmati

Sharif University Of Technology

September 19, 2018

Table of Content

Hendricks, Pinkse, Porter. “Empirical Implications of Equilibrium Bidding in First-Price, Symmetric, Common Value Auction” REStud,2003

Introduction and Literature

- Do bidders in auction markets behave as predicted by game theoretic models?
- In common values, whether bidders account for winner's curse (bidders may bid less aggressively against more rivals)
- Winning is bad, it reveals that winning bidder's signal was more optimistic than that of the other bidders
- Same may true in affiliated private value (APV) models.
- If an ex post measure of value is available
- $\Rightarrow$ alternatively compare bid levels to value measure
- Hendricks, Porter (1988): ex post values + asymmetric information + drainage tract (adjacent to tracts with oil)
- "neighbour"' firms: superior information
- asymmetric information, first-price, common value auctions: non-neighbour participate, but their number is irrelevant to

Contribution and Question

- Study bidding in first-price, sealed bid auctions with symmetric information using wildcat tract data.
- Wells drilled in search of new deposits of oil and gas are called wildcat wells, not drilled area
- Firms can seismic, no permit for exploratory drill wells.
- Firms are more or less equally informed
- Question: is bidding in wildcat auctions consistent with equilibrium behaviour?
- Method based on Laffont and Vuong (1996)
- Bidder's valuation as a function of its bid and the distribution of the maximum rival bid

Method Introduction

- In private value environments, this valuation is the firm's expected value of the object conditional on its signal
- First-order conditions used to nonparametrically identify joint distribution of bidder valuations + firm's bid function.
- In common value environments, the first-order condition identifies the firm's expected value of the object conditional on its signal being equal to the maximum signal of its rivals.
- Because this valuation depends on rivals' signals, it cannot be used to identify the firm's signal, and hence its bid function or the underlying distributions of signals.
- However, conditional expectation can be estimated if bids and ex post value are available.
- Thus, instead of inferring this value from the first-order condition, it is possible to test the condition directly.

Standard Models of Bidding

- Number of bidders as fixed
- Outer Continental Shelf (OCS) auctions, number of firms with seismic surveys
- If a binding reserve price, not all participants bid
- So, all bidders are not measure of number
- Potential bidders: seismic survey covering some tracts in area and bid on at least one tract
- Symmetric common value environment
- On the less competitive tracts, overbidding due to firms overestimating tract values
- A model in which firms ignore the information from winning is rejected by the data.

Standard Models of Bidding

- Affiliated private values model is an alternative
- Laffont and Vuong (1996): bidding data alone are insufficient to distinguish nonparametrically between them
- One approach for distinguishing: exogenous variation in the number of bidders
- First-order condition is
  - independent of number of potential bidders under private values
  - stochastically increasing under common values
- Haile, Hong and Shum (2002) provide a test based on this approach
- Impossible to use in OCS because of heterogeneity
- This paper use data on ex post values to test
- Result: OCS more consistent with common value

Literature on Structural Estimation of Auction

- Smiley (1979), Paarsch (1992) and Donald and Paarsch (1993), parametric approach, closed form solution for bid function, maximum likelihood methods
- Laffont, Ossard and Vuong (1995), simulated nonlinear least squares estimator, symmetric independent private values.
- Elyamime, Laffont, Loisel and Vuong (1994), IPV, nonparametric estimation, estimating inverse bid function
- Li et al. (2000) extend nonparametric method to conditionally independent private values (CIPV)
- Li, Perrigne Vuong (2002) extend to affiliated private values
- Bajari (1998),Bayesian likelihood, IPV, asymmetric bidders
- Hong and Shum (1999) and Bajari and Hortacsu (2002) estimate structural models of common value (CV)

Seismic and Data Acquiring

- A tract is a block of 5000 or 5760 acres, or half a block.
- Each sale over 100 tracts, over several different areas.
- Prior to sale, can seismic, not exploratory wells
- A geophysical company "shoot" a seismic survey of a large, roughly 50 block area.
- Cost:$12 million, shared by several oil companies.
- Participating firms do not know identities of partners
- The survey company keeps names secret
- Interpretation of seismic data varies across firms
- Different firms focus on different sets of tracts
- Next shoot "infill" or "crossdiagonal" on selected tracks (cost$1 million)
- Each firm typically submits bids on 80% of the tracts that it has scrutinized more closely

Data Acquiring and Bidding

- Prior to 1975, all firms were allowed to bid jointly.
- In late 1975, DOI adopted regulations barring the eight largest crude oil producers worldwide (Exxon, Gulf, Mobil, Shell, Standard Oil of California, Standard Oil of Indiana, Texaco and British Petroleum) from bidding with each other
- It is difficult for firms to keep their interest in an area secret from their rivals.
- But the firms do not know which rivals are bidding on which tracts.
- Firms often expend resources surveying tracts that have been rejected in order to disguise the location of the tracts that they think are worth pursuing.

Lease Environment

- First-price, sealed bid auction
- Reserve price $15 per acre
- DOI opens envelopes, announces bids+identities
- Government could reject bids (10% of times, usually when only one bid)
- After winning, 5 years to explore otherwise ownership reverts to government
- Fee $3 per acre, each year until either relinquishment or production begins
- If discovery, lease is automatically renewed as long as production
- Royalty rate 1/6

Model

- Potential bidder if commissioned a survey of area containing tract t
- l: number of potential bidders on tract t
- Active bidder if invests in a tract specific survey
- Decision: whether and how much to bid
- Not favorable: not worth reserve price r
- Let V denote unknown deposit on tract t
- Bidder i's private information on tract t from the area-wide survey is denoted by Z_i
- From tract-specific survey S_i drawn from a distribution with support $[\underline{s}, \overline{s}]$
- Assumption 1. $(V, Z_1, \cdots, Z_l, S_1, \cdots, S_l)$ are affiliated and exchangeable with respect to the bidder indices.

Model

- F : cdf of $(V, Z_1, \cdots, Z_l, S_1, \cdots, S_l)$, f pdf
- expected returns of i from active increasing in V
- Affiliation implies returns are nondecreasing in Z_i
- Number of active N nondecreasing $(Z_1, \cdots, Z_l)$
- z^* common signal
- Probability $N = n$ from F by computing joint probability $Z_i > z^*$ for n bidders and $Z_i < z^*$ for other $l - n$ bidders
- If $n < l$, then the distribution function of $(V, S_1, \cdots, S_n)$ is derived from F by conditioning on the event $N = n$, and setting $S_{n+j} = s$ for $j = 1, \cdots, l - n$
- Number of rivals of an active bidder i is denoted by $K = N - 1$, and K is affiliated with tract-specific signals of active bidders.

Model

- Our model endogenizes the number of active bidders but at the expense of giving each of them two signals
- Most theoretical and all empirical work in auctions assumes that each bidder's information is one-dimensional
- To reduce dimensionality, area-wide signals irrelevant to its bidding decision
- Assumption 2.
  1. V and Z_i are independent conditional on S_i , and
  2. (S_i, Z_i) are independent (across i) conditional on V
- Condition 1: Z_i uninformative for V conditional upon S_i
- Still may Z_i help to predict Z_{-i} and K
- Next lemma proof with condition 2 it is irrelevant

Model

- Lemma 1. Suppose Assumption 2 holds. Then (i) (V, Z_{-i}, S_{-i}) is independent of Z_i conditional on S_i and (ii) (V, K, S_{-i}) is independent of Z_i conditional on S_i
- Equilibrium a purification of a (symmetric) mixed strategy equilibrium, potential bidders randomize their participation decisions on individual tracts
- $\Rightarrow N$ is independent of $V \sim$ binomial distribution
- Value of tract: $U_i = u(V, S_i)$
- l, F, u are common knowledge
- i knows S_i and Z_i
- Decision to be active is not observable.

Model

- AV model, with stochastic number of bidders
- Two special cases will be of interest
  - CV when $U_i = V$
  - APV when $U_i = S_i$
- Define prob. 1 faces k active rivals, given s

$$p_k(s) = Pr(N = k + 1 | S_1 = s, N \geq 1)$$

- Let $p(s) = (p_0(s), \cdots, p_k(s), \cdots, p_{l-1}(s))$
- Define Y_1 as the maximum signal among bidder 1's rivals conditional on the event that bidder 1 has at least one active rival, and s when bidder 1 has no rivals

Model

- $H_{Y_1|S_1}(.|s)$: cdf of Y_1 when bidder 1 obtained signal s with at least one rival bidder (pdf: $h_{Y_1|S_1}(.|s)$

$$H_{Y_1|S_1}(y|s) = \sum_{k=1}^{l-1} \frac{p_k(s)}{1 - p_0(s)} F_{Y_1|S_1,N}(y|S_1 = s, N = k + 1)$$

- Probability weights have been normalized to sum to 1 by conditioning on the event that bidder 1 has at least one active rival

$$\omega(s, y) = E[u(V, s)|S_1 = s, Y_1 = y, N \geq 2]$$

- Bidder 1 utility when no active rivals

$$\omega(s) = E[u(V, s)|S_1 = s, N = 1]$$

Model

- Lemma 2.
  - i $p(s)$ first-order stochastically dominates $p(s_0)$ for $s > s_0$
  - ii $\frac{H_{Y_1|S_1}(y|s)}{h_{Y_1|S_1}(y|s)}$ is decreasing in s
  - iii $\omega(s)$ and $\omega(s,y)$ are increasing functions.
- Rival monotone increasing bidding strategy $\beta(s)$ with inverse $\eta(b)$
- Risk neutrality
- Bidder 1's optimization choosing $b \geq r$ to max

$$\Pi(b,s) = (1-p_0(s)) \int_{\underline{s}}^{\eta(b)} (\omega(s,y)-b) h_{Y_1|S_1}(y|s) dy + p_0(s)(\omega(s)-b)$$

Model

- First order condition

$$(1-p_0(s))[(\omega(s,\eta(b))-b)h_{Y_1|S_1}(\eta(b)|s)\eta'(b)-H_{Y_1|S_1}(\eta(b)|s)] = p_0(s$$

- If bidder 1's best reply is $b = \beta(s)$, put in f.o.c

$$(1-p_0(s))\left[(\omega(s,s)-\beta(s))\frac{h_{Y_1|S_1}(s|s)}{\beta'(s)} - H_{Y_1|S_1}(s|s)\right] = p_0(s)$$

- Active bidders who obtain very low signals from their seismic surveys are unlikely to bid.

$$s^*(r) = inf\{s : (1-p_0(s))E[\omega(s,Y_1)|S_1 = s, Y_1 < s]+p_0(s)\omega(s) \geq r$$

Model

- If bidder believes value conditional on winning worth reserve price: assume $s^*(r)$ exists and $> \underline{s}$
- Hence, reserve price is binding, $\beta(s^*) = r, \beta(s) = 0 for s < s^*$
- For empirical purposes, invert equilibrium, express signal as bid
- M_1 highest bid by bidder 1's rivals or the reserve price
- Latter: 1)no rival 2) rival bid reserve $(s < s^*)$: indistinguishable empirically

Model

- Conditional distribution of M_1 given B_1(bid of firm in question)

$$G_{M_1|B_1}(m|b) = [1 - p_0(\eta(b))]H_{Y_1|S_1}(\eta(m)|\eta(b)) + p_0(\eta(b))$$

- First term: prob. that highest bid among bidder 1's rivals is less than m conditional upon bidder 1's bid of b and event of at least one rival
- Second term: prob. that bidder 1 has no rival
- Note: $\{M = r\}$ positive probability
- $\Rightarrow r$ is a point of discontinuity for $G_{M_1|B_1}$
- But continuous and differentiable on (r, ∞)

$$g_{M_1|B_1}(m|b) = \frac{(1 - p_0(\eta(b)))h_{Y_1|S_1}(\eta(m)|\eta(b))}{\beta'(\eta(m))}$$

Model

- Substitute this into f.o.c

$$\omega(\eta(b)|\eta(b)) = b + \frac{G_{M_1|B_1}(b|b)}{b_{M_1|B_1}(b|b)} \equiv \xi(b, G)$$

- Vuong use it for nonparametric estimators F, β in PV
- PV $\omega(s,s) = s$, then ξ interpreted inverse bid function
- It is not possible to identify F or β in CV environments
- This paper is a test of bid behavior
- Lemma 2: $\omega(s,s)$ inc. in s $\Rightarrow \xi(b, G)$ must be monotone increasing in b
- If not, then data is not a symmetric Bayesian Nash equilibrium in monotone increasing bid functions
- A joint test of affiliation, symmetry and equilibrium.

Model

- Second test with assumption $u(V, S_i) = V$
- Then, $\omega(s,s) = E[V|S_1 = s, Y_1 = s, N \geq 2]$
- Define $\zeta(b) = E[V|B_1 = b, M_1 = b, N \geq 2]$
- ζ can be estimated if you have b , V
- From monotonicity in $\beta \Rightarrow \zeta(b) = \omega(\eta(b), \eta(b))$
- At $b = r$

$$\begin{aligned}\zeta(r) &= (1 - p_0(s^*))E[V|S_1 = s^*, Y_1 < s^*, N \geq 2] \\ &\quad + p_0(s^*)E[V|S_1 = s^*, N = 1] = r < \omega(s^*, s^*)\end{aligned}$$

- ζ downward discontinuity at r due to the possibility of no rival bid
- $b > r$, if symmetric Bayesian Nash equilibrium$\Rightarrow \zeta(b) = \xi(b, G)$
- testable implication of equilibrium bidding in CV

Model

- Test myopic bidding model
- Bid when $\omega(s)$ replaces $\omega(s, y)$
- In choosing its bid, each firm's beliefs about the probability of winning are consistent with true probability law but its beliefs about value of the tract conditional on winning are not
- In particular, its expectations are based solely on its own signal, and it ignores "bad news" associated with winning.
- derive f.o.c and same transformation $\omega(\eta(b)) = \xi(b, G)$
- Define $\gamma(b) = E[V|B_1 = b, N \geq 1]$ (estimated by b,V)
- Monotonicity implies $\gamma(b) = \omega(\eta(b))$
- myopic bidding test $\gamma(b) = \xi(b, G)$

Data

- Variables of interest:
  - V_t : value of oil and gas deposit
  - B_{it}: bid of bidder i on tract t
  - M_{it}: maximum bid of bidder i's rivals on tract t
  - l_t: number of potential bidders on tract t
- Sales of wildcat tracts off coasts of Texas and Louisiana (1954-1970)
- data: date of sale; acreage; location; identity of all bidders, bid amount; bid results; number, date, and depth of any wells drilled; monthly production
- V_t discounted (5%) revenues less drilling costs + royalty
- Costs: well data + American Petroleum Institute estimates
- Constant future prices of oil as date sale. (plausable in 1954-1970)

Data

- Data errors:
  - suvey costs of winners (no cost data of those not drilled!!)
  - production data is truncated in 1991 (may produce further, but discount is small)
- Should all bids on a tract be included?
  - Theory, potential bidders on a tract are symmetric
  - Hundreds of firms bid infrequently (uninfomred, not serious)
  - Treat these firms as “noise” bidders
  - Focus on 12 firms (rational bidding)

12 Firms and Consortia with Most Bids

- Fringe firms with "Big 12" define a joint bid
- 12 large firms account for about 80% of all bids
- Paper only consider Big 12
- In defining M_{it} include fringe bidders

Firms and consortia	Number of solo bids	Number of joint bids	Potential bidder	Participation rate
Arco/Getty/Cities/Cont.	437	114	1027	0·54
Standard Oil of California	408	76	1022	0·47
Standard Oil of Indiana	132	276	905	0·45
Shell Oil	444	3	981	0·46
Gulf Oil	201	81	801	0·35
Exxon	325	42	812	0·45
Texaco	114	178	823	0·35
Mobil	48	163	700	0·30
Union Oil of California	95	201	805	0·37
Phillips	98	65	498	0·33
Sun Oil	241	93	723	0·46
Forest	195	0	493	0·40

Data

- Number of potential bidders: number of Big 12 firms that bid on the tract or in its neighbourhood
- If interested then bid on one of them
- What about joint bids?
- Firms that did not bid on tract t and submitted only joint bids with each other on tracts in the neighbourhood of tract t are also counted as single competitors.
- May overstate number of potential bidders: they could coordinate to solo bid on neighbourhood instead of bid jointly on all of them.
- Third column: number of tracts as a potential bidder
- Participation rate on tracts (if potential bidder) evaluate validity of symmetry assumption

Sample Statistics

- 50% of tracts only one bid
- Big 12 firms bid on over 80% of tracts
- Government rejected the high bid on 7% of tracts
- Fraction drilled and hits about 75% and 50%
- Revenue include dry tracks

Sale date	#Tracts offered	#Tracts bid	#Tracts Big 12 bid	#Tracts sold	#Tracts drilled	#Hits	Mean Rev	Mean NetRev	Mean hibid
54-10-13	199	90	77	90	65	45	44·00	6·99	4·49
54-11-09	38	19	17	19	10	4	13·38	0·46	4·27
55-07-12	210	117	92	117	64	27	30·62	2·23	3·14
60-02-24	385	173	141	147	117	61	89·25	21·61	4·97
62-03-13	401	211	169	206	165	79	56·57	11·17	2·47
62-03-16	410	210	169	205	169	79	52·59	9·69	3·75
67-06-13	206	172	142	158	130	53	67·09	10·55	7·80
68-05-21	169	141	110	110	71	16	12·21	−0·87	10·72
70-12-15	127	127	57	119	112	64	68·76	19·60	15·18
Total	2145	1260	974	1171	903	428	58·60	10·48	6·19

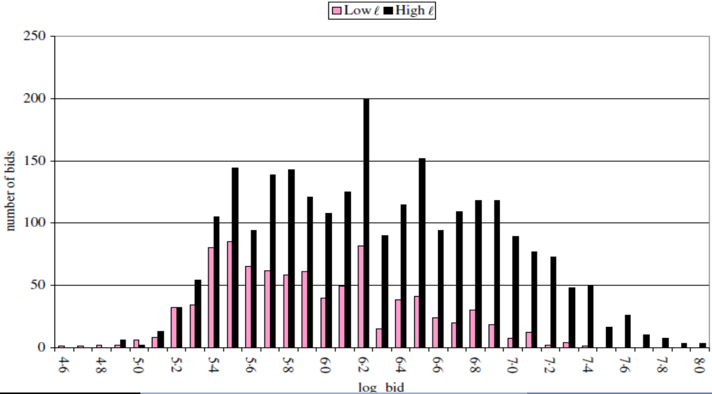
Sample Statistics

- Number of bids positively correlated with number of potential bidders
- On average one fringe bid, so excluding fringe firms is probably not introducing too much error in our measure of competition.

	Number of potential bidders (ℓ)													
	0	1	2	3	4	5	6	7	8	9	10	11	12	Total
# of tracts	7	45	74	115	72	94	101	138	164	189	160	85	16	1260
Bids/tract (All)	1·00	1·13	1·55	1·99	2·17	2·84	2·80	3·94	3·65	5·12	5·11	5·36	4·25	3·62
Bids/tract (12)	0·00	0·91	1·24	1·53	1·64	2·33	2·32	3·01	2·65	3·77	3·51	3·66	2·94	2·67
Tract hibid	0·60	1·32	2·21	2·63	2·78	4·01	2·94	6·79	5·70	9·26	11·5	8·59	13·1	6·19
	(0·38)	(1·72)	(3·82)	(4·38)	(4·08)	(6·63)	(3·62)	(11·3)	(9·36)	(13·5)	(18·7)	(12·5)	(22·6)	(11·6)
%Tract drilled	66·7	62·2	54·9	71·8	73·9	79·3	73·2	81·4	79·6	82·3	80·0	84·2	100·0	77·1
% Hits	25·0	39·1	38·5	45·6	41·7	50·8	50·7	47·6	41·3	47·7	54·2	54·7	46·7	47·4
Tract	3·60	84·8	28·0	66·1	60·2	38·2	45·2	76·8	43·8	61·1	71·5	55·8	62·6	58·6
revenue	(0·0)	(80·3)	(41·4)	(101)	(89·4)	(67·4)	(81·7)	(102)	(73·4)	(97·5)	(102)	(66·6)	(89·2)	(89·7)
Tract	−1·30	10·91	2·45	11·3	10·9	5·97	7·53	15·4	6·02	11·7	15·5	12·5	15·4	10·5
NetRev	(1·31)	(33·4)	(15·7)	(41·8)	(39·1)	(29·5)	(36·2)	(49·3)	(31·3)	(49·0)	(49·8)	(34·8)	(42·2)	(40·9)

Sample Statistics

- Stratification by number of potential bidders: high and low($l \leq 6$)
- Competitive: 752 tracts, less competitive: 501 tracts



Sample Statistics

- The classification of tracts into highly competitive and less competitive sets accounts for some tract heterogeneity

	Hibid	Drill rate	Hit rate	NetRev
Low ℓ	\$2·76	70·3	45·6	8·00
High ℓ	\$8·51	81·7	48·4	12·12

- High l tracts are more productive than low l‘ tracts.

Test Bidder Rationality

- Essentially comparisons of bids and ex post outcomes, rent should be positive
- ω_t winning bid
- ν_t our estimate of realization of V on tract t
- Average value of rents for a sample of tracts of size T

$$R = T^{-1} \sum_{t=1}^{T} [\nu_t - \omega_t]$$

Test Bidder Rationality

- Second test: positive rents conditional on winning
- Z_{0t} characteristics of tract t (observable to active bidders), includes l_t (revealed when invest in tract-specific surveys)
- $\hat{\omega_{it}}$ bidder i's valuation conditional winning with b_{it}
- Obtained by estimating $E[V_t|B_{it} = b, M_{it} < b, N_t \geq 1, Z_{0t} = z_0]$
- Then evaluating this function at $b = b_{it}$
- Difference between $\hat{\omega_{it}}$ and b_{it}: expected profit margin conditional on winning tract t
- n_t^* number of bids on tract t
- Average profit margin for a sample of tracts of size T:

$$D = T^{-1} \sum_{t=1}^{T} \sum_{i=1}^{n_t^*} {n_t^*}^{-1} [\hat{\omega_{it}} - b_{it}]$$

Local non-parametric linear regression, one regressor

- Conditional expectation function $E[V_t|B_{it} = b, N_t \geq 1]$ by

$$\{\hat{\nu}(b), \hat{r}_\nu(b)\} = argmin_{\nu,r} \sum_{t=1}^{T} \frac{1}{n_t^*} \sum_{i=1}^{n_t^*} \{V_t - \nu - r(b - B_{it})\}^2 k \left(\frac{b - B_{it}}{h} \right.$$

- T number of tracts in the sample
- h bandwidth, k kernel
- Conditional expectation $E[V_t|B_{it} = b, M_{it} < b, N_t \geq 1]$ is estimated

$$\{\hat{\nu}(b), \hat{r}_\nu(b)\} = argmin_{\nu,r} \sum_{t=1}^{T} \{V_t - \nu - r(b - W_t)\}^2 k \left(\frac{b - W_t}{h} \right)$$

- W_t winning bids

Test Bidder Rationality

- Comparison of rents and bidder profit margins across low and high l.
- "winner's curse": comparison should be substantially lower on high l tracts

	R	D
Low ℓ	\$3·75 (1·73)	\$3·76 (1·54)
High ℓ	\$3·65 (2·89)	\$3·56 (1·30)

- Standard deviations in parentheses by bootstrap
- Average rents and margins are same on each set of tracts, and not vary significantly with level of competition
- Thus, no adverse selection associated with winning, which is consistent with bidders anticipating the "winner's curse"

Test Bidder Rationality

- Assumption: entry zero (expected) profit ⇒ expected rent ≈ entry costs
- Entry costs: seismic + hiring engineers
- Did bidders bid less than their expected tract value?

$$E[V_t|B_{it} = b, N_t \geq 1, Z_{0t} = z_0] > b \qquad Test(T1)$$

- Rational bidders in a CV environment anticipate "bad news" associated with winning.
- At every bid level, bid < value conditional on winning

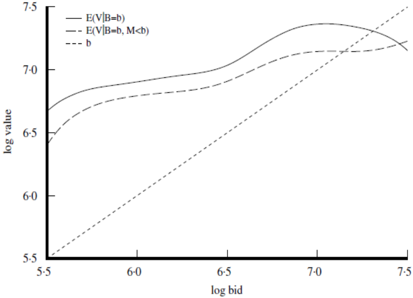
$$E[V_t|B_{it} = b, M_{it} < b, N_t \geq 1, Z_{0t} = z_0] > b \qquad Test(T2)$$

- Measure of the "winners curse"

$$\kappa(b) = E[V_t|B_{it} = b, N_t \geq 1, Z_{0t} = z_0] - E[V_t|B_{it} = b, M_{it} < b, N_t \geq 1, Z_{0t} = z_0]$$

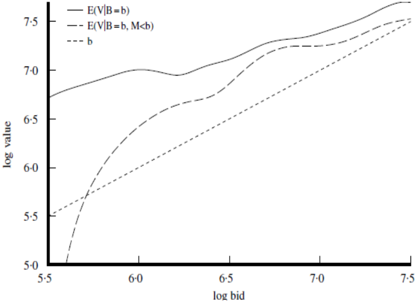
Test Bidder Rationality-Low l

- Key characteristic: number of potential bidders
- In a symmetric CV environment, the winner's curse measure greater, more competition, as winning is worse news the larger the number of potential bidders
- Bids satisfy rationality tests (T1, T2) for low l tracks



Test Bidder Rationality-High l

- "winner's curse" larger for the high l tracts
- "winner's curse" is present and increases weakly with bid



- Average winner's curse: \$273 m. on low l, \$613 m. on high l
- Winner's curse is 107% of winning bid on low l, and 75% on high l

Test of Equilibrium Bidding

- Introduce test for

$$\xi(b, G(b; z_0)) = b + \frac{G_{M_{it}|B_{it},Z_{0t}}(b|b, z_0)}{g_{M_{it}|B_{it},Z_{0t}}(b|b, z_0)}$$

- Define $\zeta(b, z_0), \gamma(b, z_0)$ by conditioning V on tract characteristics
- Test for:
  1. $\xi(b, G(b; z0))$ is strictly increasing in b
  2. $\zeta(b, z_0) = \xi(b, G(b; z_0))$
  3. $\gamma(b, z_0) = \xi(b, G(b; z_0))$
- If bidding is consistent with Bayesian Nash equilibrium, we should fail to reject (1) and (2) and reject (3)
- Key tract characteristic l

Test of Equilibrium Bidding

- ζ are computed from a bivariate locally linear regression
- Remember $\zeta(b) = E[V|B_1 = b, M_1 = b, N \geq 2]$
- Estimate from pair $B_{it}, M_{it}$and tract values V_t by

$$l\{\hat{\nu}(b,m), \hat{r_1}(b,m), \hat{r_2}(b,m)\} = argmin_{\nu,r_1,r_2} \sum_{t=1}^{T} \frac{1}{n_t^*} \sum_{i=1}^{n_t^*}$$

$$\{V_t - \nu - r_1(b - B_{it}) - r_2(m - M_{it})\}^2 \kappa\left(\frac{b - B_{it}}{h_b}\right) \kappa\left(\frac{m - M_{it}}{h_m}\right)$$

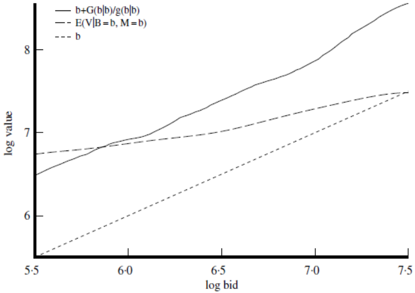
Test of Equilibrium Bidding

- Estimates for ξ obtained from an estimate of the distribution $G_{M_{it}|B_{it},Z_{0t}}$

$$\frac{G_{M_{it}|B_{it}}(b|b))}{g_{M_{it}|B_{it}}(b|b))} = \frac{h_m \sum_{t=1}^{T} \frac{1}{n_t^*} \sum_{i=1}^{n_t^*} \kappa([b - B_{it}]/h_b) I(M_{it} < b)}{\sum_{t=1}^{T} \frac{1}{n_t^*} \sum_{i=1}^{n_t^*} \kappa([b - B_{it}]/h_b) \kappa([m - M_{it}]/h_m)}$$

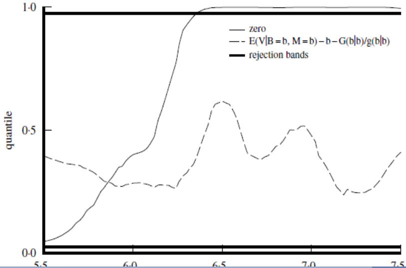
Test of Equilibrium Bidding for Low l tracts

- Estimates of $\hat{\xi}, \hat{\zeta}$
- $\forall$ b, vertical difference between $\hat{\xi}$ and 45 line=amount bidders mark down bid from conditional expectation of value
- Difference should be positive
- $\hat{\xi}$ is strictly increasing $\Rightarrow$ passes first test



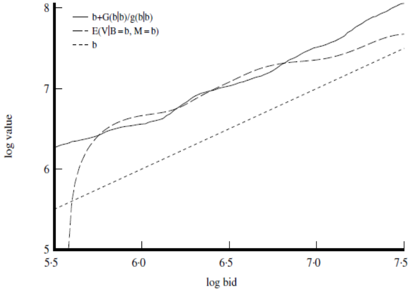
Test of Equilibrium Bidding for Low l tracts

- Formal test of equality of $\hat{\zeta}$ and ξ is needed
- Requires asymptotic distribution of $\hat{\zeta} - \hat{\xi}$
- Bootstrapped confidence bands of nonparametric regression
- The solid curve labeled "zero" gives the probability that the test statistic $\hat{\zeta} - \hat{\xi}$ takes values less than zero
- At higher bid levels, probability that difference is negative is very close to one, which represents a clear rejection of theory.



Test of Equilibrium Bidding for High l tracts

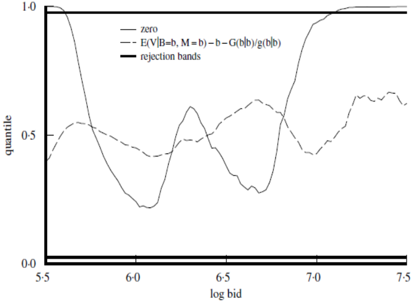
- $\hat{\xi}$ is strictly increasing $\Rightarrow$ Bayesian Nash equilibrium behavior is not rejected



- $\hat{\zeta} - \hat{\xi}$ is close to zero at most bid levels

Test of Equilibrium Bidding for High l tracts

- Hypothesis of equilibrium bidding is not rejected in the middle of the support of the bid distribution



- Test $\gamma = \zeta$ exactly same way
- At conventional confidence levels, the myopic model of bidding was rejected for both low l and high l

Bid Function

- Estimate β for high l and low l tracts
- Examine: bid less aggressively on tracts with more bidders.
- Moment restriction on the joint distribution of (S_{it}, V_t)
- Assume

$$E[V_t|S_{it} = s, Z_{0t} = z_0, N_t \geq 1] = s \quad (R)$$

- Expected value of tract is equal to value of signal

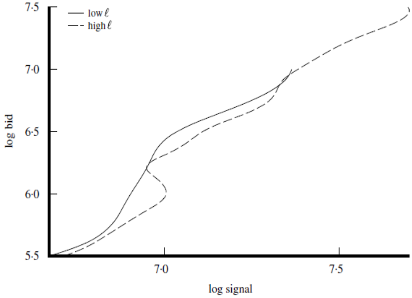
$$\begin{aligned} s &= E[V_t|S_{it} = s, Z_{0t} = z_0, N_t \geq 1] \\ & E[V_t|B_{it} = \beta(s, z_0), Z_{0t} = z_0, N_t \geq 1] \\ \Rightarrow & \quad \eta(b, z_0) = E[V_t|B_{it} = b, Z_{0t} = z_0, N_t \geq 1] \end{aligned}$$

Estimation of Bid Function

- For every bid level b on a tract with characteristics z_0, define a neighbourhood (in the space of bids, not locations) $B(z_0)$ of b
- Compute the average ex post value of all tracts with characteristics z that received a bid in $B(z_0)$
- How to implement this idea: kernel estimator of the mean ex post value in the neighbourhood of any bid b for tracts with similar characteristics

Bid Function Results

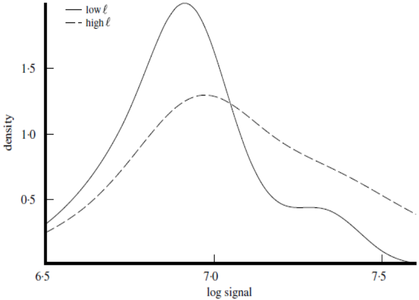
- Bid function:



- Firms bid somewhat less aggressively on high l tracts than low l tracts for a given signal

Bid Function Results

- Density of private signals for high and low l tracts:



- Distribution of signals on high l tracts stochastically dominates (in the first-order sense) distribution of signals on low l tracts.

Common Value Assumption

- Do data suggest that the common component is a quantitatively more significant factor in the bidder valuations than the private component?
- Standard approach to exploit exogenous variation in the number of bidders
- $\hat{G}(.|l)$ estimate of $G_{M|B,Z_0}$ for l potential bidders

$$\hat{\sigma}_{it} = \hat{\xi}(b_{it}, \hat{G}(b_{it}|l_t))$$

  - if PV: this is an estimate of bidder i's valuation of tract t
  - if CV: it is an estimate of $\omega(\eta(b_{it}), \eta(b_{it}))$
- So, the empirical distribution of pseudo-values should be invariant to l if values are private, and it should be stochastically increasing in l if the common component is important

Common Value Assumption

- Difficulty: unobserved tract heterogeneity. How?
- Consider model of entry: number of potential bidders increase with tract value
- Empirically V_t is stochastically increasing in l
- Notice, second highest bid 56% of highest bid
- If CV: difference from private signal
- If PV: differences because of differences in bidder specific components of valuations (ex. private exploration costs)
- If APV: valuations are best modeled as private, although they may be affiliated because of common unknown components of payoffs that may be correlated with publicly available information.
- In oil and gas private variation of cost is negligible compared to deposit values.

Common Value Assumption- Alternative Way of Testing

- Compute rents, profit margins under PV
- Winning bid is ω_t
- Estimated private valuation of winning $\hat{\sigma}_{1:t} = \hat{\xi}(\omega_t, \hat{G}(\omega_t|l_t))$
- Rents under PV:

$$\tilde{R} = T^{-1} \sum_{t=1}^{T} [\hat{\sigma}_{1:t} - \omega_t]$$

- Profit margin:

$$\tilde{D} = T^{-1} \sum_{t=1}^{T} \sum_{i=1}^{n_t^*} {n_t^*}^{-1} [\hat{\sigma}_{1:t} - b]$$

	$\tilde{R}$	$\tilde{D}$
Low ℓ	\$19·0 (2·62)	\$14·65 (1·67)
High ℓ	\$22·9 (2·50)	\$14·43 (1·30)

Common Value Assumption- Alternative Way of Testing

- Private value rents are of the order of $20 million
- Implausibly larger than entry costs (100 thousand $)
- Bidders marked down their bids independently of the number of potential bidders and by slightly more than $14 million
- Firms bid $\approx 1/9$ of V on low l tracts, $1/3$ on high l
- Bidding in the OCS auctions is not very competitive, and that participants enjoyed very high returns
- The evidence suggests otherwise
- $\Rightarrow$ bidding environment for oil and gas auctions is pure CV or CV is more important

Introduction

- Slides by Porter, Recent Developments in the Empirical Analysis of Auction Markets 2007
- Auctions have been the subject of a lot of good theory and good empirical work.
  - Game is relatively simple, with well-specified rules.
  - Actions are observed directly.
  - Payoffs can sometimes be inferred.
  - Data sets are readily available.
- Why use an auction, instead of posting or negotiating a price¿
  - Buyers willingness to pay is private information; auctions can be efficient price discovery process.
  - Identity of highest value buyer is unknown; an auction can be an efficient allocation mechanism.
  - Auctions can also be good at generating revenue.
- Information asymmetries are fundamental.

Introduction

- There are many possible auction mechanisms.
  - open outcry vs. sealed bid
  - highest bid vs. second-highest bid
  - reserve price, announced or secret
  - entry fees or subsidies
- In practice, most auctions are either first-price sealed bid (FPSB) or open, ascending price (English).
- Goals of Theory
  - Positive: describe how to bid rationally Bayesian Nash equilibrium
  - Normative: characterize optimal (e.g., revenue maximizing or efficient) selling mechanism
- Goals of Empirical Studies
  - Positive: what are the bid markups? Are buyers valuations correlated and if so, what is the source of the correlation? Is observed bidding consistent with Bayesian Nash Equilibrium (BNE)? Is there evidence of buyer risk aversion? Do agents

Introduction

- There are many structural empirical papers which posit equilibrium bidding in the auction of a single item.
- Recent surveys:
    - Athey & Haile (Handbook of Econometrics, Vol. 6, 2007)
    - Hendricks & Porter (Handbook of IO, Vol. 3, 2007)
    - Paarsch & Hong (MIT Press, 2006)
- There has been considerable progress, but there remain important open issues.
- In this talk, Porter discusses some recent developments that extend the basic empirical model of a one shot, single item auction.
- He describes some research directions that might be of interest.

Outline of Talk

1. Standard Model and Notation
2. The Structural Program
3. Seller Incentives
4. Bidder Entry and Information Acquisition
5. Dynamics
6. Multi-Unit Auctions
7. Conclusion

Standard Model and Notation

- n =number of (potential) bidders
- m =number of bids (active bidders)
- X_i =private signal of bidder i
- $X = (X_1, \cdots, X_n)$
- V =common payoff component
- $U_i = u(X_i, V)$ bidder i utility if obtain one unit
- F =joint distribution function of (X, V)
- $Y_i = max\{X_j, j \neq i\}$
- W =winning bid
- $\beta_i(x)$ bidder i's (monotone) bid strategy
- $\eta_i(b)$ inverse bid function of bidder i

Main Assumptions

- Each bidder wants only one unit.
- Utility u is non-negative, continuous, and increasing in each argument, and common across bidders.
- Bidders are risk neutral.
- $F(X, V)$ is symmetric in the signals X.
- (X, V) are affiliated.
- X_i is real-valued.
- F, n and u are common knowledge.
- The losing bidders don't care who wins.

Special Cases

- Private Values (PV) : $u(X_i, V) = X_i$
- Can normalize the signal X_i to be an unbiased estimator of expected valuation.
  - IPV: X_i's are iid, F_x is marginal distribution of X_i
  - APV: X_i's are affiliated.
- If not PV, then say have Common Values (CV).
  - Pure Common Value: $u(X_i, V) = V$
  - CICV: X_i's are independent conditional on V.
- If CV, then $E[U_i|X_i = x, Y_i < x] < E[U_i|X_i = x]$
- This is the winners curse.

2. The Structural Program

- Objective: Estimate F (and u) from bid data.
- Basic idea: Bayesian Nash equilibrium (BNE) maps private signals into bids given $F \Rightarrow$ recover primitives from bid data?
- Focus on symmetric BNE with increasing bid functions.
- In open ascending auctions, problem of interpretation of losing
- Haile & Tamer (JPE 2003) make two assumptions on bidding in an IPV , if b_i is i's highest bid:
    1. Winner pay more than final bid, and losing bidders do not submit bids greater than their values, so $x_i \geq b_i \ \forall i$.
    2. Losing bidders not willing to raise bid by Δ, so $x_i \leq w + \Delta$ for all i but the winning bidder.
- Provide upper & lower bounds on F_X, without fully specifying equilibrium play.

First Price Sealed Bid Auctions

- Expected profits from bidding b, given a signal x:

$$(b,x) = \int \eta(b)[w(x,y) - b]dF_{Y|X}(y|x)$$

where $w(x,y) = E[u(V,X)|X = x, Y = y]$

- Differentiating with respect to b and imposing symmetry:

$$[w(x,x) - \beta(x)]f_{Y|X}(x|x) = \beta'(x)F_{Y|X}(x|x)$$

- Laffont & Vuong idea: Let $M = \beta(Y)$, the highest rival bid.
- Let $G_{M|B}$ denote the distribution function, conditional on one's own bid, and $g_{M|B}$ its p.d.f.
- Then $F_{Y|X}(y|x) = G_{M|B}(\beta(y)|\beta(x))$ and $f_{Y|X}(y|x) = g_{M|B}(\beta(y)|\beta(x))\beta'(y)$
- Substitute into FOC at $b = \beta(x)$, obtain inverse bid:

$$w(\eta(b), \eta(b)) = b + (G_{M|B}(b|b)/g_{M|B}(b|b))$$

Extensions of the Standard Model

- The inverse bid equation has been adapted to estimate several variations on the standard model.
  - Unobserved heterogeneity
    - Non-parametric (Krasnokutskaya (2004))
    - Parametric (Athey, Levin & Seira (2004), Krasnokutskaya & Seim (2007))
  - Asymmetric bidders
    - Collusion (Bajari & Ye (REStat 2003))
    - Observable types (Athey, Levin & Seira)
  - Risk averse bidders (Bajari & Hortacsu (JPE 2005))
  - Identification of the CV model using ex post payoff data (Hendricks, Pinkse & Porter (RES 2003))
  - Tests of PV vs. CV
    - Variation in number of bidders (Haile, Hong & Shum (2003))
    - Binding reserve price (Hendricks, Pinkse & Porter)

3. The Incentives of the Seller

- Basic Question: What does the auction design reveal about the economic environment?
- In most structural empirical analyses, mechanism choice, or the reserve price policy, is treated as exogenous.
- But optimal reserve price is a monotonic function of the seller's valuation, which may be correlated with buyers' values, and a function of the distribution of buyers' values.
- More generally, the mechanism choice may depend on the distribution of bidders' valuations, or on their behavior.
- Examples:
  - In an IPV setting, if bidders are risk averse, the FPSB auction yields higher revenues than SPSB.
  - A seller may prefer SPSB or oral ascending if CV (Milgrom & Webers linkage principle).
  - FPSB is less vulnerable to collusion

Laffont, Ossard & Vuong (Ecma 1995): Marmande Eggplants

- Model bidding in eggplant auctions (descending price, or Dutch) as BNE of IPV model, treating the reservation price as exogenous.
- There is a strong correlation between the reserve price and the winning bid (see Figure 3 in LOV).
- If the variation in the reserve price r is exogenous, so that F_X does not vary, the winning bid covaries with r in the BNE of the IPV model.
- Here $\beta(x) = E[max\{Y, r\}|X = x, Y \leq x]$, as in FPSB.
- But it is also possible that both the reserve price r and the location and/or scale of the distribution of bidder values F_X are correlated with some factor (or factors) that are not observed by the econometrician.

Marmande Eggplants

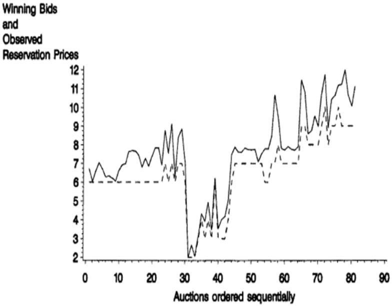


FIGURE 3.—Winning bids (continuous line) and reservation prices (dotted line).

Marmande Eggplants

- Should be cautious in imposing full seller rationality.
- The seller may have an objective other than static revenue maximization.
    - If a government agency is the seller.
    - If the seller can re-offer unsold items.
    - If buyers can also go to competing sellers.
- Nevertheless, if the reserve price is not exogenous, it may be informative about unobserved heterogeneity.
- E.g., some authors deflate bids by the reserve price, to correct for proportional shifts in the mean valuation.
- But need to be careful about higher order moments.
- E.g., is the dispersion in bids proportional to the value of the item?

4. Bidder Entry and Information Acquisition

- Auctions can be an important testing ground for studying entry.
  - Auctions are held repeatedly, firms have to make frequent entry decisions.
  - A rich variety of settings for studying entry decisions.
- If participation is costly, number should be determined as part of equilibrium to the game.
  - Who chooses to be a potential bidder?
  - Which potential bidders choose to be active?
  - Which active bidders submit a bid?
  - In each instance, what do agents observe?
  - Do auctions attract too many or too few bidders? This issue particularly important when bidders are asymmetric since, in this case, Revenue Equivalence does not hold and auction design matters (e.g., Athey, Levin & Seira), or if there are common values.

4. Bidder Entry and Information Acquisition

- Empirical problem: multiplicity of entry equilibria likelihood function is not well-defined. Strategies for dealing with this issue include:
  - Restrict payoffs so that no. of entrants in set of pure strategy equilibria is unique & define its likelihood by no. (Bresnahan & Reiss (RES 1990), Berry (Ecma 1992))
  - Change game form: sequential entry, or private entry cost information (Seim (RAND 2006))
  - Bound the probabilities of the outcomes (Tamer (RES 2003), Ciliberto & Tamer (2004))
  - Append selection rules & estimate joint distribution over outcomes & selection rules (Bajari, Hong & Ryan (2004)).
- Auctions provide a context for these strategies.
  - Sealed bid auctions simultaneous move.
  - Oral auctions sequential move.

Entry Models

- Standard model:
- All potential bidders are active; they submit a bid in the FPSB or SPSB, or participate in the open outcry auction, if their signal is above a threshold.
  - PV: Bid if $x \geq r$.
  - CV: Bid if $x \geq x^*(r, n)$,
- where $x^*(r, n) = inf\{x|E[u(V, X)|X = x, Y < x] \geq r\}$ and $x^*(r, n) > r$ is increasing in r and n.
- In the PV case, $x^*(r, n) = r$.

Athey, Levin & Seira (2004): Timber Sales

- Fixed number of potential bidders (of two types).
- Bidders are endowed with a private signal, their bid preparation cost.
- Bidders (simultaneously) choose to become active if this cost is below some threshold.
- ALS consider the type symmetric pure strategy equilibrium, where bidders take as given the (binomial) distribution of the number of active rivals of each type.
- Bidders then observe their private value, independent of their bid preparation cost, and they observe the number of active bidders.
- Bidders submit a bid if their value is above the reserve price, as in the standard model.
- The first stage is analogous to Seim's (RAND 2006) entry

Bajari & Hortacsu (RAND 2003): eBay Coins

- Model is in the spirit of Levin & Smith (AER 1994).
- Large number of potential bidders, with a common bid preparation cost.
- They (simultaneously) choose to become active.
- BH consider the symmetric mixed strategy equilibrium.
- Active bidders then observe their private signal of the common value, but not the number of active rival bidders.
- Bidders take as given the (Poisson) distribution of the number of active rivals.
- Bidders submit a bid if their signal is above the CV threshold, where this is the zero profit signal, taking expectations over the number of active rivals.
- The bidding game is SPSB with an unknown number of rivals.
- The common entry probability is uniquely determined by a

Krasnokutskaya & Seim (2007): California Highway Procurement

- KS consider two entry models.
- In the first variant, firms observe a private bid preparation cost.
- This model is essentially that of Athey, Levin & Seira, also with two bidder types.
- In California, qualified small bidders are favored. The lowest small bidder wins if their bid is not 5% higher than the lowest large firm bid.
- KS are interested in the effect on entry and bid levels for each bidder type.
- In the second model, firms have a common bid preparation cost.
- Firms randomize in their entry decisions, with type specific

Hendricks, Pinkse & Porter (RES 2003): Offshore Oil & Gas

- Model similar to McAfee & Vincent (AER P&P 1992).
- Fixed number of potential bidders, with private signal of common value.
- They (simultaneously) choose whether to become active.
- Consider the symmetric pure strategy equilibrium.
- Active bidders then observe a better signal of the common value, but not the number of active rival bidders.
- Bidders' initial signals are informative about the number of active rivals.
- Active bidders submit a bid if their second (better) signal is above the CV threshold, where this is the zero profit signal taking expectations over the number of active rivals.
- The bidding game is FPSB, with an unknown number of

Endogenous Information Precision?

- Almost all papers take the precision of information as given.
- Potential bidders may not only choose whether to acquire information, but also the accuracy of their information.
- In offshore oil and gas auctions, firms choose how much to invest in analyzing seismic data.
- Firms entry and bidding strategies will depend on their perceptions of how many serious rival bidders they face.
- Information acquisition will be influenced by the auction mechanism (e.g., Compte & Jehiel (RAND 2007)).
- A related issue: Much of the literature compares mean revenues. But in some instances bid dispersion varies with the mean bid level (e.g., offshore oil lease bidding).
- This variation may be driven by variation in the level of competition.

-