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Surrey Energy Economics Centre

3rd International Workshop on Empirical Methods in Energy Economics (EMEE2010)

Surrey Energy Economics Centre (SEEC)

University of Surrey, UK

24^{th} – 25^{th} June 2010

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“ESTIMATION OF A MODEL OF ENTRY AND BIDDING ON WILDCAT OIL LEASES”

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Outline

- OCS Wildcat Auctions
- Structural Estimation of Auction Models
- Contributions of the Paper
- Theoretical Model
- Data
- Estimation
- Counterfactual Analysis
- Conclusion

OCS Wildcat Auctions

- Leases for extraction on geographically specified tracts (5000 acres) sold in Gulf of Mexico since 1954.
- First price sealed bid auction
- Seismic and tract specific survey
- 5 years exploration period, 1/6 royalty rate.

Structural Estimation of Auction Models

- Estimation of the distribution of latent values or signals, or both.
- Policy Analysis (optimal auction mechanism)
- Donald & Paarsch (IER,1993), Laffont et al. (Econometrica, 1995)
- Guerre et al. (Econometrica, 2000)
- Selection (Participation) Issue: Bajari & Hortacsu (Rand JE, 2003), Hendricks et al. (RES, 2003)

Contributions of the Paper

- An illustration of estimating entry cost in a first price common value auction setting
- Estimation does not require the knowledge of latent signal distribution.
- Application to OCS wildcat auctions, and counterfactual simulations using endogenous entry to analyze the effect of potential competition on government's revenue

Theoretical Model

- A version of Hendricks et al. (RES, 2003) (HPP hereafter) with a simplified entry process as in Levin & Smith (AER, 1994) to facilitate the estimation.
- In the first (entry) stage potential firms decide whether to enter or not depending on the seismic signal.
- Entry involves paying additional cost to make a tract specific survey.
- Those who have decided to enter (called active bidders) receive more informative tract specific signal, and bid according to this second signal.

Entry Stage

- For a given tract t:

  V_t : The common value of tract t

  N_t : The number of risk neutral potential bidders who receive the symmetric seismic signal Z_t

  n_t : The number entering bidders (active bidders.)

  N_t is common knowledge among bidders but V_t and n_t are not.

Entry stage (continued)

- $(V_t, Z_t, S_{1t}, \ldots, S_{nt})$ are affiliated, and exchangeable in its last n components wrt to bidder indices.
- $(Z_t, S_{1t}, \ldots, S_{nt})$ are independent conditional on V_t
- S_{it} is more informative than Z_t
- Potential firms use symmetric mixed strategies for entry where entry probability is determined endogenously by the zero profit condition.

$$K_t(Z, N) = \int \Pi_t(s) f_{s|z}(s \mid z) ds$$

where $\Pi_t(s)$ is the expected profit of a participating bidder who receives signal s in the bidding stage.

Bidding Stage

- Consider the problem of an active bidder i who receives signal S_{it} = s in the second stage
- Let $p_k(s,z) = Pr(N = k+1 | S_{it}=s, Z_t=z, N)$ be the probability that bidder i has k active rivals given signals s and z.
- Since entry is solely determined by the seismic signal Z_t, S_{it} does not update the probability: $p_k(s,z)= p_k(z)$

Bidding Stage (Continued)

Let $\mathrm{Y}_{it} = \max_{i \neq j} S_{jt}$ be the maximum signal of bidder i's active rivals.

The cdf of the maximum rival signal when firm i has at least 1 rival bidder can be written as:

$$H_{Y_{it}|S_{it}}(y \mid s) = \sum_{k=1}^{N_t} \frac{p_k}{1 - p_0} F_{Y_{it}|S_{it}}(y \mid S_{it} = s, n = k+1)$$

where $F_{Y_{it}|S_{it}}(y \mid S_{it} = s, n = k+1)$ is the conditional cdf Y_{it} when i has exactly k active rivals

$$w_{it}(s, y) = E[V_t \mid S_{it} = s, Y_{it} = y, n \geq 2] \qquad w_{it}(s) = E[V_t \mid S_{it} = s, n = 1]$$

Bidder's Problem

Assuming that firms follow symmetric increasing and differentiable strategies, β(s), bidder i's problem can be posed as:

$$\max_{b>r} \Pi_{it}(b,s)$$

where,

$$\Pi_{it}(b,s) = (1-p_0)\int_{\underline{s}}^{\eta(b)} (w(s,y)-b)h_{Y_{it}|S_{it}}(y\,|\,s)dy + p_0(w(s)-b)$$

and $\eta(b)$ is the inverse bid function

$FOC:$

$$(1-p_0)[(w_{it}(s,\eta(b))-b)h_{Y_{it}|S_{it}}(\eta(b)\,|\,s)\eta^{'}(b) - H_{Y_{it}|S_{it}}(\eta(b)\,|\,s)] - p_0 = 0$$

Bidder's Problem (Continued)

Plugging $\beta(s)$ in the FOC gives,

$$(1-p_0)[(w_{it}(s,s)-\beta(s))\frac{h_{Y_{it}|S_{it}}(s|s)}{\beta^{'}(s)}-H_{Y_{it}|S_{it}}(s|s)]-p_0=0$$

Recalling the monotonicity of the bid function above equation can be rewritten in terms of observed bid values:

$$w_{it}(\eta(b),\eta(b))=b+\frac{G_{M_{it}|B_{it}}(b|b)}{g_{M_{it}|B_{it}}(b|b)}=\xi(b,G) \quad \text{where,}$$

$$G_{M_{it}|B_{it}}(m|b)=[1-p_0]H_{Y_{it}|S_{it}}(\eta(b)|\eta(m))+p_0 \quad \text{and}$$

$$g_{M_{it}|B_{it}}(m|b)=\frac{[1-p_0]h_{Y_{it}|S_{it}}(\eta(b)|\eta(m))}{\beta^{'}(\eta(m))}$$

are the conditional cdf and pdf of the maximum rival bid when there is at least one rival

Data used in Estimation

TABLE 1					
Summary of Wildcat Sales: sold, drilled, big twelve, more than 2 potential bidders, 1954-1970					
	Total # of Tracts	Hits	Mean Rev	Mean Net Rev	Mean Hibid
Summary Statistics	837	402	58.94	13.89	8.00

* Dollar figures are in million of 1982 dollars.

Estimation (Bidding Stage)

Bids are assumed to be lognormally distributed conditional on V,N, and n as follows:

$$G_{b_{it}|V_t,N_t,n_t}(b\,|\,V,N,n) = \log norm((\mu(V_t,N_t,n_t),\sigma(V_t,N_t,n_t))$$

$$\mu(V_t,N_t,n_t) = \beta_1 + \beta_2 V_t + \beta_3 N_t + \beta_4 n_t$$

$$\sigma(V_t,N_t,n_t) = \beta_5 + \beta_6 V_t + \beta_7 N_t + \beta_8 n_t$$

$$L_t(\sigma_t,\mu_t\,|\,V_t,N_t,n_t) = \prod_{i=1}^{n_t} g_{b_{it}|V_t,N_t,n_t}(b_{it}\,|\,V_t,N_t,n_t)$$

$$(\hat{\beta}_1,\ldots,\hat{\beta}_8) = \underset{\beta_1,\ldots,\beta_8}{\arg\max}\left\{\log\sum_{t=1}^{T} L_t(\sigma_t,\mu_t\,|\,V_t,N_t,n_t)\right\}$$

Estimation (Entry Stage)

Because firms' entry decisions are affilated through V_t

I assume entry decisions have binomial distribution

conditional on V, N, and n as follows:

$$p_{n_t} = p(V_t, N_t, n_t) = \frac{\exp(\alpha_1 + \alpha_2 V_t + \alpha_3 N_t + \alpha_4 n_t)}{1 + \exp(\alpha_1 + \alpha_2 V_t + \alpha_3 N_t + \alpha_4 n_t)}$$

$$L_t(\alpha_1, \alpha_2, \alpha_3, \alpha_4 \mid V_t, N_t, n_t) = p(V_t, N_t, n_t)^{n_t} (1 - p(V_t, N_t, n_t))^{N_t - n_t}$$

$$(\hat{\alpha}_1, \hat{\alpha}_2, \hat{\alpha}_3, \hat{\alpha}_4) = \arg\max_{\alpha_1, \alpha_2, \alpha_3, \alpha_4} \left\{ \log \sum_{t=1}^{T} L_t(\alpha_{11}, \alpha_{12}, \alpha_{13}, \alpha_4 \mid V_t, N_t, n_t) \right\}$$

Estimation Results

TABLE 2: Estimation of the Entry Process

		p	
Variables	Coefficient	Estimate	s.e
Cost C	α_1	-0.19109	0.12685
Value V	α_2	-0.03591	0.06288
Number of Potential Bidders N	$*\alpha_3$	-0.32024	0.01777
Number of Bidders n	$*\alpha_4$	0.6654	0.02063

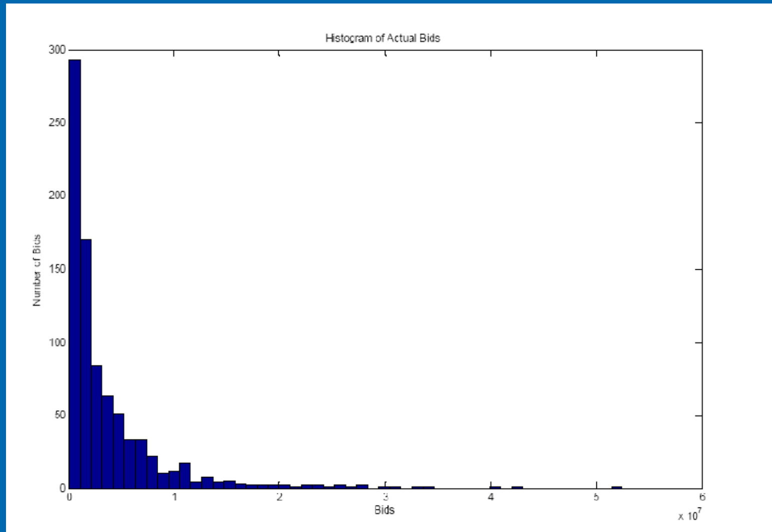
* Significant at 95%

TABLE 3: Estimation of the bid distribution

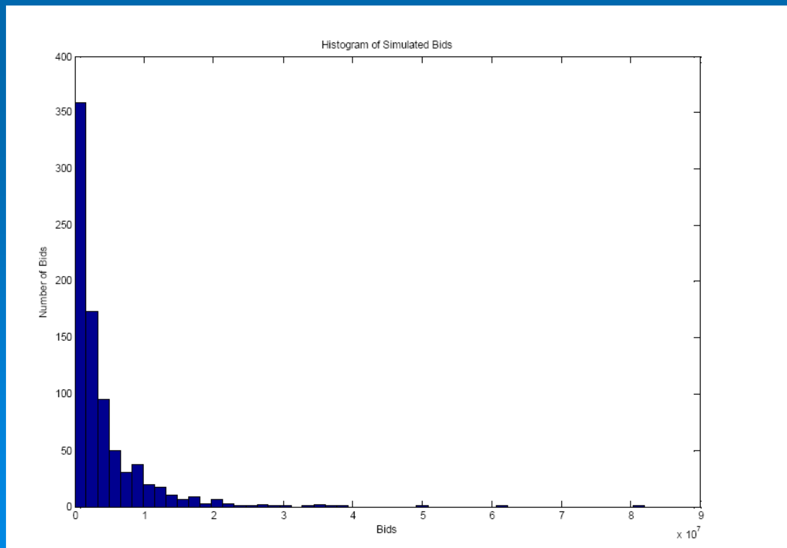
	mean			variance		
Variables	coefficient	estimate	s.e	coefficient	estimate	s.e
Cost C	$*\beta_1$	1.61493	0.08108	$*\beta_5$	1.03705	0.05775
Value V	$*\beta_2$	0.00020	0.00005	β_6	0.00005	0.00005
Number of Potential Bidders N	$*\beta_3$	0.02286	0.01119	β_7	-0.00227	0.00798
Number of Bidders n	$*\beta_4$	0.25482	0.01251	$*\beta_8$	0.04612	0.00947

* Significant at 95%

Model Fit



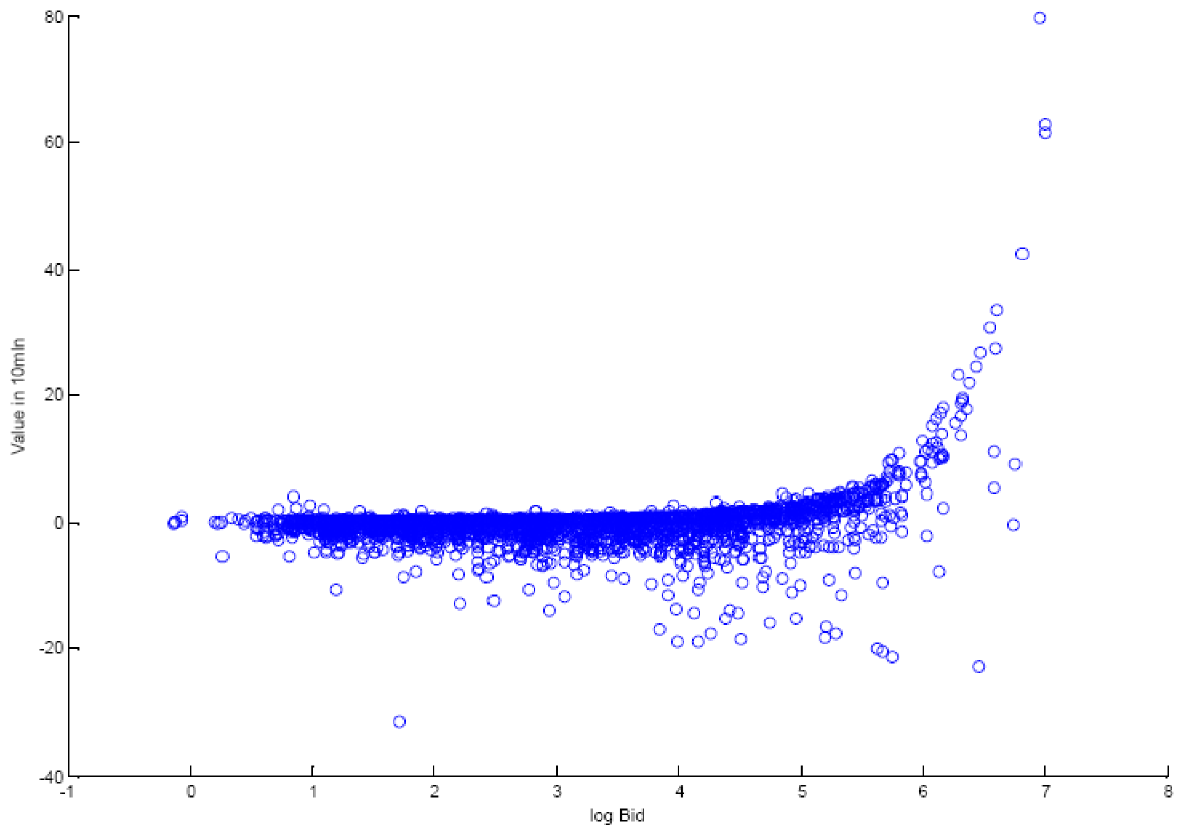
Histogram of Actual Bids
Number of Bids
Bids
300
250
200
150
100
50
0
0
1
2
3
4
5
6
x 10^7



Histogram of Simulated Bids
Number of Bids
Bids
400
350
300
250
200
150
100
50
0
0
1
2
3
4
5
6
7
8
9
x 10^7

An Empirical Test of Equilibrium

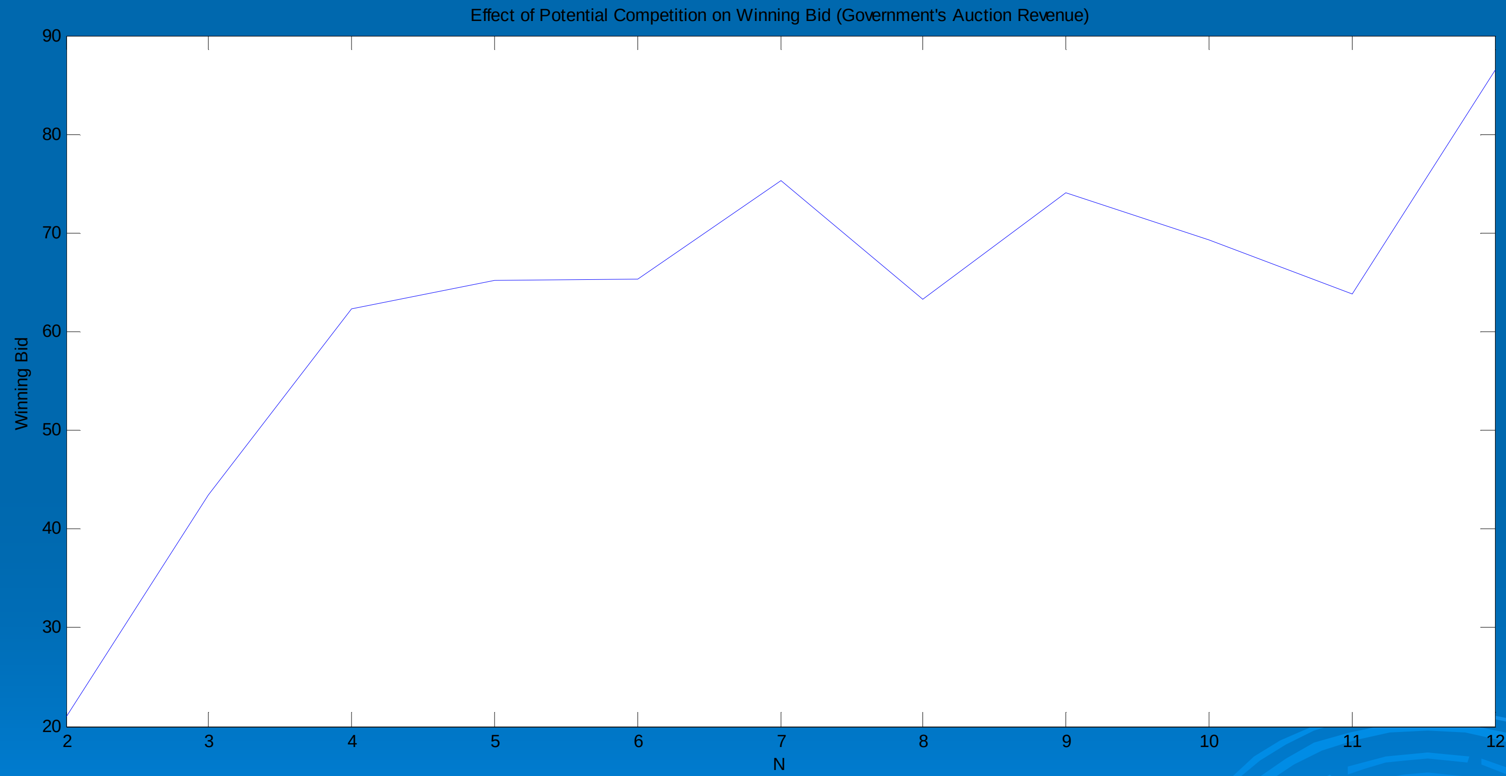
$$w_{it}(\eta(b),\eta(b)) - \left(b + \frac{G_{M_{it}|B_{it}}(b|b)}{g_{M_{it}|B_{it}}(b|b)}\right)$$



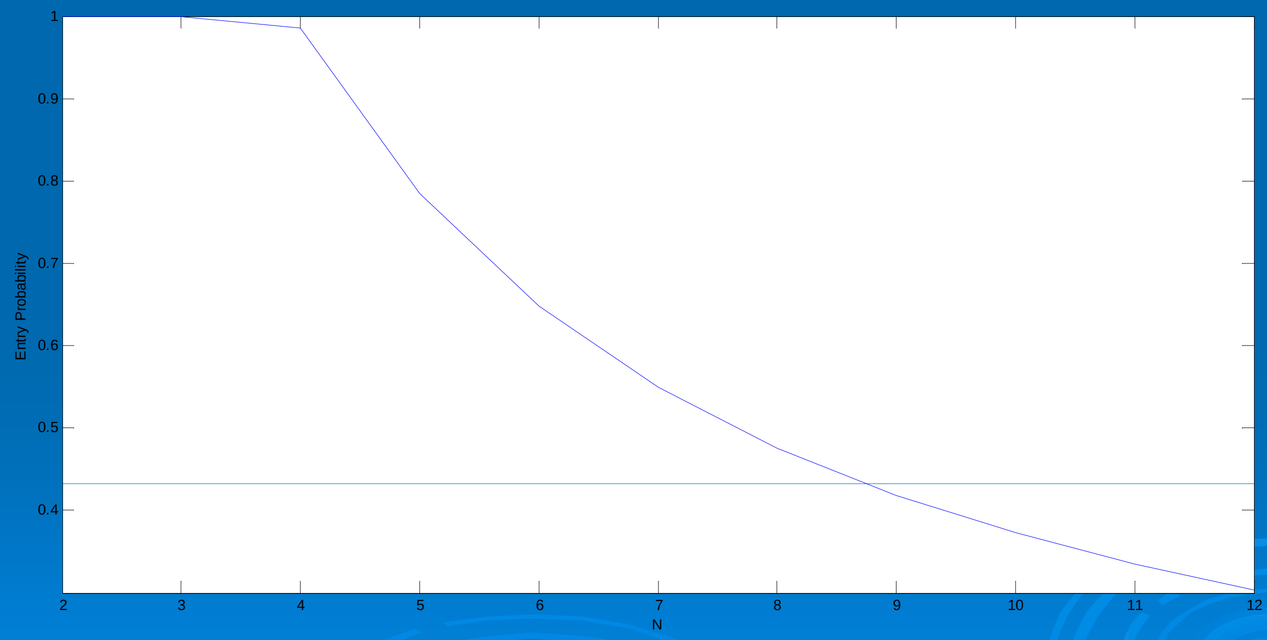
Entry Cost

- For tract #1684 that has ex-post value \$15M and N=8, entry cost is estimated to be \$1.7M with standard error \$0.54M.

Effect of Potential Competition on Winning Bid



Entry Probability



Thank you for listening

Conclusion

- Competition appears to be dominating other counteracting effects
- To improve the analysis heterogeneity to the entry stage can be added as in HPP
- 1/6 royalty rate does not contradict with the empirical finding

An Ex-Post Optimality Analysis for the Royalty Rate