Competition or Collusion in Recent Offshore Oil and Gas Bidding?

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PRELIMINARY

Introduction

The US Mineral Management Service (MMS) uses auctions to allocate exploration and drilling rights on federal lands on the Outer Continental Shelf (OCS).

The federal offshore leasing program began in 1954, and there have been few alterations in the auction mechanism.

Offshore oil and gas today accounts for about a third of US production.

The stakes are high, and the leasing program has generated considerable revenue for the government.

Excellent data are available.

Our research asks positive questions concerning bidder behavior.

E.g., Is observed behavior consistent with some equilibrium model? Is there evidence of collusion in exploration or bidding?

We are also interested in normative issues.

Could different auction rules improve revenues or efficiency?

Is an auction the appropriate allocation mechanism?

The OCS Auction Mechanism 1954-1982

1. Government announces area is available for exploration.
2. Seismic testing and analysis (2-D) of area by industry.
3. Bidding consortia negotiations.
4. Wildcat lease sale.
   - at least 100 tracts offered simultaneously (up to 515)
   - tracts are typically 5,000 or 5,760 acres (up to 9 square miles)
   - each tract sold in a first-price, sealed bid (bonus) auction
   - announced minimum bid: $15 per acre
   - terms: pay bonus at sale date, 1/6 royalty rate on revenues
5. Government bid adequacy decision.
   - based in part on MMS's independent assessment of tract value
6. Exploratory drilling of wildcat tracts.
   - fixed lease term (5 years)
   - automatic renewal if productive
   - fixed (minimal) rental fees during exploration
7. Drainage and developmental sales.
   - previously explored areas, near productive tracts
   - some wildcat tracts reoffered after relinquishment or high bid rejection

OCS Data

Sample: Tracts receiving at least one bid, 1954 - present.

Tract Information:

- date of sale(s)
- location and acreage
- auction rules (e.g., minimum bid, royalty rate)
- lease type (wildcat, drainage, or developmental)
- identity of all bidders and the amounts bid
- if joint bid, the participants and their shares
- whether high bid was rejected
- if lease transferred, date of transfer and new owner(s) identity
- number and date of wells drilled
- monthly production data through 2007
  - oil, condensate, natural gas, other hydrocarbons

Can construct ex post discounted tract value (revenues minus costs), and government share of that value (bonus bid plus royalties).

Also know how many tracts offered in a given sale did not receive bids.

Findings for 1954-1979

Wildcat Sales:
- Bidding coalitions
  - frequent, although less common on marginal tracts
  - equal division sharing rules among large firms
- Bidding
  - competitive, but with considerable dispersion
  - consistent with Bayesian Nash Equilibrium with common values
- Drilling
  - non-cooperative plans in areas with multiple lease owners
  - delay and duplication at lease term deadline
- Returns
  - government captures large share of rents
  - bids and royalty payments of similar magnitude

Drainage sales:

Asymmetric information favors owners of neighboring wildcat leases.

Government share of rents is smaller than on wildcat leases.

Beneficiaries are neighboring owners.

Research Questions

There have been many important changes in the last 30 years.

- wide swings in oil and gas prices
- new areas of exploration (most notably, deep water)
- beginning in 1983, Area Wide Leasing (AWL)
- changes in allocation (auction) rules
- royalty rate changes (e.g., 1995 Deepwater Royalty Relief Act)
- industry consolidation via mergers
- widespread adoption of 3-D seismic analysis in the 1990s
- changes in drilling technology
    - directional drilling
    - "measurement-while-drilling"
    - both complement the improvements in seismic analysis

    "The rig site has become a server."

What are the effects of changes in the allocation mechanism?

What are the effects of seismic (and related) advances?

The OCS Auction Mechanism 1983-present

With the advent of Area Wide Leasing (AWL) in 1983:

Wildcat lease sale:

- at least 3,500 tracts offered simultaneously (range: 3,647 – 8,868).
- announced minimum bid now $25 per acre

Deep water:

- Drilling costs are much higher (esp. platform costs)
- 1/8 royalty rate if water depth is more than 400m
- longer lease term (8 or 10 years)
- 1995 Deepwater Royalty Relief Act
  - leaseholders exempt from royalties on production below a fixed amount
  - relief contingent on oil prices not exceeding $35/bbl (except in 1998-1999)

Government bid adequacy decision:

- MMS no longer computes independent assessment of tract value.
- lower rejection rates

Drainage and developmental sales:

- with advent of AWL, many tracts near previously explored areas

The Effect of Improved Seismic Information

In a first price sealed bid common value auction, what are the effects of more precise bidder information?

Consider Wilson's symmetric "mineral rights" model, in which bidder signals are unbiased estimates of the unknown pure common value, and bidder signals are drawn from the same distribution.

Suppose that the number of potential bidders is fixed.

Then the effect of more precise signals is straightforward:

Winner's curse is less of a concern, and bids are more aggressive for a given signal. Bids for a given tract are higher and less disperse.

Moreover, signals themselves are more precise estimates of value.

Thus a valuable tract (one with value above the reserve price) is more likely to be sold, and the winning bid is closer to the value, in expectation and with lower mean square error.

In OCS auctions, however, one must also consider the effect on the decisions to acquire a signal, to enter into a joint bidding consortium or to bid solo, and to drill after acquiring the lease.

Table 1: Summary of Offshore Oil and Gas Lease Sales, Gulf of Mexico 1954-2006*

Period	# of Tracts Offered	# of Tracts Bid	Bids per Tract	# of Tracts Sold	Total Winning Bids	Mean Winning Bid	# of Bids Rejected	Mean Rejected Bid
1954-82	7,175	3,974	3.24	3,525	53,104	15.065	449	2.302
1983-87	71,243	3,763	1.47	3,473	9,424	2.714	285	1.802
1988-92	60,228	3,811	1.16	3,701	1,956	0.528	107	0.436
1993-97	52,563	5,183	1.52	5,017	2,501	0.498	149	0.328
1998-06	57,946	6,175	1.37	5,951	3,667	0.616	236	0.455
1954-06	249,155	22,906	1.71	21,667	70,653	3.261	1,226	1.427

*Dollar figures are in millions of 1982 dollars.

Before and After Area Wide Leasing

1954-1982:

- 3,525 tracts sold (49% of tracts offered for sale)
- 64% of tracts received at least 2 bids
- 3.2 bids per tract
- Mean high bid (in 1982 dollars): $15.07 million
- Total winning bids (in 1982 dollars): $53.10 billion
- Government rejection rate: 11.2%

1983-2006:

- 18,142 tracts sold (7% of tracts offered for sale)
- 25% of tracts received at least 2 bids
- 1.3 bids per tract
- Mean high bid (in 1982 dollars): $0.967 million
- Total winning bids (in 1982 dollars): $17.55 billion
- Government rejection rate: 4.0%

Table 2: Bidding 1954–1984 and 1996-2005 by Number of Bidders*

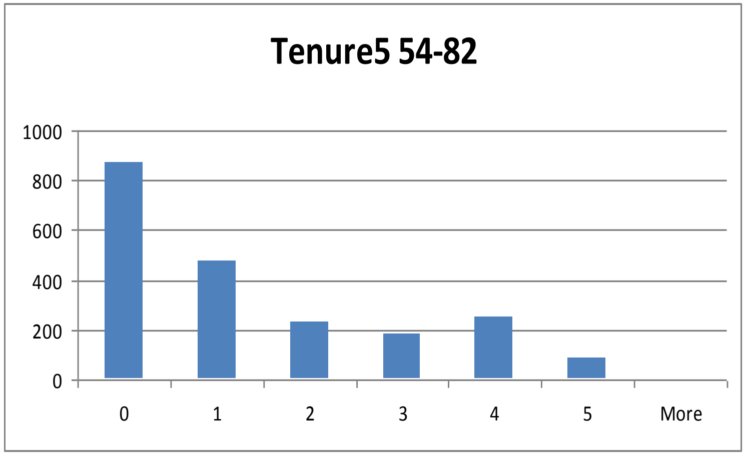
	Number of Bidders							
	1	2	3	4	5–6	7–9	10–18	Total
1954-1979								
# of Tracts	902	463	255	212	264	234	180	2,510
B1	5.285	10.987	16.767	22.753	32.426	58.098	89.717	22.814
(B1–B2)/B1	—	0.55	0.49	0.46	0.39	0.34	0.30	0.44
1980-1982								
# of Tracts	292	131	72	47	59	39	15	655
B1	3.952	10.675	16.759	26.102	34.126	44.545	50.589	14.497
(B1–B2)/B1	—	0.56	0.39	0.42	0.37	0.31	0.28	0.44
1983-1984								
# of Tracts	1,479	438	128	67	51	15	0	2,178
B1	2.270	4.827	7.640	7.741	11.077	13.698	-	3.553
(B1–B2)/B1	—	0.42	0.41	0.41	0.34	0.33	-	0.41
1996-2000								
# of Tracts	3,983	879	352	131	96	32	6	5,479
B1	0.508	1.066	1.301	2.422	3.888	4.444	4.905	0.781
(B1–B2)/B1	—	0.48	0.45	0.41	0.41	0.34	0.70	0.46
2001-2005								
# of Tracts	3,356	667	230	82	36	7	2	4,380
B1	0.459	0.868	1.935	3.591	6.403	5.679	12.869	0.721
(B1–B2)/B1	—	0.43	0.48	0.48	0.32	0.26	0.14	0.44

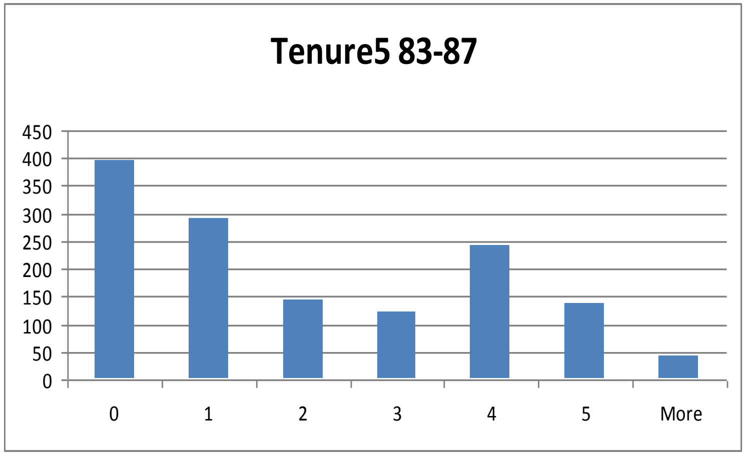
*B1 denotes the highest bid on a tract, and B2 the second highest bid. Dollar figures are nominal, except for 1954-1979, where they are in millions of 2000 dollars.

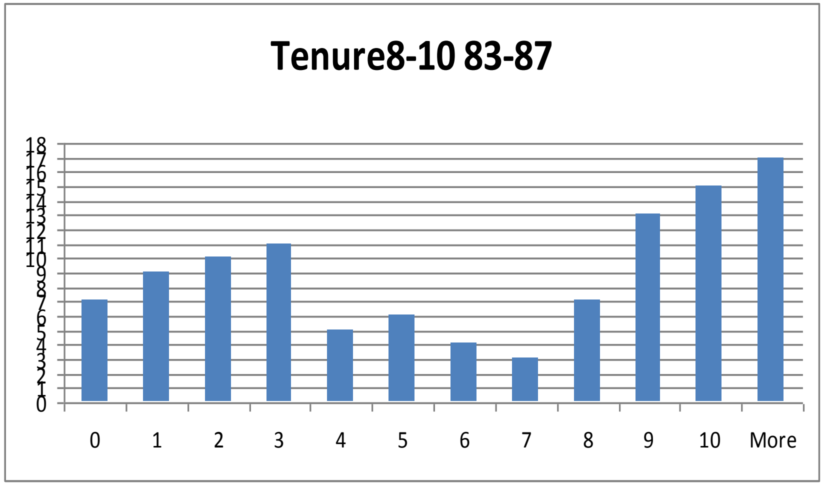
Table 3: Drilling and Production 1954-2006

	1954-82	1983-87	1988-92	1993-97	1998-06
# of Tracts Sold	3,525	3,468	3,591	5,035	6,305
# Drilled	2,256	1,479	968	1,053	1,009
(fraction of sold)	(0.64)	(0.43)	(0.27)	(0.21)	(0.16)
# Productive (by 2006)	1,121	589	403	472	395
(fraction of drilled)	(0.50)	(0.40)	(0.42)	(0.45)	(0.39)
(fraction of sold)	(0.32)	(0.17)	(0.11)	(0.09)	(0.06)
# Productive in 2006		294	185	313	373

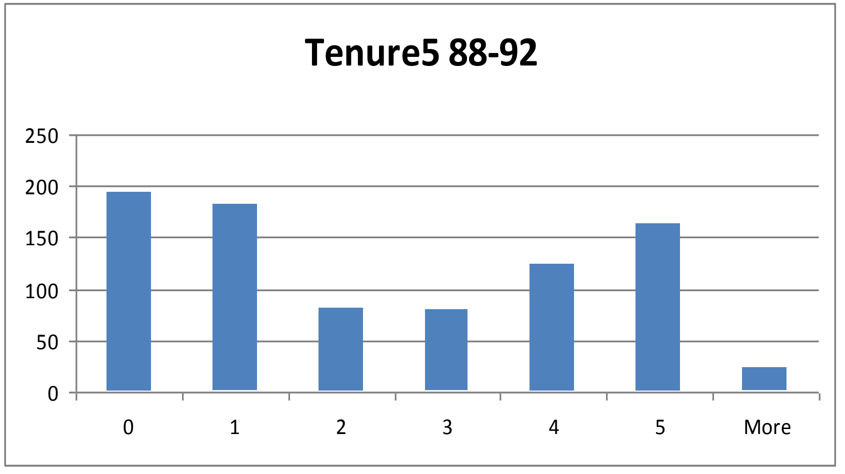
Drilling Lags by Lease Term 1954-1987

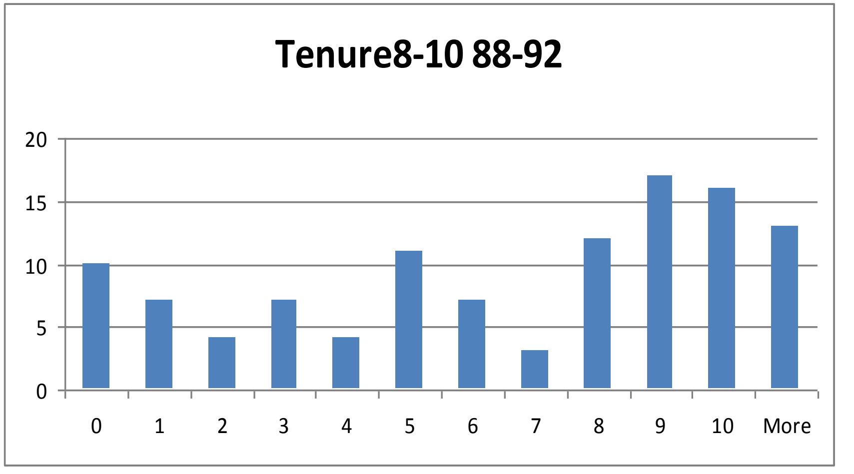


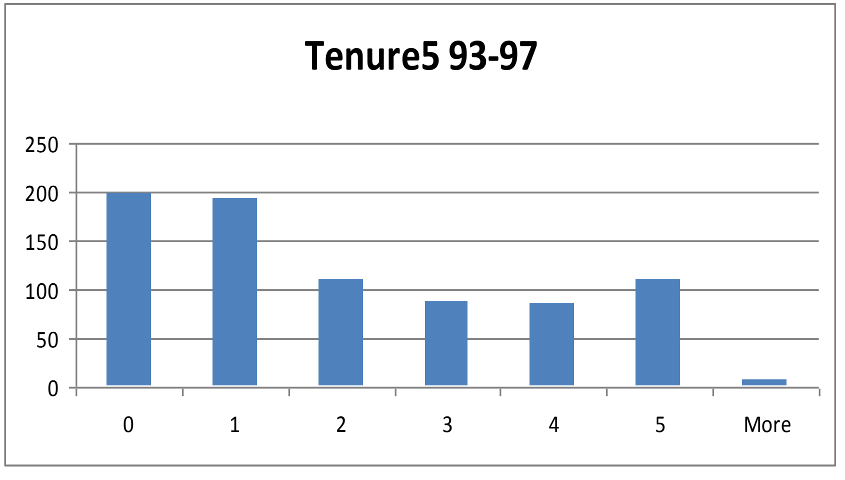




Drilling Lags by Lease Term 1988-1997







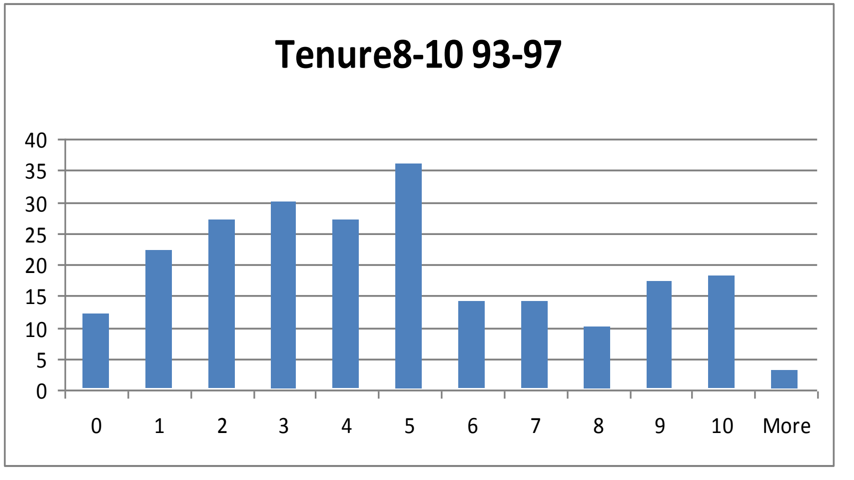


Table 4: Profits and Government Receipts 1954-1997*

	1954-72	1980-82	1983-87	1988-92	1993-97
Average Crude Price		28.97	23.86	18.54	17.11
# of Tracts Sold	1,527	612	3,468	3,591	5,035
Revenue per tract drilled					
Actual prices		33.18	36.80	26.63	22.05
Sale date prices	28.89	34.83	37.86	16.58	11.16
Cost per tract drilled	9.98	28.02	16.74	13.56	14.33
Mean Bid per tract sold	9.54	17.21	2.71	0.53	0.50
Bid + Royalty per tract sold					
Actual prices		20.51	4.89	1.56	1.19
Sale date prices	13.35	20.74	5.00	1.18	0.86
Profit per tract sold					
Actual prices		(16.99)	3.67	1.96	0.42
Sale date prices	1.60	(16.10)	4.01	(0.37)	(1.52)

*Dollar figures are in millions of 1982 dollars. Profit = Revenue – Cost – Bid – Royalty.

Competition or Collusion?

Question: Are the entry & bidding patterns since the advent of AWL in 1983 consistent with competitive behavior?

Or are the patterns more consistent with firms coordinating exploration or bidding?

Under competition, there are three explanations for few, low bids.

1. Most tracts are marginal.

   But aggregate ex post returns are not low.

2. Better seismic information leads to more aggressive bidding, and hence less entry.

   But bid dispersion, conditional on number of active bidders, has not fallen.

3. Increases in concentration via mergers.

   Possible, especially in deep water, where there are few potential bidders.

Under collusion, the explanation is coordinated entry.

We seek to distinguish between the explanations by focusing on tracts with active neighboring leases.

Table 5: Bidding and Neighboring Lease Status 1988-1992*

	No Neighbor	Active Neighbor			Drilled Neighbor		
		No Neighbor	Neighbor		No Neighbor	Neighbor	
		N Bid	Lose	Win	N Bid	Lose	Win
# of Tracts Sold	399	2,183	125	603	1,656	90	273
Mean # of Bids	1.17	1.36	3.17	1.37	1.45	3.32	1.59
Fraction Neighbor Win	---	---	0.83		---	0.75	
Mean Bid	0.369	0.572	1.715	0.716	0.597	1.839	0.958
Number Drilled	27	644	60	147	555	48	95
Number Productive	9	268	32	71	238	25	52
Mean Profit	0.366	(0.406)	3.353	2.623	(0.798)	(3.502)	(1.524)

*Dollar figures are in millions of 1982 dollars. Profit = Revenue – Cost – Bid – Royalty.

Ideas for Testing

Participation rates:

Information in non-participation distorted under (simple) collusion

Failures of affiliation under collusion:

- second neighbor participation or bid not correlated with ex post value

- second neighbor participation or bid not correlated with high neighbor bid

Neighbors fail to respond to variation in the severity of the winners' curse, associated with changes in the number of neighbors.

Non-neighbor participation and bids invariant to number of neighbors.

Model and Notation

FPSB with reserve price r

Pure common value with value V, affiliated signals

n = number of firms owning neighboring leases

m = (fixed) number of non-neighbor potential bidders

X_i = private signal of neighbor bidder *i*, real valued

$X = (X_1, \dots, X_n)$

Z_i = private signal of non-neighbor bidder *i*

$Z = (Z_1, \dots, Z_m)$.

F_{VX} = joint distribution function of (V, X)

Assume each X_i has continuous marginal pdf; w.l.o.g. assume X_i is U[0,1]

$Y_i = \max\{X_j, j \neq i\}$

$B_i = \beta(x; n)$ neighbor bidder *i*'s (monotone) bid strategy

$\eta_i(b; n)$ inverse bid function of bidder *i*

Data: n, m, r, all bids (including non-participation), ex post value V.

Competitive Behavior

Submit bid if signal exceeds thresholds $x^*(n)$, $z^*(n)$.

Neighbor threshold determined by:

$x^*(n) = \inf\{x| E[V| X_i = x, Y_i < x, \max\{Z_j\} < z^*(n)] \geq r\}$

Boundary condition: $\beta(x^*(n); n) = r$; similarly for non-neighbor bids.

Neighbor bids characterized by:

$v(x;n) = \beta(x;n) + G(\beta(x;n)|\beta(x;n);n)/g(\beta(x;n)|\beta(x;n);n)$

where, if M is the maximum (neighbor or non-neighbor) rival bid,

$v(x;n) \equiv E[V| X_i = x, M = \beta(x;n); n]$

and G is the distribution function of M conditional on B (and g the associated denstiy function).

Information in Non-Participation

Idea: Collusive non-participation by neighbors when $n > 1$ will distort the mapping between quantiles of bids and quantiles of signals that holds with equilibrium behavior. The biggest distortion will be at the screening level, since we incorrectly associate "no bid" with a signal below the screening level.

This can be detected because there is no such distortion when $n=1$.

Focus on the behavior of neighbors.

By the normalization of signals, under competitive bidding

$$x^*(n) = \Pr\{B<r \mid N=n\}.$$

The RHS is observed and can be used to form an estimate $x^*(n)$. When $n > 1$ and neighbors collude, the event $\{B<r, X>x^*(n)\}$ can/will happen due to collusive non-participation, and this will distort estimates of $x^*(n)$. When $n = 1$, there is no scope for collusion among neighbors

Testable Implications

Assume exogenous variation in n: For all n′ and all n<n′, F(V,X;n) is identical to the marginal distribution of $(V,X_1,\ldots,X_n)$ obtained from F(V,X;n′).

Under this assumption, $E[V|X_i = x, n]$ is invariant to n.

Let $G_B^{-1}(\cdot;n)$ be the inverse of the marginal distribution of neighbor bids conditional on n.

Under the assumption of competitive bidding, for any $x \in [x^*(n),1]$

$$E[V|X_i = x, n] = E[V|B=\beta(x;n),n] = E[V|B=G_B^{-1}(x;n),n]$$

where the final equality follows from the normalization of signals.

Since $E[V|X_i = x, n]$ does not depend on n, we have the following testable restriction of competitive bidding.

Proposition: Under the exogeneity assumption and competitive bidding, the following expectations are invariant to $n \in \{1,\ldots,n\}$.

(i) $E[V|\ B=G_B^{-1}(x^*(n);n),\ n]$,

(ii) $E[V|\ B<G_B^{-1}(x^*(n);n),\ n]$, and

(iii) $E[V|\ B>G_B^{-1}(x^*(n);n),\ n]$

What happens under collusion?

Collusion

Prefer not to specify the model of collusion, but need examples to asses the power of a testable restriction against the collusive alternative.

Designated Bidder Model

Cartel includes all neighbors. One firm is designated to bid before signals are realized. Non-neighbors act as if there is only one neighbor.

Information Pooling Model

Cartel includes all neighbors. Neighbors pool their signals and submit one cartel bid when $E[V|\ X = x, \max\{Z_j\} < z^*(n)] \geq r$.

Any cartel bid best responds to the distribution of non-neighbor bids, given its information X. Non-neighbors have correct beliefs about the joint distribution of (V,B,X).

Phantom Bidding

Trivial to modify the models above to one serious bid plus some phantom bids. Phantom bids don't change the behavior of either non-neighbors or the serious cartel bidder.

Some testing approaches could be foiled by sophisticated phantom bidding.

Designated Bidder Model

Here, for all n, Pr{cartel bids} = Pr{$X_i \geq$ x*(1)} = 1 - x*(1).

Let x^(n) be the screening level inferred from auctions with n neighbors.

Ignoring sampling error

x^(n) = 1 - Pr{neighbor i bids|n}

= ((n-1)/n)(1) + (1/n)x*(1)

= ((n-1) + x*(1))/n

where the second line follows from the fact that n-1 of the neighbor bids are zero in every auction.

Typically x^(n) will not equal the true x*(n) -- unless the winner's curse is quite severe, x^(n) will be too large due to the excess nonparticipation.

The Proposition suggests an indirect test based on the fact that quantiles of distribution of bids among neighbors do not map to quantiles of signals when they are colluding.

Two Bidder Example

Consider n = 2.

The Proposition suggests that we compare

$E[V|\ B \le G_B^{-1}(x\text{^}(2);2),\ n = 2]$

$= E[V|\ B \le r,\ n = 2]$

$= (1/2)E[V] + (1/2)E[V|$ designated bidder does not bid$]$

$= (1/2)E[V] + (1/2)E[V|\ X \le x^*(1)]$

$= (E[V|X_i \le 1] + E[V|\ X_i \le x^*(1)])/2$

to

$E[V|\ B \le G_B^{-1}(x\text{^}(2);1),\ n = 1]$

$= E[V|\ X_i \le x\text{^}(2)]$

$= E[V|\ X_i \le (1+x^*(1))/2]$.

If n takes on additional values, the equality must hold at other weighted averages (i.e., using weights (1/n) and ((n-1)/n) as in the Proposition).

Finally, even if all these restrictions held, there would be no reason to expect the other two implications in the Proposition to hold.

Affiliated Participation and Bids

Under competitive neighbor bidding, neighbor bids are affiliated, and so are neighbor participation decisions, conditional on n.

Under collusion with no phantom bids, neighbor participation rates are negatively correlated for any $n > 1$:

$\Pr\{B_i \geq r | B_j \geq r, n\} < \Pr\{B_i \geq r | n\} < \Pr\{B_i \geq r | B_j \leq r, n\}$

Similarly, participation is affiliated with ex post value under competition.

E.g., $\Pr\{B_i \geq r, B_j \geq r | V\}$ is

(i) increasing in V under competition, but

(ii) invariant to V if cartels are inclusive and submit no phantom bids.

Missing Winners' Curse

Idea: colluding neighbors don't worry about outbidding other neighbors, so winner's curse effect is missing.

Proposition: Under the exogeneity assumption, v(x;n) decreases in n.

This can, at least in principle, be tested using bids and the first-order condition, or directly from ex post values and bids using

$$v(x;n) = E[V|\ B = \beta(x;n),\ M = \beta(x;n),\ n]$$

$$= E[V|\ B = G_B^{-1}(x;n),\ M = G^{-1}(x;n),\ n].$$

In either case, this is similar to Haile, Hong & Shum (2003), but with the presumption of common values, so that failure to find the winner's curse is interpreted as evidence of collusion.

In the designated bidder model, v(x;n) is invariant to n.

With information pooling, conjecture that the average of v(x;n) over a fixed range of quantiles (x′,1) would be increasing in n, since signals are better predictors of V.

Remarks

The benefit of allowing firms to collude in exploration is greater efficiency: lower search costs, and all tracts with positive expected value are explored.

If 3-D signals are relatively informative, the social gains from more than one firm investing in a survey may be low.

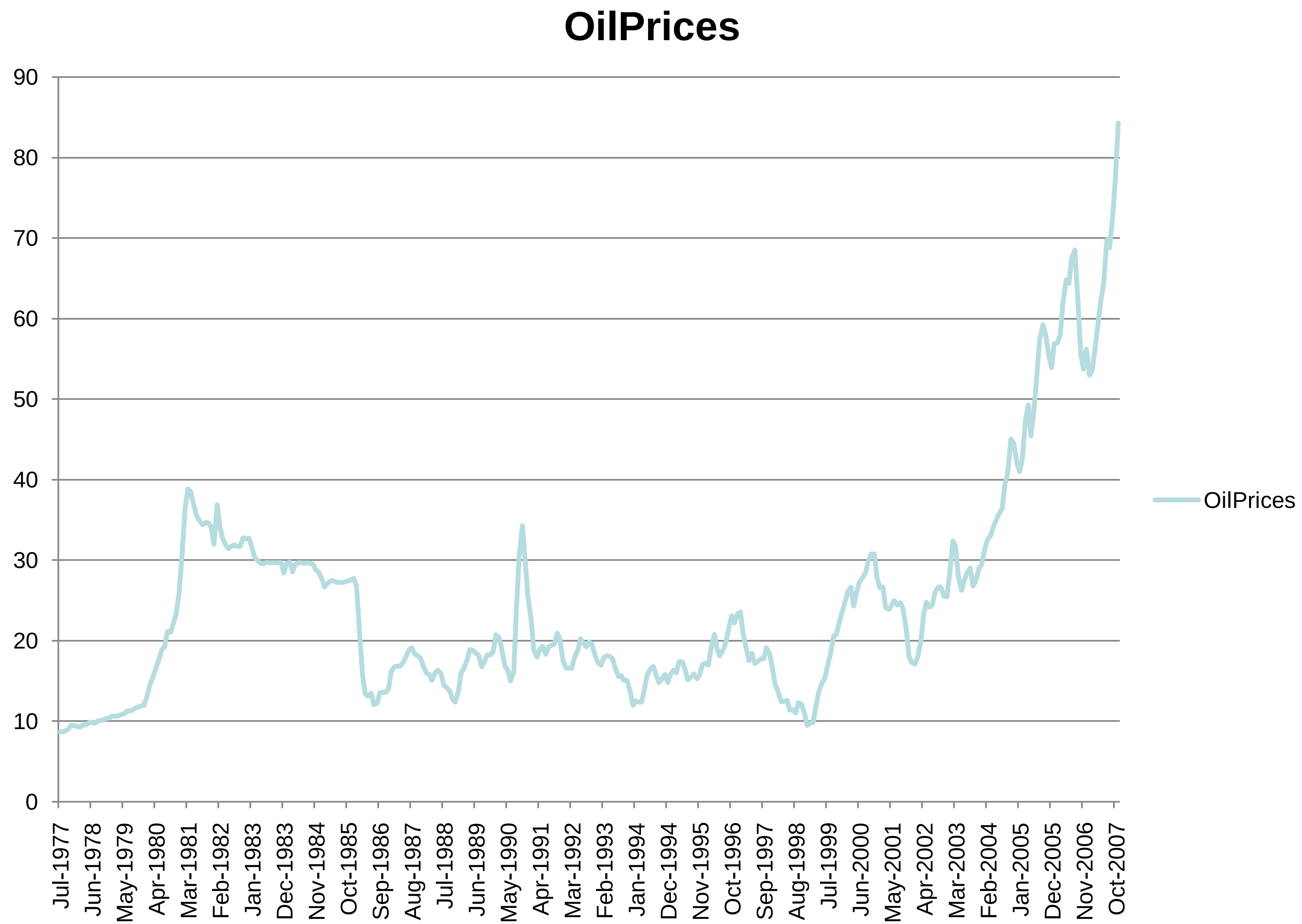
Then coordination leads to more tracts being explored and more production.

The cost to the government is reduced revenues from less competition.

But, if tracts are marginal, the foregone revenues are likely to be small.

Then auctions may be a poor mechanism for allocating production rights, e.g., a more efficient mechanism may select via royalty rates.

But royalties distort exploration and production at the margin.



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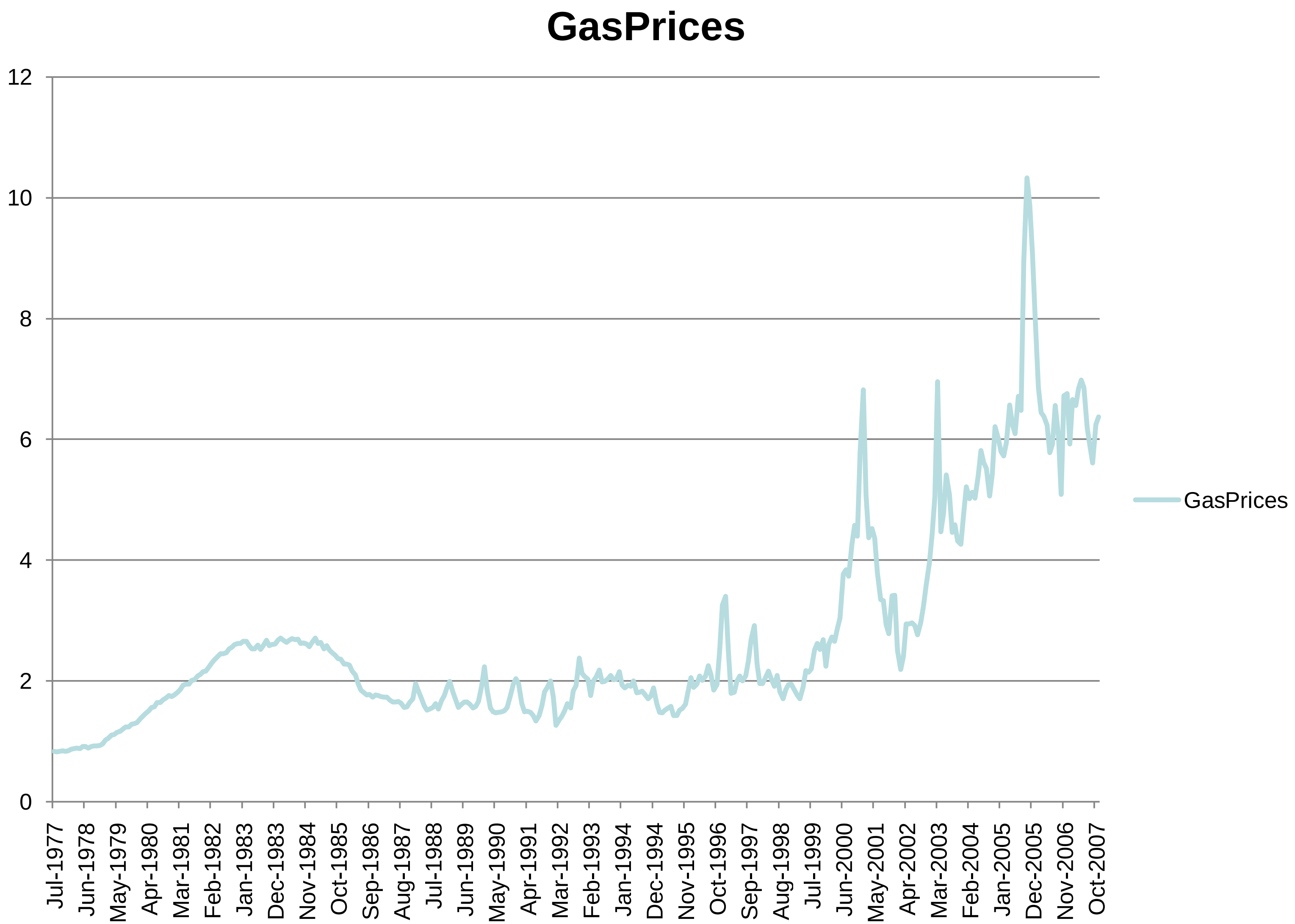
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