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Abstract

A prior model of competitive bidding for offshore petroleum leases is subjected to more extensive empirical testing based on underlying geological data prepared by the US Geological Survey. The current results strongly reinforce the tentative conclusions advanced in the previous paper, and demonstrate the robustness of the model. In light of the current results, it seems very likely that participants in offshore lease sales behave as if their operations were physically constrained such that only a limited volume of petroleum reserves are pursued in any one sale.

# FURTHER RESULTS ON EQUILIBRIUM PATTERNS OF COMPETITION IN OCS LEASE SALES

## I. Introduction

Previous studies have examined factors that influence the degree of competition in the auction market for outer continental shelf (OCS) petroleum leases. In general, these studies concur in finding that the underlying "quality" or economic potential of an offered tract is a primary determinant of the number of bidders it will draw. For example, Gaskins and Teisberg [1976] present a game-theoretic model in which the equilibrium number of bidders for an individual tract is determined directly as a function of the tract's inherent value. The bidding models of Rothkopf [1969] and Wilson [1977] are consistent with this result. At the empirical level, studies by the U.S. Geological Survey [1978] and Gribbin et. al. [1979] demonstrate that the number of bidders for individual tracts is highly correlated with many widely varied measures of perceived tract quality.

Although the studies cited above focus on the degree of competition to obtain a single tract, we have previously demonstrated (Smith [1982]) how their approach can be extended to characterize the spatial distribution of bids when multiple tracts are offered simultaneously. The intuition is simple. When several tracts are offered simultaneously, a bidder will generally not be indifferent regarding the choice of specific tracts on which to bid. For example, a large and promising geological structure which underlies a tract may offer the potential for considerable profit, and thereby attract many bidders. However, we do not expect less promising tracts to be neglected entirely, because alert firms would

recognize that against no competition even lower quality properties can be acquired on a profitable basis. Thus, it seems reasonable to expect a pattern of competition to develop that equalizes expected profit opportunities among all offered tracts and render potential bidders indifferent regarding the tracts on which they bid. Any spatial distribution of bids that does not equalize expected profit opportunities cannot be in equilibrium since participating firms would have an incentive to redirect their bids.

In the previous paper we developed a theoretical model of the auction market that embodies this intuition. The model is consistent with previous studies in that variations in the degree of competition across tracts are directly related to variations in inherent economic value. However, the equilibrium distribution of bids is also influenced by structural characteristics of the market itself. Specifically, the extent of variations in the degree of competition across tracts is damped somewhat if auction participants are constrained by physical limitations on the volume of petroleum reserves which they can pursue at one time; and damped completely if auction participants are constrained by financial limitations on the amount of money they can expose at any one time. Variations in the degree of competition across tracts were shown to be greatest if the auction participants were subject to no bidding constraints, apart from the general objective to maximize expected profits. The distinctive implications that devolve from the three behavioral assumptions (unconstrained bidding, physically constrained bidding, and financially constrained bidding) can then be used to judge which behavioral assumption is most consistent with observed bidding patterns.

Using data available in the public domain, we demonstrated previously that the assumption of financially constrained bidding can be rejected quite strongly. Using a much smaller data set (59 tracts taken from two OCS sales) made available to the author by a major U.S. oil company, we also showed that the hypothesis of unconstrained bidding can be rejected in favor of the alternative hypothesis of physically constrained bidding. In the present paper, we present new results which strongly reinforce these conclusions on the basis of a much broader data set provided by the U.S. Geological Survey (657 tracts taken from seven OCS sales). Our new results are significant not only because they are based on a more complete sample, but also because they are based on underlying geological data prepared by a separate source.

## 2. Review of the Model

We assume that T distinct tracts are auctioned simultaneously, and that these tracts constitute independent investment opportunities. The $t^{th}$ tract is characterized by its expected petroleum reserve volume, $R_t$, and expected net economic value $V_t$; where:

$$(1) \qquad V_t = \alpha \cdot R_t^{\varepsilon} \qquad \text{for } t = 1,\ldots,T.$$

Parameter $\varepsilon$ is an index of scale economies in reserve development. Its value must exceed unity since it is known that a greater deposit size enhances the net economic value of each unit of reserves.

The number of competitors for the $t^{th}$ tract is denoted by $n_t$, and the expected value of the winning bid by $B_t(n_t)$; where:

$$(2) \qquad B_t(n_t) = \frac{n - \gamma}{n} \cdot V_t \qquad \text{for } t=1,\ldots,T.$$

Parameter $\gamma$ represents an arbitrary constant (cf. Smith [1982]).

Under these assumptions, we can write explicitly the necessary condition for an unconstrained competitive equilibrium:

$$(3) \qquad \frac{n_i}{n_j} = \left[\frac{R_i}{R_j}\right]^{\varepsilon/2} \qquad \text{for all i and j.}$$

Similarly, the condition for a physically constrained equilibrium is:

$$(4) \qquad \frac{n_i}{n_j} = \left[\frac{R_i}{R_j}\right]^{(\varepsilon-1)/2} \qquad \text{for all i and j.}$$

Given data regarding the number of bidders and volume of reserves associated with respective tracts, Equations (3) and (4) provide alternative estimates of the scale parameter, $\varepsilon$. The estimates are derived as follows. First estimate the simple linear model:

$$(5) \qquad \ln(n_i/n_j) = \hat{\beta} \cdot \ln(R_i/R_j).$$

The hypothesis of unconstrained bidding then implies the following estimate of scale economies: $\hat{\varepsilon}_u = 2 \cdot \hat{\beta}$. The hypothesis of physically constrained bidding implies a somewhat different estimate: $\hat{\varepsilon}_c = 2 \cdot \hat{\beta} + 1$. The plausibility of the alternative hypotheses can then be judged in terms of their respective implications regarding the magnitude of economies of scale, about which we do have some prior information. Specifically, we would reject any hypothesis that implies an estimate of $\varepsilon$ that is significantly less than 1.

## 3. The Data

The model is implemented in the manner reported previously (Smith [1982]). Data regarding number of bidders per tract are taken from the U.S. Geological Survey [1978a]. Estimates of the volume of reserves (oil plus gas equivalent) underlying each tract were also provided to the author by the U.S. Geological Survey. These data reflect the best estimates, as of the date of sale, of the recoverable reserves underlying each tract. Specific tracts and lease sales included in the analysis are recorded in Table 1.

TABLE 1

DESCRIPTION OF THE DATA SET

| OCS Sale Number | Date | Location | Number of Tracts Receiving Bids | Number of Tracts Included in Study* |
|---|---|---|---|---|
| 33 | 03/28/74 | Louisiana | 114 | 103 |
| 34 | 05/29/74 | South Texas | 123 | 111 |
| 35 | 12/11/75 | South California | 70 | 61 |
| 36 | 10/16/74 | Louisiana | 157 | 115 |
| 37 | 02/04/75 | South Texas | 143 | 110 |
| 39 | 04/13/76 | Alaska | 81 | 69 |
| 40 | 08/17/76 | Mid-Atlantic | 101 | 88 |

*Only tracts for which petroleum reserve data were not available have been excluded from the analysis.

## 4. Results

Estimates of the scale parameter ($\varepsilon$) derived by the procedure described above are reported in Table 2. We can summarize the results by saying that the data strongly favor the hypothesis of physically constrained bidding and completely reject the hypothesis of unconstrained bidding. Under the hypothesis of physically constrained bidding, the implied estimates of $\varepsilon$ are significantly greater than 1.0 at the 90%

confidence level (one-tailed test) in five of seven sales. For the other two sales, the estimates of $\varepsilon$ are close to, but insignificantly different than 1.

TABLE 2

ESTIMATES OF THE SCALE PARAMETER

| | | Estimated Returns to Scale ($\varepsilon$) (standard errors in parentheses) | |
|---|---|---|---|
| | $\hat{\beta}$ | Unconstrained ($\hat{\varepsilon}_u$) | Constrained ($\hat{\varepsilon}_c$) |
| Sale 33 | 0.189<br>(0.065) | 0.379<br>(0.130) | 1.379<br>(0.130) |
| Sale 34 | 0.104<br>(0.058) | 0.209<br>(0.117) | 1.209<br>(0.117) |
| Sale 35 | 0.080<br>(0.055) | 0.160<br>(0.110) | 1.160<br>(0.110) |
| Sale 36 | -0.017<br>(0.042) | -0.034<br>(0.085) | 0.966<br>(0.085) |
| Sale 37 | 0.048<br>(0.056) | 0.096<br>(0.113) | 1.096<br>(0.113) |
| Sale 39 | 0.275<br>(0.055) | 0.551<br>(0.110) | 1.551<br>(0.110) |
| Sale 40 | 0.401<br>(0.241) | 0.803<br>(0.482) | 1.803<br>(0.482) |
| All Sales (pooled) | 0.156<br>(0.035) | 0.312<br>(0.071) | 1.312<br>(0.071) |

Estimates of $\varepsilon$ derived under the hypothesis of unconstrained bidding behave quite differently. All of these estimates are significantly less than 1.0, with the exception of sale #40 where the estimated value is still appreciably less than 1.0 in magnitude, but with a large standard error.

In order to obtain a comprehensive test of the alternative hypotheses, data from all seven sales were pooled to form a single data set. Equation (5) was then re-estimated on the basis of pooled data, with results as shown at the bottom of Table 2. Again, the hypothesis of unconstrained bidding is strongly rejected ($\hat{\varepsilon} = .312$), while the hypothesis of constrained bidding yields an estimate of $\varepsilon$ that is quite plausible ($\hat{\varepsilon} = 1.312$). Thus, the behavior of the estimating equation is quite consistent across all sales and conforms very closely to the results reported in the previous paper (Smith [1982]).

## 5. Conclusions

The model discussed above appears to be quite stable and robust. It has been tested against bidding patterns in seven OCS lease sales using two independent sources of petroleum reserve data. The results are consistent across sales and invariant to the choice of data source. The tentative conclusion advanced in the previous paper is strengthened considerably in light of this analysis. It now seems very likely that participants in OCS sales behave as if their operations were physically constrained such that only a limited volume of reserves can be pursued in any one sale. Such constraints might arise, for example, if firms attempted to maintain targeted reserve inventory levels, or if they are constrained by limited geological and managerial staff available to appraise offshore prospects and formulate appropriate bids. Subject to constraints of this type, bidding behavior does appear to be consistent with the principle of expected profit maximization. At least these assumptions yield an estimated scale parameter that is

plausible. This much cannot be said for the alternative behavioral assumptions that were examined in this and the previous paper.

The significance of these results for public leasing policy is quite clear. The Secretary of Interior has recently announced a rapidly accelerated schedule of lease sales that would open vast amounts of acreage for leasing and confront industry with an unprecedented number of OCS tracts. Numerous objections have been raised to this plan, motivated primarily by environmental concerns and the fear that capital requirements necessitated by accelerated leasing would exceed the industry's ability to raise money. Our results do not support the argument that capital constraints have bound firms' actions in the past, although it is clear that under an accerlerated leasing schedule future capital requirements would be larger than those experienced previously. Our results do raise a separate concern, however, that the industry may be constrained in its pursuit of tracts by physical or operating factors that restrict the total volume of petroleum reserves that can enter the exploration and development process within a relatively short period of time.

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