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Joint Bidding, Information Pooling, and the Performance of Petroleum Lease Auctions

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ABSTRACT

This paper uses a game-theoretic bidding model to examine the effect of joint bidding in offshore petroleum lease auctions. While previous research on the costs and benefits of joint bidding has been inconclusive, we show that joint bidding increases both the efficiency and the equity of petroleum tract auctions. These results follow from the fact that pooling of information concerning a priori unknown tract values allows for more accurate estimates. The anti-competitive effect of a reduced number of bidders is more than offset by the well-known fact that better informed participants bid more aggressively. Our findings are even more striking in that the model abstracts entirely from the effects of increased entry and greater risk diversification, the two common arguments in support of joint bidding.

1. Introduction

Since the oil price revolution of 1973-74, auction procedures and bidding practices in the market for offshore petroleum tracts have become the subject of widespread interest and debate. The market for offshore tracts effects a transfer of public mineral resources to the private sector. Design of the transfer mechanism poses a public policy problem that is twofold. First, it is important to design a transfer scheme that achieves allocative efficiency, as measured by the extent to which "profitable" tracts are identified and exploited by industry. Second, it is important that the scheme be regarded as equitable, in the sense that the government receive fair market value in exchange for all resources given over to industry. There is no guarantee, of course, that these dual objectives will always be compatible. For example, it is easy to imagine provisions for extracting fair market value that would distort subsequent development and production decisions, and thereby diminish the value of the underlying resources. In this light, economists have extended the literature on competitive auctions to evaluate the performance of alternative bidding formats (see, for example, Reece [1978] and Ramsey [1980]).

The present paper examines the effect of joint bidding on the two policy objectives mentioned above. Joint bidding occurs whenever two or more independent firms form a joint venture and submit a single bid. For many years this practice has been a common, but controversial, feature of the market for offshore tracts. The major policy concern is that joint bidding might be used to reduce or eliminate competition from the marketplace, which would have a negative impact on market prices and government revenue. This concern is mitigated by the realization that joint bidding also serves as a vehicle for entry of small firms that would otherwise be excluded from the market. Moreover, joint bidding facilitates the diversification of risk, which reduces the cost of capital and enhances the value of offshore tracts. Whether these positive factors outweigh the negative aspects of joint bidding has been a question of continuing debate among economists and policymakers alike.

Although several studies have discussed the pros and cons of joint bidding in qualitative terms (Mead [1967], Gaskins and Vann [1976], Wilcox [1974]), no study has succeeded in measuring and weighing the relative costs and benefits, or to quantify the net effect of joint bidding on the outcome of the auction.[1] As a result, the debate regarded joint bidding remains inconclusive and policymakers have adopted an ambivalent position. Prior to 1976 no restrictions were placed on the formation of joint bidding ventures; since that time, however, joint bidding has been prohibited among a select group of large firms but permitted elsewhere.

In this paper we present new evidence regarding the net effect of joint bidding on market performance. By adapting a game-theoretic bidding model that is common to this literature, we are able to characterize equilibrium bidding strategies and expected market outcomes as a function of the extent of joint bidding. The results are striking. Very briefly, our results indicate that joint bidding enhances both the efficiency and equity of the market for offshore petroleum tracts. That is, joint bidding increases the economic value of offshore petroleum resources and the fraction of this value captured by government via the competitive bidding process.

The intuition behind these results centers on the information structure of the auction. Prior to bidding, each firm performs a "test" (e.g., geophysical research) that increases its knowledge of the tract's uncertain value. Formation of a joint bidding venture is tantamount to pooling the results of several independent tests, which further increases the stock of information on which the subsequent bid will be based.[2] There are two principal consequences both of which have a positive impact vis a vis the two policy objectives discussed earlier. First, bidders are able to more accurately identify worthwhile prospects; i.e., tracts for which the market value of reserves exceeds the cost of recovery (Reece [1978]). The implication is that the auction market is more efficient under a regime of joint bidding.[3] Second, as bidders become more knowledgeable regarding tract value they tend to bid more aggressively, thereby increasing the expected value of the winning bid in both absolute and relative terms (Matthews [1982]).

We illustrate these effects by presenting numerical results applicable to the market for offshore petroleum tracts. The results indicate that both government revenue and the value of offshore tracts to society at large increase under a regime of joint bidding. In addition, the percentage of submarginal tracts that draw bids decreases significantly under a regime of joint bidding.

These favorable results are especially compelling because they devolve from a model that abstracts entirely from the two most common arguments in favor of joint bidding. Specifically, our model assumes all bidders to be risk-neutral. Therefore joint bidding's potential for enhanced diversification of risk is not represented in the results summarized here. In addition, our model does not allow joint bidding to be used as a vehicle for market entry; thus the total number of participants in the auction is fixed. Consequently, the number of independent bidding entities decreases unambiguously under our regime of joint bidding due to the consolidation of potential rivals. Relaxing either of these model restrictions would produce even stronger evidence in favor of joint bidding.

2. The Model

The government leases offshore tracts in a first-price sealed bid auction. The tract is either awarded to the highest bidder at the stated price, or it remains unsold in the event that no bids are submitted. Following Wilson [1977] and Reece [1978], we model the auction as a noncooperative game with incomplete information.

The major assumptions of the model are as follows. There are n identical bidders competing for a single offshore oil tract. The *in situ* value of the petroleum reserve is a random variable (v) that follows a known lognormal probability density function represented by $h(v|\mu_v,\sigma_v)$, where μ_v and σ_v are the mean and standard deviation, respectively. The assumption of lognormality has been used by a number of previous authors in this area (e.g., Reece [1978]). *In situ* value is measured net of all recovery costs except the cost of exploratory drilling, which is assumed to be a known constant (fc). Thus, the net value of the tract (V) is given by the relation: $V = v - fc$.

Prior to the auction, each participant obtains an estimate(s) of *in situ* value.[4] The estimates are drawn from independent, identically distributed, and unbiased lognormal sampling distributions represented by the density function $g(s|\mu_s(v),\sigma_s(v))$, with cumulative distribution denoted as $G(s|v)$. Finally, each bidder is assumed to be risk neutral and to know the number (n) of participants in the auction.

Each participant is free to associate with others via the formation of joint bidding ventures. To illustrate the effect of varied degrees of cooperative action, the number of members in each joint venture is parameterized by the value m. Thus, the degree of joint bidding is assumed to be uniform throughout the industry, and the number of independent bidding entities that result is simply N, where $N = n/m$.[5] Values for parameter m may vary from 1 (the case of no joint bidding) to n (in which case all bidders belong to a single joint venture). The prevailing value of m is assumed to be known by all participants.

One effect of joint bidding is to reduce the number of potential competitors; this is, of course, the anti-competitive aspect. However, the act of joint bidding has the additional effect of changing the information structure of the auction. By pooling the information of its members, each joint venture acquires a vector of m independent and identically distributed value estimates ($\underline{s} = \{s_1,\ldots,s_m\}$) characterized by the following joint density function:

$$g_m = (\underline{s}|v) = \prod_{i=1}^{m} g(s_i|\mu_s(v),\sigma_s(v)).$$

Conditional on the hypothesized degree of joint bidding, the problem faced by each joint venture is to identify a bidding strategy, $b_N(\underline{s})$: $R^m \to R$, that maximizes expected profits:

$$(1) \qquad \int_{v=0}^{\infty} \int_{s_1=0}^{\infty} \cdots \int_{s_m=0}^{\infty} [v-fc-b_N(\underline{s})]\cdot F_N(b,v)\cdot g_m(\underline{s}|v)\,d\underline{s}\;dv;$$

where: $b_N(\underline{s})$ represents the bid entered when the consortia observes value estimates $\underline{s}$, and

$F_N(b,v)$ represents the probability of winning the lease when true value is v and bid b is submitted.

Solution for optimal bidding strategies based on Equation 1 is unduly complicated. The problem may be simplified by noting that the geometric mean of value estimates obtained by a joint venture (i.e., $\bar{s} = \prod_{i=1}^{m} s_i^{1/m}$) is a sufficient statistic for v. Thus, an equivalent problem for the joint venture is to identify a bidding strategy, $\bar{b}_N(\bar{s}):R \to R$, that determines the bid solely as a function of the geometric mean of the sample. Therefore, we can rewrite the problem without loss of generality as:

$$\text{(2)} \qquad \max_{\bar{b}_N(\bar{s})} : \int_{v=0}^{\infty} \int_{\bar{s}=0}^{\infty} [v-fc-\bar{b}_N(\bar{s})]\cdot F_N(b,v)\cdot \bar{g}(\bar{s}|v)\ d\bar{s}\ h(v)dv;$$

where: $\bar{g}(\bar{s}|v) = g(\bar{s}|\mu_s(v), \frac{\sigma_s(v)}{m})$, and

$$\bar{G}(\bar{s}|v) \int_{0}^{\bar{s}} \bar{g}(s|v)ds$$

The favorable effect of joint bidding should by now be apparent. The standard deviation of the joint venture's estimating process varies inversely with the number of members. Consequently, larger joint ventures are better able to estimate v, and to determine whether the tract is economic (i.e., $v-fc > 0$). The anti-competitive effects of joint bidding are equally clear. The act of bidding jointly reduces the number of independent competitors by $n(\frac{m-1}{m})$ relative to the case of solo bidding. To illustrate the net impact of these countervailing forces, it is necessary to investigate the outcome that results from such an auction, and the manner in which the outcome is affected by the hypothesized degree of joint bidding.

In order to examine expected auction outcomes, we adopt the equilibrium concept due to Nash. A Nash equilibrium strategy, $\overline{b}_N^*(\overline{s})$, is determined such that no individual bidder has an incentive to depart from $\overline{b}_N^*(\overline{s})$, given that all his rivals are using this strategy. In equilibrium, all bidders use identical strategies. Consequently, the function $F_N(b,v)$ is, in equilibrium, simply the probability that no competitor obtains a higher mean value estimate of <u>in situ</u> value:

$$(3) \qquad F_N(\overline{b}_N^*(\overline{s}),v) = \overline{G}(\overline{s}|v)^{N-1} \qquad \text{if } \overline{b} > 0$$

$$= 0 \qquad \text{otherwise.}$$

As shown by Wilson [1977], the equilibrium bidding strategy for each firm is determined from the first-order condition obtained by differentiating Equation 2 and making the substitution indicated by Equation 3. The resulting condition appears as follows

$$(4) \qquad \frac{d\ \overline{b}_N^*(\overline{s})}{ds} = \frac{\int_0^\infty [v-fc-\overline{b}_N^*(\overline{s})](N-1)\ G(\overline{s}|v)^{N-2} g(\overline{s}|v)\ell(v|\overline{s})dv}{\int_0^\infty G(\overline{s}|v)^{N-1}\ \ell(v|\overline{s})dv}$$

In Equation 4, $\ell(v|\overline{s})$ represents the conditional distribution of <u>in situ</u> value given the signal $\overline{s}$, as derived by Bayes theorem from $\overline{g}(\overline{s}|v)$ and $h(v)$.

Once the appropriate initial condition has been specified, Equation 4 can be integrated to determine a unique equilibrium bidding strategy function. Reece [1978] suggests that an appropriate initial condition is that each bidder shall tender a positive (i.e., non-zero) bid only if the expected profit from doing so is non-negative. This requires:

$$(5) \qquad \bar{b}_N^*(\bar{s}_0) = 0;$$

$$\text{where } \bar{s}_0 \text{ satisfies: } \int_0^\infty (v-fc)\cdot \bar{G}(\bar{s}_0|v)^{N-1}\cdot \ell(v|\bar{s}_0)dv = 0.$$

In principle, Equations 4 and 5 characterize completely the equilibrium bidding strategy for each firm. In practice, however, the equations do not permit a general analytic solution. Therefore the results that follow are based on particular numerical solutions obtained for specified values of the input parameters.

Before presenting any numerical results, it is necessary to define reasonable criteria for judging the outcome of the auction. Here we follow Reece [1978] quite closely. Maximum potential expected value (MPEV) of the tract to society is simply the expected net value of the tract computed under the assumption that fixed exploration costs are incurred if and only if the tract is economic:

$$(6) \qquad MPEV = \int_{fc}^\infty (v-fc)h(v)dv.$$

The expected fraction of MPEV captured by the industry (f_I) can be written as a function of the degree of joint bidding:

$$(7) \qquad f_I(m) = \frac{N\int_0^\infty \int_0^\infty [v-fc-\bar{b}_N^*(\bar{s})]F_N(b,v)\cdot g(\bar{s}|v)\cdot h(v)d\bar{s}\, dv}{MPEV}.$$

The expected fraction of MPEV captured by the government (f_G) is given by:

$$(8) \qquad f_G(m) = \frac{N\int_0^\infty \int_0^\infty \bar{b}_N^*(\bar{s})F_N(b,v)\bar{g}(\bar{s},v)h(v)d\bar{s}\, dv}{MPEV}.$$

Finally, the expected fraction of MPEV captured by society as a whole (f_S) is simply:

(9) $$f_S(m) = f_I(m) + f_G(m).$$

The reader should note that since there always exists some uncertainty regarding tract value, f_S can never reach 100 percent. However, as we demonstrate below the effect of joint bidding is to reduce uncertainty, thus causing f_S to increase. There are two mechanisms through which this occurs. First, the conditional probability that a tract will be leased, given that it is economic, varies directly with the degree of certainty regarding its value. Second, the conditional probability that a tract is economic, given that it is leased, also varies directly with the degree of certainty regarding its value. These results are due to Reece [1978], who showed the following:

(10) $$\text{Prob (leased} | \text{economic)} = \frac{\int_{fc}^{\infty} (1-\overline{G}(\overline{s}_0 | v)^N)\cdot h(v)dv}{1 - H(fc)}$$

(11) $$\text{Prob (economic} | \text{leased)} = \frac{\int_{fc}^{\infty} (1-\overline{G}(\overline{s}_0 | v)^N)\cdot h(v)dv}{\int_{0}^{\infty} (1-\overline{G}(\overline{s}_0 | v)^N)\cdot h(v)dv}$$

In the next section, we demonstrate the effects of joint bidding with illustrative calculations based on Equations 6 - 11. The hypothesized degree of joint bidding (m) will be varied parametrically in order to isolate its influence on the results.

3. Numerical Results

To realistically assess the quantitative impact of joint bidding on the outcome of the auction, it is necessary to choose realistic numerical values for all model parameters. Reece [1978] has developed a set of parameter values that approximate the environment of offshore petroleum leasing. Our results are based on Reece's parameter values because we feel they are a good approximation of real-world conditions, and because this allows comparisons of our results to Reece's findings. The specific parameter values employed are described below.

The lognormal distribution of tract value (v) is characterized by the expectation (μ_v) and variance (σ_v^2) of log v. These parameters are given respective values of 1.0 and 2.0 in the present study. Fixed development costs (fc) are determined, conditional on μ_v and σ_v^2, such that the probability that the tract is economic is 15 percent; i.e., fc satisfies the equation:

$$\int_{fc}^{\infty} h(v|\mu_v,\sigma_v) = 0.15.$$

The conditional estimating distribution g(s|v) is characterized by the expectation (μ_s) and variance (σ_s^2) of log s. Parameter σ_s^2 is alternately assigned the values 0.3, 0.6, 1.2, and 1.6, with the higher value being more appropriate to unexplored or "wildcat" regions. Given a value for σ_s^2, the value of μ_s is then determined exactly by the requirement that the conditional estimating distribution be unbiased (i.e., $\mu_s = \ln v - \sigma_s^2/2$).

The number of independent firms (n) is initially set at 20. The number of firms permitted to enter into a single joint venture (m) is varied to guarantee integer values of N, the number of distinct bidding entities. Thus, m varies over 1, 2, 4, 5 and 10 implying values of N = 20, 10, 5, 4 and 2 respectively.[6]

Table 1 shows how the expected division of economic rent between industry and government is affected by the degree of joint bidding. Four separate environments are considered (σ_s^2 = 0.3, 0.6, 1.2, and 1.6); these scenarios correspond to situations of decreasing precision in the value-estimating procedure available to individual participants. The degree of joint bidding is measured along the horizontal scale. The first column (with m = 1) corresponds to the well explored case where joint bidding is prohibited.[7] All table entries have been derived by solving Equations 4 and 6 - 9 with the assistance of numerical integration routines supplied by IMSL (International Mathematical and Statistical Libraries, Inc.).

Perhaps the most significant result in Table 1 is that, under all four cases, the expected value of the tract to society at large (f_S) increases directly with the degree of joint bidding. Because there are greater benefits to pooling information when the estimating procedure is less precise (i.e., high σ_s^2), the benefits of joint bidding become more pronounced in moving from case 1 to case 4. At one extreme (σ_s^2 = 1.6), joint bidding increases the total social value of the tract by 12.6% (cf. column 1 with column 4). At the other extreme (σ_s^2 = 0.3), joint bidding increases the total social value of the tract hardly at all.

Even when joint bidding exerts little influence on the total social value of the tract (e.g., case 1), it does significantly affect the

TABLE 1

Distribution of Rent with Joint Bidding
n = 20 for all cases

		N =	20	10	5	4	2
		m =	1	2	4	5	10
Case 1:	$\sigma_s^2 = 0.3$	f_G =	.853	.902	.919	.920	.903
		f_I =	.124	.090	.077	.076	.096
		f_s =	.977	.992	.996	.996	.999
Case 2:	$\sigma_s^2 = 0.6$	f_G =	.792	.860	.887	.890	.867
		f_I =	.161	.128	.105	.105	.129
		f_s =	.953	.988	.992	.995	.996
Case 3:	$\sigma_s^2 = 1.2$	f_G =	.717	.799	.844	.848	.821
		f_I =	.193	.171	.146	.144	.176
		f_s =	.910	.970	.990	.992	.997
Case 4:	$\sigma_s^2 = 1.6$	f_G =	.686	.769	.819	.825	.799
		f_I =	.199	.189	.167	.166	.198
		f_s =	.885	.958	.986	.991	.997

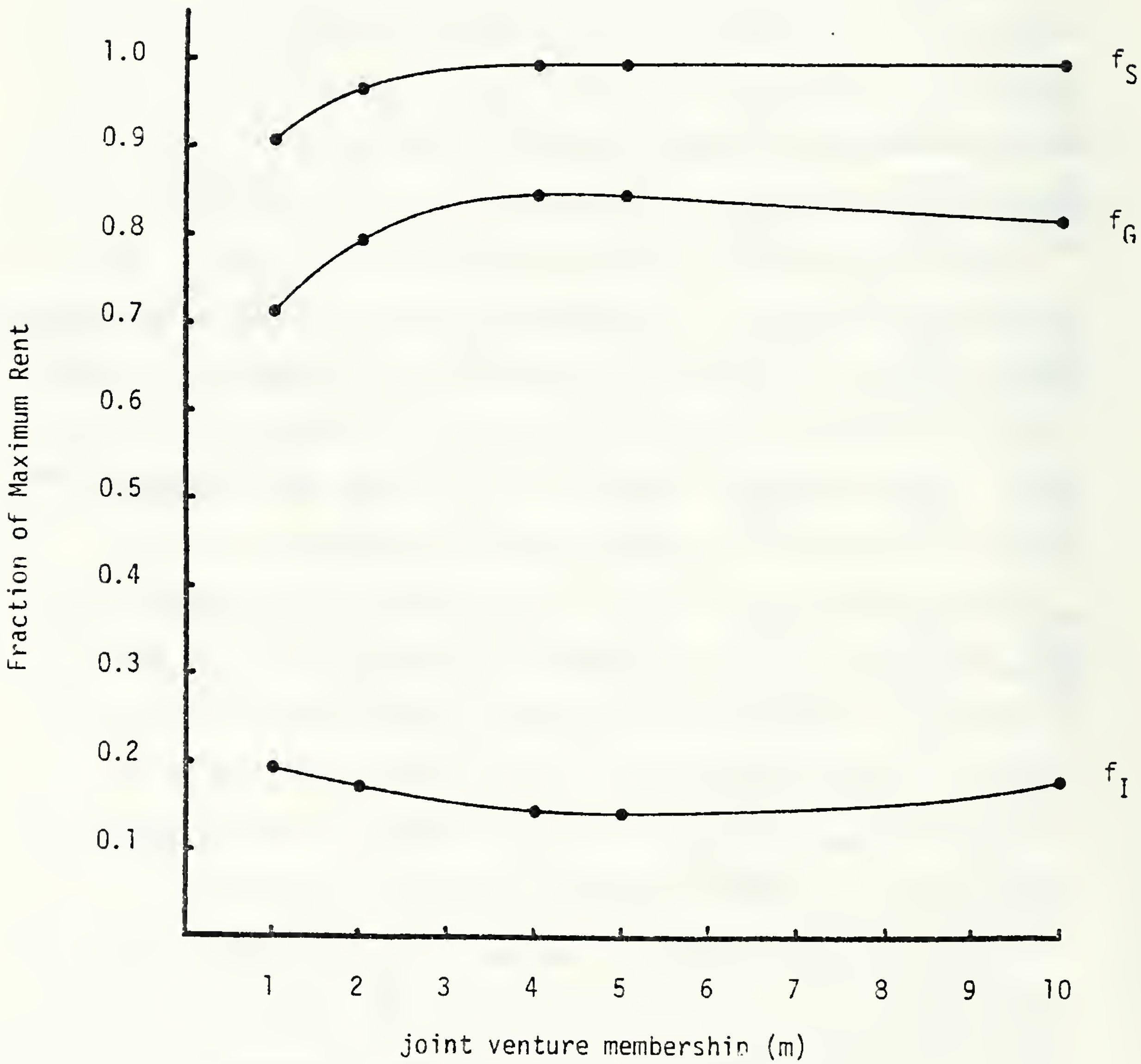
distribution of rent between industry and government. Generally speaking, the effect of joint bidding is to increase government's share at the expense of industry. It is apparent, however, that government revenues do not increase monotonically with the degree of joint bidding. For example, as joint venture membership grows from 5 to 10 (i.e., the number of independent bidding entities drops from 4 to 2), the anti-competitive effect of joint bidding begins to dominate and government share declines. However, it is important to note that even in the extreme case ($m = 10$) we see that expected government revenues exceed the level that would be obtained in the absence of joint bidding ($m = 1$), ceteris paribus.

Thus, we find that both the "size of the pie", f_S, and the share captured by the seller, f_G, increase when firms are allowed to enter joint bidding ventures. If one were interested solely in maximizing the share of the rent captured by government, it appears that some limit on the degree of joint bidding is called for. For all the cases represented in Table 1, the seller's revenue decreased as the number of venture partners increased from 5 to 10. It is clear that the well-known anti-competitive effect of a reduced number of competitors is quite strong in this range. However, the main point is clear; even when joint ventures are carried to the extreme and the industry is reduced to only two joint ventures, the rent to society as well as to the government is higher than in a situation where joint bidding is prohibited.

Figure 1 presents a graphical account of joint bidding's effect on the distribution of rent for the special case where $\sigma_s^2 = 1.2$. This is the case described by Reece [1978] as being most representative of frontier

FIGURE 1

Effect of Joint Bidding on Division of Rent



or wildcat offshore areas. It is instructive to note that Reece (1978) found that, ceteris paribus, decreasing the number of bidding entities caused the share of rent captured by industry to rise sharply while both the government's share and the total fraction captured by society dropped. By this point, the reason we find the opposite result should be obvious. In Reece's work, decreasing the number of competitors had only the anti-competitive effect on bids submitted. In the present context, this anticompetitive effect is more than offset by the fact that the bidders, although fewer in number, are better informed and act more aggressively.

Table 2 presents results that indicate the impact of joint bidding on the allocative efficiency of the auction. As in table 1, as the degree of joint bidding increases (reading left to right), favorable effects on the efficiency of the auction are experienced. These results are also plotted in Figures 2 and 3 in order to provide additional insight regarding the mechanism by which joint bidding enhances tract value and government revenues. In Figure 2 we have plotted the conditional probability that the tract will be leased, given that it is economic.[8] Better informed bidders are less likely to overlook such tracts; therefore, the probability of receiving at least one bid increases with the degree of joint bidding. As shown in the diagram, the quantitative impact of this effect can be substantial. In Figure 3 we have plotted the conditional probability that the tract is economic, given that it has received at least one bid. Again, the quantitative impact of joint bidding appears to be substantial. Joint bidders are better informed bidders, and this translates into fewer mistakes in identifying worthy offshore prospects.

TABLE 2

Effects of Joint Bidding on Tract Exploitation

P(E|L) = Probability that a Tract is Economic Given that it is Leased

P(L|E) = Probability that a Tract is Leased Given that it is Economic

		N =	20	10	5	4	2
		m =	1	2	4	5	10
Case 1:	$\sigma_s^2 = 0.3$	P(E|L) =	.870	.928	.959	.966	.980
		P(L|E) =	.879	.932	.961	.967	.982
Case 2:	$\sigma_s^2 = 0.6$	P(E|L) =	.813	.897	.945	.953	.972
		P(L|E) =	.836	.904	.942	.954	.980
Case 3:	$\sigma_s^2 = 1.2$	P(E|L) =	.737	.853	.918	.931	.960
		P(L|E) =	.779	.867	.922	.934	.961
Case 4:	$\sigma_s^2 = 1.6$	P(E|L) =	.699	.830	.904	.920	.954
		P(L|E) =	.751	.849	.911	.925	.955

FIGURE 2

Conditional Probability that an Economic Tract will be Leased

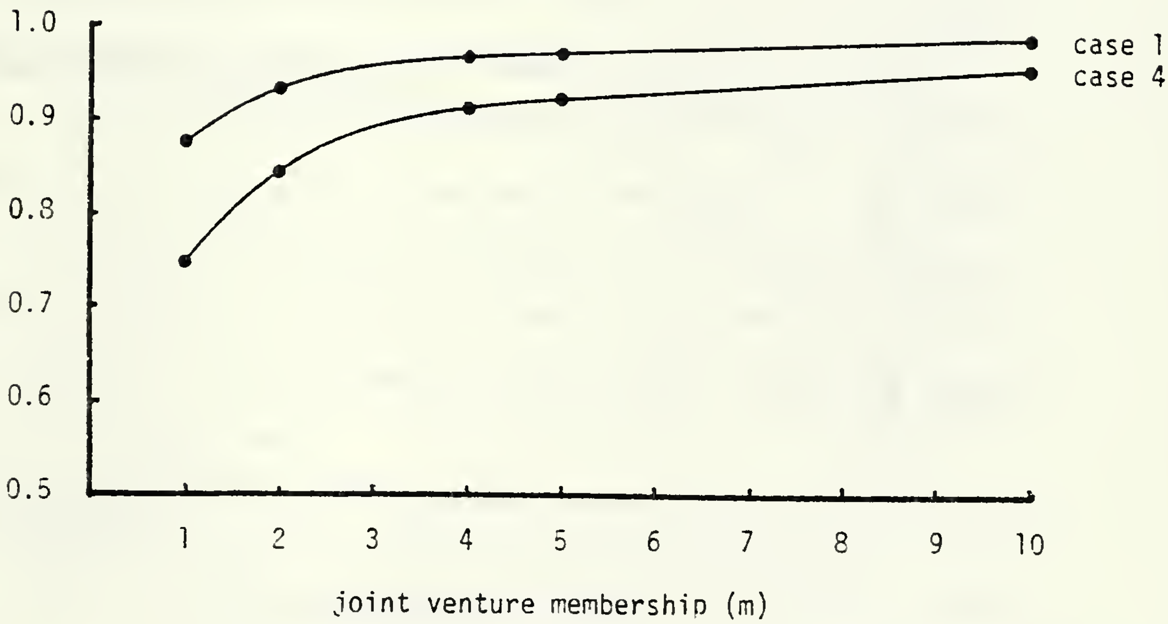
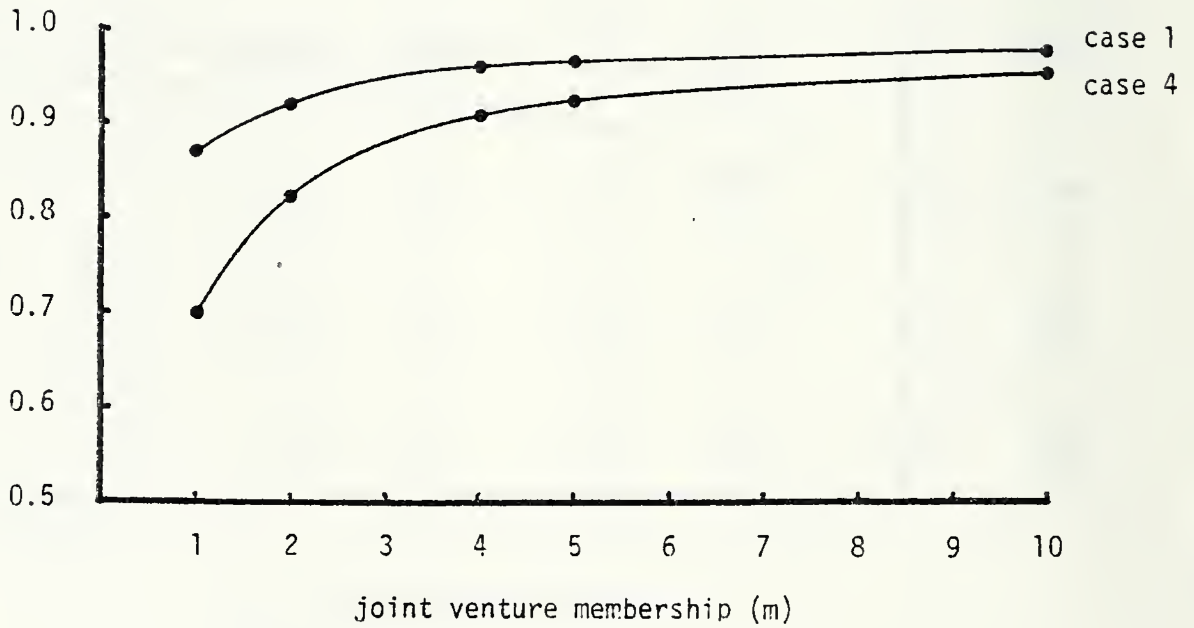


FIGURE 3

Conditional Probability that a Leased Tract will be Economic



Before turning to the conclusion, it is important to note some casual empirical verification of the positive effects of joint bidding described in this paper. Of all offshore petroleum tracts auctioned prior to 1970, 37% eventually reached production. However, when the tracts are broken down into those won by joint bidding ventures and those won by solo bidders, the relevant percentages are 44% and 35%, respectively.[9] These figures support the hypothesis that joint bidding results in more efficient identification and exploitation of the available (but a priori unknown) resource.

Additionally, Zimmerman and Merewitz (1974) provide further evidence as to the efficiency of joint bidding. In their study of cost overruns in the construction of the Bay Area Rapid Transit system, they found that cost overruns (as a percentage of contract bids) were significantly smaller when joint bidding ventures were involved. In fact, they found that the percentage of cost overrun declined with increasing membership in the joint venture. This is as the present model predicts; the addition of members to the joint venture implies better information and more efficient outcomes.

4. Conclusions

Previous research on the effects of joint bidding has left considerable doubt and uncertainty regarding the net impact of this controversial practice. Positive and negative aspects are widely cataloged in the literature, but there has been little analysis of the inherent tradeoffs between the two. As a result, policymakers maintain an ambivalent stance vis a vis joint bidding.

The present paper attempts to extend our understanding of joint bidding by the use of a model that explicitly incorporates both positive and negative aspects. Analysis of the model reveals that joint bidding facilitates the exchange of proprietary information and reduces the level of uncertainty that impinges on the market for offshore tracts. The end result is more efficient exploitation of the potential resources and a more equitable distribution of available economic rents. Although certain anti-competitive effects devolve from joint bidding due to the consolidation of potential rivals, our analysis shows that they do not dominate in the final market outcome. Significantly, our favorable conclusions regarding joint bidding would be strengthened considerably if we also took into account the probable benefits from increased entry and diversification of risk that are associated with joint bidding.

The major policy conclusion to emerge from this study is that the benefits from joint bidding are substantial and not confined only to the case of small firms. Whereas previous authors (e.g., Wilcox [1974] and Mead [1967]) have suggested that large firms may not benefit appreciably from the enhanced potential for market entry and diversification that joint bidding affords, it is clear from our analysis that society at large benefits significantly from joint bidding, whether the participants be small firms or large. The fraction of total available rent captured by society increases monotonically with the degree of joint bidding, provided only that all firms do not collapse into a single monopsonistic bidder.

FOOTNOTES

[1]Wilcox, Mead, and Gaskins and Vann all suggest that since major oil companies are unlikely to benefit significantly from joint bidding's facility for entry and risk diversification, joint ventures between majors should be prohibited. As we later demonstrate, this argument neglects a major benefit of joint bidding.

[2]This point was first noted by Klein in his short but insightful discussion of joint bidding ventures. However, Klein's discussion stops short of considering the impact of information pooling on the outcome of a game-theoretic bidding model.

[3]In their Congressional testimony, Gaskins and Vann point out the potential significance of information pooling among joint venture partners. However, they consider only the adverse case where partners exchange information regarding intent to bid, somewhat akin to market allocation arrangements. The effect of pooling information regarding tract value estimates is neglected entirely.

[4]For example, this estimate can be obtained by performing a geophysical survey of the tract in question.

[5]Since firms are identical, the degree of joint bidding appropriate for one is appropriate for all. Consequently, the restriction to a uniform degree of joint bidding is made without loss of generality. However, an implicit constraint on m is that is be chosen to result in integer values of N.

[6]The value m = 20 (i.e., N = 1) is not included for the obvious reason; when a monopsony market structure prevails the non-cooperative bidding framework collapses.

[7]The reader will note that column one confirms previously published results which indicate that more information, ceteris paribus, leads to more aggressive bidding on the part of auction participants.

[8]Only case 1 ($\sigma_s^2 = .3$) and case 4 ($\sigma_s^2 = 1.6$) are depicted in figure 2. As is clear from the table, the intermediate cases fall between the two cases represented in the figure.

[9]These statistics are reported on page 86 of Gribbin et. al. [1979].

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