Resource information policy and federal resource leasing

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An important observation in recent studies of federal resource information policy is that there may be overinvestment in acquiring resource information by the private sector in federal resource leasing. One policy conclusion is that the federal government should provide information about the resource being leased. This article provides conditions under which it pays the government to provide resource information. It also briefly evaluates a policy alternative, namely, the use of a contingent reservation bid scheme to solve the problem of overinvestment in resource information.

1. Introduction

Recently, questions about resource information policy were raised in connection with the federal leasing of energy resources. These questions were inspired by statements that the federal government should provide more resource information about tracts to be leased. The first reason in favor of such a policy is that resource exploration and development are risky. An increase in the amount of public resource information will help to transfer risk from the energy developers to the government, which can bear risk more efficiently. The second reason is that overinvestment in resource information gathering is socially wasteful, and provision of public resource information will not only reduce socially wasteful investment in resource information but will attract more competition in the leasing of promising tracts. The purpose of this article is to shed light on the policy relevant question of whether the federal government should provide public information about resources, or more specifically, under what conditions the federal government should provide such information.

In Section 2, the policy question is studied in a game-theoretic framework. Several new and interesting results are derived. First, both pure strategy and mixed strategy Nash equilibria exist. Second, it is found that if the cost of information is the same to both the government and the energy developers, there exist conditions under which it pays the government to provide public resource information. Under the pure strategy Nash equilibrium, it always pays the government to provide public resource information. Under the mixed strategy Nash equilibrium, conditions under which it pays the government to provide public resource information are given. Three alternative statements of these conditions are provided. The most intuitive one is that if the cost of information to the government is less than the expected cost of information to the energy developers, then the government can capture the gains in efficiency by bearing the cost of information.

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and providing the information to the energy developers free of charge. Thus, if information is socially wasteful, public provision of information could be a second-best solution.

Third, it is shown that even if public provision of information is worthwhile to the federal government, an alternative policy exists. Namely, the government can implement a contingent reservation bid scheme to lease resource tracts. This scheme requires that the reservation bid on a resource tract depend on how many energy developers have information, and it has the effect of nullifying incentives to purchase private information. If however, private developers have already gathered information, a reservation bid may outbid all bidders and leave the resource tract inactive.

Finally, Section 3 summarizes the results of this article and provides a tentative statement on resource information policy in federal resource leasing.

2. Resource information and federal resource leasing

A simple model suffices to capture the most important aspects of resource information in federal resource leasing. Consider the leasing of a resource tract. The tract can take on one of two values, designated by \( V_H \) for a high value tract and \( V_L \) for a low value tract. The likelihood that the tract will take on the high value is given by a probability \( p \) and the likelihood of the low value by a probability \( 1 - p \). The subsequent cost of development is assumed to be less than \( V_L \), that is, the tract will be developed once it is leased. Thus, information is assumed to be socially wasteful.

Let there be two bidders interested in this particular tract. The probability values are public knowledge to the bidders. Suppose at a cost \( K > 0 \), bidders can acquire a piece of perfect information revealing the true value of the tract. Let

\[
p(1 - p)(V_H - V_L) > K.
\]  

(1)

This ensures that the piece of information has private value to the bidders. The reason for assuming this will be apparent later on. A rivalry situation is, therefore, created in the form of a two-stage game, à la Milgrom. The first stage involves the decision of each bidder with regard to information acquisition. The second stage involves the bidding decision of each bidder, given the information acquisition decisions of the bidders in the first stage.

Some additional assumptions are required. First, the decision choice of bidder \( i, i = 1, 2 \), is characterized by a triplet \( d_i = (K_i, b_i^H, b_i^L) \), where

\[
K_i = \begin{cases} 
K & \text{if information is purchased}, \\
0 & \text{otherwise};
\end{cases}
\]

\( b_i^H \) = bid on a tract if information indicates a high value;
\( b_i^L \) = bid on a tract if information indicates a low value.

The convention adopted for the case of no information acquisition is that \( b_i^H = b_i^L = b_i \). Second, for the moment, the seller is assumed to be passive, so that he does not provide public information, and pessimistic, so that his reservation bid is always set equal to \( V_L \).

Three cases are considered.

Case 1: Both bidders acquire the information: \( K_i = K, i = 1, 2 \). Since bidding is competitive, if the true value of the tract is revealed to be high, each bidder will bid \( V_H \). If one bidder bids less than \( V_H \), the other bidder can win the lease by bidding a small amount above that. It is obvious that no one will bid more than \( V_H \). Thus, the claim is proved. The same line of argument will lead to the conclusion that if the true value of the tract is revealed to be low, each bidder will bid \( V_L \). Thus, the equilibrium decision choice is \( d_i = (K, V_H, V_L), i = 1, 2 \). But then the expected profit for each bidder will be
\( \pi_i = -K < 0 \). Each bidder will sustain a loss equal to the cost of information. Define \( V_e = pV_H + (1 - p)V_L \). It is clear that the expected profit to the seller \( \pi_s \) is:

\[
\pi_s = V_e .
\]

(2)

Case 2: In this case, only one bidder acquires the resource information. Without loss of generality, let bidder one acquire the information. Suppose bidder two’s decision choice is
d_2 = (0, V_L, V_L).

Then bidder one’s decision choice ought to be
d_1 = (K, V_L + \epsilon, V_L),

where \( \epsilon \) is a very small positive number. However, bidder two’s response should be
d_2 = (0, V_L + \epsilon + \delta, V_L + \epsilon + \delta),

where \( \delta \) is another very small positive number. But then bidder one will have an incentive to raise his bid if the tract is of high value. Bidder two will either raise his bid and the process of outbidding one’s opponent continues, or bidder two will return to bid \( V_L \). Thus, there is no pure strategy Nash equilibrium for the bidding stage of the game. If the possibility of a mixed strategy is introduced, a Nash equilibrium exists for the bidding stage of the game. \(^1\) This equilibrium is given by:

d_1 = (K, F(b), V_L),

d_2 = (0, G(b), G(b)),

\(^1\) The author would like to thank Joel Sobel for suggesting this mixed strategy equilibrium. See also Wilson (1967), Waverbergh (1979), Milgrom (1981), and Engelbrecht-Wiggans and Weber (1979). We shall provide a straightforward demonstration of the equilibrium here. First, note that the expected profit maximization problem of an informed bidder is given by:

\[
\max_{F(\cdot)} \int\dot{V}_F \left[(V_H - b)G(b)\right]dF(b) - K,
\]

where \([V_F, \dot{V}_F]\) is the support of the probability distribution \(F(\cdot)\). The expected profit maximization problem of an uninformed bidder is given by:

\[
\max_{G(\cdot)} \int\dot{V}_G \left[p(V_H - b)F(b) + (1 - p)(V_L - b)\right]dG(b),
\]

where \([V_G, \dot{V}_G]\) is the support of the probability distribution \(G(\cdot)\). Second, with the following observation, the two control problems are easy to solve. In choosing a probability distribution, the informed bidder would put positive probability weight on only those values of \(b\) for which \((V_H - b)G(b)\) is greatest; similarly, the uninformed bidder would give positive probability weight to only those values of \(b\) for which \(p(V_H - b)F(b) + (1 - p)(V_L - b)\) is greatest. Let

\[
C_1 = \max_{\text{support of } G}(V_H - b)G(b), \quad \text{and}
\]

\[
C_2 = \max_{\text{support of } F}[p(V_H - b)F(b) + (1 - p)(V_L - b)].
\]

The value \( C_1 \) is attained by every \( b \) in the support of \( F \), and the value \( C_2 \) is attained by every \( b \) in the support of \( G \). Hence, it follows that the support of \( G \) is the same as the support of \( F \). Third, note that an uninformed bidder makes zero expected profit in bidding against an informed bidder. Therefore,

\[
C_2 = 0, \quad \text{and} \quad F(b) = \frac{(1 - p)(V_H - V_L)}{p(V_H - b)}.
\]

Together with the observations that \( F(V_F) = 0 \) and \( F(\dot{V}_F) = 1 \), we have \( V_G = V_F = V_L \) and \( V_F = \dot{V}_F = V_e \). Now \( G(\dot{V}_G) = G(V_e) = 1 \) implies \( C_1 = (1 - p)(V_H - V_L) \). Therefore,

\[
G(b) = \frac{(1 - p)(V_H - V_L)}{V_H - b}.
\]

This completes the proof.
where

\[ F(b) = \begin{cases} 
1 & \text{if } b > V_e \\
\frac{(1 - p)(b - V_L)}{p(V_H - b)} & \text{if } V_e \geq b > V_L \\
0 & \text{if } b \leq V_L
\end{cases} \]

and

\[ G(b) = \begin{cases} 
1 & \text{if } b > V_e \\
\frac{(1 - p)(V_H - V_L)}{V_H - b} & \text{if } V_e \geq b \geq V_L \\
0 & \text{if } b < V_L.
\end{cases} \]

Note that the informed bidder will only randomize his bid if the tract is found to be of high value, otherwise he will bid \( V_L \). Also note that no bidder will ever bid above \( V_e \). Last of all, note that \( F \) stochastically dominates \( G \). Thus, if the tract is valuable, the informed bidder will on average bid higher than the uninformed bidder. If the tract is poor, the uninformed bidder will consistently bid more than the informed bidder will. Thus, even though in equilibrium the uninformed bidder has a positive probability of winning a good tract, his expected profit remains zero. The expected profit of the informed bidder is \(^2\)

\[ \pi_i = p(1 - p)(V_H - V_L) - K. \]

The seller's expected profit is

\[ \pi_s = V_e - p(1 - p)(V_H - V_L). \quad (3) \]

\textit{Case 3:} Suppose neither bidder acquires the information. Then the two bidders will have identical equilibrium bids. If not, the higher bidder can lower his bid by a small amount and still win. Moreover, the equilibrium bid should be equal to \( V_e \). If both were to bid more than \( V_e \), each would have a negative expected profit, and it would pay one of the bidders to bid less. (To lose in the bidding and to make zero profit is a definite improvement in that event.) If the identical bid were less than \( V_e \), both bidders would have a positive expected profit. It would then pay one of the bidders to break the tie by bidding slightly higher, to win the bid, and to make a higher expected profit.

Thus, one concludes that the equilibrium decision choice of the two bidders is given by

\[ d_i = (0, V_e, V_e), \quad i = 1, 2. \]

\(^2\)Recall footnote 1. The informed bidder's profit function is given by

\[ \pi_i = p \int_{V_L}^{V_e} (V_H - b)G(b)dF(b) - K \]

\[ = (1 - p)(V_H - V_L)^2 \int_{V_L}^{V_e} \frac{1}{(V_H - b)^2} db - K \text{ by appropriate substitution} \]

\[ = p(1 - p)(V_H - V_L) - K. \]

The seller's expected profit is given by:

\[ \pi_s = p \int_{V_L}^{V_e} bG(b)dF(b) + \int_{V_L}^{V_e} [(1 - p)b + pbF(b)]dG(b) + (1 - p)V_LG(V_L). \]

The third term picks up the probability mass of \( G(\cdot) \) at \( V_L \). With appropriate substitution and simple but tedious calculus, we have

\[ \pi_s = V_e - p(1 - p)(V_H - V_L). \]
The expected profits of the bidders are zero. The seller’s expected profit is
\[ \pi_s = V_e. \] (4)

The results obtained so far are summarized in Table 1 in the form of a payoff matrix. The payoff matrix shows two asymmetric, nonequivalent and noninterchangeable pure strategy Nash equilibria for the information acquisition stage of the game. Without coordination, overinvestment in information acquisition may result.

The asymmetry can be removed by considering a mixed strategy Nash equilibrium. The mixed strategy Nash equilibrium is given by a pair of probabilities \((r, 1 - r)\), where \(r\) is the probability that a bidder will acquire information and \(1 - r\) is the probability that he will not. Note that
\[ r = 1 - \frac{K}{p(1-p)(V_H - V_L)} . \]

Thus the probability of overinvestment in information is \(1 - (1 - r)^2\), and the probability of zero investment in information is \((1 - r)^2\). Moreover, at a mixed strategy equilibrium of the information acquisition stage of the game, the expected profit of each bidder is zero. The seller’s expected profit is
\[ \pi_s = V_e - 2r(1 - r)p(1 - p)(V_H - V_L). \] (5)

Observing the possibility of overinvestment in information acquisition, one may hastily conclude that noncompetitive leasing is preferable to competitive leasing. This conclusion could be dubious for at least two reasons. First, in the analysis above, the seller is assumed to be passive. If the seller is not passive, he may provide the information to the two bidders free of charge. It is obvious that both bidders will make use of the free information, and their expected profits are zero. The expected profit of the seller is

**TABLE 1  Payoff Matrix of a Two-Stage Game of Information Acquisition and Bidding When the Seller Is Passive and Pessimistic**

<table>
<thead>
<tr>
<th>Bidder 1's Decision Choices</th>
<th>Acquires information</th>
<th>Does not acquire information</th>
</tr>
</thead>
<tbody>
<tr>
<td>Acquires information</td>
<td>((-K, -K))</td>
<td>((0, p(1 - p)(V_H - V_L) - K, 0))</td>
</tr>
<tr>
<td>Does not acquire information</td>
<td>((0, p(1 - p)(V_H - V_L) - K))</td>
<td>((0, 0))</td>
</tr>
</tbody>
</table>

3 A demonstration of the mixed strategy equilibrium of the information acquisition stage of the game is straightforward. Recall the payoff matrix in Table 1. Let bidder 2’s mixed strategy be represented by a probability value \(r\) and bidder 1’s mixed strategy by \(r'\). Bidder 1’s expected profit maximization problem is given by:

\[
\max_{r'} [-rK + (1 - r)[p(1 - p)(V_H - V_L) - K]] + (1 - r')\{0\}.
\]

We see that \(1 > r' > 0\) only if \(-rK + (1 - r)[p(1 - p)(V_H - V_L) - K] = 0\) or \(r = 1 - K/p(1 - p)(V_H - V_L)\). By symmetry \(r' = r\).

4 Recall equations (2), (3), and (4) in the text. The seller’s expected profit under the mixed strategy equilibrium of the information acquisition stage of the game is given by:

\[
\pi_s = r^2V_e + (1 - r)^2V_e + 2r(1 - r)[V_e - p(1 - p)(V_H - V_L)]
\]

\[
= V_e - 2r(1 - r)p(1 - p)(V_H - V_L).
\]

5 This is a policy position taken by Hughart (1976) for the case of zero information cost. For an analogous statement, see Milgrom and Weber (1981). But it is shown later on in this article that this statement is not necessarily true if information is costly.
\[ \pi_s = V_e - K, \quad (6) \]

which could be greater than his expected profit in the private information case.

Consider the pure strategy Nash equilibrium of the information acquisition stage of the game. Recall from (3) that in this case the seller's expected profit is \[ \pi_s = V_e - p(1 - p)(V_H - V_L). \] From (1)—the assumption that information has private value to the bidders—it follows that this level of profit is clearly less than that in (6), the expected profit in the public information case. Thus, it always pays the seller to provide public information in the pure strategy Nash equilibrium case when the cost of information is the same to the bidders and the seller.

Now consider the mixed strategy Nash equilibrium of the information acquisition stage of the game. Comparing (5) and (6), we see that making the information public will yield the higher expected profit for the seller if \[ K < 2r(1 - r)(p(1 - p)(V_H - V_L)). \] The economic intuition behind this condition is as follows. Since information is socially wasteful, the bidding game is, in essence, a zero-sum game. Thus, gains to bidders are losses to the seller. Recall Table 1. Bidders can make positive profits only when there is one informed bidder. The expected revenue of the informed bidder is \[ p(1 - p)(V_H - V_L). \] The probability that there is only one informed bidder is given by \[ 2r(1 - r). \] Hence, in considering the provision of public information, the seller should ask whether the cost of information is less than the expected bonus bid loss of the seller due to the presence of a single informed bidder. (This expected bonus bid loss of the seller is equal to the expected revenue of a single informed bidder which is equal to \[ 2r(1 - r)p(1 - p) \times (V_H - V_L). \]) If the answer is yes, then by providing public information the seller can capture the expected revenue of an informed bidder. This is the first statement of the public information condition.

The second statement of the public information condition is \[ K < p(1 - p) \times (V_H - V_L) - K. \] Note that the right-hand side of the inequality is the expected profit of an informed bidder if he is the only informed bidder. Thus, the condition restated is simply that the seller should ask whether the cost of information is less than the profit he can capture from a single informed bidder.

The third statement of the public information condition is \[ K < 2rK. \] This statement of the public information condition is an efficiency criterion statement. It asks whether the information cost to the seller is less than the joint expected information cost of the two bidders. If the answer is positive, then it pays the seller to provide public information because the seller can reap the gains in efficiency.

Thus, a conclusion can be drawn. If the reservation bid is set at the low value, and if the bidders and the seller face the same information cost, it always pays the seller to provide public information in the pure strategy Nash equilibrium case. In the mixed strategy Nash equilibrium case, there exist conditions under which it pays the seller to provide public information. Overinvestment in information is reduced to a certain degree. A second-best solution is attained.

The public information conditions can be generalized to the case where bidders and sellers face different information costs. Let \( K_i \) be the information cost to bidder \( i, i = 1, 2 \). Let \( K_s \) be the information cost to the seller. Consider a special case:

\[ K_i < K_s < p(1 - p)(V_H - V_L), \quad i = 1, 2 \]

so that both bidders have an incentive to purchase the piece of information. In the pure strategy Nash equilibrium case, it pays the seller to provide public information. The

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6 Substitute \( r = 1 - K/p(1 - p)(V_H - V_L) \) into the first statement of the public information condition and rearrange terms.

7 Lee (1981) shows that the third statement of the public information condition obtains even if the bidders have to submit bids without knowing with certainty whether their opponents are informed.
interesting fact about this special case is that the cost of information to the seller is higher than that of either bidder.

Consider the mixed strategy Nash equilibrium case. Let \( r_i \) be the probability that bidder \( i \) will acquire information, \( i = 1, 2 \). The first statement of the public information condition can be generalized to

\[
K_s < \sum_{i=1,2} r_i (1 - r_i) p (1 - p) (V_H - V_L).
\]

The second statement of the public information condition can be generalized to

\[
\frac{K_i}{\prod_{i=1,2} (1 - r_i)} < \sum_{i=1,2} p (1 - p) (V_H - V_L) - K_i \left(1 - r_j\right).
\]

The third statement of the public information condition can be generalized to

\[
K_s < \sum_{i=1,2} r_i K_i.
\]

There is a second reason that the suggestion of using noncompetitive leasing in place of competitive leasing could be of dubious value. Namely, the analysis giving rise to the suggestion assumed that the seller was pessimistic. If the seller is not pessimistic, he may implement a contingent reservation bid scheme as follows. The seller sets the reservation bid at \( V_H - K/p \) when there is only one informed bidder and at \( V_L \) otherwise. In that event, the decision choice of the informed bidder becomes

\[
d = \left( K, \frac{V_H - K}{p}, V_L \right).
\]

The expected profit of the informed bidder is then zero. The payoff matrix of the two-stage game is then reduced to Table 2. In equilibrium, neither bidder will acquire information. The seller’s expected profit is given by \( V_e \).

Thus, if the seller sets the reservation bid appropriately, the seller will have no incentive to provide public information. Moreover, the bidders will have no incentive to purchase private information. But, if a bidder has already acquired information, it would be \textit{ex post} inefficient to have a reservation bid because the resource tract under consideration might not be leased.

3. Summary and conclusion

Using a two-stage game model, resource information policy is analyzed. Conditions under which it pays the federal government to provide public resource information on tracts to be leased are established. Interpretations of these conditions are provided.

<table>
<thead>
<tr>
<th>TABLE 2</th>
<th>Payoff Matrix of a Two-Stage Game of Information Acquisition and Bidding When the Seller Implements a Contingent Reservation Bid Scheme</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bidder 1’s Decision Choices</td>
<td>Bidder 2’s Decision Choices</td>
</tr>
<tr>
<td>Acquires information</td>
<td>((-K, -K))</td>
</tr>
<tr>
<td>Does not acquire information</td>
<td>((0, 0))</td>
</tr>
</tbody>
</table>

\(^8\) The author would like to thank Paul Milgrom for suggesting the generalization of the statements of the public information condition.
situation of socially wasteful information, public resource information provision could be a second-best solution.

Moreover, in the case of socially wasteful information, a first-best solution is for the federal government to implement a contingent reservation bid scheme so as to nullify the incentive to acquire private information. If, however, a bidder has already acquired information, it would be ex post inefficient to have a reservation bid because the resource tract under consideration might not be leased.

References


