Sealed-bid versus oral-auction timber offerings: implications of imperfect data

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The central issue regarding sealed-bidding versus oral-auction timber offerings focuses on the question of revenue generation. On this point, the literature provides no consistent answer. This study measured the difference in bid price between sealed-bid and oral-auction timber offerings in the Northern Region of the U.S. Forest Service. A two-step estimation process, involving a probit model followed by a linear regression model, was used. That two-step process did not produce the expected results because the timber offering data used did not correspond to quality expectations; specifically, sale method was not always assigned on the basis of offering characteristics. Subsequent analyses indicated that when timber offerings in the Northern Region are randomly assigned a sale method, sealed-bid sales generated about \$6 per 10^3 board ft (1 board ft = 2.4 dm^3) more than oral auction sales. When the sale method is based on offering characteristics, oral auction sales produced revenues of about \$9 per 10^3 board ft higher than sealed-bid offerings. Recommendations for handling data quality problems are provided.

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Le principal aspect relatif à l'offre de bois sur pied au moyen de l'enchère « scellée » par rapport à l'enchère « criée, » porte sur la question de génération de revenu. La littérature ne fournit pas de réponse cohérente à ce sujet. La présente étude a mesuré les différences de prix entre les deux types d'enchères, lors de l'offre de bois sur pied dans la Région-Nord du Service forestier des États-Unis. La démarche d'évaluation s'est faite en deux étapes, impliquant un modèle exploratoire suivi de régression linéaire. Cette double démarche n'a pas donné les résultats attendus parce que les données utilisées dans l'offre de bois sur pied ne correspondaient pas aux prévisions de qualité; particulièrement, la méthode de vente n'était pas toujours choisie en fonction des caractéristiques de bois offert. Des analyses subséquentes ont montré que, lorsque dans les offres de bois de la Région-Nord on assignait une méthode de vente au hasard, les ventes par enchères scellées procuraient environ 6 \$ de plus par 10^3 pieds-planche (1 pied-planche = 2.4 dm^3) que les ventes par enchères criées. Quand la méthode de vente tenait compte des caractéristiques de l'offre, les ventes par enchères criées généraient des revenus d'environ 9 \$ plus élevés par 10^3 pieds-planche que les offres au moyen d'enchères scellées. Des recommandations pour traiter les problèmes concernant la qualité des données sont fournies.

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Introduction

The question of whether the U.S. Forest Service should use sealed bids or oral auctions to sell timber offerings has long been a contentious issue (Bentley 1968). Proponents of oral auctions argue that maintenance of a healthy local forest products industry requires unfair competition by outsiders be controlled (Craig 1979). Proponents of sealed bids often emphasize the expected higher financial returns when bidders are forced to compete, sight unseen, for timber offerings (Bentley 1969). Although some analyses support the contention that sealed bids yield higher returns (Weiner 1979), other analyses suggest that revenue-generation superiority depends on the circumstance (Johnson 1979; Haynes 1980; Mead et al. 1981; Adams and Haynes 1991). Hansen's (1986) analysis concluded there is no difference in revenue generation.

This study initially set out to measure the difference in bid prices between sealed-bid and oral-auction timber offerings in the Northern Region of the U.S. Forest Service. Surprisingly, the analytical methods did not generate the results expected. Subsequent examination revealed that the data from actual Forest Service timber offerings did not correspond to quality expectations. This has substantial implications for analysis comparing sealed bids and oral auctions, and probably is far more prevalent than might otherwise be thought.

Conceptual background

The issue of revenue generation dominates the literature of sealed-bid versus oral-auction timber offerings, although a wide range of other topics are also addressed (Mead 1967). Simply stated, the central question is: Which method of selling timber generates the higher revenues? Brannman (1991) looked at this issue as a matter of economic efficiency versus inefficiency. Following Vickrey (1961), Hansen (1986) discussed this issue in terms of the "revenue equivalence theorem," which holds that open- and sealed-bid auctions will, with risk-neutral bidders, yield equivalent revenue for the seller.

Analytical aspects of the revenue issue are easily addressed in a world of perfect data, one where the analyst has available a large amount of timber offering data. Of course for unambiguous results, the decision as to sale method (sealed or oral) for each offering *must* be random, as possibly occurs when a "fair" coin is flipped to determine the sale method. Then, a simple linear regression model would be adopted:

$$[1]\quad BP = \beta_0 + \beta_{SM} SM + \varepsilon$$

where BP is bid price measured in dollars per 10^3 board ft (1 board ft = 2.4 dm^3) of timber, β_0 is the intercept (the mean of the oral auction sales in this case) SM is a dummy

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TABLE 1. Difference between bid prices for sealed-bid and oral-auction timber offerings

Location and equation	Model	Sealed–oral difference ($ per 10^3 board ft)	Significance test (P)
Pacific Northwest[a]			
3	$BP = \mu + \Sigma\beta_i OC_i + \beta_{SM} SM + \varepsilon$	$15.27	<0.05
4	$BP = \mu + \Sigma\beta_i OC_i + \beta_{SM'} SM' + \varepsilon$	$1.16	ns
Northern Region			
3	$BP = \mu + \Sigma\beta_i OC_i + \beta_{SM} SM + \varepsilon$	$0.10	ns
4	$BP = \mu + \Sigma\beta_i OC_i + \beta_{SM'} SM' + \varepsilon$	−$4.29	<0.01

NOTE: ns, nonsignificant.
[a]Adapted from Hansen (1986).

variable representing sale method (0, oral auction; 1, sealed bid), β_{SM} is the coefficient depicting the average increase or decrease in bid price for sealed-bid offerings, and ε is is the error term with its usual assumptions. The null hypothesis (H_0) tested for revenue equivalence is $\beta_{SM} = 0$. Failure to reject the H_0 supports the notion of equivalent revenues.

Data variability (with random sale method)

One problem encountered with timber sale data is that they are frequently quite variable, in terms of the relationship between bid price and sale method. Hence, even if one sale method yields a higher bid price than the other, the H_0 cannot be rejected. A likely cause of excessive variability in bid price data is uncontrolled (and unaccounted for) timber offering characteristics: offering size, species, number of bidders, and so on. Three remedies have been proposed.

Wiener (1979) proposed changing the dependent variable measuring revenue generation from bid price to overbid (OB) or bid premium. Overbid is the difference between a timber offering's appraised value and the bid price. A timber offering's appraised value typically reflects offering characteristics, but not sale method. The high degree of variability in timber offering characteristics, it was reasoned, is responsible for the great variability in bid price. By focusing solely on overbid, the variance associated with uncontrolled offering characteristics is eliminated from the analysis. Under this convention, the simple linear regression model is

$$[2]\quad OB = \beta_0 + \beta_{SM} SM + \varepsilon$$

where β_0 is the intercept (the mean overbid for oral auction sales in this case), and other symbols are as before. The H_0 tested for revenue equivalence is $\beta_{SM} = 0$. A variant of this approach focuses on the bid–appraisal ratio as the dependent variable (Mead et al. 1981).

A second remedy is to stratify timber offering data according to one or more offering characteristics. Timber volume is a common characteristic used in such stratifications. For example, Wiener (1979) stratified timber offerings into volume classes of "large" and "small" and then assessed the effect of sale method. Mean bid prices for sealed-bid and oral offerings in each of the strata were compared.

The third remedy expands the original simple linear regression into a multiple linear regression (Draper and Smith 1981) where offering characteristics (OC) are used as the independent variables. In this case, the analytical model for the bid price (BP) model is

$$[3]\quad BP = \beta_0 + \Sigma\beta_i OC_i + \beta_{SM} SM + \varepsilon$$

where $\Sigma\beta_i OC_i$ refers to the linear effect of all offering characteristics on bid price. Other variables are as before. Again, the H_0 tested is $\beta_{SM} = 0$. Because the unexplained error (ε) in the eq. 3 approach is smaller than with an eq. 1 approach, the H_0 is more likely to be rejected with multiple linear regression (Snedecor and Cochran 1967). Even with no change in the estimated coefficient, β_{SM}, the magnitude of the t-statistic increases, thus increasing the likelihood of finding a statistically significant difference in the effect of oral and sealed bidding on bid price. Using an eq. 3 type formulation, Mead et al. (1981, p. 217) stated that by "taking full account of differences between timber sales (both in size quality, and administrative characteristics) we can measure the independent effect of sealed-bid sales..."

Nonrandom sale method

Another problem with assessing the effect of sale method of revenue generation is that sale method may not have been assigned randomly. That is, the decision as to sale method could be influenced by one or more offering characteristics, such as offering size or proximity to a timber-dependent community. For example, a decision rule might exist that assigns sealed bidding to smaller offerings and oral auction to larger offerings. Hansen (1986) referred to this as the "selection problem." In this case, an estimate of effect of sale method on bid price, independent of the effect of offering characteristics, is not possible (Hansen 1986).

Hansen suggested a remedy based on a two-step process proposed by Heckman (1976). In this process, a probit or logit model (Pindyck and Rubinfeld 1981) is estimated, using offering characteristics to estimate the probability (P) of an offering being sold using sealed (or oral) procedures (e.g., $P(SM) = \text{sealed} = f(OC_i)$). That estimated probability is used directly as an instrumental variable representing sale method, SM′, replacing the original 0 or 1 dummy variable (SM) (G.S. Maddala, University of Florida, personal communication). These probability-based measurements, now purge the bid price equation of the selection problem, because it is these measurements that account for selection problem (Heckman 1976; Maddala and Lee 1976; Lee 1978; Maddala 1983). Analysis proceeds as in eq. 3:

$$[4]\quad BP = \beta_0 + \Sigma\beta_i OC_i + \beta_{SM'} SM' + \varepsilon$$

where $SM' = g(P(SM = \text{sealed}))$ and other symbols are as before. The H_0 tested is $\beta_{SM'} = 0$. Arguing that eq. 4 is *the* correct approach, Hansen (1986, p. 126) stated that "all previous work, however, must be faulted for not recognizing a serious selection problem."

Hansen (1986) compared the eq. 3 and eq. 4 approaches in testing the revenue equivalence theorem with data from 867

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TABLE 2. Selected characteristics of estimated bid price models for timber offerings in Northern Region, based on method of assigning sale method

Equation and model	Sale method assignment	β_{SM} or $\beta_{SM'}$	Standard error	Model R^2
Equation 1	Characteristics	−8.03	7.97	0.00
$\mu + \beta_{SM}SM + \varepsilon$	Programmed	28.91	9.90	0.08
	Random selection	6.19	5.36	0.00
	Overall	1.94	3.99	0.00
Equation 3	Characteristics	−17.04	6.37	0.58
$\mu + \Sigma\beta_i OC_i + \beta_{SM}SM + \varepsilon$	Programmed	ne	ne	ne
	Random selection	6.16	3.82	0.54
	Overall	0.10	2.82	0.56
Equation 4	Characteristics	−30.05	12.07	0.63
$\mu + \Sigma\beta_i OC_i + \beta_{SM'}SM' + \varepsilon$	Programmed	ne	ne	ne
	Random selection	ne	ne	ne
	Overall	−45.56	12.32	0.57

NOTE: ne, not estimated.

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timber offerings in the Forest Service's Pacific Northwest Region (Oregon and Washington) during 1977. Some of Hansen's results are shown in the upper portion of Table 1. Using the eq. 3 approach which fails to account for the selection problem, results indicated that sealed bidding yields a (statistically significant) \$15.27 per 10^3 board ft higher bid price than oral auctions. After properly accounting for the selection problem, the eq. 4 formulation revealed a nonsignificant difference of \$1.16 per 10^3 board ft. Hansen (1986, p. 136) concluded that the revenue equivalence cannot be rejected and stated that the "nation's forest managers should take as a working hypothesis that any change in auction format will cause bidding strategies to change to keep revenue exactly the same."

Approach

The initial study objective was to replicate the test of the revenue equivalence theorem, following the general approach outlined by Hansen (1986). Two of Hansen's models were tested: Eqs. 3 and 4 as described earlier. Data were obtained for 819 timber offerings from the 13 National Forests in the Forest Service's Northern Region (Montana and the northern one-third of Idaho) that occurred between 1987 and 1990. Forest Service personnel provided the data by accessing the timber management database (mainly FS Form 2400-17) maintained at the agency's Fort Collins Computer Center.

A probit model was estimated to assess the probability of an offering being sold as a sealed-bid offering, based on three offering characteristics: (*i*) sawtimber volume harvested, (*ii*) base rates, and (*iii*) percent volume skyline yarded. The resulting probit model was used to estimate that probability for each of the 819 offerings. The eq. 4 model was estimated, using Statistical Analysis System (SAS Institute Inc. 1987) software for all analyses and tested for multicollinearity and violation of statistical assumptions (Belsley et al. 1980). The resulting model was evaluated by multiplying $\beta_{SM'}$ by the difference in average probit-produced probabilities for sealed-bid and oral-auction offerings, rather than by directly using $\beta_{SM'}$ as did Hansen (1986) (R.G. Hansen, Dartmouth College, personal communication); because SM′ is no longer a simple dummy variable (as was SM), the associated coefficient estimate no longer measures the difference in bid price between sealed bid and oral auction. Results that are statistically significant at $\alpha = 0.01$ are termed "highly significant," at $\alpha = 0.05$ are "significant," at $\alpha = 0.10$ are "moderately significant;" other results are termed "nonsignificant."

Results

Results shown in the bottom portion of Table 1 indicate no statistically significant difference between bid prices for oral-auction and sealed-bid timber offerings under the eq. 3 approach, but the difference of −\$4.29 per 10^3 board ft found under the eq. 4. approach was highly significant. Oral auction produced higher revenues. These results conflict sharply with those found by Hansen, who found the eq. 3 difference significant (with sealed bidding producing higher revenues), but found the eq. 4 difference nonsignificant. Why did these results differ from those found by Hansen?

The major assumption underlying the eq. 4 approach is that the decision regarding sale method is driven by offering characteristics, not by a random assignment. Consistency with that assumption was evaluated by contacting appropriate personnel in each of the Region's 13 National Forests. It was found that although some of the personnel based the sale-method decision on offering characteristics, most did not.

The sale-method decision was determined in some combination of three ways. First, six of the 13 National Forests in the Northern Region based sale method on offering characteristics. These forests accounted for 269 offerings, only 33% of the offerings used in this study. Although the actual characteristic-based decision rule varied from forest to forest, timber volume was commonly used in the decision rule; large-volume sales were typically assigned the sealed bid sale method and low volume sales to oral auction. These 269 offerings correspond to the kind of timber offering data quality needed for an eq. 4 analysis.

The second method used was the "programmed" decision rule. Under this approach, all offerings within a given forest were sold by one method only. In this study, 27 oral-auction and 70 sealed-bid offerings resulted from these programmed decisions; they accounted for 12% of the offerings studied.

Third, some forests based sale method on a random assignment. One forest, for example, carried this to the point that when a timber offering is to be sold, Ranger District personnel contact the appropriate person in the Forest Supervisor's Office; that person reaches into and draws from

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TABLE 3. Difference between bid prices for sealed bid and oral auction timber offerings in Northern Region, based on method of assigning sale method

Equation and model	Sale method assignment	No. of offerings	Sealed–oral difference ($ per 10^3 board ft)	Significance test (P)
Equation 1	Characteristics	269	−$8.03	ns
$\mu + \beta_{SM}SM + \varepsilon$	Programmed	97	$28.91	<0.01
	Random selection	453	$6.19	ns
	Overall	819	$1.94	ns
Equation 3	Characteristics	269	−$17.04	<0.01
$\mu + \Sigma\beta_i OC_i + \beta_{SM}SM + \varepsilon$	Programmed	97	ne	ne
	Random selection	453	$6.16	<0.10
	Overall	819	$0.10	ns
Equation 4	Characteristics	269	−$9.36	<0.01
$\mu + \Sigma\beta_i OC_i + \beta_{SM'}SM' + \varepsilon$	Programmed	97	ne	ne
	Random Selection	453	ne	ne
	Overall	819	−$4.29	<0.01

NOTE: ns, nonsignificant; ne, not estimated.

a sock containing 10 balls: four white balls (for oral auction) and six black balls (for sealed bidding); the offering is then specified as either an oral-auction or sealed-bid offering depending on the color of the ball drawn. These random decisions resulted in 453 offerings (55%).

Finally, some forests used a combination of decision rules. For example, the Nez Perce National Forest randomly determines sale method for timber offerings under 10×10^6 board ft, but uses oral auctions exclusively for offerings 10×10^6 board ft and larger. Because some forests used a combination of decision rules, timber-offering records (often at the Ranger District level) had to be closely inspected to determine if the sale method was based on offering characteristics, a programmed decision rule, or a random assignment. This meant that individual timber offerings from a given forest could be treated under different assignment methods.

Analyses associated with eq. 1, 3, and 4 were reconducted, now in light of known data quality or imperfections. Table 2 shows selected characteristics associated with models estimated, including R^2s showing that overall model quality ranged from 0 to 63% of the variation explained. In the case of probit models supporting the first step of eq. 4 analyses, the "overall" model had a McFadden R^2 (Ameniya 1981) of 0.29 and a 77.7% correct classification rate while the "characteristics" model had a McFadden R^2 of 0.07 and a 64.3% correct classification rate.

A series of eq. 1 analyses were conducted, one for each approach to specifying sale method. Overall, sealed-bid offerings produced revenues of $1.94 per 10^3 board ft greater (nonsignificant) than oral-auction offerings (Table 3). The portion of Table 3 referring to the eq. 1 approach shows that the overall difference of $1.94 is made up of three very dissimilar differences. For those timber offerings where sale method was either all sealed or all oral (the programmed decision), bid prices for sealed-bid offerings exceeded oral offerings by an estimated average of $28.91 per 10^3 board ft.[2] The estimated difference between sealed and oral offerings is negative (−$8.03) where sale method is tied to offering characteristic and positive ($6.19) where method is determined randomly; however, variability was so great that neither estimate was significantly different from zero. Since the estimated overall difference ($1.94) reflects these three components and their variability, the overall difference also is so variable that it was not significantly different from zero.

The possibility of nonsignificant differences was discussed earlier with the eq. 1 formulation. Recall, one solution to excessive variability was to adopt an eq. 3 formulation. Results are shown in the eq. 3 portion of Table 3. Two points are noteworthy. First, although the magnitude of the difference between sealed and oral bids for the random selection offerings are almost identical ($6.16 versus $6.19 per 10^3 board ft), the difference under the eq. 3 formulation is moderately significant, whereas the difference is nonsignificant using the eq. 1 formulation. That is, the eq. 3 approach correctly accounted for the influence of offering characteristics on bid price, allowing for a more sensitive test of the influence of sale method.

Second, the estimated difference of −$17.04 per 10^3 board ft where sale method depends on offering characteristics became highly significant. However, this outcome is suspect, since this is exactly the selection problem (i.e., where sale method is based on offering characteristics) described by Hansen.

Consequently, analysis was expanded to an eq. 4 formulation for the characteristics approach, as suggested by Hansen. The eq. 4 portion of Table 3 shows that the estimated difference between sealed and oral bid offerings changed considerably (−$17.04 per 10^3 board ft dropped to −$9.36), but remained highly significant. The differences as estimated by the eq. 3 and eq. 4 approaches, suggests the selection problem was an important problem in this study.

The eq. 4 portion of Table 3 also displays the −$4.29 overall difference between sealed and oral bid offerings shown earlier in Table 1. Though comparable with Hansen's results, this difference is artificial because it results from analysis of a mixture of appropriate- and inappropriate-quality data.

[2]Results of analysis performed on bid prices from programmed decisions (all sealed or oral sales) have no managerial meaning. Results simply reflect overall timber quality, competition, sale size, and so on of the forests that choose each method. Those results are included for comparison only.

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Discussion

This study started to replicate Hansen's (1986) test of the revenue equivalence theorem. But when results differed markedly from his, an explanation was sought through an in-depth investigation of the data used. Four conclusions seem warranted.

First, real-world data probably are routinely imperfect, in the sense that they deviate from the analyst's quality expectations. In this study, fully 45% of the offerings did not meet the quality expectation of a random assignment; about 69% did not meet the quality expectation of assignment based on offering characteristics; and 12% (the programmed decision) of the offerings defy any analysis because their bid price is invariant to sale method.

Second, the analytical tool used to assess the revenue equivalence theorem should be tailored to the data quality at hand, not to the data quality expected. For example, if data correspond to a random assignment of sale method, an eq. 1 approach (or a two sample *t*-test) could be adequate. (For random assignment offerings in this study, the eq. 1 difference was nonsignificant.) If the test for differences between methods is nonsignificant, use an eq. 3 approach to control variation owing to offering characteristics. (For random assignment offerings in this study, eq. 3 analysis showed that sealed bidding yielded \$6.16 per 10^3 board ft (moderately significant) more than oral auctions.) However, if sale method is a nonrandom assignment as based on offering characteristics, use the eq. 4 approach suggested by Hansen (1986).[3] (For this type of offering in this study, sealed bidding yielded \$9.36 per 10^3 board ft (highly significant) less revenue than did oral auctions.) Finally, if the data reflect a mixture of all sealed-bid and all oral-auction offerings (programmed decisions), do not bother with analyses; these data are not adequate to test the revenue equivalence theorem.[4]

Third, resist the temptation to routinely conduct an eq. 4 analysis in all circumstances, believing it will automatically detect and correct for a selection problem, if one is present. For example, we conducted an eq. 4 analysis of the 453 timber offerings where sale method was based on a random decision. That analysis showed oral auction to produce \$1.79 per 10^3 board ft more revenue than sealed bidding, though the difference was not statistically significant; that result erroneously supports the conclusion that revenues are equivalent. In fact, for those random sales, sealed bids produced \$6.16 more revenue than oral auctions.

Finally, be cautious about generalizing results. As timber offering data were inspected and sequential analyses performed, it became clear that an unsuspecting analyst could be easily lulled into a false sense of security, trusting in the assumption of data homogeneity and compatibility with quality expectations. For example, had this study's initial results been consistent with those found by Hansen (1986), further analysis would not have been conducted, the heterogeneous nature of the data would not have been discovered and understood, and the wrong conclusions would have been reached.

[3]Note that both the eq. 3 and eq. 4 approaches assume that offering characteristics have the same effect on bid price for both methods; the term $\Sigma\beta_i OC_i$ applies to both methods. If this assumption is not plausible, the alternative procedure outlined by Maddala (1983, p. 121) should be used.

[4]That sealed bidding produces \$6.16 per 10^3 board ft more revenue than oral auctions for random sales and that oral auctions produce \$9.36 more revenue than sealed bidding for characteristics sales probably reflects differences in markets and purchaser behavior for the individual forests.

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