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ORIGINAL ARTICLE

The Choice among Sales Mechanisms: Auction v. Negotiated Sales of Private Timber

Randal R. Rucker[1] · Keith B. Leffler[2] · Ian A. Munn[3]

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Abstract

For many non-industrial private forest (NIPF) landowners, the standing timber on their property is an important component of their investment portfolios. The value of their timber is determined not only by the biological and physical attributes of their timber tracts, but also by the transaction costs associated with different contracting practices, pricing schemes, and sales mechanisms. In this paper, we examine the determinants of the choice by landowners between the two predominant sales mechanisms for selling standing timber—auctions and negotiations. Our examination provides industry participants with a framework for thinking about the benefits and costs of the choice between these two alternatives. Further, it provides them with information on empirical relationships among sales mechanisms and their determinants. We also discuss potential implications of our results for the USDA Forest Service (Forest Service), which is required to sell almost all of its tracts through auctions.

Implications

The objective of this study was to identify factors that affect the choice between auction and negotiated sales mechanisms for private timber sales. Factors having significant impacts on the choice of sales mechanism include the tract's timber volume and the proportion of the tract comprised of sawtimber, whether the tract is sold on a per unit or lump sum basis, whether the tract is to be clear-cut, thinned or is a salvage sale, whether a timber consultant is involved, the number of prospective bidders in the sale region, and the density of timber on the tract

Keywords Auctions · Negotiations · Timber sales · Transaction costs · Sale procedures

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Introduction

For many non-industrial private forest (NIPF) landowners, the standing timber on their property is an important component of their investment portfolios. The value of their timber is determined by a wide range of biological and physical attributes, including the age of the tract, the density of timber on the tract, species composition, grade, location, and accessibility, as well as market conditions that vary over time and sometimes across space. The price received for a tract of timber depends not only on these physical attributes and market conditions, but also on a number of contractual terms, e.g., the time allowed for harvest to be completed, whether payment is to be made on a lump sum or per unit basis, and whether the tract is to be clear cut or thinned.

The net benefits received by a landowner from selling a tract of timber are affected not only by the price she receives for her standing timber, but also by the transaction costs associated with different contractual terms, pricing schemes, and sales procedures.[1] Leffler et al. (2000) examine relevant aspects of these costs in timber cruising practices, while Leffler and Rucker (1991) investigate the transaction costs that determine the choice between pricing provisions on private timber contracts. In the present paper, we examine how the transaction costs associated with the two predominant alternative sales mechanisms (auction and negotiations) affect the choice between these alternatives. This paper represents the first published paper to examine this choice in the context of private timber sales. Our empirical investigation of the determinants of the choice between auctions and negotiations, which employs detailed primary data we collected on 360 individual timber sales contracts from North Carolina, provides industry participants with a framework for thinking about the benefits and costs of the choice between these two alternatives.

We note up-front that the data we use in this study were collected in the early 1990s and provided the foundation for a 1993 dissertation (Munn 1993). We do not believe the age of the data diminishes the value of the insights gleaned from the analysis presented in this paper. Our justification for this belief is threefold. First, in the course of our research on the industry and our communications with industry observers and participants, we have encountered no reason to believe that the fundamental determinants of a landowner's choice between auctions and negotiations has changed over time. In both the 1990s (when the timber sales in our data were collected) and today, such factors as the level of uncertainty regarding the value of the standing timber for sale, whether the tract will be clear cut or trimmed or salvaged, the tract's timber density, and the intensity of competition among buyers for the tract are fundamental factors that affect the choice of sales procedure. Given this, the age of our data does not reduce the value of the insights gained from our analysis

[1] Economists refer to the costs of negotiating and enforcing an exchange agreement as "transaction costs," a term we use throughout this paper. Coase (1937 and 1960) is generally viewed as the father of transaction costs economics. Williamson and Barzel each published several papers that provided important early contributions to economists' thinking regarding these costs. A host of other authors have since added to those contributions.

below.[2] Second, as we demonstrate in the literature review below, there is no existing analysis of the choice between auctions and negotiations in the context of private timber sales. As such, even though our data were collected some time ago, they allow us to address an important unanswered question and provide new insights into our understanding of timber markets and landowner decision making. Third, industry participants and observers have indicated that relevant aspects of the industry have changed little in the particular markets we analyze in the time since our data were collected. Those industry sources also indicated that there are, for example, relevant technologies that are currently in the process of changing in segments of the private timber industry that are not the focus of our analysis. The conceptual framework we present below for thinking about the choice of sales mechanism allows us to predict the impacts of such ongoing changes. We elaborate and provide additional specifics related to this latter set of issues in our Conclusions section below.

Previous Literature Examining the Choice Between Auctons and Negotiations

There is a relatively small number of previous studies that examine issues relevant to the focus of the present paper. The paper that is most closely related to ours is Leffler and Rucker (1991) in which the choice between lump-sum and per-unit pricing provisions is analyzed in timber harvesting contracts. As one relatively minor component of their analysis, the authors explain how per-unit contracts provide buyers with an incentive to "high grade" when harvesting and demonstrate that the transaction costs associated with this incentive can result in the seller's optimal choice of sale procedure being a negotiation. Their empirical results demonstrate (as they predict) that the likelihood of landowners choosing auctions is less for per-unit sales than for lump-sum sales.

In an earlier analysis, in a dissertation chapter that effectively serves as a preliminary draft of the current paper, one of the authors finds that the probability of an auction being selected (over a negotiated sale) increases as (1) the uncertainty regarding the tract's value increases and (2) the expected level of competition for the tract increases (Munn 1993). The analysis we present below expands greatly on the earlier preliminary analysis by Munn.

More recently, Roberts and Sweeting (2013) develop a theoretical model to compare the revenues generated by a simultaneous bid auction and a sequential bids mechanism (a negotiation) in the context of Forest Service timber sales. Their modeling assumptions regarding costly information acquisition by prospective buyers align well with cruising practices in timber markets. Because the vast majority of Forest Service timber is sold in competitive auctions, Roberts and Sweeting conduct numerical simulations to compare auctions with negotiations. Using this

[2] Because there is no practical way to test whether this list of factors has changed in the past 30 years, one can view as a maintained hypothesis our assertion regarding the temporal constancy of the fundamental factors affecting the choice we study.

quasi-empirical approach, they find that the sequential (negotiation) mechanism they model yields higher seller revenues than the auction mechanism in almost all the scenarios they examine. We comment briefly on this result in our conclusions below.

In another recent paper, Grove et al. (2020), report the results of an e-mail survey designed to elicit information from timber consultants regarding "contract terms, timber sale practices, and market conditions on private sales" (p. 221). In findings related to the present paper, they find that (1) negotiations tend to be preferred on thinning sales, (2) auctions are typically preferred on final harvest (clear cut) sales with high-valued products, and (3) sales involving timber consultants generally use auctions. Grove et al. make no attempt to develop a formal conceptual framework for thinking about private landowners' choices between auctions and negotiations.

Another context in which the choice between auctions and negotiations has been examined is the market for cattle, with the analysis by Swanser (2005) being most similar to our analysis in the present paper. Other empirical studies of the choice of sales mechanisms in that context include Hobbs (1997); Arnold and Lippman (1995); Schmitz et al. (2003); Allen (1993).

In an analysis that employs an approach quite similar to ours, Bajari et al. (2008) analyze the factors related to the use of auctions and negotiations in the awarding of building contracts in Northern California. They find auctions are less likely when (1) the building projects are relatively complex and (2) the number of potential building contractors is small.

An important conclusion to be drawn from this literature review is that there is no previously published analysis of the choices made by private landowners between auctions and negotiations for the sale of their standing timber that is even remotely similar to the analysis our data allow us to undertake.[3] The analysis we undertake below thus provides an important missing piece in our understanding of private landowners' choices regarding the management of their timber stands.

Predictions[4]

In our empirical analysis, we will examine the impacts that differences (across timber sales) in several variables have on the probability that landowners choose to sell their standing timber using an auction. The first two predictions below are based on the fact that when a landowner decides to sell her standing timber, she faces at least two types of uncertainty regarding the value of the timber. First, the seller does not know which of the potential buyers will place the highest value on the tract. And

[3] Several papers have been published using the data from the 1993 dissertation mentioned in the introduction. See Munn and Rucker (1994, 1995, 1998) and Leffler et al. (2000). While these papers examine various aspects of private timber markets, only one of them even mentions the choice of sales mechanisms, and in that publication, this choice is mentioned only in passing. Thus, none of those earlier papers address the issues we analyze in the present paper. We thank an anonymous reviewer for raising the issue of overlap between the present paper and our prior work.

[4] More detailed discussions of the logic and intuition underlying the predictions below are presented in Appendix I.

second, it is not known with certainty (either to the seller, or to prospective buyers) what the value will be of the timber products produced from the logs harvested from the sale tract. These sources of uncertainty correspond to the alternative nature of the uncertainty in the two primary theoretical auction models that have been developed by economists. In the independent private value (IPV) auction model, each buyer has a different value of the tract, and the seller does not know those valuations. In the common value (CV) auction model, all prospective buyers are assumed to have the same (realized) value of the tract, but none of them know the realized value at the time of the sale. An increase in these two alternative types of uncertainty has opposite impacts on the likelihood that a seller will choose an auction.

To see this, consider first the IPV model. Wang (1993) develops an IPV model in which he demonstrates that, *ceteris paribus*, as individual buyers' valuations of a sale item become more dispersed, auctions are more likely to be preferred to negotiations. This is our first prediction from the literature. Wang refers to this prediction as a "common belief" (p. 848), but provides little intuition. We offer our intuition for the prediction in Appendix I.

Our second prediction, which is generated from the CV auction model, is that an increase in the uncertainty regarding the actual value of a timber tract will decrease the likelihood of an auction. In this model, because buyers do not know the tract's actual value, they have an incentive to undertake presale measurement—i.e., to cruise sale tracts—to get better information on that value. It has been shown that (1) information collection (both individual and the aggregate across buyers) increases with the *ex-ante* uncertainty regarding the value of a timber tract and (2) the seller bears the aggregate cost of buyers' presale measurement efforts.[5] This implies that, *ceteris paribus*, the seller's net returns from an auction will be lower—and hence, auctions will be less likely—the greater is the buyers' uncertainty concerning the value of a timber tract.

Our third prediction is that the likelihood of an auction being chosen with a lump sum contract is greater than with a per unit contract. This prediction was derived by Leffer and Rucker (1991) in their study of timber harvesting contracts. They examine the factors that determine the choice between lump-sum and per-unit payment provisions, which are the predominant provisions used on private timber sale contracts in the region from which they obtained their data. Briefly, their argument is that with lump-sum contracts, the transaction cost of primary concern is related to presale measurement activities.[6] With per-unit contracts, on the other hand, the relevant transaction cost is related to the costs incurred by sellers to limit "high-grading" by timber buyers.[7] Within this framework, Leffler and Rucker derive the

[5] See French and McCormick (1984); Leffler and Rucker (1991); Leffler et al. (2000).

[6] See Barzel (1982) for a general discussion of issues related to presale measurement incentives and activities. See Leffler and Rucker (1991) and Leffler et al. (2000) for discussions of timber cruising as presale measurement in the context of standing timber.

[7] High grading is a timber-industry term used to describe the incentive of buyers to harvest less timber when the per-unit payment increases. Such incentives do not exist with lump-sum payments. The high-grading problem is analogous to the shirking problem in share tenancy contracts and the early-shutdown problem on oil-leasing contracts with royalty payments.

prediction that the likelihood of landowners choosing auctions is greater with lump-sum sales than with per-unit sales.

The fourth prediction concerning the choice among sales procedures is that an increase in the inherent complexity of a transaction leads to a decrease in the likelihood of an auction. This prediction comes initially from the work of Goldberg (1977) and was later extended by Bajari and Tadelis (2001) and Bajari et al. (2008) to examine the choice between auctions and negotiations in the context of procurement of building contracts. They find that, *ceteris paribus*, an increase in the complexity of a transaction corresponds to a decrease in the likelihood that an auction is used.

Our fifth prediction is intuitive—auctions are more likely to be chosen when the seller employs an agent to assist with selling a good. Milgrom (1989, p. 19) reasoned that "Public auctions offer fewer opportunities for kickbacks and behind-the-scenes agreements between the seller's agent and a single buyer than do negotiated agreements." That is, the transaction costs incurred by a seller to prevent her agent from behaving opportunistically are lower with an auction.

Our final prediction—that sales where more bidders are available are more likely to be auctioned—has been attributed to the formal theory of auctions. As summarized in McAfee and McMillan (1987, p. 711), "increasing the number of bidders (in an auction) increases the revenue on average of the seller." Milgrom (1989) suggests that when there is sufficient competition among buyers, auctions will be preferred to negotiations. Bajari et al. (2008) suggest that this result is a standard result of auction theory and that it can be easily shown in an IPV setting (p. 380). In a CV context, Wilson (1977) states "the sale price converges almost surely to the 'true value' as the number of bidders increases..." (p. 517).

Timber Sales Procedures

To understand the basis for our predictions regarding the impacts of various factors on the choice of sales mechanism, an understanding of the particulars of timber sales practices is required. Forest products companies seeking timber in private stumpage markets in the United States typically employ professional foresters to procure the raw materials for their mills. The professional foresters are experienced, expert timber buyers, adept at estimating timber volumes and other relevant timber tract attributes. These experts are well informed of current market prices and conditions.[8]

[8] Although the focus of the present paper is on the choice of sales procedures for privately owned standing timber, it is interesting to note that federally managed timber is predominantly sold at public auctions. With few exceptions, for example, the USDA Forest Service is required to offer timber in competitive sales through either sealed or oral auctions (see the Code of Federal Regulations, title 36, chapter 11, parts 223.85 and 223.88 at https://www.law.cornell.edu/cfr/text/36/223.85). The underlying explanation for the prevalent use of this sales mechanism seems clear enough—accusations that the public's wealth is being given away by bureaucrats in secretive negotiations are avoided. The fact, however, that private timber owners often choose to use negotiated sales suggests that the expected net returns from auctions are sometimes less than from negotiating. Recognition of this fact and identification of the factors that determine the relative net returns has the potential to clarify the costs associated with public agencies' predominant use of a single sale mechanism.

Our primary data set contains information on individual timber tracts offered for sale by NIPF landowners in North Carolina. In contrast to the buyers of these tracts (typically mills or independent loggers), most of these private landowners rarely participate in timber markets. They are therefore likely to be unfamiliar with current market prices when they do sell, and also to lack the necessary forestry expertise to determine on their own, the timber volumes or other attributes of their tracts. Consequently, these landowners typically have little basis for valuing their timber, and any information regarding this value is potentially important. Accordingly, these landowners frequently employ forestry consultants to assist with the sale of their timber. Like timber buyers, forestry consultants are professional foresters who are experienced at estimating timber volumes and other tract attributes and are well informed of current market conditions.

When employed by a landowner, a consultant typically prepares the tract for sale, conducts a "cruise" to estimate the relevant attributes of the sale tract, informs potential buyers of the upcoming timber sale and provides them with pertinent tract information, prepares a timber sale agreement that protects the landowners' interests, sells the timber either by direct negotiation or sealed-bid auction, monitors the logging operation, and enforces the contract specifications. In exchange, the consultant receives a fee, most often a percentage of the gross revenues from the timber sale.[9]

Prior to selling standing timber, the seller (or her agent, a timber consultant) typically announces the forthcoming sale, provides prospective buyers with relevant information on the tract, and allows the buyers to inspect the tract. The buyers then cruise the tract to estimate the type, quality, and volume of timber and the tract's likely value. A typical cruise involves sampling a certain percentage of a tract's area, and then extrapolating from the sample information to obtain an estimate of the tract's value.[10] The buyers will also estimate the cost of accessing and harvesting the timber, the cost of building any required roads to gain access, and the cost of any post-harvest reclamation.

The contractual arrangements between small landowners and buyers almost always specify the transfer of standing timber to the buyer, thereby making the buyer the residual claimant from harvesting activities.[11] Timber sales contracts typically provide the buyer with 24 months or less to complete harvesting operations and specify harvest levels in terms of "merchantable" timber or minimum diameters to be removed. Timber contracts also specify other performance criteria—related, for example, to road conditions or post-harvest physical tract characteristics—as well as

[9] An earlier study of consultant fees in North Carolina found that the average fee was about 8.5 percent (Kronrad and Albers 1983). More recently, Grove et al. (2020) report that "The average commission charged on thinning sales was 9.5 percent compared to 8.4 percent on final harvests" (p. 224).

[10] See Leffler et al. (2000) for discussion and analysis of issues related to this form of presale measurement in general, as well as in the context of timber sales. See also Wenger (1984) for further details on the mechanics of cruising.

[11] See Leffler and Rucker (1991) for a discussion of the choice among alternative ways of organizing timber production and Barzel (1997, Chapter 1) for a discussion of related issues in a more general context.

penalties for violations of contract provisions. Payment provisions on private contracts generally call for either lump-sum (the buyer agrees to pay a stated amount regardless of the volume and composition of logs actually removed from the tract) or per-unit (the buyer agrees to pay a specified amount per unit of logs removed from the tract) payment, with the latter typically varying across the grades and species on the tract.

North Carolina forests from which we obtain our data contain various species of timber including such hardwoods as maple, oak, and poplar, as well as pine sawtimber, chip-and-saw, and pulpwood timber. The type of timber and its quality, as determined by size, age, and pest infestation, determine the likely end use of the timber. The highest valued end use is sawtimber for the production of dimensional lumber. Lower quality logs are used to produce chips, pulp, firewood, and hogged fuel. Maple, oak, and pine sawtimber can yield sawmill products with a substantial variance in value depending upon the particular characteristics of the individual trees.[12] In contrast, chip-and-saw and pulpwood timber yield primarily low value products such as pulp stock and firewood with little variance in per unit values by tree characteristic.

Most timber sales are "clear-cut" sales in which the landowner sells all commercial timber on a piece of land. Thinning sales, however, represent about 20 percent of the contracts in our primary North Carolina data set. These are sales that occur because trees attain their maximum wood density if they are properly spaced. Given the vagaries of nature, however, such proper spacing typically requires that the forest be thinned periodically. A common practice in these sales is for the landowner (or, his agent, a timber consultant) to mark the individual trees to be harvested. The landowner or his agent will often have pre-sale conversations with prospective buyers to clarify the sale terms and will then monitor rather closely the harvesting activities of the buyer to assure that the correct trees are harvested in ways that do not harm other standing timber.

In addition to clear-cut and thinning sales, salvage sales are a third type of timber contract. These sales typically occur after high winds blow down weaker and more exposed trees. Salvage sales constitute 5 percent of the contracts in our data set. As with thinning sales, these sales require pre-sale discussions between the landowner and prospective buyers, followed up by close monitoring of—and possibly on-going adjustments in—the buyer's logging activities. These considerations combine to suggest that the inherent complexity of conditions underlying both thinning and salvage sales is greater than for clear-cut sales.

[12] This variation in value is indicated by the following typical examples of Appalachian hardwood market prices taken from the *Weekly Hardwood Review* (June 10, 2005, p. 4): The average price of first grade red oak is 207 percent of that of #2 common red oak ($1,595/mbf as compared with $770/mbf); first grade hard maple has a value that is almost 230 percent of the value of #2 common hard maple ($1,820/mbf as compared with $795/mbf.). Similarly, top grade pine 1×6's and 2×8's sell for more than triple the price of #3 grade products (*Random Lengths*, June 10, 2005, p. 7).

Data, Variable Descriptions, and Predicted Coefficient Signs

Below we report the results of testing the predictions discussed above using a data set that contains information (obtained from surveys described below) on individual timber harvesting contracts from North Carolina. In addition, we conducted surveys and constructed two other data sets that contain Mississippi buyer and seller responses regarding the impact of several variables on their relative use of auctions and negotiations. The North Carolina data set contains information on private timber-harvesting contracts collected primarily from timber buyers and forestry consultants throughout the state. Collection of these data from buyers was initiated by mailing to all timber buyers listed in 1989 Buyers of Forest Products in North Carolina a brief description of the research project and a request to indicate their willingness to participate. A similar approach was used to contact timber consultants operating in North Carolina. Those who agreed to participate were mailed questionnaires that asked detailed questions about individual sales.[13] Through this process, we collected usable information from 44 individual contacts on 360 contracts that we are able to use for the empirical analysis discussed below.

We use a logistic regression approach for our primary analysis of the North Carolina timber contract data set. A description of the dependent and independent variables employed in the analysis follows. Tables 1 and 2 display summary statistics and pairwise correlation coefficients. The dependent variable in our analysis is Auction, a dichotomous variable that we assign a value of one for auction sales and zero for negotiated sales. Of the 360 contracts in our sample, 189 (52.5 percent) are auction sales and 171 (47.5 percent) are negotiated.

The first explanatory variable we consider relates to predictions (1) and (2) in the third section above. The variable is the proportion of sawtimber on a tract, which we label Proportion Sawtimber. These predictions, which are based on the theoretical CV and IPV auction frameworks, both relate to the dispersion of expected values—the first to the sellers' expectations about the buyers' actual values, the second to individual buyers' expectations regarding the actual value of the goods being sold.[14]

Briefly, insofar as IPV auction concepts are most important in our sample of timber sales, an increase in the proportion of sawtimber will increase both the IPV-type uncertainty regarding which buyer has the highest valuation of a tract and the likelihood that a seller selects an auction format. Alternatively, if CV auction concepts predominate in our data, then an increase in the proportion of sawtimber on a tract will increase the CV-type uncertainty related to the tract's value, buyers will have an incentive to engage in more presale measurement, and the likelihood that sellers (who bear the aggregate costs of buyer presale measurement) choose an auction will

[13] For an in-depth discussion of the procedures used to collect these data, see Appendix II to this paper and also Munn (1993, Chapter 3).

[14] We readily acknowledge that timber sales almost certainly have elements of both the IPV and CV auction frameworks. See the much more detailed discussion of our first two variables (and several of the other variables) in Appendix III for elaboration on this point.

be reduced. Thus, the estimated coefficient on Proportion Sawtimber has the potential to provide insights into which auction framework predominates in this dimension of our sample of timber sales.

The Total Volume of timber plays a similar role. Under the IPV framework, an increase in this variable corresponds to an increase in the variation in prospective buyers' valuations and results in an increase in the likelihood an auction is selected by NIPF sellers. Under the CV auction framework, *ceteris paribus*, an increase in Total Volume leads to an increase in the CV-type uncertainty related to a tract's value, which induces sellers to be less likely to select an auction. Again, the estimated coefficient on Total Volume has the potential to provide insights into which auction framework plays a more important role in our timber sales sample.

Our third prediction is that—because of the transaction costs considerations discussed in Leffler and Rucker (1991)—sales with per-unit payment provisions are less likely to involve an auction mechanism than lump-sum sales. The corresponding variable in our regression analysis is Per Unit, an indicator variable that we assign a value of one for per-unit sales and a value of zero for lump-sum sales. We expect the estimated coefficient on this variable to be negative.

Our fourth prediction concerns differences in the inherent complexity of harvesting timber from tracts with varying characteristics. As discussed in the Predictions section above, thinning and salvage sales are inherently more complex than clear-cut sales, which decreases the likelihood they will be auctioned. The corresponding 0–1 indicator variables in our analysis are Thinning Sales and Salvage Sales, both of which we predict will have negative estimated coefficients. Our fifth prediction is that auctions are more likely to be preferred when forestry consultants are involved in a timber sale. The corresponding variable in our analysis is Consultant, a 0–1 indicator variable that we assign a value of one for sales with consultants involved and zero otherwise.[15] We predict a positive sign for this variable's coefficient.

The final prediction discussed in the third section is that a decrease in the number of available bidders decreases the likelihood of an auction being chosen. About 10 percent of the timber sales contracts in our data set are from relatively remote mountainous regions where there are few nearby mills. To test this prediction, we include Mountain Region—a 0–1 indicator variable—that we predict will have a negative estimated coefficient.

We also include another variable related to the presale measurement issue that arises in common value auctions. As we have discussed above, the greater the expected aggregate presale measurement expenditures by buyers, the less profitable will be the auction form of sale. Differences in the level of presale measurement costs (due, say, to differences in the marginal costs of measuring different timber tracts) may affect the choice among sale procedures. The variable we use as a proxy for this dimension of the cost of buyer measurement efforts is the density (volume per acre) of the timber on a tract. Holding total volume constant, the more dense the timber, the lower will be the cost of any given percentage timber cruise by buyers.[16]

[15] Issues related to the simultaneous choice by landowners of payment provisions, sales procedures, and the use of timber consultants are discussed in the context of our empirical estimation below.

[16] See Appendix III for the logic of this statement.

Table 1 Summary statistics for variables used in regression analysis. Number of observations = 360

Variable	Mean	Minimum	Maximum	Standard Deviation
Auction	0.525*	0	1	
Proportion Sawtimber	64.267	0	100	27.865
Total Volume (1000 mbf)	0.476	0.012	4.381	0.551
Density (mbf/acre)	8.869	0.971	49.450	5.425
Thinning Sale	0.200*	0	1	
Salvage Sale	0.050*	0	1	
Mountain Region	0.092*	0	1	
High Quality	0.172*	0	1	
Good Access	0.403*	0	1	
Per Unit	0.158*	0	1	
Consultant	0.539*	0	1	

*For each of these 0–1 dichotomous variables, the mean represents the proportion of the sales in the sample with a value of one. The standard deviations for these variables are omitted because they provide no information beyond that provided by the means

This does not, however, imply that there will necessarily be less buyer measurement on more dense tracts because this cost variable relates to the marginal, and not the total, cost of measurement.[17] The ambiguity of the effect on total measurement expenditures from, say, a decrease in the marginal costs of measurement implies that the impact of this factor on the auction-negotiation choice is an empirical issue. Note, however, that a statistically significant estimated coefficient on this variable (whether positive or negative) is evidence of the importance of CV considerations in the choice of timber sales procedures.

In the course of our research on timber contracts, industry participants have indicated a belief that the value of a tract is important in determining, e.g., the amount of presale measurement and the choice of whether to hire a consultant.[18] Insofar as differences in values do indeed affect these decisions, it might also be argued that tract values are a determinant of the choice between auctions and negotiated sales. Our model of presale measurement, however, suggests that the potential gains from presale measurement result from the level of uncertainty concerning the value of the good and not from the good's expected value, per se.[19] Thus, we predict that, controlling for the uncertainty concerning the value of a tract, a change in the value of the tract will not affect the choice between auctions and negotiated sales. To test for the impacts of value, we include the variables High Quality and Good Access. These are dichotomous variables that we construct from survey responses by assigning values of one for tracts judged by survey respondents (primarily buyers

[17] Whether a buyer's total measurement costs increase or decrease with an increase in density depends on the elasticity of the marginal benefits of measurement. We have no priors regarding this elasticity.

[18] See Leffler et al. (2000), and Munn and Rucker (1998) for discussions of this issue.

[19] See Appendix III for the intuition underlying this prediction.

Table 2 Correlation matrix. Pearson correlation coefficients / N = 360

	Auction	Proportion Sawtimber	Total Volume	Thinning Sale	Salvage Sale	Mountain Region	Density	High Quality	Good Access	Per Unit	Consultant
AUCTION	1.000										
% SAWTIMBER	0.143*	1.000									
TOTAL VOLUME	0.253*	−0.137*	1.000								
THINNING SALE	−0.095	0.310*	−0.101	1.000							
SALVAGE SALE	−0.216*	−0.044	−0.131*	−0.115*	1.000						
MOUNTAIN REGION	−0.122*	0.322*	0.039	0.419*	0.015	1.000					
DENSITY	0.315*	0.025	0.189*	−0.244*	0.025	−0.173*	1.000				
HIGH QUALITY	0.169*	−0.261*	−0.023	0.085	−0.105*	0.008	0.296*	1.000			
GOOD ACCESS	0.010	0.007	−0.030*	0.000	0.019	−0.143*	0.086	0.120*	1.000		
PER UNIT	−0.365*	−0.061	−0.134*	0.183*	0.285*	−0.006	−0.166*	−0.097	0.094	1.000	
CONSULTANT	0.682*	0.137*	0.239*	0.045	−0.069	−0.054	0.181*	0.082	−0.081	−0.255*	1.000

*Asterisk indicates that correlation coefficients are significantly different from zero at the 0.05 level

and consultants) to be of high quality and to have good accessibility for logging. If higher value tracts are more likely to be auctioned, then the estimated coefficient on these variables will be positive. Our model of presale measurement, however, predicts that the estimated coefficients on these variables will be zero.[20]

Empirical Results

North Carolina Survey—Individual Sales Data (360 Observations)

The results of our empirical analysis of the determinants of the choice between auction and negotiated sales procedures using our North Carolina data set are presented in Table 3.[21] Because the dependent variable in the analysis—Auction—is a dichotomous variable, logit regressions, rather than ordinary least squares regressions are estimated.[22] Model 1 in Table 3 indicates that increases in both Proportion Sawtimber and Total Volume lead to increases in the likelihood that auctions are used. The estimated effects are highly statistically significant (p-values for both estimated coefficients are less than 0.001). The results are consistent with the prediction from an IPV auction model, suggesting that factors related to this framework have the predominant impact in this dimension of timber sales. Also as predicted, Thinning and Salvage Sales are found to be negatively correlated with the choice to use auctions, although the estimated coefficient for Thinning Sales is not significant in models 1 or 2. The negative (and statistically significant) coefficient on Mountain Region indicates that, as predicted, auction sales are less likely in the North Carolina mountains than in the Coastal Plains and the Piedmont. Reductions in the (marginal) costs of presale measurement (through increases in Density) are found to significantly increase the probability that auctions are chosen, suggesting that CV factors play an important role in this dimension of the choice between sales procedures. This result supports our notion that both auction frameworks play a role in timber sales.

The estimated marginal effects in Table 3 generally suggest economic significance that correlates highly with statistical significance. The variable with the smallest marginal effect in model 1 is Thinning Sales, whose coefficient is not statistically significant. Of the three continuous variables (Proportion Sawtimber, Total Volume, and Density), all have positive estimated coefficients, are significant at the 0.01 level, and have marginal effects of (roughly) a 15 percent increase in the probability of auctions in response to a one standard deviation increase in their values. Similarly, *ceteris paribus*, Salvage Sales are 54 percent less likely to be auctioned than

[20] In our earlier research we found that (consistent with our measurement theory) value per se affected neither the amount of presale measurement nor the decision to hire a consultant. See Leffler et al. (2000) and Munn and Rucker (1998).

[21] To accommodate word limits, the two Mississippi data sets we collected and the results of our statistical analysis of them are discussed in Appendix IV.

[22] In our preliminary analysis we also estimated the specifications reported below using linear probability models. The results from these models (which we discuss in Appendix V) are qualitatively the same as those we report and discuss below.

Table 3 Logit regressions: the choice between auction and negotiation. Number of observations = 360

Dependent Variable: Auction (1 if Auction, 0 if Negotiation)							
Variable	Predicted Sign	Model #1		Model #2		Model #3	
		est. coeff. (st. error)	Marginal Effect[a]	est. coeff. (st. error)	Marginal Effect[a]	est. coeff. (st. error)	Marginal Effect[a]
Intercept		−2.526 (0.438)***		−2.444 (0.453)***		−3.406 (0.640)***	
Percent Sawtimber	>0 (IPV) <0 (CV)	0.020 (0.005)***	0.139	0.019 (0.005)***	0.132	0.013 (0.007)*	0.090
Total Volume	>0 (IPV) <0 (CV)	1.189 (0.311)***	0.163	1.189 (0.312)***	0.164	0.583 (0.406)*	0.080
Thinning Sale	<0	−0.206 (0.343)	−0.051	−0.219 (0.346)	−0.055	−0.661 (0.516)*	−0.163
Salvage Sale	<0	−3.701 (1.450)***	−0.538	−3.574 (1.417)***	−0.529	−3.188 (1.156)***	−0.505
Mountain Region	<0	−1.123 (0.495)**	−0.265	−1.142 (0.599)**	−0.269	−0.848 (.660)*	−0.205
Density	?	0.124 (0.028)***	0.168	0.119 (0.029)***	0.161	0.128 (0.035)***	0.173
High Quality	0	—	—	0.240 (0.360)	0.050	—	—
Good Access	0	—	—	−0.086 (0.251)	−0.021	—	—
Per Unit	<0	—	—	—	—	−1.975 (0.668)***	−0.424
Consultant	>0	—	—	—	—	3.517 (0.367)***	0.705

*, **, *** Asterisks indicate significance at the 10, 5, and 1 percent levels. For the variables with signed predictions—Percent Sawtimber, Total Volume, Thinning Sale, Salvage Sale, Mountain Region, Per Unit, and Consultant—significance levels are for one-tailed tests. For the other variables (Density, High Quality, and Good Access), significance levels are for two-tailed tests

[a]Marginal effects are calculated at the sample means of the explanatory variables. For each continuous variable, the marginal effect shown is the change in the probability of consultant participation that results from a change of one standard deviation in the explanatory variable. For binary variables, the marginal effect shown is the change in the probability of an auction being selected that results from a change in the explanatory variable from zero to one

clear-cut sales, and tracts in the Mountain Region are about 27 percent less likely to be auctioned.

Model 2 augments the specification of model 1 with the two proxies for value—High Quality and Good Access. The inclusion of these variables has no substantive impact on the other estimated coefficients and, as predicted by our theory of measurement, neither of the estimated coefficients on these variables is significantly different from zero. Moreover, their estimated marginal effects are small enough to be considered economically unimportant. Our interpretation of this result is that industry observers who suggest tract values are important in, for example, determining presale measurement efforts (and hence the choice of sales mechanism) may not be distinguishing between the impacts of uncertainty and value. We note that these two variables are likely to be highly correlated in practice.

We argue above that (1) auctions are less likely to be the preferred sales procedure on sales with per-unit (rather than lump-sum) payment provisions and (2) auctions are more likely to be used on sales where the landowner chooses to employ a timber consultant. A problem with including the dichotomous variables Per Unit and Consultant in the regressions in Table 3 is that the landowner simultaneously makes the decisions regarding payment provisions, sales procedures, and whether to hire a timber consultant. Because all these decisions are likely affected by the same set of exogenous factors, viable instruments for dealing econometrically with this simultaneity are not available. To get an indication of the magnitude of possible simultaneity bias, we initially estimate regressions without Per Unit and Consultant (models 1 and 2) and then in model 3, we add Per Unit and Consultant to the specification of model 1.

We offer two observations regarding the results displayed for model 3. First, for the most part, the addition of Per Unit and Consultant does not have substantive impacts on the estimated coefficients of the other variables.[23] All variables that were previously significant remain significant (although two of the variables are now significant at the 10 percent level, rather than at the 1 or 5 percent level). Moreover, the estimated marginal effects are altered, but not dramatically. Note that not only is the estimated coefficient on Thinning Sales (marginally) significant at the 10 percent level in model 3, this variable's estimated marginal impact is also large enough to be considered economically important. These results provide some evidence that the simultaneity bias at issue is relatively limited.

Our second observation is that, as predicted, the estimated coefficients in model 3 indicate that auctions are less likely to be chosen when per-unit payment provisions are used, and more likely to be chosen when a consultant's services are acquired. Both estimated coefficients are significant at the 0.01 level, with substantial marginal effects. We note that the estimated coefficient on the Consultant variable measures the impact of the use of a timber consultant on the likelihood that an auction is chosen. Moreover, this impact is in addition to (or independent of) the impacts of

[23] Comparing, e.g., models 1 and 3, with one exception, the signs and significance (at the 10 percent level) of the coefficient estimates are not altered by the addition of Per Unit and Consultant. The exception is the Thinning Sale variable mentioned in the text.

the other variables in the regression that simultaneously affect the choice of both sales procedures and whether to hire a consultant. The estimated coefficient on Per Unit has a similar interpretation.

The results of model 3 should not be interpreted as suggesting there is a one-way causation from hiring a consultant, or from specifying per-unit payment provisions, to choosing an auction. Rather, our argument that the choices among sales procedures, between payment provisions, and whether or not to hire a timber consultant are made simultaneously suggests that causality among these variables running in the other direction is likely. Suppose, for example, that a landowner is constrained (say, by provisions of her deceased parents' will) to hire a timber consultant when she sells her standing timber. The fact that a timber consultant's industry knowledge and experience may reduce the costs associated with conducting an auction would suggest that an auction is more likely to be used when a consultant is exogenously employed. Unfortunately, there is no way to conduct an experiment to generate data that allow measurement of the impacts of exogenously determined use of consultants or per unit payment provisions on the choice between auctions and negotiations. We present results from our further examination of this issue in Appendix VI, where we also discuss issues associated with—and results from—the addition of survey-contact-fixed-effects to our regressions. Neither of these extensions result in substantive changes in our findings regarding the determinants of sales mechanisms for timber sales.

Conclusions

We analyze the determinants of the choice by NIPF landowners between auctions and negotiations for the sale of standing timber and identify several tract attributes, market considerations, and contractual provisions that play a role. These factors include the level of uncertainty regarding tract values, the nature of the timber sale (clear cut vs salvage vs thinning), the level of competition among prospective buyers, the pricing provisions (per unit vs lump sum), whether a timber consultant is involved in the sale, and the costs of presale measurement. As such, our results have the potential to provide landowners and forestry consultants with useful insights when selecting a sale mechanism for their standing timber.

We mention at the end of the introduction above that the data used for our analysis were collected some time ago. Before commenting on further insights gained from our analysis, it is worth commenting on how we think the passage of time might have impacted the relevance of our results.[24] For that purpose, we identify two changes whose impacts warrant discussion. First, a 2017 annual report by Timber Mart South (Hood et al. 2017) finds that the use of auctions has fallen over the preceding 15 years or so. Grove et al. (2020) suggest that this change may be the result of a reduction in the proportion of timber sales with seven or more bidders (possibly as a result of

[24] We thank an anonymous reviewer and the associate editor for encouraging us to consider this issue in more detail.

consolidation in the logging and forest products industry). This change in the use of auctions is consistent with our prediction that a reduction in the number of bidders will reduce the likelihood auctions are chosen. Another change since our data were collected is that the technology for timber cruising is advancing with the advent of such innovations as GIS, drones, LiDAR, and computer software.[25] A useful way to characterize these changes in the context of our model is as a reduction in the marginal costs of cruising, whose possible impacts we discuss in section V above.[26] Thus, although the values of explanatory variables may have changed (e.g., the numbers of bidders and the marginal costs of cruising), our conceptual framework provides useful insights into the likely effects of those changes. Moreover, we have no reason to suspect the algebraic signs of the relevant correlations have changed and are confident that there is still much to be learned from our analysis and the data we use to conduct it.

In addition to the potential insights mentioned above (regarding the choice of sales mechanisms by landowners and consultants), our analysis also provides insights into at least three other issues. The first such insight relates to the sale of publicly managed timber.[27] The Forest Service, under restrictions imposed on its decisions by the *Code of Federal Regulations*, sells the vast majority of its timber through public auctions. The observation that negotiations are often chosen by wealth-maximizing private timberland owners raises the possibility that the Forest Service might gain by negotiating the sale of some tracts. In a paper that examines this possibility, Roberts and Sweeting (2013) run simulations and suggest the Forest Service would gain by negotiating the sale of most of its timber. Their model, however, does not account for the important principal-agent considerations that must be addressed if public employees negotiate the sale of public timber behind closed doors. Our data on the choice of sales mechanism in private contracts suggests that a middle ground—in which some tracts are auctioned, and others are negotiated—may be preferred to the extremes, assuming, of course, that an economical method can be devised to hold the negotiating bureaucrats accountable.

The second insight speaks more broadly to sales (and purchases) of goods and resources other than timber. There exists a relatively limited literature examining theoretical issues regarding the choice between auctions and negotiations and an even smaller literature that examines these choices empirically using actual transaction data. Regarding the former, some important papers in the literature (e.g., Bulow and Klemperer 1996, 2009) suggest that auctions should almost always be preferred to negotiations. One interpretation of this result (see Bajari et al. (2008)) is that it may hold well in a context where the item being offered for sale (or being purchased) is simple. In

[25] Industry experts we contacted indicated these innovations are playing much less of a role for the small NIPF landowners that are the focus of our analysis than for larger private landowners.

[26] Another change has been the advancement of timber-harvesting technology along various margins. If we characterize this change as reducing the marginal costs of harvesting, then in the context of our model, it would increase tract values. In our measurement-based model, *ceteris paribus*, a change in a tract's value has no impact on the auction/negotiation choice. We note that, as with new cruising technology, these advances in harvesting technologies are being used substantially less on NIPF sales than on sales by larger private landowners.

[27] Bajari et al. (2008) make points analogous to those below in a broader context.

contexts where the sale item is relatively complex and difficult to evaluate, however, negotiations may offer advantages over auctions. In this paper, we identify a number of factors that play a role in the choice between auctions and negotiations in the context of private timber sales, which are relatively complex sales items. Our empirical results provide strong support for the predictions from the theoretical literature. The factors we identify as likely to affect the choice between auctions and negotiations are, for the most part, highly significant and have the predicted algebraic signs. Moreover, their estimated empirical impacts can be reasonably viewed as being economically significant.

The third insight from our analysis relates to a comparison of results from studies similar to ours. As we indicate above, our analysis has similarities with the analyses of private construction contracts by Bajari et al. (2008), and cattle sales by Swanser (2005). Our discussion above of these articles suggests that, while there clearly are similarities across industries and applications in the factors that determine the choice among sales mechanisms, there are also differences. Careful consideration of institutional details and relevant transaction costs that are specific to timber markets leads us to identify several factors that are important in choosing among sales procedures for timber, but likely play little role in, for example, construction contracts or cattle sales. For instance, timber consultants are third party specialists in timber markets that are hired by NIPF landowners who do not sell timber on a regular basis. We find that, as expected, sales involving timber consultants are more likely to be auctioned. There appear to be no comparable third-party specialists in the sale of cattle or the procurement of construction contracts. Responses to uncertainty regarding the value of timber tracts also play an important role in our context (and in cattle sales) but were not a factor considered in the study of construction contracts by Bajari et al. (2008). We find that higher volume sales and sales with higher proportions of sawtimber are more likely to be auctioned, a result that suggests the uncertainty associated with an IPV auction framework plays a more predominant role than the uncertainty associated with a CV framework in this dimension of timber sales. We also find, however, that an increase in tract density increases the likelihood of an auction, a result that suggests the presale measurement costs from a CV auction framework do play a role in the choice among sales procedures, confirming our priors that both types of uncertainty play a role in timber sales, and likely in other contexts, as well.

An important lesson to be learned, therefore, from the limited number of existing empirical studies of the choice among sales mechanisms is that there is not a single comprehensive list of factors that determines the optimal sale procedure in all contexts. Although there may be common factors across markets for different goods, it is essential to conduct a careful examination of the particular institutional details of any given market to identify the relevant set of factors—and associated transaction costs—that determines the choice among sale mechanisms in that market.

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Declarations

Study Specific Approval by Ethics Committee Not applicable.

Informed Consent Not applicable.

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