Timber appraisal from French public auctions:

How to set the reserve price when there are unsold lots?

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Abstract

Timber stumpage appraisal is an important issue for Public Forest Services so as to set a relevant reserve price and to obtain a fair market value. The hedonic price function approach is a useful method to infer the appraisal timber value since so many characteristics may influence the stumpage price. Indeed, lots are different from each other (inter lots heterogeneity), but they are also made up of heterogeneous wood (intra lot heterogeneity). We adopt the transaction-evidence timber appraisal using a data set including timber auctions in Lorraine (Eastern France) carried during fall of 2003. An econometric problem arises from the fact that a large number of lots remain unsold at the end of the sales. In addition, the seller reserve price is not announced in French timber auctions. We study the variables that determine the probability that a lot will be sold or not and the implicit prices of the characteristics of the lots. We correct the bias due to the existence of unsold lots using the sample selection model of Heckman.

Key words: Timber auctions, transaction evidence timber appraisal, hedonic prices, unsold lots.

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1 Introduction

Timber stumpage appraisal is an important issue for Public Forest Services so as to set a relevant reserve price and to obtain a fair market value in timber sales. But what is a fair market price for such a product? There is quite a difference between forest production (which spreads over a long period of time) and timber supply (which is a harvesting decision). So without real references to production costs, the seller has to consider other elements to assess the value of the good and to determine his own reservation value. Concretely, the seller has to estimate market demand. Introduced in the 1980s the “transaction evidence” approach has replaced the traditional “residual value” for predicting stumpage prices in the USDA Forest service. With transaction-evidence appraisal, timber value is estimated directly from market prices obtained in past timber sales. The buyers estimate the value of a standing wood lot in a different way since they have more information on harvesting costs, on what they will produce with the wood and at what price they will be able to sell their products. It is therefore easier for buyers to measure their willingness to pay for the lot, i.e. to determine their reservation value.

Adopting this transaction evidence approach, we are interested in the auction results of timber sales. Most timber sales are conducted through auctions, but in the literature on sequential auctions, it is often assumed that the items put successively on sale are perfectly identical. This assumption is difficult to justify in the case of timber auctions, but also in many other types of auctions, such as art, wine and real estate auctions. Heterogeneity in the product is probably the most important feature of timber auctions. Lots are different from each other, lots differ in volume, composition, localization, harvesting conditions, etc. (inter lots heterogeneity). But a lot is also composed of different species and qualities (intra lot heterogeneity). Thus, lots are not only different from one another, but there are also made up of heterogeneous wood. These issues of inter- and intra-lot heterogeneity are related to the nature of the good and persist with any sale mechanism. Heterogeneity raises various questions about the valuation of the different lots that are put on sale, as well as about the allocative efficiency of a sequential mechanism.

Another problem arises in timber auctions from the fact that many lots remain unsold at the end of the sale. The percentage of unsold lots in French timber auctions can reach 50 percent and represents a non-negligible phenomenon in the study of the sale mechanism. Which are the characteristics that determine if a lot will be sold or not? What is the impact of the heterogeneity on the auction price? How should be determined the reserve price? This paper attempts to answer these questions.

Most empirical studies on sequential auctions analyze price evolutions (Ashenfelter, 1989; Ashenfelter and Genesove, 1992; Vanderporten, 1992; Lusht, 1994; Beggs and Graddy, 1997; Gandal, 1997; Deltas, 1999; Deltas and Kosmopoulou, 2000; Lambson and Thurston, 2003, Ginsburgh and van Ours, 2003; Picci et Scorcu, 2003). Most of these studies find that prices for the same items decrease as the auction proceeds, with price premiums to items sold early during the auction. However unsold items are rarely taken into account. To our knowledge, there are no studies that test whether the decreasing price phenomenon is also observed in timber auctions. It is true that the analysis is complicated by the presence of heterogeneity and by the fact that unsold lots have to be taken into account.

The data set built by Costa and Préget (2004) on timber auctions allows us to study the impact of lots heterogeneity on auctions from an empirical perspective. Econometric studies can help to better understand the auction mechanism and test assumptions used in the theoretical literature. Costa and Préget's data set includes timber auctions in Lorraine (Eastern France) carried out during the fall of 2003. This data set is particularly rich and includes many lots characteristics.

Heterogeneity makes the hedonic price function approach useful in order to infer the appraisal timber value. Many characteristics may influence the stumpage price. A hedonic price function allows to predict the market value of a wood lot, but it also gives the relative importance of the various characteristics of the wood lots. Indeed, the hedonic price method is based on the implicit marginal price of each characteristic.

We propose to study the impact of inter- and intra-lot heterogeneity not only on auction price level but also on the probability that a lot will be sold or not. Indeed, the percentage of unsold lots in French timber auctions is particularly high. Taking the unsold lots into account is therefore a fundamental and original element of our econometric analysis. Contrary to North American timber auctions, the reserve price of the seller is not announced in French public timber auctions, which raises another problem. A reserve price is reported for each lot in the data base, but that price is not the real seller's reservation price since many lots are sold at a lower price. This means that the French public Forest Service decides to sell or not a lot at the last moment and does not commit to any reserve price before the auction.

In the United States, most studies on timber auctions analyze the comparison between oral and sealed bid auctions (Johnson, 1979; Hansen, 1986; Brannman, Klein et Weiss, 1987; Brannman, 1991, 1996; Athey et Levin, 2001; Athey, Levin et Siera, 2004). But this topic is not a current issue in France where almost all the sales are sealed bid first price auctions.

Our analysis is closest to the timber stumpage appraisal literature. Prescott and Puttock (1990) and Puttock, Prescott and Meilke (1990) propose a hedonic price function to forecast stumpage prices in Southern Ontario timber sales. Their model and estimation procedure are simpler than our methodology since they do not have any unsold lots in their data base. Huang and Buongiorno (1986) propose an transaction evidence appraisal of timber market value taking into account unsold lots using a Tobit model. Boltz, Carter and Jacobson (2002) did the same for timber auctions in North Carolina. They highlight the importance of intra-lot heterogeneity on auction prices of mixed species lots. Results, corrected for the endogenous participation of bidders, for market conditions, for production costs and for the quality and species characteristics, show that increased heterogeneity leads to lower sale prices. Their study gives in some way an estimation of the opportunity cost for biodiversity. The Tobit model is not applicable to our data set since the reserve price is not announced in French public timber auctions. We correct the bias due to the existence of unsold lots using the sample selection model of Heckman.

Thus, our study contributes to the literature on timber value appraisal since we propose an empirical model to asses the value of heterogeneous goods from sequential auctions with secret reserve price and unsold lots. We confirm that lot heterogeneity leads to a lower price and we determine the factors that influence the probability that a lot will be sold or not in French timber auctions.

In the next section, we describe the institutional framework of French public timber auctions. Section 3 describes the data set. The methodology is detailed in section 4 and section 5 presents the results. Section 6 concludes our research.

2 Institutional framework

Competitive bidding is widely used in timber sales in France. In particularly, the French National Public Forest Service (ONF[1]) uses sealed bid first price auctions to sell timber from public forest. Timber auctions of the ONF, which represent 40% of the timber sold each year in France, generally concern standing timber. The auction mechanism seems to be the best way to determine an "objective" or a fair market value for such a heterogeneous product.

2.1 Presentation of French timber auctions

French timber auctions are different from auctions traditionally analyzed in the economics literature for several reasons. First, timber auctions are sequential since many lots (usually more than one hundred) are put on sale one after the other; the result of the auction of a lot is given before the next lot is put on sale. The first lot is usually randomly drawn, and then the auctioneer follows the catalogue order. The sale catalogue details one by one all the lots. Nevertheless, no information is given about the seller's reserve price. That price is kept secret to preserve the private information of the seller so as to avoid bidders to eventually lower their bids. This singular practice has been studied in the literature, but is difficult to justify theoretically. Elyakime, Laffont, Loisel and Vuong (1994) show in an independent private value auction model that it is strictly better for the seller to fix a minimum bid instead of keeping the reserve price secret. According to their model, the seller is always better off announcing his reserve price, but if the reserve price is kept secret, then it is optimal to fix it to his reservation value. The practice of secret reserve price is sometimes justified either by the fact that announcing a reserve price reduces the participation of the bidders or by a common value component (Vincent, 1995). Risk aversion is also mentioned to justify a secret reserve price (Li and Tan, 2000). There is no clear answer to justify a secret reserve price. However, a lack of competition for some lots and the willingness of the ONF to maintain a reasonable timber price may also explain this practice. A secret reserve price may also be used to prevent collusion between bidders at the reserve price. In fact, we guess that a good

[1] ONF stands for Office National des Forêts.

reason to keep secret the reserve price is because it is easier for the seller since he does not know the exact value of his reservation value at the auction time.

There is no commitment from ONF to stick to the reserve price (unknown to the bidders). Indeed, the reserve price is estimated before the sale, but it may be changed during the sale and even when the bids are opened. So, the seller can lower the reserve price if he sees that many lots remain unsold. With that privilege, the seller keeps a certain flexibility to manage the sale, but that practice may lead to some costs for the seller from an auction theory point of view. Indeed, without firm and credible commitment, the auctioneer may lose a part of the benefit of an auction. If the bidders anticipate that the seller can modify the rules of the game, then bidders will take this into account when they determine their bidding strategy, which may be costly for the seller and/or may lower the efficiency of the bidding mechanism.

Nevertheless, the indetermination of the seller on reserve prices shows his difficulty to estimate the value of a lot.

During a sale, bidders are not interested in every lot. Each bidder has a more or less precise demand about species, volume, and quality. Thus, the number of bidders for a particular lot is fairly small and it is quite usual that there is only one bid or even no bid at all. Besides, bidders are asymmetric: they have different goals (sawyer, merchant, etc.), different business sizes, different needs and different localizations.

2.2 Heterogeneity in timber auctions

At harvesting time, the ONF does not choose the characteristics of the products. It has to sell what came out of the forest, which is heterogeneous by nature. Thus, lots are heterogeneous (different from one another), but they are also made up of heterogeneous wood. In particular in standing wood sales, a lot may contain many species of different diameter and of different quality. Auctioning such a product raises the problem of the optimal lot composition. The successive auctions correspond to different lots, but there might be interrelated. Some lots may be close substitutes. On the contrary, others may present synergies. For example, it may be only profitable for some buyers to harvest two or more lots that are close to each other.

Taking into account the heterogeneity of the lots raises many practical issues. First, although there is a catalogue published before the sale that detail the characteristics of the lots, potential buyers visit themselves the lots they intend to buy. Moreover, since bidders are not guaranteed to obtain the lots they want, they have to prospect 5 to 10 times more lots. That leads to non-negligible prospecting and estimation costs for the bidders. These search costs, which are directly linked to the heterogeneity of the product, are wasteful from a social perspective. Reducing the cost of preparing a bid in timber auctions may increase the number of bidders. It is then possible that the seller would be better off sharing all the information he has. Anyway, the seller also needs to assess as correctly as possible the value of any given lot so as to define a relevant reserve price.

2.3 Unsold lots and their negotiation

An interesting feature of French timber auctions is the high percentage of lots that remain unsold at the conclusion of the sale. The percentage of unsold lots can reach 50%. This raises questions about the adequacy between the supply and the demand and about the relevance of the auction mechanism. If supply exceeds demand, an auction sale does not seem to be a priori the best procedure to maximize the revenue of the seller. We may also think that reserve prices are too high, or that the sequential aspect of timber auctions does not allow an efficient allocation. For example, some bidders may neglect first lots in order to reserve themselves for following lots.

The importance of unsold lots and the intuition that an efficient allocation may be difficult to reach with sequential auctions of heterogeneous goods lead the ONF to negotiate the unsold lots. Although that practice aims to reduce the number of unsold lots, it may have a non-negligible impact on the auction results. Actually, bidders may anticipate the possibility to negotiate unsold lots and adapt their bidding strategy, which may be bad for the seller.

Some lots receive no bids. This fact is particularly deplorable in an auction and seems to show a priori that such lots have no demand. Now, some of those lots are nevertheless negotiated after the auctions. This fact suggests many strategic actions occur during the auctions. For example, a potential buyer who sees that there is no bid for a lot may not propose a price so as to keep his private information and let the seller think that his lot has no value in order to start the negotiation with an advantage. To sum up, the practice of negotiation after the auctions and the non-commitment to reserve prices may have important consequences on auction results.

3 Data

The data set we use in this article is part of the data collected by Costa and Préget (2004).

3.1 Fall 2003 Lorraine timber sales

The data set of Costa and Préget (2004) relies on the auction results of the ten Fall 2003 timber sales of Lorraine, a Region of the eastern part of France. During those ten sales, 2262 lots have been put on sale between September 9th and October 28th 2003, for a total volume exceeding 1 million cubic meter (m^3), which is about 750 000 m^3 stem volume[2]. That volume is composed of more than 80% by the principal species, which are the oak (20%), the beech (30%), the fir and the spruce (30%). Thus there is a relative homogeneity in the total supply. Nevertheless, it is not necessarily the case at the lot level. Actually, lots may be very heterogeneous and made up of many species. Costa and Préget (2004) propose to use the Herfindahl index so as to measure that intra lot heterogeneity.[3]

Since there are many differences between hardwood and softwood valuations[4], we select only pure hardwood lots, i.e. lots that are composed of more than 99% of hardwood.

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[2] Stem volume is the total volume minus the volume of the crown and the coppice.

[3] The Herfindahl index is the sum of the square volume proportion of each species. Here the number of species is limited to 7, then the Herfindahl index varies from 0.14 to 1. The more homogeneous is the lot, the closer is the index to one.

[4] We have first tested the stability of the hedonic price function for the different types of lots. An F-test indicated us that the price functions were different for Hardwood (1205 lots), Mixed lots (370 lots) and Softwood (687 lots).

Out of the 1205 pure hardwood lots put on sale, 26% come from domainal forests and 74% from communal forests. Moreover, only 48% of the lots are put on sale for the first time; thus 52% of the lots correspond to previously unsold lots.

At the end of the auctions, lots may be first classified according to the auction results. A lot sold during the auction is said to be "auctioned", whereas the others are what we call "unsold lots". The total percentage of unsold lots in the ten sales is 45% and shows a relatively difficult wood market conjuncture in the Lorraine area during that period.

It is useful to distinguish between lots that got one or more bids but have nevertheless been withdrawn by the auctioneer and those that got no bid at all, referred to as the "no bid" category. This first distinction corresponds to the "intermediate status". A second classification, referred to as "final status", decomposes unsold lots in two other subsets: the "negotiated lots", i.e. sold by negotiation after the last sale on October 28th, and the "not sold lots", which are still unsold at the end of the sale campaign arbitrarily fixed to December 31st 2003, more than two months after the date of the last sale.

Table 1 is a synthetic way to present sale results. Notice that a non-negligible number of lots without any bid (28) are nevertheless negotiated (they represent 27% of the negotiated lots), besides, most of the withdrawn lots (77%) remain unsold at the end of the sale campaign. 62% of the unsold lots remain so because the seller has withdrawn them and 38% did not receive any bid. Nevertheless, 20% of those 510 unsold lots are then negotiated.

Table 1. Lot repartition according to their status

Intermediary status \ Final status		Sold lots		Non sold lots	Total
		Auctioned lots	Negotiated lots		
Auctioned lots		695 (58%)			695 (58%)
Unsold lots	Withdrawn lots		74 (6%)	244 (20%)	318 (26%)
	Non submitted lots		28 (2%)	196 (14%)	192 (16%)
Total		695 (58%)	102 (8%)	408 (34%)	1205 (100%)

3.2 Database

The database of Costa and Préget (2004) includes more than one hundred variables that represent a large part of the information given in the catalogues. It also contains private information of the ONF (harvesting conditions, quality of the lot, secret reserve price), data about the auction results (the amount of each bid and the identity of the bidder, the auctioned or the negotiated prices) and computed data (Herfindahl index, density, prices in m^3). This database is particularly rich since it contains not only detailed information on lot composition, but also a lot of information on submitted bids associated to each lot. Moreover, it is an exhaustive database since it contains all the standing timber lots from public forests put on sale in the region during the fall of 2003.

The following two tables give summary statistics of variables used in our econometric study.

Table 2. Descriptive statistics for binary variables

Variable	Mean
No restrictions	0,3718
Cutting	
arranged cutting	0,5270
other cutting	0,0440
selection cutting	0,0108
accidental products	0,0274
regeneration cutting	0,3909
Previously unsold	0,5178
Harvesting conditions	
easy logging & extraction	0,2722
normal logging	0,5876
difficult logging	0,0274
difficult logging & extraction	0,0797
very difficult logging & extraction	0,0315
Mitraille (scrap-iron, grape-shot from the first world war)	
no mitraille	0,7743
light mitraille	0,1369
average mitraille	0,0598
heavy mitraille	0,0274
Negotiated	0,0846
Stand, crop	
high forest	0,2971
conversion of a stand	0,6241
coppice forest	0,0058
coppice with standards	0,0730
Landing area	
unarranged	0,8041
arranged	0,1593
none	0,0365
Domanial estate	0,2589
Quality	
very good	0,0407
good	0,3485
normal	0,4564
mediocre	0,1261
bad	0,0266
Sales	
sale 1	0,0988
sale 2	0,0083

sale 3	0,0705
sale 4	0,0680
sale 5	0,1801
sale 6	0,1635
sale 7	0,0008
sale 8	0,1884
sale 9	0,0000
sale 10	0,2216

Table 3. Descriptive statistics for continuous variables

Variable	Mean	Std. Dev.	Min	Max
Surface (in hectare)	12,41	10,38	0,20	104,04
Number of trees	238,27	205,63	21	2259
Number of poles	267,07	663,76	0	11366
Herfindahl index	0,6007	0,1949	0,3337	1,0000
Stem volume of the mean-tree	1,0623	0,7314	0,0596	4,7190
Oak volume without crown	94,51	115,98	0	859,98
Beech volume without crown	136,83	164,09	0	1365,80
Other hardwood volume without crown	67,66	97,25	0	838,60
Crown hardwood volume	166,62	153,64	0	1196,47
Coppice volume	0,33	5,39	0	153,83
Relative order of the auction	0,50	0,29	0	1

Next, all continuous variables are put in log except variables define in percentage such as the Herfindahl index and the variable used to give the relative order of the auction in the sale and the stem volume of the mean-tree.

40% of the sold lots are sold at a price lower than the seller reserve price (36% of the auctioned lots and 72% of the negotiated lots). These figures show that the seller does not commit to a credible reserve price and takes his decision to sale or not at the last moment. Thus, the reserve price of our data set has no clear signification. According to Table 4, lots that were negotiated above the reserve price only received few bids compared to the other lots. Since the seller is not required to reveal the secret reserve price when no bid has been submitted, it is possible that some negotiated lots are still sold above the reserve price. On the contrary, when bidders know the reserve price of an unsold lot (because it has been withdrawn), this lot is rarely negotiated at a price higher than the reserve price.

Table 4. Number of bids according to the auction results

	Number of lots	Average number of bids
auction price < reserve price	253	3.82
auction price > reserve price	436	4.34
negotiated price < reserve price	73	2.66
negotiated price > reserve price	22	0.14

4 Methodology

1.1 Hedonic prices

Given that lots have objectively different characteristics, we can apply the method of hedonic prices that decomposes the price of differentiated product y_l into a set of implicit prices associated with its characteristics x_l:

$$y_l = p(\mathrm{x}_l) = \beta_1 x_{l1} + \ldots + \beta_K x_{lK} + \varepsilon_l$$

where indices l and k respectively correspond to lot l (l = l, ..., L) and to characteristics k (k = 1, ..., K) and where β_k is the implicit price of characteristic k and ε_l is an unobservable component. These implicit prices result from market equilibrium and can therefore not be interpreted as willingness to pay of the bidders. See Rosen (1972) and Epple (1987).

4.2 Sample selection

Assessing the impact of the heterogeneity of a lot on its auction price is complicated by the fact that a large number of the lots are not sold and that the reserve price is not communicated to the bidders before the auction. We consider two cases: the lot is sold during the auction (with a price above or below the secret reserve price set by the seller) or it is unsold. If the reserve prices were announced (as in the US), we could apply the Tobit model, which is:

$$\begin{cases} y^* = X\,\beta + \varepsilon \\ y = \max\{0, y^*\} \end{cases}$$

where y^* is the auction price minus the reserve price[5], X is the matrix of explanatory variables and ε is the unobservable component. However the *effective* reserve price is different from the reserve price stated by the seller since in many cases the seller sold lots for which the best bid was inferior to the declared reserve price. In this case, it is more relevant to apply the sample selection model of Heckman. The selection equation is:

$$y_2 = \begin{cases} 1 & \text{if } w_2 = X\,\beta_2 + \varepsilon_2 > 0 \\ 0 & \text{otherwise} \end{cases}$$

where w_2 represents the value of the lot minus the effective random reserve price. In the second step, we observe the auction price, y_1, on the sample of lots sold during the auction

$$y_1 = X\,\beta_1 + \varepsilon_1 \qquad \text{if } y_2 = 1$$

This model can be estimated by the method of maximum likelihood if we assume that the unobservable variables (ε_1 and ε_2) have a bivariate normal distribution.

Computing the partial effects are complicated by the fact that some variables that influence the probability of a lot to be sold, $p(y_{2l} = 1)$, also influence the auction price.[6] For a continuous variable, the partial effect p_k can be computed from

$$E(y_{1l} \mid x_l, y_{2l} = 1) = x_l\,\beta_1 + \gamma_1\,\phi(x_l\,\beta_2) / \Phi(x_l\,\beta_2).$$

[5] We use the difference between the auction price and the reserve price to take into account of the fact that the truncation level varies from one lot to the other.

[6] STATA only computes marginal effect at the mean of the sample and treats binary variables as continuous. Partial effects computed in this way did not return sensible results. Partial effects computed in this section are easier to interpret.

Thus

$$p_k = \partial E(y_{1l} \mid x_l, y_{2l} = 1)/\partial x_{lk} = \beta_{1k} + \gamma_1 [\phi(x_l \beta_2)(-x_l \beta_2)\beta_{2k} \Phi(x_l \beta_2) - \phi^2(x_l \beta_2)\beta_{2k}] / \Phi^2(x_l \beta_2)$$

$$= \beta_{1k} - \gamma_1 \beta_{2k} \lambda(x_l \beta_2)[x_l \beta_2 + \lambda(x_l \beta_2)]$$

where $\lambda(\cdot) = \phi(x_l \beta_2) / \Phi(x_l \beta_2)$ is the inverted Mill's ratio. The average partial effect is simply obtained by taking the mean across observations:

$$(1/L) \sum_l \beta_{1k} - \gamma_1 \beta_{2k} \lambda(x_l \beta_2)[x_l \beta_2 + \lambda(x_l \beta_2)] \qquad (l = 1, ..., L)$$

For a binary explanatory variable, x_{lj}, the partial effect is simply given by

$$E(y_{1l} \mid x_l, y_{2l} = 1, x_{lj} = 1) - E(y_{1l} \mid x_l, y_{2l} = 1, x_{lj} = 0)$$
$$= \beta_{1j} + \gamma_1 [\lambda(x_{l1}\beta_{21} + ... + \beta_{2j} + ... + x_{lK}\beta_{2K})$$
$$- \lambda(x_{l1}\beta_{21} + ... + x_{lj-1}\beta_{2,j-1} + x_{lj+1}\beta_{2,j+1} + ... + x_{lK}\beta_{2K})]$$

The average effect is again computed by taking the mean across the lots. Formulas for the standard errors of the partial effects can be obtained by the delta method but are cumbersome to compute, and thus are reported in Appendix 1.

5 Results

5.1 The hedonic price function for hardwood lots in French public auctions

First, we apply the previous methodology on auctioned lots only. To take into account the fact that some unsold lots are negotiated at the end of the sales, we use the same methodology to estimate the price function of negotiated lots. An F-test indicates that there is no significant difference between the price function for the auctioned lots and the negotiated lots. Thus, the implicit price of each characteristic is the same if we look at auctioned lots or negotiated lots. This result shows that our hedonic price function is robust to the selling method and that we can analyze auctioned and negotiated lots together in our regressions. Table 5 gives the implicit prices of the characteristics of hardwood lots. The dependent variable is the log of the sale price.

Nevertheless, the ordinary least squares regression of sale prices with a binary variable for the selling method (1 if the lot has been negotiated, 0 if the lot has been auctioned) shows that this variable is significant (at the 10% level with OLS and at the 5% with Heckman procedure). In Table 5, the coefficient for the selling method dummy indicates that negotiated lots are sold between 10-12% less than auctioned lots.

The first two columns give the coefficients estimated by ordinary least squares (ignoring sample selection issues) and the standard errors. The next two columns give the estimation results obtained by the Heckman methodology using the method of maximum likelihood. The partial effects are either the estimated coefficient if the variable does not appear in the selection equation or the expressions obtained in section 4 and Appendix 1 for variables that also influence the selection process. The selection equation indicates the factors that influence whether a lot will be sold or not.

Table 5. Estimation results for hardwood lots

	OLS		Heckit		Partial effects	
Variables	Coeff.	Std. Err.	Coeff,	Std, Err,	Coeff.	Std. Err.
No restrictions	-0,0787	0,0409	-0,0760	0,0380	-0,0760	0,0380
Cutting (ref. arranged cutting)						
other cutting	-0,2466	0,0850	-0,1766	0,0769	-0,1766	0,0769

selection cutting	0,1815	0,3010	0,7208	0,2774	0,2848	0,2807
accidental products	-0,3473	0,1480	-0,1533	0,1491	-0,3787	0,1515
regeneration cutting	0,0953	0,0427	0,1111	0,0381	0,1111	0,0381
Previously unsold	-0,1499	0,0446	-0,1406	0,0407	-0,1406	0,0407
Harvesting conditions (ref. normal)						
easy logging & extraction	0,1610	0,0484	0,1293	0,0438	0,1293	0,0438
difficult logging	0,1273	0,0967	0,1226	0,0877	0,1226	0,0877
difficult logging & extraction	-0,1139	0,0630	-0,1377	0,0558	-0,1377	0,0558
very difficult logging & extraction	-0,1785	0,1004	-0,2008	0,0873	-0,2008	0,0873
Herfindahl index	1,3293	0,1536	1,0947	0,1566	1,3616	0,1745
Number of trees	0,4941	0,0436	0,4731	0,0457	0,5204	0,0689
Number of poles	-0,0121	0,0166	-0,0027	0,0177	0,0160	0,0501
Surface	0,0560	0,0345	0,0834	0,0381	0,0375	0,0623
Other hardwood vol. without crown	0,0865	0,0201	0,0792	0,0182	0,0792	0,0182
Oak volume without crown	0,2317	0,0188	0,1746	0,0195	0,2173	0,0834
Crown hardwood volume	0,0693	0,0142	0,0826	0,0155	0,0544	0,0929
Beech volume without crown	0,1294	0,0159	0,1127	0,0149	0,1127	0,0149
Coppice volume	-0,0402	0,0545	-0,0558	0,0510	-0,0558	0,0510
Mitraille (scrap-iron, grape-shot from the first world war) (ref. none)						
light mitraille	0,0101	0,0532	0,0233	0,0570	0,0114	0,0578
average mitraille	-0,1303	0,0715	-0,1771	0,0672	-0,1771	0,0672
heavy mitraille	-0,2558	0,1031	-0,2592	0,1141	-0,3307	0,1143
Negotiated	-0,1187	0,0588	-0,0921	0,0528	-0,0921	0,0528
Relative order of the auction	0,2512	0,0558	0,1922	0,0509	0,1922	0,0509
Stand, crop (ref. other)						
conversion of a stand	0,1882	0,0472	0,1595	0,0433	0,1595	0,0433
coppice forest	-0,2390	0,2478	-0,2883	0,2086	-0,2883	0,2086
coppice with standards	0,2102	0,0705	0,1357	0,0641	0,1357	0,0641
Landing area (ref. non arranged)						
arranged	0,0653	0,0463	0,0890	0,0515	0,0618	0,0516
none	-0,0631	0,0951	0,0650	0,1045	-0,0079	0,1044
Domanial estate	0,0455	0,0395	-0,0858	0,0450	0,0480	0,0478
Quality (ref. normal)						
very good	0,2667	0,0774	0,2122	0,0734	0,2122	0,0734
good	0,2032	0,0371	0,2005	0,0340	0,2005	0,0340
mediocre	-0,1002	0,0529	-0,0289	0,0486	-0,0289	0,0486
bad	0,0278	0,1080	-0,0194	0,1180	0,0334	0,1181
Sale (ref. sale 1)						
sale 2	-0,3034	0,2286	-0,3586	0,2008	-0,3586	0,2008
sale 3	-0,0019	0,0995	-0,0964	0,1008	-0,0388	0,1013
sale 4	-0,1688	0,0864	-0,3086	0,0888	-0,2126	0,0898
sale 5	-0,1181	0,0845	-0,0895	0,0745	-0,0895	0,0745
sale 6	-0,2542	0,0775	-0,2278	0,0697	-0,2278	0,0697
sale 8	0,0988	0,0705	0,0830	0,0695	0,1159	0,0700
sale 10	0,1651	0,0768	0,1714	0,0707	0,1714	0,0707
Stem volume of the mean-tree	0,5126	0,0468	0,5457	0,0479	0,5457	0,0479
Constant	2,7755	0,1858	3,4716	0,1967	3,4716	0,1967
Selection equation						
selection cutting			-1,3554	0,4320		
accidental products			-0,7672	0,2569		
Herfindahl index			1,0592	0,2301		
Number of trees			0,1879	0,0806		
Number of poles			0,0742	0,0238		
Surface			-0,1820	0,0752		
Oak volume without crown			0,1693	0,0296		

Crown hardwood volume		-0,1118	0,0289	
light mitraille		-0,0470	0,1078	
heavy mitraille		-0,2676	0,2299	
landing area: arranged		-0,1058	0,1060	
landing area: none		-0,2730	0,2024	
Domanial estate		0,5691	0,0987	
bad quality		0,2211	0,2286	
sale 3		0,2411	0,1665	
sale 4		0,4197	0,1616	
sale 8		0,1333	0,1022	
Constant		-1,2949	0,3222	
rho		-0,9194	0,0217	
sigma		0,5277	0,0192	
lambda		-0,4852	0,0270	
R2	0,82			
Obs.	797	1205		

All unsold lots were previously unsold during a previous sale. In our sample, all new lots have been immediately sold during the auction or by negotiation. This is why the variable ‘previously unsold’ does not appear in our selection equation.

The signs and the value of the implicit prices are coherent and intuitive, except for the variable ‘no restriction’ for which the coefficient is surprisingly negative. The model explains 82 percent of the variance of the sale prices, which is a good fit.

With respect to the main issues of the article, three elements should be pointed out.

First, the coefficient associated with the inverted Mill's ratio (lambda) is significantly different from zero, which means that the sample selection bias can not be ignored for hardwood lots. Accordingly, implicit prices obtained by ordinary least squares are relatively different from the partial effects computed from the coefficients estimated by the sample selection model.

Secondly, the degree of heterogeneity of the lot significantly influences the probability that a lot will be sold and its sale price. Thus, concentrated lots with an Herfindahl index close to 1 (in other words lots that are not heterogeneous) have a sale premium: an increase of 1% of the concentration index increases the sale price by 1.36%.

Thirdly, the coefficient associated with the relative position of a lot in the auction is significantly positive. This indicates that lots sold at the end of an auction have a higher price, once we control for quality differences. This last result implies that the decline in prices often observed in sequential auctions is not present in our timber auctions and that prices on the contrary increase for hardwood lots. This could be due to cautious behavior of the bidders in the beginning of the auction and more aggressive bids at the end of the auction before the negotiation phase.

5.2 Tradeoff between few unsold lots and high reserve price

We now turn to the discussion about unsold lots and the mechanism to set reserve prices.

Among the 408 unsold lots, 22% had a highest bid above our estimated hedonic value. Moreover the seller sets a reserve price above our estimated hedonic value for 53% of the lots. These percentages indicate that the reserve price of the seller could be improved. This could also explain why so many lots are sold at a price lower than the reserve price.

Table 6. Comparisons with the hedonic value

Variable	Obs	Mean	Std. Dev.	Min	Max
Reserve price / hedonic value	1205	1,0910	0,4744	0,0838	4,4097
Auction price / hedonic value	695	1,0841	0,3968	0,1336	3,0260
Seller's estimated value / hedonic value	1205	1,2857	0,5304	0,1761	5,4273
Negociated price / hedonic value	102	1,0808	0,4760	0,2434	2,5576
Best offer / hedonic value	1013	1,0480	0,4110	0,1336	3,0260
Probability of a lot to be sold	1205	0,6573	0,1610	0,0497	0,9825

From table 6, we see that on average, reserve prices, auction prices, seller's estimated values, negotiated price and highest bids are above our estimated hedonic values. This is partly due to the fact that we take into account the probability of a lot to remain unsold in the computation of the expected value. Indeed, the average probability that a lot will be sold is 66%, which means that there is a high likelihood in our sample that a lot remains unsold. Nevertheless, the standard deviations of these ratios are quite large. It also worth stressing that the estimated seller's value is off our hedonic value by almost 30%.[7] Again, these percentages indicate that the reserve price of the seller could be improved

[7] Note that the estimated seller's value does not represent the seller's reservation value since the reserve price is almost always fixed under that value. The estimated seller's value is probably an estimation of the "fair" market value.

Since many lots remain unsold it is important to distinguish between the revenue raised during the auction and the implicit value of the unsold lots.

First we assess the “ex ante value” of the lots put on sale, which we evaluate to the sum of the hedonic values of all lots. We get 13 112 540 €.

Second, we compute the “ex post value” for the seller which is the sum of the hedonic values of the 408 unsold lots plus the sum of the sale prices of the 797 auctioned and negotiated lots. We get 3 422 988 € + 10 425 880 € = 13 848 868 €

As we have discussed, 303 lots have been sold below their hedonic value whereas 88 lots were not sold although there were bids above their hedonic value. So we can propose to set the reserve price at the hedonic value and to forbid any negotiations after the auctions. Under these assumptions, the ex post value is now the sum of the maximum value between the hedonic value and the high bid (assuming that the bidders do not change their bidding strategy). In this case, 686 lots remain unsold which represent a value of 7 088 040 € and only 519 lots would be auctioned for a total receipt of 8 112 626 €. The total value reaches then 15 200 666 €.

Although the auction revenue would decreased by 2 313 254 € the new total ex post value would increase by 1 351 798 €.

So, if the seller has to raise a minimum amount of money, we suggest that he sets his reserve price to a fraction of the hedonic value so as to meet his financial requirements. We can also use this strategy to ensure that a certain fraction of the lots will be sold during the auctions: the lower the reserve price, the lower the number of unsold lots.

6 Conclusion

Using detailed data set on timber auctions in Lorraine, we have highlighted the importance of the heterogeneity of a lot on its auction price. First, we have shown that the hedonic price equation is different for hardwood lots, mixed lots and softwood lots. It is therefore necessary to group similar lots in order to estimate implicit prices of the characteristics more precisely. Secondly, several characteristics of the lots significantly influence the auction prices, which stresses the importance of the inter-lots heterogeneity. The existence of unsold lots does not seem to create sample selection biases for mixed and pure softwood lots. On the contrary, we have found that implicit prices of the characteristics of hardwood lots are subject to a sample selection bias that we have corrected using the Heckman estimation procedure. Thirdly, the most homogenous lots are sold with a premium, while the most heterogeneous lots are sold at lower prices. This results emphasizes the impact of intra-lot heterogeneity. This result is comparable to the finding of Boltz, Carter and Jacobson (2002). We can use our estimation results to assess the opportunity cost of biodiversity. Indeed, the policy of preserving biodiversity gives priority to lots with different types of wood. However, our results indicate that such a policy penalizes the wood production function by reducing the value of these lots due to their heterogeneity. Lastly, we have shown that the negotiated lots are sold at lower prices but the hedonic price associated to each characteristic is the same that the one estimated on auctioned lots. This last result leads us to suggest that the seller should forbid negotiations on unsold lots and should use our hedonic prices to determine better the reserve price of each lot. Besides, our hedonic price function for stumpage value gives interesting information about the implicit price of each lot characteristic for the optimal lot composition.

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Appendix 1

In this appendix, we report the formulas for derivative of the partial effects that can be used to apply the delta method in order to compute standard errors. There are K_2 characteristics that influence the probability that a lot will be sold. We now assume that the first K_2' characteristics are continuous while the next are binary. The derivatives of the partial effects, p_k, with respect to β_1 are

$$\partial p_k/\partial \beta_{1j} = \begin{cases} 0 & \text{if } j \neq k \\ 1 & \text{otherwise} \end{cases} \qquad k = 1, \ldots, K_2', \; j = 1, \ldots, K_1$$

Derivatives with respect to β_2 are given by:

$$\partial p_k/\partial \beta_{2j} = (1/L) \textstyle\sum_l (-\gamma_1) \{1(i=j)\, \lambda(x_l\, \beta_2)\, [x_l\, \beta_2 + \lambda(x_l\, \beta_2)] + \beta_{2k}\, x_{lj}\, (1 - [x_l\, \beta_2 + \lambda(x_l\, \beta_2)]\, [x_l\, \beta_2 + 2\lambda(x_l\, \beta_2)])\} \quad (l = 1, \ldots, L)$$

For the next $K_2 - K_2'$ binary variables, the derivatives of the partial effects with respect to β_1 are given by

$$\partial p_k/\partial \beta_{1j} = \begin{cases} 0 & \text{if } j \neq k \\ 1 & \text{otherwise} \end{cases} \qquad \text{for } k = K_2'+1, \ldots K_2 \text{ and } j = 1, \ldots, K_1.$$

Derivatives with respect to β_2 are given by:

$$\partial p_k/\partial \beta_{2j} = \begin{cases} (1/L) \textstyle\sum_l \gamma_1\, x_{lj}\, \lambda(x_l\, \beta_2)\, [x_l\, \beta_2 + \lambda(x_l\, \beta_2)] \text{ if } k = j \quad (l = 1, \ldots, L) \end{cases}$$

$\lfloor$ otherwise

for $k = K_2'+1, \ldots K_2$ and $j = 1, \ldots, K_2$.

Finally, derivatives of p_k with respect to γ_1 are simply given by

$$(1/L) \textstyle\sum_l \beta_{2k} \, \lambda(\mathrm{x}_l \, \beta_2) \, [\mathrm{x}_l \, \beta_2 + \lambda(\mathrm{x}_l \, \beta_2)] \qquad (l = 1, \ldots, L)$$

for continuous variables and by

$$(1/L) \textstyle\sum_l [\lambda(x_{l1}\beta_1 + \ldots + \beta_j + \ldots + x_{lK}\beta_K) - \lambda(x_{l1}\beta_1 + \ldots + x_{lj-1}\beta_{j-1} + x_{lj+1}\beta_{j+1} + \ldots + x_{lK}\beta_K)]$$

for binary variables ($l = 1, \ldots, L$).