THE ECONOMICS OF TIMBER AUCTIONS IN SOUTHERN ONTARIO*

by

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Abstract

For the multi-unit auctions conducted by the county of Simcoe it seems reasonable to assume that the independent-private-values model describes the bidding behavior of the participating sawmills. The bidders exhibit asymmetries on account of technology, location, and frequency of participation. While the fringe firms bid competitively, the nonfringe firms seem to be coordinating their bidding strategies on the basis of their bidding experience in the first five years of the sample period. Some support is provided by the data for aggressive/nonaggressive bidding strategies that characterize the bidding behavior of bidders with multi-unit demand facing budgetary restrictions or capacity constraints that has been discussed by Engelbrecht-Wiggans and Weber (1979); the evidence is however, not conclusive. The large differences in the winning bid and the second-highest bid noted by Engelbrecht-Wiggans and Weber (1979) could be due to asymmetries in bidders valuations. The sawmills also seem to learn from subsequent sales in a year. Since the county allows a year's harvesting time, and resources for harvesting timber are limited, I cannot assume that the sales are independent. Neither the woodlots in a sale, nor the environment across sales is homogenous.

Key Words: Aggressive/nonaggressive, asymmetry, coordination games, first-price sealed-bid, fringe, multi-unit.

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1 Introduction

The aim of this paper is to provide a statistical analysis of the bidding decision of the sawmills participating in the first-price, sealed-bid auctions conducted by the county of Simcoe in Southern Ontario for standing timber in the woodlots that it owns.[1] Ascertaining key aspects of the bidding decision of the sawmills is of interest to the county of Simcoe since it will aid the county in designing an auction that satisfies its two-fold aim in conducting these auctions. One is to get a fair market value for the standing timber on the woodlots that it owns. Second, is to support a viable forest industry since the benefit to the rural community in terms of economic development and environmental protection is significant. The auctions can be viewed as an insurance for the sawmills since they ensure the availability of timber on a periodic basis.

The bidding behavior of the sawmills participating in the sales conducted by the county of Simcoe is interesting for *at least* three reasons.

First, the auctions conducted by the county of Simcoe are *multi-unit* auctions, with the standing timber on multiple woodlots being put up for sale in each auction. Several papers in recent years have pointed out the additional issues that arise on

[1] Prior to 1996, the Ministry of Natural Resources was conducting these auctions on behalf of the county of Simcoe.

account of the multi-unit aspect of the auction. The *key issue* is that the auction of a unit, a woodlot in the current context, cannot be regarded to be independent of the auction of the other units within a sale. The bidders bid strategically across woodlots within a sale. For example, Donald, Paarsch and Robert (1997), in the context of a sequential, oral, ascending-price, open-exit auction with multi-unit demand, point out that the winning prices in an auction form an increasing sequence in the case where potential bidders demand more than one unit and no resale is allowed.

Second, I identify three types of *asymmetries* in bidder's valuations: asymmetries due to harvesting technology, location of the sawmill of a bidder, and the frequency of participation. As a result, I *cannot* assume that the bidders valuations are drawn from the same distribution; the bidders are not identical. The *key* issue now is that in a first-price, sealed-bid auction the winner may not be the bidder with the highest valuation.[2] In view of the literature on asymmetric auctions,[3] it is straightforward to handle asymmetries in bidder's valuations due to the harvesting technology and location of the sawmill. The asymmetry in bidder's valuations due to the frequency of participation adds an *additional* dimension to the bidding strategies of the sawmills. The equilibrium strategy of a bidder is now affected by not just the potential competition she expects, but by the probability of participation of bidders, as well.

Third, the bidders who are bidding frequently seem to be *coordinating* their bidding strategies so that they avoid competing with each other. I find the frequent bidders bidding on woodlots with different average volume per tree.

Given the fact that our knowledge of the bidding strategy of the bidders in a multi-unit, asymmetric setting, with noncompetitive bidding is limited, commenting on an optimal auction form or ranking auction forms in terms of expected revenue of the seller becomes even more difficult. The auctions conducted by the county are a classic example of the inappropriateness of the existing results on ranking of auction forms when a single object is being auctioned.[4] For example, the Ontario Ministry of Natural Resources has experimented with English auctions in the past; this practice was given up since the bids received were lower than the usual bids. This is contrary to the result obtained for a single-unit auction by Milogram and Weber (1982, p. 1095) that an English auction generates higher revenue than a first-price, sealed-bid

[2]The effect of asymmetry on the bidding strategies is minimal in the case of the English auction or the second-price auction. It is still optimal for the bidder to bid her valuation; the revenue to the seller is still the second-highest valuation. In a first-price, sealed-bid auction, the equilibrium strategy of a bidder is again to bid the expected value of the second-highest valuation conditional on his valuation being the highest. Since valuations are not drawn from the same distribution, the high bidder need not be the high type bidder.

[3]Assuming the independent-private-values model, with bidders drawing their valuations independently from *different* distributions, LeBrun, 1999, and Bajari, 1998 prove the existence and uniqueness of a pure strategy equilibrium for a first-price, sealed-bid auction of a single object. They also assume that the bidders are risk neutral.

[4]Excellent survey of this literature is provided in Milogram and Weber (1982) and McAfee and McMillan (1987).

auction if the bidder's value estimates are statistically dependent; this is the case in the auctions conducted by the county as I will show below.[5]

Empirical work which takes into account the additional issues that arise from the multi-unit aspect of the auction is limited. Two notable exceptions are the work by Donald, Paarsch and Robert (1997) and Hendricks, Porter and Boudreau (1987) and Porter (1995). The former paper studies sequential, oral, ascending-price, open-exit auctions of Siberian timber export permits within an independent private-values framework. The latter set of papers studies US government first-price, sealed-bid auctions of oil and gas leases for the Outer Continental Shelf (OCS) from 1954 through 1969. In the terminology of Weber (1983), these are *simultaneous-independent* auctions with multiple tracts up for lease in each auction or sale. Since the value of the tract is unknown till drilling and production of oil and gas commences, Hendricks, Porter and Boudreau justify a common-value model for these auctions.

The auctions conducted by the county of Simcoe are similar to the OCS auctions in that they are simultaneous-independent, first-price, sealed-bid auctions, where multiple woodlots are put up for sale in each auction. Unlike the OCS auctions, I cannot justify the common-value model as an appropriate bidding model. I will attempt to justify that, for the auctions conducted by the county of Simcoe, the private-values model seems more appropriate. Further, I will try to establish that the private estimates of the bidders for the standing timber on the woodlots are independent after taking into account the observable variations between the bidders, as well as, the woodlots.

I emphasize again that the attempt here is neither to construct a theoretical model of bidding nor carry out any estimation; these will be attempted in future research. Rather the aim is to isolate key components of the participation and bidding decision in order to proceed with this future research.

I describe the auction mechanism in section 2. In section 3 a description of the data and important summary statistics are given. I also motivate why woodlots should be classified as hardwood and softwood lots. Explanation is also provided for why no bids were received on some woodlots even though the right to harvest timber on these woodlots was auctioned off more than once. At the same time there were woodlots on which no bids were submitted the first time they were part of an auction, but got sold the second time they were part of an auction.

In section 4, I categorize the participating sawmills in three ways corresponding to the three asymmetries noted earlier. Since the technology to harvest and process hardwood and softwood is different, I classify the sawmills into hardwood and softwood sawmills. Of the 109 sawmills participating in these auctions, the sawmill of

[5]In the English auction described by Milogram and Weber (1982, p. 1104) the price is posted on an electronic display; this price is raised continuously. A bidder who wishes to be active at the current price depresses a button; once he has released the button, he has withdrawn from the auction and does nor re-enter the auction. In this "button" auction, the bidder observes the price level, as well as, the number of active bidders since these appear on the electronic display continuously.

only four bidders is located within the county of Simcoe, giving them a distinct cost advantage over the bidders who have their sawmills outside the county of Simcoe. On this basis, I classify the sawmills as *insiders* and *outsiders*. Finally, I see three sawmills bidding consistently throughout this period, and the rest bidding sporadically, leading to a possible incentive on the part of the former to coordinate their strategies. On this basis I classify the sawmills as *fringe* and *nonfringe* sawmills. The three nonfringe sawmills will be called X, Y and Z.[6] A preliminary bidding model is also proposed.

I am able to recover some evidence of strategic bidding across auctions within a sale on the basis of the money left on the table and the preliminary bidding model proposed. As a result, it is inappropriate to *ignore* the multi-unit aspect of the sales conducted by the county of Simcoe.

Section 5 discusses the entry equilibrium in sales in a year. Conditional on participation in a sale, entry equilibrium in auctions within a sale is also discussed. Section 6 outlines a model of participation and bidding. Section 7 concentrates on three nonfringe sawmills X, Y and Z. I suggest in this section that these three bidders seem to be coordinating their bidding strategies by bidding on woodlots with different volume per tree to avoid competing with each other. Competition for these nonfringe sawmills comes from the fringe sawmills; this is discussed in Section 8. Section 9 concludes.

2 Description Of The Auction Mechanism

The county of Simcoe organizes up to three sales each year to transfer the harvesting rights to the standing timber on the woodlots that it owns. A sale involves auctioning off *multiple* woodlots; a first-price, sealed-bid auction is conducted separately for each woodlot. Thus each sale consists of the simultaneous but independent right to harvest the standing timber from multiple woodlots.

At the beginning of each year, on the basis of silvicultural reasons, the county officials mark down the trees that are to harvested in different woodlots across the various townships of Simcoe and some townships in the adjoining county of Dufferin. The woodlots differ in terms of the number, species and diameter of the trees that are to be harvested. The County aggregates the trees into "units" or woodlots; the "units" are apportioned into sales. Multiple sales, to a maximum of three, are held each year to sell the right to harvest the marked trees on these woodlots.[7]Details of

[6]Sawmills are being indicated by alphabets to ensure that the identity of the sawmills is not made public.

[7]The aim of the County in conducting three sales in a year instead of conducting just one sale in a year is to enable bidders to take advantage of the information revealed in the previous sales in the year. In this sense the multiple sales in a year in Simcoe are comaparable to the multiple bidding rounds in the PCS spectrum auctions. *Unlike* the PCS spectrum auctions, the county learns from a sale in that it can be strategic in the subsequent sales in that year in the manner in which it puts up the woodlots. The County has held 4 sales in 1999.

each sale are announced *only prior* to a sale.

A sale begins with the county mailing a tender notice to all sawmills on the mailing list maintained by the county. Note that only bidders on the mailing list are eligible to submit bids.[8] The information provided by the county to the sawmills in the tender notice consists of the time and date on which the tender will be closed, and the time at which the tender will be opened, which is normally 1-2 hours after the tender is closed. All bids have to be submitted before the time and date at which the tender is to be closed. For each woodlot in an auction, the township in which the woodlot is located, the number, species, average diameter of the trees of a particular species, and an estimate of the standing timber on the woodlot is also provided in the tender notice. Prior to the sale, the county conducts an information session and a non-mandatory site tour of all the woodlots for which the right to harvest timber is being transferred in the sale. The time of this site tour is included in the tender notice mailed by the county to the sawmill.

The sawmill submits a sealed bid individually for the woodlots on which it wants to bid prior to the closing of the tender. It can bid on more than one woodlot which introduces the *multi-unit* aspect of these auctions. Twenty five percent of the sealed bid submitted by the sawmill for a woodlot has to be deposited by the sawmill as downpayment with the sealed bid. This amount is returned by the county to the sawmill if the sawmill does not have the highest bid on a woodlot. At the specified time, the county opens the sealed bids for each woodlot. The sawmill that submits the highest bid on a woodlot is awarded the contract for harvesting timber on that woodlot. It has to pay the balance of the bid that it submitted within thirty days or before it begins harvesting the woodlot, whichever is first. The identity and the bid of all the bidders on each woodlot is made public by the county.

When a sawmill wins the right to harvest the standing timber on a tract, it has a year to harvest the timber. Resale of the right to harvest timber by the winning sawmill to another sawmill is strictly forbidden by the county. Note that southern Ontario is well-developed in terms of transportation and communication so that the winning sawmills do not have to expend time and resources on building roads to access the woodlots. The county does provide special instructions as to how the felled timber is to be removed from the woodlot so that other trees on the woodlot are not damaged; fines are issued if these instructions are not met.

While there is no announced **reservation price**, the county participates in the auctions by retaining the right to reject a bid if it finds the bid to be too low. The county bases this assessment on a private estimate of the value of the woodlot. In my sample, there were 15 woodlots on which the right to harvest timber was not transferred to the bidder with the highest bid because the county found the bid too

[8]The mailing list is revised periodically by the county. A sawmill on the mailing list who has not won an auction in the past two years is removed from the list. The county adds sawmills to its mailing list on the basis of requests from these sawmills. The mailing list was last revised in January, 1995.

low. This is just 4% of the 339 woodlots that were auctioned across these years. It *seems* that the secret reserve price set by the county is non-binding.

3 Description Of The Data

My study focuses on the sales conducted by the county of Simcoe between the years 1987-1998.[9] In this time period 29 sales that involved the right to harvest the standing timber on 379 woodlots were held; a total of 704 bids were submitted. Of these 379 woodlots, no bids were submitted on 91 woodlots; I examine why bids were not submitted in these woodlots at the end of this section.

Table 1
List of Variables

Variable	Symbol	Unit of Measurement
Number of trees	T	-
Volume	V	cubic metre
Real Bid on a Woodlot	B	$ (canadian)
Real Winning Bid on a Woodlot	W	$ (canadian)
Real Second Highest Bid on a Woodlot	B2	$ (canadian)
Money Left on the Table on a Woodlot	W-B2	$ (canadian)
(Volume)/(Number of Trees)	V/T	cubic metre per tree

For each woodlot, I have data on the number of trees, species and average diameter of the trees, an estimate of the volume of standing timber, and the identity and bid of the sawmills that submitted bids for this woodlot. The location of each woodlot is also known. For bidders who own sawmills within the county of Simcoe, I know the exact location of their sawmills. For bidders who have sawmills located outside the township of Simcoe, I know the township in which the sawmill is located.

Table 1 lists some of the variables.[10] Since the county of Simcoe is known for its good quality softwood and I know the species of the trees on a woodlot, I have categorized all the woodlots into three categories, softwood, hardwood and mixed-wood. I have included pines of all kinds under softwood and the rest of the species as hardwood. When a woodlot contains only softwood trees, I call that a softwood lot and similarly for hardwood lots. When a woodlot contains both softwood and hardwood trees I call it a mixedwood lot. On an average each sale consisted of 6 softwood lots, 3 hardwood lots and 5 mixedwood lots. Of the 288 tracts on which bids were submitted, I observe that on an average 3 sawmills submitted bids on each tract, the average bid per cubic meter per tree, B/V/T, being 0.0163 $/m3/tree.[11]

[9] For the years 1994 and 1995 I have data on only a single sale even though three sales were held in each year.

[10] All monetary variables have been expressed in real Canadian dollars. The lumber and timber industrial price index, with 1986 as the base year, has been used to convert all nominal variables into real variables.

[11] m3 indicates cubic metre, the unit in which volume is measured.

Mixedwood lots do not lend themselves to easy interpretation. The reason is that there were just two mixedwood lots that contained roughly the same volume of hardwood and softwood tress. Further, there is just one key sawmill, Y, which every once in a while, bids for woodlots with large diameter, hardwood trees; I find that 20% of the bids submitted by Y are on large diameter hardwood lots.[12] Other sawmills seem to be targeting either softwood or hardwood in these auctions.

On this basis I categorized the mixedwood lots further into primarily softwood lots and primarily hardwood lots if more than 60% of the volume on a woodlot came from softwood or hardwood species, respectively. By this categorization, 198 primarily softwood lots and 181 primarily hardwood lots were put up for sale in this period. Table 2 presents summary statistics with this categorization. There are three points to note here.

Table 2
SAMPLE DESCRIPTIVE STATISTICS BY TYPE OF WOODLOT

Variable	Mean	St.Dev.	Min	Max
(1) Primarily Softwood Lots				
Participants	2.46	1.52	1	8
V/T	0.3063	0.1405	0.0441	0.8444
B/V/T	0.0100	0.0311	0.0008	0.3714
W/V/T	0.0129	0.0419	8.35E-05	0.3714
(W-B2)/V/T	0.00551	0.0227	0.2525	0
(2) Primarily Hardwood Lots				
Participants	2.43	1.73	1	9
V/T	0.3736	0.2434	0.0494	1.6261
B/V/T	0.0259	0.0362	0.0064	0.2235
W/V/T	0.0263	0.0374	0.0004	0.2235
(W-B2)/V/T	0.01128	0.0207	0.1702	0

First, the average number of participants is the same on both types of woodlots. Given the fact that the county of Simcoe is known for its softwood, I had expected competition to be more intense on the softwood lots.

Second, the average bid/m3/tree is higher on the hardwood lots than the softwood lots, again contrary to the fact that Simcoe is known for it's softwood. A possible explanation could be the average volume of timber per tree, which is higher in the former than the latter since hardwood trees typically have larger diameter. However, though the average volume/tree is only 27% higher in hardwood lots compared with softwood lots, the average bid/volume/tree is more than double in the former than the latter.

[12]County officials inform me that Miller is supplying processed lumber for electricity poles which require large diameter, hardwood trees.

Hardwoods *typically* have higher market value than softwoods. While this could explain both features of the data mentioned in the last two points, it is not consistent with what I observe for the maximum volume/tree and bid/volume/tree when I compare the two types of woodlots. I find that the maximum bid/m3/tree is 40% higher in the softwood lots than the hardwood lots. The corresponding volume/tree is 15% lower on the softwood lot compared with the hardwood lot; it is 0.59 m3/tree on the former and 0.68 m3/tree on the latter. It is also important to note that the primarily hardwood and softwood lots on which the maximum bid/volume/tree was submitted contained *exclusively* hardwood and softwood trees, respectively.[13]

These observations seem to indicate that there are some sawmills whose valuation of the woodlot is affected by factors, some of which may be *observable*, other than the volume of timber per tree on a woodlot and the market price of lumber. This becomes clear in the next section, where I show that there is heterogeneity amongst the bidders in terms of the species and the quality of the trees in a woodlot they prefer to bid on, whether their sawmills are located within the county of Simcoe or not, and the demand they face in the processed lumber market.

The third point concerns the money left on the table or the difference between the winning bid and the second-highest bid. I find that for both type of woodlots, the average money left on the table, (W-B2)/V/T, is approximately half of the average winning bid, W/V/T; in other words, the winning bid is twice the second-highest bid. Engelbrecht-Wiggans and Weber (1979) describe an equilibrium in aggressive/nonaggressive strategies for a multi-unit auction with budgetary restrictions or capacity constraints and *without* resale, where the spread between the winning and the second-highest bid is similar to the one that I have noted. Hendricks, Porter and Boudreau (1987, p. 524) also note a similar spread in the OCS wildcat auctions. As Weber (1983, pp. 179-181) points out, even when the different units in the multi-unit auction are similar, bidders bid aggressively on some units and less aggressively on others. The aggressive bidding is done in an attempt to ensure that at least *some* woodlots are won in an auction. This could be either because the sawmill has an order for processed lumber of a particular type, or to ensure that some minimum timber is available to keep the sawmill running. I have mentioned above that the auctions are like an insurance for the sawmills in that they promise a regulated supply of timber. The less aggressive bidding is done because a sawmill, knowing that resale is not allowed by the county, wants to ensure that it does not win *too many* woodlots. A possible reason is that the sawmill does not want to overcommit harvesting resources on one auction within a year. That is, capacity constraints in the form of limited local resources to harvest timber is a possible reason. This gets support from the fact that I see firms with sawmills outside the county bringing in their own equipment to harvest the timber. The key point is that the sawmill bids less aggressively on these woodlots,

[13] This was not the case for the woodlots which had the maximum volume/tree; the bid submitted on these woodlots, as a result, was low. Thus the highest bid submitted on the primarily hardwood lot with the largest volume/tree, 1.63 m3/tree, was only 0.07 $/m3/tree because 80% of the trees in this woodlot were large diameter, damaged hardwood trees which could be used only for fuelwood.

expecting to win these woodlots if the other sawmills also bid unaggressively, and as a result win them at a bargain price.

Engelbrecht-Wiggans and Weber (1979) and Weber (1983) assume simultaneous, but independent, auction of *identical multiple* units, with no resale, to arrive at the equilibrium in aggressive/nonaggressive strategies that I have described above. The following assumptions are made about the environment in which the buyers and sellers interact. The bidders are assumed to be risk-neutral and *identical* and face budgetary restrictions and capacity constraints. The bidders face no uncertainty about the "true" value of the object being auctioned; further, the private-values of the bidders are independent.

I will show below that two *key* assumptions which deliver the equilibrium in aggressive/nonaggressive strategies described by Engelbrecht-Wiggans and Weber (1979) are violated in the auctions conducted by the county of Simcoe; the woodlots in a sale are not identical and the bidders are **asymmetric**. The large difference in the winning bid and the second-highest bid could, as a result, be on account of asymmetries in bidders valuations and not the aggressive/nonaggressive strategy of bidders in multi-unit auctions with capacity constraints.

I now analyze the 91 woodlots on which bids were not submitted. 20 of these woodlots were part of only one auction; the county withdrew them from future auctions. 40 woodlots were part of 75 auctions but still received no bids.[14] Finally there were 16 woodlots on which no bids were submitted the first time they were part of an auction. Bids were received on these woodlots the second time they were part of an auction with the highest bidders winning the woodlot. Why was it that the county was successful in auctioning off some of these woodlots the second time they were part of an auction and not the others.

First, the woodlots which received no bids are scattered all over the county of Simcoe; there does not seem to be any particular geographical area where the sawmills are systematically not submitting bids.

Second, I observe that the average volume per tree is 43% higher in the woodlots that eventually got auctioned-off compared with the ones that did not; the average volume per tree was 0.2369 m3/tree, which is below the average given in Table 2. Thus bidders systematically rejected poor quality woodlots or woodlots yielding low volume per tree.[15]

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[14] A woodlot, if it receives no bid the first time it is part of an auction, is in most instances part of three consective auctions. If no bid is received even then, the county may arrange an across the counter sale.

[15] This is also consistent with the practice in auctions held before 1992 of having stand improvement sales. The county auctioned off the right to harvest trees on these woodlots for silvicultural reasons. That is, selective thinning improved the health of the forest even though the felled trees had marginal commercial value. Considerable operational dollars were saved by this process as the alternative was for the county to hire private operators to carry out this selective thinning. This was common knowledge.

What still needs to be explained is why sawmills bid on the 16 woodlots the second time they were part of an auction, while they did not bid the first time. 12 bidders won these 16 woodlots the second time they were put up for sale. 9 of them were inactive in the first auction when the woodlot was put up for sale and no sawmill bid on it. The remaining three were however active, with the sawmill of two of these bidders located outside the county of Simcoe. Their behavior seems to be consistent with the aggressive/nonaggressive bidding strategy in multi-unit auctions with capacity constraints that I have discussed earlier; the bidders do not bid on these woodlots the first time they are put up for sale because they do not want to overcommit capital. An additional explanation for the two bidders who have sawmills located outside the county of Simcoe is the high fixed costs of bringing in non-local resources to harvest timber; once these fixed costs are incurred, it is in their interest to bid on as many woodlots subject to the constraint imposed by these non-local resources.

4 Categorizing Asymmetries in Sawmills

I observe three types of asymmetries in the valuations of the participating sawmills. First, there is **technological** asymmetry on account of the difference in the harvesting technology. Second, there are **locational** asymmetries depending on whether the sawmill of the participant is located within the county of Simcoe or outside it. Third, there are asymmetries in valuation of the bidders on account of the **frequency** with which they participate in the auctions. I now discuss these three asymmetries.

Hardwood trees typically have larger diameter than softwood trees thereby requiring different kinds of technology to harvest the trees from the woodlots, as well as, to process the lumber from the two types of species. Hardwood trees are felled manually with chain-saws while mechanical harvesters are typically used to fell softwood trees. Harvesters cannot be used for felling hardwood trees because they are scattered over a woodlot making it impossible to use a harvester without damaging other trees in the woodlot; softwood trees, on the other hand, are grown in rows, making them more amenable to mechanical harvesters.

Table 3
Analysis of Number of Bids Submitted by Softwood and Hardwood Firms

Variable	Softwood	Hardwood Firms
# of Sawmills	33	76
Average # of Bids	13.58	2.74
Maximum # of Bids	99	19
St. Dev. of # of /bids	24.24	2.84

On this basis, I have classified all sawmills into hardwood firms and softwood firms. If 80% of the bids of a sawmill are on primarily softwood lots, I categorize it as a softwood firm; if 80% of the bids of a sawmill are on primarily hardwood lots, I classify it as a hardwood firm. I report, in Table 3, statistics on number of bids submitted, based on this classification. Even though the number of hardwood firms is twice the number of softwood firms, the average number of bids submitted by the latter is approximately seven times more than the former. Given the fact that approximately the same number of primarily softwood and hardwood lots were put up for sale, Table 3 clearly indicates that bidding on the softwood lots was more intense than the hardwood lots. Since hardwood trees have to be felled manually while softwood trees are felled with mechanical harvesters, technology makes it *feasible* for a softwood sawmill to bid frequently compared to a hardwood sawmill.

I have indicated in Section 3 that the sawmills of some bidders are located within the county of Simcoe, and of other bidders outside of the county of Simcoe. I will indicate the former as *insider* firms and the latter as *outsider* firms. This distinction is important because the *insiders* hire local resources to harvest timber. These local resources comprise the harvesting equipment, which the bidder may own or rent locally, and qualified cutter-skidder operators who may either be the employees of the bidding sawmills or contracted by them locally. The outsiders, on the other hand, have to bring in both the harvesting equipment and the operators from outside the county of Simcoe since local resources are limited and hired by the bidders who have sawmills located in the county of Simcoe. Hence, this "outsideness" gives the insiders a distinct cost advantage over the outsiders; this is supported by the first three rows of Table 6 which is discussed below. Further, having incurred the sunk or fixed cost of bringing in harvesting equipment and qualified cutter-skidder operators from outside the county of Simcoe, it may be in the interest of an outsider to bid frequently in the year she is "in".

There are 109 sawmills participating in these auctions in the period under study. There are four insider firms, that is, bidders who have sawmills within the county; while one of them is a hardwood firm, the other three are softwood firms. The rest are outsiders and again could be either softwood or hardwood firms.

Table 4
Analysis by Number of Bids

Categories	# of Sawmills	# of Bids	# of Wins	$\frac{\#of Wins}{\#of Bids}$
1	46	46	12	0.26
2-10	51	169	47	0.28
11-30	9	178	83	0.47
Greater than 30	3	251	138	0.55

I next wanted to ascertain whether the sawmills who participated in these auctions were bidding equally frequently. If they were not, then were the sawmills who bid more frequently learning from their past bidding decisions and as a result winning more frequently. The next Table indicates that the number of times a sawmill participates varies substantially across sawmills and there is *some* evidence that firms who bid more frequently also win more frequently. In Table 4, I have categorized the sawmills in terms of the number of bids they submit. The second column of the table gives the number of firms in that category. In the third and the fourth columns I have the total number of bids and wins of these sawmills respectively; the last column is the hit rate, which is the ratio of the number of wins to the number of bids. As an example, 9 sawmills submitted between 11-30 bids. These 9 sawmills submitted a total of 178 bids and won 83 woodlots on which they submitted bids.

A number of points are worth noting in Table 4. First, about 42% of the 109 participants in the auctions submitted just one bid. Another 56% submitted more than one but less than thirty bids. Except for two, these 98% participants who submitted less than 30 bids, are **outsiders**. What is to be noted about the participation of these firms is that they bid **sporadically** across auctions and years.

Second, three sawmills were bidding **consistently** throughout the sample period; these are the sawmills who submitted more than 30 bids. I will refer to these three sawmills by X, Y and Z; all three are softwood firms. While the former was an outsider firm, the latter two were insiders with their sawmills located in the township of Springwater in the county of Simcoe. While sawmill Z and Y participated in all sales every year, X participated in all sales every alternate year till 1995.

A possible explanation for sawmill X bidding every alternative year till 1995 and the sporadic bidding pattern mentioned in the last point is the feature of the "outsideness" of these sawmills that I have discussed previously. Another explanation for the sporadic bidding of the outsider sawmills is that since their sawmills are not located in the county of Simcoe, they find it cost-effective to obtain hardwood from other counties in Southern Ontario that are known for their valuable hardwood. I will elaborate on this point in the next Section.

Third, I find some evidence of bidders who bid more frequently also winning more frequently if I consider the softwood sawmills. Softwood sawmills submitting one bid have a hit rate of 26%. The wins of these sawmills are attributed either to "luck", or to their bidding experience in the counties surrounding Simcoe. The hit rate increases to 38% for sawmills submitting between 2-30 bids. Note that all these sawmills, with the exception of two, are outsiders. The *key* point about the sawmills in the 2-30 category is that they are outsiders who bid in sales once in a while, and not consistently through the sample period.

Finally there are three softwood sawmills who submit more than 30 bids; they have a hit rate of 55%. These sawmills are the three key players whom I have mentioned before. They bid consistently through the sample period. The fact that they are winning more frequently will get further support in the sections below, when I show that after the first couple of sales, these three firms seem to be coordinating their bidding strategies perhaps on the basis of the learning from the first couple of sales.

The observation that three sawmill bidding consistently throughout the period for which this study is being done, and the rest bidding sporadically across the sales, motivates a further classification of the sawmills who participated in these auctions as *fringe* and *nonfringe* firms, with X, Z and Y being the nonfringe firms. The key feature of "fringeness" is that nonfringe firms have an incentive to coordinate their strategies since they are active in the auctions all the time. The fringe firms, on the other hand, may find it impossible to coordinate their bidding since a large number of them bid just once. The ones who bid more than once, just go in and out without any systematic pattern.

Table 5
Classification of Sawmills

		Softwood Firms	Hardwood Firms	Total
Nonfringe	Insider	Y, Z	0	3
	Outsider	X	0	
Fringe	Insider	A	B	106
	Outsider	29	75	

∗ A and B are two *fringe* insider sawmills.

In Table 5, I summarize the different ways in which the participating sawmills are classified. There are 105 outsider firms and 4 insider firms, with no hardwood, nonfringe sawmill. All three key players are softwood, nonfringe sawmills, with two being insiders and one being an outsider. For softwood lots, I will henceforth concentrate on the bidding behavior of the 3 softwood, nonfringe firms and the softwood, fringe firms; for hardwood lots, I need to consider only fringe firms since there are no hardwood sawmills bidding consistently in each sale for the period under study.

In Table 6, I have given the number of bids, wins, the ratio of wins to bids, average V/T, average B/V/T, across the years 1987-98 for the sawmills classified according to Table 5.

An *important message* of this table is that pays to be an insider. Sawmills Y and Z, the two insiders, have the highest win/bid ratio;[16] both are winning more than half the woodlots on which they are bidding. What could be the reason for this? Two explanations come to mind.

First, being insiders, Y and Z are better informed about the value of the woodlot than the outsiders. In other words, the auctions under study are common-value auctions with bidders not knowing the "true" value of the woodlot till they have actually harvested the woodlot, and the insiders have a less noisy signal of the "true" value of the woodlot than the outsiders. Since there is little uncertainty about the cost of harvesting the woodlots, this argument implies that the estimate of the volume of timber and other information about the woodlot provided by the county in the tender

[16] I have noted that there are two more insider firms. Both are however fringe firms and do not bid very often. Hence I do not focus on them seperately but study them with the fringe firms because they seem to be exhibiting features of "fringenesss" rather than "insideness".

notice is a noisy signal of the value of the tract. I have mentioned in Section 2, that the county participates in the auction as a bidder by having a secret reserve price which is based on the information about the tract that it provides to all bidders. In the entire sample period, only 4% of the woodlots put up for sale were withdrawn by the county on account of the highest bid submitted being very low. On this basis it is reasonable to conclude that the information provided by the county about the woodlot gives the bidders a fairly accurate idea about the "true" value of the tract.

Table 6
Individual Sawmill Statistics

	# Bids	# Wins	$\frac{\#wins}{\#bids}$	Average* V/T	Average* B/V/T
Y	97	61	0.629	0.4364	0.0211
X	65	28	0.354	0.3539	0.0096
Z	102	57	0.559	0.3249	0.0055
Fringe Softwood	198	59	0.298	0.4057	0.0137
Fringe Hardwood	223	73	0.327	0.4646	0.0261

∗ The average is over the number of sawmills on which the bidder bids.

A second and more plausible reason is that being insiders gives them a distinct cost advantage; I have discussed earlier that the insiders hire local resources to harvest timber.

5 Entry Equilibrium for the Fringe and Nonfringe

I show that participation by sawmills is linked to auction-specific characteristics; the absence of these characteristics constitute entry costs which deter sawmills from participating in all auctions in a sale. These characteristics are isolated in this Section. The auctions in the sample are then partitioned into sub-groups on the basis of these characteristics. The aim of this partitioning is to examine the entry equilibrium of sawmills classified according to Table 5. The partitioning accomplishes this in two ways.

First, it creates *sub-group* of auctions that can be considered *identical* to an approximation.

Second, it allows me to ascertain which category of sawmills in Table 5 *targets,* or *habitually* bids on, which sub-group of auctions. I then have to focus only on what a sawmill is doing in this targeted category of auctions.

However I do observe sawmills participating in auctions they do not habitually bid on. This leads me to define a *demand saturation effect* across sub-groups of auctions in a sale: when the demand a sawmills faces in the secondary market is not satisfied by the sub-group of auctions in a sale on which it habitually bids, it participates in auctions that do not belong to its targeted sub-group.

5.1 Classification of Auctions by Woodlot-specific Characteristics

I have observed in the last two Sections that sawmills on the mailing list of the County participate in neither all the sales nor all the auctions in a sale; this consideration motivated the classification of sawmills in Table 5. Table 7 shows that of the 287 auctions in the sample, while the fringe and the nonfringe participated in 75% and 63% of the auctions respectively, they bid together on just 38% of the auctions. This seems to suggest that participation by a sawmill may be linked to auction-specific characteristics. That is, sawmills *target* auctions with specific characteristics.[17]

Table 7: Participation in Auctions

Nonfringe	0	1	2 or 3
Fringe			
0	0	52	20
Greater than 0	105	63	47

In Table 8 the auctions in the sample have been classified by auction-specific characteristics and the number of nonfringe bidders. The column "0 NF" refers to auctions with *only* fringe bidders; NF indicates nonfringe sawmills. The columns "1 NF and Fringe" and "2 or 3 NF and Fringe" refers to auctions in which the fringe compete with 1 and 2 or 3 nonfringe bidders, respectively.. The numbers in the brackets are proportion of auctions of that type; for example, in the first row and column, only fringe bidders participated in 29% of the 152 auctions held in "good" years.

Two auction-specific characteristics that influence the participation decision of sawmills have been already isolated in Table 5. Classifying sawmills as hardwood *vs* softwood sawmills was prompted by the *type* of auction - hardwood or softwood - in which a sawmill participated.

The *insider-outsider* classification of the sawmills suggests that it may be the case that *outsiders* participate more frequently in the auctions held in townships on the boundary of Simcoe and *insiders* on the central townships. In Table 8 auctions are classified into Boundary *vs* Central auctions depending on the township in which the woodlot is located.[18] The fringe is participating in roughly the same proportion of auctions held in the boundary and central townships. However when I look at the auctions in which only the fringe participates, then the participating rate is 46%

[17] If participation is affectecd by auction-specific charcatrestics then the number of bidders on the mailing list of the county is not an appropriate measure of potential competition in an auction.

[18] From the map of the county of Simcoe in Figure 5, the townships of Clearview, Adjala-Tosorontio, New Tecumseth, West Gwillimbury, Ramara and Severn in the County of Simcoe are boundary townships. The townships of Mulmur and Mono in the Dufferin County which adjoins Simcoe are also classified as boundary townships.

in the boundary as opposed to 33% in the centre. On examining the 38 boundary auctions in which the fringe participated, I observe that 29 auctions are for woodlots that have less than 2000 trees; [19] the remaining have a volume per tree that is below the average in the sample. Further, all the 67 central auctions in which only the fringe bids have one common feature - the number of trees on the woodlot is less than 2000.

Table 8: Classification of Auctions by Number of Nonfringe Bidders and Auction-Specific Characteristics

Categories	0 NF (105)	1 NF (52)	1NF and Fringe (63)	2 or 3 NF (20)	2 or 3 NF and Fringe (47)	Total (287)
Good Year	44 (0.29)	25 (0.16)	41 (0.27)	6 (0.04)	36 (0.24)	152
Bad Year	61 (0.45)	27 (0.2)	22 (0.16)	14 (0.1)	11 (0.08)	135
Softwood	31 (0.18)	39 (0.23)	42 (0.25)	20 (0.12)	39 (0.23)	171
Hardwood, Fuelwood	72 (0.63)	13 (0.11)	21 (0.18)	0 0	8 (0.07)	114
Boundary	38 (0.46)	19 (0.23)	13 (0.16)	5 (0.06)	7 (0.09)	82
Central	67 (0.33)	33 (0.16)	50 (0.24)	15 (0.07)	40 (0.2)	205
High V/T	42 (0.31)	17 (0.12)	36 (0.26)	7 (0.05)	35 (0.26)	137
Low V/T	59 (0.42)	30 (0.21)	27 (0.19)	13 (0.09)	12 (0.09)	141
Large # of Trees	22 (0.18)	26 (0.21)	30 (0.25)	14 (0.12)	25 (0.21)	122
Small # of Trees	78 (0.46)	21 (0.01)	33 (0.19)	6 (0.04)	22 (0.13)	171

This leads me to conjecture that it may *not* be the *distance* aspect of the auctions in the boundary townships that leads to the higher participation by the fringe on them. Small number of trees combined with a low volume per trees could account for the lower participation rate of the fringe in auctions held in the central townships of Simcoe.

I find that the lumber and timber price index used in this paper is constant till 1991 and starts rising thereafter.. On this basis I classify the period 1987-1991 as

[19]The average number of trees on a woodlot is 2411.

bad years and 1992-1998 as good years. The conjecture is that participation maybe higher in good years compared to bad years. In Table 8, I find the fringe and nonfringe participation in almost identical proportion of auctions held in good *vs* bad years. But I also find the fringe and nonfringe competing in a larger proportion of the auctions held in good *vs* bad years. The fringe and the nonfringe compete in 50% of the auctions held in good years compared with only 25% in bad years. This seems to suggest that in good years, the demand that the fringe or nonfringe face in the secondary market is not *saturated* by the type of auctions they habitually bid on. This makes them bid on auctions targeted at the other group.

Table 9: Three-Way Classification of Woodlots

		Softwood	Hardwood	Total
Large # of Trees	High V/T	38	74	117
	Low V/T	65		
Small # of Trees	High V/T	32	37	160
	Low V/T	31		
Total		172	114	

On the basis of the discussion above I present a three-way classification of the auctions or woodlots in the sample in Table 9; hardwood *vs* softwood, low *vs* high volume per tree and small *vs* large number of trees. Woodlots with volume per tree less than 0.25 cubic meter per tree are classified as small diameter auctions.[20] Woodlots with above average volume per tree are classified as high diameter auctions. If less than 2000 trees are to be harvested on a softwood lot, I classify it as an auctions with small number of trees; the rest of softwood auctions are auctions with a large number of trees. Except for 15 auctions, most of the hardwood auctions are also auctions where less than 2000 trees have to be harvested. This is not surprising in view of the fact that hardwood trees are grown interspersed with softwood trees in an area that is known for its softwood species. Hence for hardwood auctions small number of trees refers to woodlots with less than 500 trees. I will ignore the volume per tree distinction for hardwood trees since hardwood trees have large diameters in general. The low volume per tree in hardwood lots is due to the presence of old and damaged, large diameter hardwood trees.

Auctions in each *sub-group* will be considered *identical* to an approximation.

[20]This cut-off was selected on the following basis. I will show in Section 9 that the nonfringe bidders are coordinating their straegies in softwood auctions on the basis of volume per tree. A reasonably representative sample of the type of auctions in which the nonfringe bid are softwood auctions with just one nonfringe bidder; Table 9 indicates there are 39 auctions of this kind. I have taken the average volume per tree of woodlots on which sawmill Z bids as the cut-off; amongst the three sawmills, sawmill Z bids on woddlots with the lowest volume per tree.

5.2 Linking Sawmills with Target Sub-Groups

In this Section I show that the fringe sawmills, whether hardwood or softwood, seem to target "small" woodlots and the nonfringe "large" woodlots; I will expand on the meaning of "large" and "small" below. This is consistent with Palfrey (1983, p. 475) that bidders with high valuations for goods prefer bundled auctions while bidders with low valuations prefer separate auctions *ex ante,* if "large" woodlots are viewed as "bundled" versions of "small" woodlots.[21] The nonfringe bidders are high valuation bidders for the lumber from Simcoe since Simcoe is the chief source of supply for lumber for the nonfringe. The fringe, on the other hand, obtain lumber from Simcoe occasionally; a large number of them play the role of nonfringe bidders in the counties adjoining Simcoe. Hence their valuation for lumber from Simcoe is low, or the fringe are low valuation bidders. The practice of the county in always making available both "small" and "large" woodlots in each sale, targeting former towards the fringe and the latter towards the nonfringe, is also consistent with Palfrey (1983, pp. 479-482) that with large number of bidders, incentives operate for a profit maximizing seller to "unbundle" the goods. Note that there are 106 fringe and just three nonfringe sawmills in the sample.

For the 114 hardwood auctions, I find the fringe active in auctions with both small and large number of trees. This is consistent with there being 75 fringe hardwood sawmills and only one nonfringe sawmill, sawmill Y, bidding consistently on hardwood lots. [22] The fringe participates in 95% of the auctions with small number of trees and 85% of the auctions with large number of trees; it wins 91% of the former and 75% of the latter. The nonfringe sawmills, which is essentially Sawmill Y, bids on 22% of the former and 46% of the latter; it wins 14% of the former and 37% of the latter. Further in the 6 auctions with small number of trees on which the fringe and nonfringe compete, they win 3 auctions each. But in the 23 auctions for large number of trees in which they compete, the fringe wins less than half of the number of auctions won by the nonfringe. It seems that the fringe prefer auctions with small number of trees and the nonfringe auctions with large number of trees. For the hardwood auctions,

[21] Palfrey (1983) proves this for a discriminatory, first-price, sealed-bid auction for J goods with greater than two bidders and each bidder desires more than one of the J goods. The only assumption made about bidders valuations is that bidders **know** their own valuations with certainity and the values are **additive**. I have already justified the *private-values* nature of these auctions. Additivity of valuations seems a reasonable assumption in view of the county undertaking strategic aggregation of woodlots prior to putting them up in a sale. If this strategic aggregation was not being done by the county, there would be a case for subadditive valuations for the nonfring and superadditive valuations for the fringe.

Palfrey's result holds irresepctive of the assumptions of symmetry of the bidders and dependence across bidders valuations. However he points out that the result holds only *exante* when there are more than two bidders. Hence it is possible that the fringe targetting "small" auctions and nonfringe "large" auctions is because the former are risk loving and the latter risk averse. However I do see both types of bidders bidding in a substantial number of auctions which are not targetted at them.

[22] Sawmill Y participates in 17 of the 29 sales across the sample period; it bids in 33 of the 114 hardwood auctions. Sawmill X participates in 7 of the 29 sales; it bids in just 13 auctions, 7 of which are in one sale. Sawmill Z participates in just 2 of the 29 sales and only two auctions.

Palfrey's (1983) results apply with "small" and "large" referring to the number of trees.

For the 171 softwood auctions, if I look at the 31 softwood auctions in which *only* the fringe participates, I can ascertain the type of auctions the fringe is targeting.. While 15 of these 31 auctions were for small number of trees, 16 were for large number of trees. *All* 31 auctions were auctions with low volume per tree.

Evidence about the *size* of the woodlot, in terms of number of trees, deterring entry of fringe softwood sawmills comes from Table 10 where I have classified all softwood auctions according to volume per tree and number of trees. The numbers in the brackets express total bids by the fringe and nonfringe as a proportion of the total number of auctions in the relevant sub-group. The column "competes" gives the number of auctions in the relevant sub-group in which the fringe and nonfringe bid together. Controlling volume per tree, the participation of the fringe in auctions with large number of trees is between 5-10% higher than it's participation in auctions with small number of trees.

Table 10: Participation in Softwood Auctions

# Trees	V/T	Fringe		Competes	Nonfringe		Total
		Total Bids	Wins		Total Bids	Wins	
Small	Low	21 (0.68)	15	11	21 (0.68)	16	31
Small	High	24 (0.75)	11	21	29 (0.91)	21	32
Large	Low	37 (0.57)	24	23	41 (0.76)	50	65
Large	High	31 (0.71)	12	27	32 (0.91)	40	44

The nonfringe is active in all types of softwood lots. This is not surprising since Simcoe constitutes the chief source of lumber for the nonfringe sawmills. The nonfringe does seem to be more active on woodlots which have high volume per tree and/or large number of trees. It participates in over 90% of the auctions with high volume per tree and 70% of the auctions with low volume per tree. In auctions with low volume per tree, it participates in 10% more of auctions with large *vs* small number of trees. Finally, in the auctions in which the fringe and nonfringe compete, while they win the same number of low volume per tree auctions,[23] the nonfringe wins double the number of high volume per tree auctions.[24]

It seems that for softwood auctions, Palfrey's (1983) results apply in terms of the *total volume* of lumber that can be obtained from a woodlot.[25] *That is*, the fringe softwood sawmills target auctions which provide low volume of lumber and the nonfringe which provide high volume of lumber.

[23]The fringe wins 5 and the nonfringe wins 6 of these auctions.

[24]The fringe wins 8 and the nonfringe wins 19 of the 27 auctions on which they compete.

[25]For hardwood auctions, large number of trees also implies a high *total volume* of lumber from the woddlot since there are few hardwood auctions with old and damaged trees.

5.3 Entry Equilibrium

I first ascertain what determines participation of a sawmill in a sale. Next, conditional on participation in a sale, how does a sawmill decide participation in auctions within a sale. Finally, is participation by a sawmill in subsequent sales within a year linked.

Participation in a **sale** by three categories of sawmills seems to be determined by some unobservable random shock. The three categories are the fringe softwood and hardwood sawmills participating in sales with softwood and hardwood auctions, respectively, and the nonfringe when it participates in sales with hardwood auctions.[26] The infrequency of participation in sales across the years points to this random nature of participation.[27] This random shock is most likely the demand faced by a sawmill in the secondary market. The entry equilibrium of the fringe, and of the nonfringe on hardwood lots, is stochastic.

The infrequency of participation in sales would also seem to be consistent with *mixed strategies* of the kind discussed by Levin and Smith (1994). *That is*, a sawmill enters a sale with some probability q and stays out with probability $1 - q$; it does this for each sale in a year. This seems unlikely for the following reason. There is a gap of 3-4 months between each sale in a year. Since sawmills in this are known not to carry inventories of lumber, they would prefer bidding on the first sale held since the arrival of a purchase order. That is, sawmills do not value each sale equally.

The **nonfringe** sawmills participate in nearly all the **sales** in the sample with **softwood** auctions.[28] The entry equilibrium of the nonfringe in sales with softwood auctions is an *asymmetric pure strategy* equilibrium; the nonfringe participate in **all** sales in the sample because softwood auctions are a part of each sale, and the nonfringe bid on some of the softwood auctions in each sale.[29] Deterministic equilibrium of this kind has been discussed, for auctions instead of sales, has been discussed by Samuelson (1985), Engelbrecht-Wiggans (1987) and McAfee and McMillan (1987).

Conditional on participation in a sale, the following considerations are pertinent in determining a sawmills's **participation** in **auctions within a sale.**

First, sawmills classified according to Table 5 have a preference over auction subgroups as classified in Table 9. I have indicated that the fringe, being the low valuation bidders, prefer "small" over "large" auctions; this preference is reversed for the high valuation bidders, the nonfringe sawmills.

Second, a sawmill bids for lumber to satisfy the demand it faces in the secondary market for processed lumber. Conditional on participation, a sawmill seems to select auctions within a sale that provide the *closest* match to this demand shock. If, relative

[26] It is almost as if the nonfringe behave **like** the fringe when participating in hardwood auctions.

[27] Sawmills X,Y and Z participate in 7, 17 and 2 sales across 4, 8 and 2 years, respectively.

[28] Note that all sales have both softwood and hardwood lots.

[29] When a nonfringe bidder participates in a sale, she **always** bids on some softwood lots; she **may** bid on some hardwood lots as well. I have mentioned that the most frequent nonfringe participant is Sawmill Y; she participates in 17 of the 29 sales in the sample.

to this demand shock, there are either none or too few auctions on which it habitually bids in a sale, this sawmill will participate in the auctions in a sale which does not belong to the sub-group it targets or prefers.[30] This is the *demand saturation* effect working across sub-groups of auction within a sale.

Finally, a sawmill seems to select auctions within a sale that provide not just the closest match to this demand shock, but rather the *closest* match in the most *cost-effective* manner.

An additional factor which affects nonfringe participation in softwood auctions in a sale is coordination of the nonfringe on the basis of the diameter of softwood trees. The three nonfringe sawmills avoid competing with each other by bidding on woodlots with different volume per tree. This will be discussed in Section 7.

On the basis of these considerations, each sawmill builds a preference ordering over subsets of auctions in a sale. The subset of auctions in a sale that is most preferred are the auctions in a sale that this sawmill bids on.

I illustrate participation in auctions within a sale with an example that recurs frequently in the sample. Consider a sale that comprises of three auctions for hardwood trees with 750, 150 and 128 trees. Consider the bidding process of a nonfringe sawmill who has a demand for lumber which is the equivalent of 875 trees. There are two aggregations of auctions that would be pertinent: $\{750, 250\}$ and $\{750, 128\}$. The woodlot with 750 trees can be viewed as a "bundled" version of woodlots with smaller number of trees so that Palfrey's (1983) results apply. The *demand-saturation* effect operates in this sale since the high-value nonfringe bidder will bid on a woodlot with small number of trees to satisfy her demand for 125 trees that is not fulfilled by the sub-group of hardwood lots with large number of trees on which she habitually bids. Suppose in addition, the woodlots with 750 and 250 trees are located in the same township and the woodlot with 128 trees is located in a township that is at the other end of Simcoe. Then $\{750, 250\} \succ \{750, 128\}$ due to the distance factor; but the cost of cutting and maintaining inventory of 125 trees till the next order arrives may reverse the preference to $\{750, 128\} \succ \{750, 250\}$. The auctions in the sale on which the sawmill bids will depend on the effect which dominates..

[30] There are numerous instances of this. I give two examples. I have already cited the example of sawmill Y bidding on hardwood lots with small number of trees; in these sales no hardwood lost with large number of trees were available. Sawmill W participates in auctions with small number of trees. In two of the six sales it participates in, it bids on woodlots with large number of trees. The first is the second sale in 1991; there were no woodlots with small number of trees in neither this sale nor the subsequent sale in the year. The second time it participates in an auction with large number of trees is the second sale in 1996. In this sale, four woodlots with large number of trees and five with small number of trees were offered; it participated in two of each. I find that most of the small number of trees woodlots on which it does not bid are promarily fuelwood lots; hence it does not bid on these. The two large number of trees woodlots on which it does not bid have above 2000 trees. This is in contrast to the less than 1000 trees on the two large number of trees woodlots on which she bids; these lots are clearly distinguishable.

The above discussion also provides an explanation for why sawmills are participating in sub-groups of auctions in a sale that are not targeted at them. An alternative explanation for this could be that conditional on participation, the sawmills play mixed strategies whereby they enter all auctions in a sale, irrespective of the sub-group to which it belongs, with some positive probability between 0 and 1. This would be a plausible explanation if sawmills were indifferent about participation in the different auctions within a sale. But the key feature of these auctions or woodlots are their differences; even amongst the homogenous sub-groups of auctions that I have created in Table 10, an auction can be distinguished on the basis of some auction-specific characteristic.

Finally, I examine if **participation across sales** in a year is related. The multiple sales in a year seem comparable to the multiple rounds in the PCS spectrum auctions. There are at least two reasons to believe that bidders learn from the information gained in previous sales in a year.

First, is the strategic manner in which the County is putting up auctions in the multiple sales across the years. Prior to commencement of sales in a year, the county knows the woodlots that have to be auctioned. It splits them into multiple sales to ensure that each sale has auctions that are habitually targeted by a group; a break-up of each sale in a year by sub-groups of auctions created in Table 9 reveals this. The County, in conducting multiple auctions, wants to ensure that bidders who are able to obtain only a part of their first-best aggregation of auctions in a sale that meets their secondary market demand, have an opportunity to satisfy the *residual* demand in subsequent sales.[31]

Second, bidding patterns in subsequent sales within a year also lend credibility to learning across sales in a year. I observe sawmills bidding in subsequent sales if they have bid in some or all of the auctions in previous sales and lost some of the auctions.

However I also find sawmills bidding in subsequent sales even if they have won *all* the auctions they bid on in the previous sale. This could be due to a purchase order that arrived in the time between subsequent sales; in this scenario meeting the purchase order will most likely take precedence over strategic bidding by the sawmill. The above bidding pattern could also be consistent with aggressive-nonaggressive bidding behavior across sales. Even though a sawmill has no outstanding purchase order, it bids to carry inventories till the next purchase order arrives. In this case there is learning across sales in the year. This kind of speculative bidding can be ruled out for three reasons. First, if this aggressive-nonaggressive bidding was going on, I would see a larger number of sawmills active in later compared to earlier sales in the year; there is no evidence of this in the data. Second, the Simcoe auctions are "fell-and-sell" auctions.[32] Third, multiple sales would then not be "optimal" for the

[31]Conversations with County officials has revealed a similar story. Note that this residual demand could also be the demand due to a new purchase order in the secondary market that arrived between the time subsequent sales are held.

[32]An approximate figure for inventories quoted by the County is about 10% of the bidding volume

County. It would then auction off all the woodlots that it has marked down in the beginning of the year in **one** simultaneous, first-price, sealed-bid sale.

Hence it seems to be the case that demand in the secondary market is responsible for the sawmills bidding in subsequent sales even if they have won all auctions they participated in the previous sale.

In the next section this participation model is summarized; conditional on participation, a bidding model is also outlined on the basis of the discussion in the previous Sections.

6 A Preliminary Model of Participation and Bidding

In the discussion below, I will indicate a sale by the subscript t, an auction within a sale by the subscript j, and a bidder by the superscript i. To remind the reader, each sale, t, organized by the county of Simcoe involves a first-price, sealed-bid auction for each of the multiple woodlots that are being auctioned off in that sale. A bidder i who is participating in the t-th sale can submit bids on as many woodlots, j, that she wants, thereby introducing the multi-unit aspect of these auctions.

The participation and bidding in the Simcoe auctions can be viewed as a three stage game.

The first stage belongs to the County. I have explained in Section 2 that at the beginning of each year, the County officials, on a *purely* silvicultural basis, mark down the trees to be felled. In the first stage of the game the County, on the basis of the sawmills active on the mailing list, makes two decisions: *aggregation* of trees into woodlots and *apportioning* woodlots into multiple sales. Aggregation is done with a view to deterring entry through "size" of the woodlot; "large" woodlots are created to deter entry of the low valuation fringe bidders. The County also wants to give the sawmills who have bid but lost in previous sales an opportunity to obtain their next-best aggregation of auctions; apportioning woodlots into multiple sales is used to accomplish this.

The second stage of the game is the participation stage: participation in a sale, and then conditional on participation in a sale, participation in auctions in a sale. The entry equilibrium of the nonfringe in a **sale** is deterministic; they participate in **all** sales in the sample. The entry equilibrium of the fringe in a sale is stochastic, but not a mixed strategy equilibrium; the fringe participate in a sale conditional on the arrival of a purchase order.

in a year by the nonfringe. This is unlike the sawmills in Northern Ontario who carry inventories to the extent of 70% of the volume on which they bid. Speculative bids are also discouraged by the county through the deposit that a sawmill has to submit for each auction that it participates in.

Conditional on participation in a sale, the sawmills construct a preference ordering over subsets of auctions in a sale. Suppose $\{1, ..., M_t\}$ woodlots are being auctioned in a sale t. Indicate by $\wp_t = \{P_{1_t}, ..., P_{\tau_t}, ..., P_{k_t}\}$ the set of all subsets of the M_t woodlots, $\{1, ..., M_t\}$, where k_t is the cardinality of P_{k_t}.[33] A sawmill constructs a preference ordering over elements of $\wp_t$. I have outlined the factors it takes into consideration in constructing this preference ordering. The utility function used to construct the preference ordering is assumed to be additive. Indicating by U^i_τ the utility for sawmill i from subset P_{τ_t}, and by $v^i_{j,t}$ the valuation of bidder i in auction j of sale t, $U^i_{\tau_t} = \sum_j^{\tau_t} v^i_{j,t}$. I have discussed in the last Section that additivity seems reasonable in view of the County having performed a strategic aggregation of trees prior to conducting a sale.

The third stage is where the bidding transpires conditional on participation. A general bidding model is described below; assumptions regarding the relationship between bidders valuations will be discussed in Sections 7 and 8.

A sawmill will submit a bid to harvest the trees on a woodlot in a sale on the basis of it's valuation of the woodlot. This valuation is the sum of two components. The first component is the difference in the market price of the timber on that woodlot and the cost a sawmill will incur in harvesting the timber from the woodlot. From the discussion above it is reasonable to assume that the cost of harvesting timber from a woodlot is *known* to the bidders; I will indicate the harvesting cost incurred by bidder i, on woodlot j in the t-th sale by $c^i_{j,t}$. $mp_{j,t}$ is the market price of timber available on woodlot j in sale t. I am assuming this is *known* to all bidders since it will be a function of past lumber prices and the bids submitted on similar woodlots in the past sales.[34] The second component of a bidder's valuation is the demand that this bidder faces in the market for processed lumber; this is *private information* of a bidder. The first component of a bidder's valuation is nonstochastic. Orders for processed lumber, which is the second component of the value of a woodlot to a bidder, is stochastic. I will indicate the stochastic component by $\eta^i_{j,t}$; this is the demand that bidder i faces in the secondary market for the kind of lumber that is available on woodlot j in sale t. The equilibrium bidding rule is then given by:

$$b^i_{j,t} = e^i(v^i_{j,t}), with \tag{1}$$

$$v^i_{j,t} = \left(mp_{j,t} - c^i_{j,t}\right) + \eta^i_{j,t}; \tag{2}$$

where $b^i_{j,t}$, $v^i_{j,t}$ and $c^i_{j,t}$ are the bid, valuation, and cost, respectively, of bidder i in the j-th auction held in sale t. $e^i(\bullet)$ is a strictly increasing function.

On the basis of the analysis in Sections 3 and 4, I assume the log-linear bidding rule in equation (3) below describes the equilibrium bidding behavior of *only* softwood

[33] Note that $k_t \leq M_t$ and $\bigcup_{\tau=1}^{k_t} P_\tau = M_t$.

[34] There is a reasonably well documented cycle in the Canadian lumber and timber industrial prices.

firms in the sample. I consider only softwood firms because from Table 5, I observe that all hardwood firms are fringe firms. All of them, with the exception of one, are also outsiders; but this firm is, for all practical purposes, an outsider since it's sawmill is located on the boundary of the county of Simcoe and the adjoining county of Dufferin. Hence the hardwood firms in the sample are all outsider, fringe firms. They will, as a result, not display the insider-outsider and fringe-nonfringe dynamics that I am expecting to capture through this regression.[35]

$$\begin{aligned}\log(b^i_{j,t}) &= \beta_o + \beta_1(PRICE)_t + \beta_2(V/T)_{j,t} + \beta_3(TYPE)_{j,t} + \beta_4(PTP)_{j,t} \\ &\quad +\beta_5(OutFr)^i + \beta_6(InNFr)^i + \beta_7(InFr)^i + \\ &\quad \beta_8(NWINS)^i_{-jt} + \beta_9(CAPACITY)^i_{-t} + \epsilon^i_{j,t}. \qquad (3)\end{aligned}$$

$\log(b^i_j)$ is the nominal bid submitted by a bidder i in auction j in the sale held at time period t. The results of a least squares regression for equation (3) are summarized in Table 11.[36]

There are four types of explanatory variables in the regression given in (3): variables specific to a sale, variables specific to an auction or a woodlot in a sale, variables specific to a bidder, and variables specific to a bidder within a sale t. The only variable in the first category is PRICE; this is the lumber and timber industrial price index with 1986 as the base year and available on a monthly basis. I observe that an increase in the price of lumber leads to more aggressive bidding, with a 1% price increase leading to a 1.6% increase in the nominal bid.

There are three auction or woodlot specific variables within a sale; I have indexed them by the subscript j, t indicating aspects of the j-th woodlot in the t-th sale. $(\mathrm{V/T})_{j,t}$ is the volume per tree, expressed in m3/tree, on woodlot j in sale t. Woodlots with higher volume per tree receive higher bids; bidders increase their nominal bid by 1% with an additional cubic meter per tree.

Table 11
Results from Regression in Equation (3)

[35] The hardwood firms will exhibit the aggressive-nonaggressive bidding strategy that characterizes the multi-unit aspect of the auction.

[36] The coefficients in the regression are rates of change in the nominal bid due to a change in the exogeneous variable, *ceterus paribus*.

Variable	Coefficient	Estimate	Standard Error	t-value	Prob ¿|t|
constant	β_0	5.795	0.292	19.819	0
PRICE	β_1	1.601	0.154	10.408	0
(V/T)	β_2	1.029	0.396	2.599	0.010
TYPE	β_3	−0.404	0.128	−3.163	0.002
PTP	β_4	0.199	0.036	5.465	0
OutFr	β_5	−0.243	0.171	−1.425	0.155
InNFr	β_6	0.115	0.165	0.699	0.485
InFr	β_7	−0.041	0.253	−0.162	0.872
NWINS	β_8	0.047	0.026	1.769	0.078
CAPACITY	β_9	0.028	0.034	0.180	0.418

$(\text{TYPE})_{j,t}$ is a dummy variable which takes values 0 or 1. Since I have included only softwood firms in this regression, I consider only primarily softwood lots; these were woodlots where more than 60% of the timber, in terms of volume, was from softwood trees. $(\text{TYPE})_{j,t}$ takes value 0 if the woodlot j in sale t is *exclusively* softwood and 1 otherwise. The coefficient for the variable TYPE is negative indicating that softwood firms bid more aggressively on woodlots that are *exclusively* softwood lots. Softwood firms value exclusively softwood lots since the hardwood on the primarily softwood lots is of limited commercial value to these firms in view of the fact that resale is not allowed by the county of Simcoe.

$(\text{PTP})_{j,t}$ is the number of participants in the auction j in sale t; it is being used as a proxy for potential competition. This seems reasonable since there is no announced reserve price. Further, as I mentioned in Section 3, only 4% of the woodlots were withdrawn from the sale because the county found the bid too low, leading me to conclude that the secret reserve price is non-binding. Sawmills submit bids that are 0.2% higher with potential competition from an additional bidder.

There are three bidder specific variables. All three are dummy variables, which together with the constant capture the fringe-nonfringe and insider-outsider dynamics of the bidding sawmills; these are indexed by the superscript i for the bidder. $(\text{OutFr})^i$ is 1 if the bidder i is an outsider, fringe firm and 0 otherwise. $(\text{InNFr})^i$ is 1 if the bidder i is an insider, nonfringe firm and 0 otherwise; and $(\text{InFr})^i$ is 1 if the bidder i is an insider, fringe firm and 0 otherwise. β_6 and the difference, $\beta_7 - \beta_5$, are the insider-outsider difference in log bids of the nonfringe and the fringe sawmills, respectively. Both have positive signs indicating that the insider firms bid more aggressively than the outsiders because the former have a cost advantage in employing local resources to harvest timber.[37] β_5 and $\beta_7 - \beta_6$ are the fringe-nonfringe difference in log bids of the outsider and the insider firms, respectively; I will analyze these in the next two Sections.

[37] The F-statistics for the null hypotheses, $\beta_7 - \beta_5 = 0$ is 0.93 and the tail-area probability, Pr ¿F, is 0.505.

There are two variables specific to a bidder i in a sale t. $(\text{NWINS})^i_{-jt}$ is the number of auctions that a sawmill i wins in sale t *excluding* the current auction j; it can be viewed as a proxy for the number of auctions, excluding the current auction, bidder i expects to win in sale t. This variable captures two effects. First is the *demand* effect; this is private information of the bidder. A bidder that has a large order for processed lumber will want to win a large number of woodlots in a sale. She will, as a result, bid aggressively on woodlot j, even if she is expecting to win a large number of woodlots, other than the j-th woodlot, in sale t. The second effect is the aggressive-nonaggressive bidding by a sawmill that characterizes the mutli-unit aspect of these auctions as described in Engelbrecht-Wiggans and Weber (1979). If a bidder is expecting to win a large number of woodlots in sale, she will want to obtain an additional woodlot at only a bargain price; hence she will bid nonaggressively on this additional woodlot. That is, if in sale t, a bidder has won a large number of woodlots, she will want the j-th woodlot at only a bargain price; she will hence bid nonaggressively on woodlot j. These two effects work in opposite directions. It is interesting to observe that the sign of the coefficient for the variable $(\text{NWINS})^i_{-jt}$ is positive indicating that the demand effect is dominating the aggressive/nonaggressive bidding effect; as I have explained the latter follows from the multi-unit aspect of the sales. A bidder will increase her bid by 0.05% for each additional woodlot that she wants to win.

Finally, $(\text{CAPACITY})^i_{-t}$ is the number of woodlots won by bidder i in the sales held in the previous calender year excluding the current sale. Let t be a sale held in April 1998; then $(\text{CAPACITY})^i_{-t}$ is the number of woodlots won by a bidder i in sales held between April 1997 and April 1998, excluding the sale held in April, 1998. The county allows a harvesting time of one year from the date of the sale. A bidder who has won a large number of woodlots in April 1997, will bid less aggressively in the subsequent sales in 1997 since she is constrained by the harvesting resources available to her; in the sale held in April 1998 she will bid aggressively since she will not face a capacity constraint from the resources she had committed in April 1997. In other words, the harvesting resources committed in April 1997, will be available in April 1998, and as a result, she will bid more aggressively. Similarly, a bidder who wins a small number of woodlots in the sale held in April 1997, will bid aggressively in the subsequent sales held in 1997 to avoid being shut out. Having won a large number of woodlots in these subsequent sales in 1997, she will face a capacity constraint in April 1998; hence she will bid less aggressively in the sale held in April 1998. I observe a positive sign for the coefficient on this variable in Table 11 supporting this conjecture.

7 Analysis of Nonfringe Softwood Sawmills

In this Section, I analyze the bidding strategies of the 3 nonfringe softwood firms X,Y and Z, with X being an outsider firm. One message of Table 6 is that the three key nonfringe bidders X, Y and Z are bidding on woodlots with different average volume per tree; this is reflected in their average bid/m3/tree too. This is now examined in further detail to see if these three sawmills are coordinating their bidding strategy on the basis of the diameter of the trees on a woodlot.

In Figure 1, I plot the average volume per tree, V/T, for the four sawmills X, Y, Z and the softwood, fringe sawmills for the years 1987-98.[38] Since all these are softwood firms, I am trying to ascertain whether V/T characterizes a woodlot to some extent and helps me to distinguish between these sawmills on this basis. Since 20% of the bids submitted by Y are on primarily hardwood lots, and hardwood lots typically have trees with large diameters, I am computing the average V/T for Y on only the primarily softwood lots that it bids on.

I observe that prior to year 5 sawmills X, Y and Z are bidding many times on the woodlots with the same average V/T. Examples are X and Z in years 2 and 4, and Z and Y in year 3. After year 5, I see that these three sawmills are bidding on woodlots with different V/T, with Y bidding on the woodlots which have trees with large diameter, X coming next and Z bidding on woodlots with trees with the smallest diameter. It is as if on the basis of their bidding experience in the first four years, the three sawmills have coordinated their bidding strategies and are not bidding against each other. Several examples of coordination games of this kind are discussed in Osborne and Rubinstein (1998, pp 15-16) and Tirole (1988, 406-408).

Table 12[39]
Payoffs in a Coordination Game

	Type 3 Woodlot	Type 1 Woodlot
Type 1 Woodlot	(2,1,1)	(0,0,0)
Type 3 Woodlot	(0,0,0)	(1,1,1)

Visualize the following scenario. There are three types of woodlots, Type 1, Type 2 and Type 3, corresponding to woodlots with trees that have large, medium and small diameter, respectively. In Table 12, I have made a matrix of payoffs of the three sawmills X, Y and Z, with (i, j, k) standing for their payoffs respectively. In this matrix, I have assumed that X bids on woodlots with trees of medium diameter or Type 2 woodlots.[40] The diagonal elements correspond to the two pure strategy Nash equilibria. These two equilibria correspond to the situation where the main concern of X,Y and Z is *not* to bid against each other, even though Y prefers woodlots with

[38] I have excluded the years 1994 and 1995 from this sample since I have information only about the first auction for these two years.

[39] Here Y and Z are bidding on Type 1 or Type 3 woodlots and X on Type 2 woodlots. (i, j, k) are the payoffs of (Y,X,Z).

[40] There will be two more matrices in addition to the one in Table 6. One will correspond to Miller bidding on Type 2 and Fryer and Ricthie bidding on woodlots with trees that have large and small diameter. The second will have Ritchie bidding on Type 2 and Fryer and Miller bidding on Type 1 or Type 3 woodlots. Thus there will be six pure strategy Nash Equilibria corresponding to each sawmill bidding on a Type 1, Type 2 or Type 3 woodlot.

high diameter softwood trees since he is bidding on woodlots with large diameter, hardwood trees. Off-diagonal elements are zero corresponding to the situation where at least two sawmills compete with each other by bidding on the same type of woodlot. Clearly, once they decide to coordinate their bidding strategies, competing against each other is a Pareto inferior bidding strategy for each of the three sawmills.

Support for the conjecture that X, Y and Z are coordinating their bidding strategies after period 5 comes from two additional sources. In Figure 2 I have plotted the average real bid/volume/number of trees for these three nonfringe sawmills and the fringe sawmills. Figures 1 and 2 together support the hypothesis of bidders coordinating their strategies after period 5 as follows. Volume per tree is a key variable that affects the bid submitted by a bidder once account is taken of the heterogeneity of the bidders in that they are softwood or hardwood firms and insiders or outsiders. This is evident from the peaks and the troughs in Figures 1 and 2 for all sawmills occurring in the same years; all bidders submit high or low bids depending on whether the trees to be harvested on a woodlot have high or low volume per tree. The positive coefficient for the variable (V/T) in equation (3) supports this hypothesis too.[41] Hence, like Figure 1, I find that after year 5, Y submits the highest bid/m3/tree, with X coming next, and then Z. On the other hand, in years 2 and 4, I find X and Z, submitting similar bid/m3/trees. This supports the conjecture that these three sawmills are coordinating their bidding strategies after year 5 and bidding on softwood lots with different V/T.

As further evidence of the hypothesis that X, Y and Z are coordinating their bidding strategies after period 5, I carried out a Chow test. The Chow test involves two regressions. In the first regression, given by equation (3), I assume that no coordination of strategies is taking place in period 5. The fringe-nonfringe difference in bids will then be due to the demand effect that I have mentioned earlier. The *fact* that the nonfringe firms are bidding consistently in these auctions, which motivated this classification of the sawmills, is *because* they have orders for processes lumber that is their private information. Hence I should observe the nonfringe firms bidding more aggressively than the fringe firms. I see in Table 11, that the estimates of β_5 and $\beta_7 - \beta_6$ are negative. This regression will be called the *restricted* regression.

In the second regression, which I call the *unrestricted* regression, the fringe-nonfringe difference in bids, up to year 5, will be due to the demand effect discussed above. After year 5, when these three sawmills start coordinating their strategies, I expect that on an average, the bids of the nonfringe sawmills will be lower than the bids of the fringe firms. In effect since they do not compete with each other, the nonfringe sawmills benefit in terms of being able to win with lower bids. Y and Z are nonfringe insiders and X is a nonfringe outsider firm; I am expecting the following to change, prior to, and post coordination. The expected bid of the outsider nonfringe firm, X will change; this is given by the coefficient β_o. Further, the fringe-nonfringe

[41] The value of the t-statistic is in the tails of the t-distribution indicating that (V/T) is statistically significant.

difference in bids of insiders, $\beta_7 - \beta_6$, the fringe-nonfringe difference in the bids of the outsiders, β_5, and the insider-outsider difference in bids of nonfringe firms, β_6, will be different. The fringe-nonfringe difference in the bids of the outsiders or insiders should decrease after coordination since the fringe will continue to bid as before, but the nonfringe will bid less aggressively. The insider-outsider difference in the bids of the nonfringe firms is the difference in the bids of the insiders, Y and Z, and the outsider, X. Prior to coordination, the difference in their bids was due to the fact that X's sawmill was outside the county of Simcoe and the fact that the three were competing against each other. Once they start coordinating their bidding strategies, the difference in their bids is *only* on account of the former. Hence, the insider-outsider difference of the nonfringe firms should decrease after coordination.[42]

Table 13
Results from Unrestricted Regression Prior to Coordination

Variable	Estimate	Standard Error	t-value	Prob ¿|t|
constant	5.782	0.292	19.798	0
OutFr	−0.470	0.332	−1.416	0.16
InNFr	0.247	0.323	0.765	0.45
InFr	−0.365	0.613	−0.595	0.55

I will indicate the coefficients before coordination by the three nonfringe sawmills starts by "*nc*" and after coordination starts by "*cr*". Thus the unrestricted regression can be split into two parts. Upto year 5 when the three sawmills are not coordinating their bidding strategies, I will run the regression in equation (3) with β_o, β_5, β_6, β_7, $\epsilon_{j,t}^{i}$ replaced with β_o^{nc}, β_5^{nc}, β_6^{nc}, β_7^{nc}, $\epsilon_{j,t}^{i,nc}$, respectively. Note that the constant term in these regression is the log bid of the outsider nonfringe firm, X; and I am expecting X to bid differently once he starts coordinating his bidding with the other two nonfringe sawmills. After year 5, when the three nonfringe sawmills coordinate their bidding strategies, the regression in equation (3) is run with β_o, β_5, β_6, β_7, $\epsilon_{j,t}^{i}$ replaced with β_o^{cr}, β_5^{cr}, β_6^{cr}, β_7^{cr}, $\epsilon_{j,t}^{i,cr}$, respectively. I have reported the results of these two regressions in Tables 13 and 14, respectively. The results confirm the conjectures made above about the differences in bids, prior to, and post coordination.

Table 14
Results from Unrestricted Regression Post Coordination

Variable	Estimate	Standard Error	t-value	Prob ¿|t|
constant	5.786	0.139	41.38	0
OutFr	−0.114	0.160	−0.713	0.476
InNFr	0.008	0.168	−0.049	0.039
InFr	−0.045	0.225	0.198	0.843

[42]I am not expecting a change in the insider-outsider difference in bids of fringe firms, $\beta_7 - \beta_5$, once coordination by the nonfringe firms commences. The expected bids of the insider and outsider fringe firms, $\beta_o + \beta_7$, and $\beta_o + \beta_5$, will be unchanged as well.

The basic idea of the Chow test is that if the three bidders, Y, X and Z are coordinating their bidding strategies after year 5, the residuals from the restricted and the unrestricted regression will be different. The null hypothesis under which the Chow test is performed is that there is no coordination in bidding strategies by the nonfringe sawmills from year 5 onwards; that is,

$$H_o : \beta_o^{nc} = \beta_o^{cr}, \beta_5^{nc} = \beta_5^{cr}, \beta_6^{nc} = \beta_6^{cr}, \beta_7^{nc} = \beta_7^{cr}.^{43}4 \tag{4}$$

The value of the F-statistic for the Chow test is 2.054. The tail-area probability, Prob ¿F, is 0.0862. Hence the data **supports** the coordination hypothesis, and as a result the fringe-nonfringe dynamics.

Table 8 also support the coordination hypothesis; a single nonfringe bidder is present in 50% of the 171 softwood auctions in the sample. Contradicting the coordination hypothesis I also observe either 2 or 3 nonfringe bidders bidding together in 35% of the 171 softwood auctions. 35 of these 67 auctions were held *prior* to 1992, the year when coordination begins. Each of the remaining auctions is a central auction, with more than 2000 and volume per tree varying between 0.24-0.78 cubic metre per tree. I sort these auctions on the basis of the winner of the auction. I find that the average volume per tree for the auctions won by a nonfringe bidder are different and follow the pattern described by Figure 1 and 2; the average volume per tree for woodlots won by sawmills X,Y and Z is 0.41, 0.56 and 0.34 respectively. *Post* coordination, when the three nonfringe sawmills bid together on softwood lots, sawmills Y, X, Z win the high, medium and low diameter lots respectively. Though the nonfringe is bidding together in some softwood auctions *post* coordination, they may not be competing in these auctions. There could be one "serious" nonfringe bidder and the remaining nonfringe bids could be "phantom" bids; this has been observed previously in Sareen (1999).

Alternatively, these 30 odd auctions post coordination in which the nonfringe bid together could be evidence of mixed bidding strategies which are equilibrium strategies as well in coordination games. In that case I would observe a nonfringe bidder bidding aggressively when anticipating competition from an additional nonfringe bidder. She would, as a result, win a larger proportion of the auctions she enters when she anticipates competition from an additional nonfringe bidder. If she was playing pure strategies instead, her win/bid ratio would be unchanged irrespective of the number of competing nonfringe bidders.

To ascertain whether the nonfringe is playing pure or mixed strategies I collect all the auctions in the sample with two nonfringe bidders; all nonfringe bidders are treated in a symmetric manner. I then partition this sub-sample of auctions into two depending on whether an additional nonfringe bidder was present in the sale or not. The presence of this additional nonfringe bidder represents potential competition for the two nonfringe bidders in the auction; if these two nonfringe bidders randomized

[43] Since β_6 is the same, prior to, and post coordination, $\beta_7 - \beta_6$ will be unchanged with coordination if and only if β_7 is the same prior to, and post coordination.

with respect to the additional bidder, then I would observe the win/bid ratio for these two nonfringe bidder to increase when this additional nonfringe bidder was present in the sale compared to when she was not.[44] I give an example to illustrate this point. Suppose sawmills X and Y are present in an auction in the sub-sample of auctions with two nonfringe bidders. If sawmill Z is present in the sale, then an additional nonfringe bidder is present in the sale; sawmill Z is a proxy for potential competition for sawmills X and Y. The conjecture is that if sawmills X and Y randomized with respect to Z, they would have a higher win/bid ratio when sawmill Z was present in the sale compared to when she was not present. If they were playing pure strategies, the win/bid ratio would be unchanged. Table 15 presents the results of this exercise.

Table 15: Proportion of Wins in Auctions with Two Nonfringe Sawmills

Additional NF in Sale	Bids	Wins	Wins/Bids
0	44	19	0.43
1	66	29	0.44

Since the wins/bids ratio is unchanged I can assume that the nonfringe sawmills are playing pure strategies in softwood auctions.

While volume per tree and the *observable* bidder heterogeneity explain the difference in the bids submitted by the different bidders, Figures 1 and 2 show that these observable factors cannot explain *all* the variation in the bids. Several examples can be given to illustrate this point; I give two examples here.

First, compare X and Z in year 4 in Figure 1 and Figure 2. Both are softwood, nonfringe sawmills. I have also indicated that they are coordinating their bidding only after year 5. From Figure 1, I see that in year 4 they bid on woodlots with similar average volume per tree; their average bid/m3/tree is also identical from Figure 2. This seems surprising since X being an outsider has to obtain harvesting resources from outside of Simcoe and then transport them to his sawmills that are located outside the county of Simcoe. I have observed in the last section that insider-outsider difference in log bids for the nonfringe firms is given by the coefficient β_6 in equation (3), and Table 8 provides support for the existence of insider-outsider dynamics for nonfringe firms.

Second, compare Y and Z in Figures 1 and 2. Both are softwood, insider, nonfringe sawmills. In year 4 their average bid/m3/tree is identical (see Figure 2) even though they are bidding on woodlots with different volume per tree (see Figure 1).

[44] A similar exercise could be done with all auctions with just one fringe bidder and the fringe; Table 8 indicates that there are 63 auctions of this kind. A large number of these auctions belong to the sub-group targetted by the fringe; nonfringe sawmills "go it alone" when they are bidding on sub-groups of auctions not targetted at them. Coordination is being done only on auctions on which they habitually bid. Hence here the presence of additional nonfringe bidders in the sale is not an appropriate measure of potential competition for the single nonfringe bidder in the auction; fringe bidders have to be taken account of as well.

The R^2 for the regression in equation (3) is 0.445 pointing to about 50% variation in log bids that is unexplained by the observable woodlot, sale or bidder specific characteristics.

On the basis of the discussion above, I can make the following assumptions about the bidding environment for the nonfringe firms, Y, X and Z, which to a first approximation describe their bidding behavior. First, the three bidders draw their valuations from different distributions; this asymmetry in the bidders is on account of the location of their sawmills. While X's sawmill is located outside the county of Simcoe, the sawmills of the other two softwood nonfringe sawmills is located in the county of Simcoe. Second, there is residual variation in the bid per cubic meter per tree which *cannot* be accounted for by *observable* bidder, woodlot and sale specific variations. I have also explained why the bidders having a fairly good idea about the "true" value of the tract. Further, the coefficient on the variable PTP is positive indicating that bidding is more aggressive as potential competition increases, an observation consistent with the private-values model for the bidders. On the basis of these observations, a private-values environment for these auctions seems a reasonable assumption. Third, I am assuming that the private-values of the bidders are independent. Correlations in valuations could be possible if there is a general state of excess supply or demand for lumber; thus, all bidders would face a high demand in the market for processed lumber if there was a general state of excess demand. Since there is a well-documented cycle of lumber prices, bidders do not face any uncertainty in their valuation from this source. Hence in equation (2), the stochastic part of a bidder's valuation can be assumed to be drawn independently of other bidder's valuations. Fourth, prior to period 5, Y, Z and X bid competitively; after period 5, they appear to be coordinating their bidding strategies but are still playing pure strategies.

8 Competition From Fringe Sawmills

The above discussion still leaves me with the question as to what the fringe sawmills are doing? There are 30 softwood, fringe firms, all of whom, with the exception of Breen are outsiders. I have indicated earlier that the difference in the coefficients, $\beta_7 - \beta_5$, in equation (3) is the insider-outsider difference in log bids of fringe softwood sawmills, and that data supports insider-outsider dynamics. The 76 hardwood, fringe firms, are all outsiders except for one; his sawmill is located in the township of Adjala-Tosorontio, on the border of the county of Simcoe and Dufferin. Hence for all practical purposes, this sawmill can be considered to be an outsider as well.

I first focus on the softwood, fringe sawmills. Both Figure 1 and 2 show that the fringe softwood sawmills are not bidding on softwood lots of any particular type in terms of average volume per tree. I see them bidding on woodlots which have trees with high, medium or low diameter. It is the **fringe** softwood mills that are **competing** with the **nonfringe** softwood mills as the latter have coordinated their bidding strategies in the manner described above. This is obvious from Figure 3 where I have plotted on the y-axis on the left, the number of bids, and on the y-axis on the right, the number of wins to number of bids across the years for the softwood, fringe and the three softwood, nonfringe firms X, Y and Z. The hypothesis is that the years in which the softwood, fringe bidders submit a small number of bids are the years in which the softwood, nonfringe wins a large proportion of the woodlots on which they bid; year 2 and years 4-7 are examples. One year that stands out in terms of the large number of bids submitted by the softwood, fringe is year 9; that year the softwood, nonfringe won just 35% of the woodlots on which they bid.

I have mentioned before that the one softwood, nonfringe firm that bids, once in a while, on large diameter hardwood lots is Y. Then is it the case that in these years Y has a high win/bid ratio only if the hardwood, fringe firms submit a small number of bids? Figure 4 is a counterpart of Figure 3 for hardwood, fringe sawmills and Y in his role as a hardwood, nonfringe sawmill; thus I am considering only the hardwood lots on which Y bid in this sample. I see that when Y bids on hardwood lots, his bidding is so aggressive that he wins almost all woodlots on which he bids. Further the years when the fringe is submitting the maximum number of bids, years 2,7 and 8, also happen to be the years when Y has a win/bid ratio close to 1. It seems that while bidding on hardwood lots, Y is not exhibiting the kind of fringe-nonfringe dynamics that I noted for softwood sawmills. Hence, to a first approximation, I can assume that there are *only* hardwood, fringe sawmills in my sample and *no* hardwood, nonfringe sawmill.

The fact that fringe firms do not coordinate their strategies and compete with each other, as well as, the nonfringe firm gets support from the win/bid ratio in column 3 of Table 6 for fringe firms. Comparing rows 4 and 5 with rows 1-3, I find that the win/bid ratio for the fringe firms is the lowest.

On the basis of this discussion above I suggest the following bidding model for the fringe sawmills. First, the fringe bidders are *not* identical. They exhibit two types of asymmetries, technological and locational. Technological asymmetry follows from the fringe bidders comprising of both softwood and hardwood sawmills. Locational asymmetry follows from the presence of both outsiders and insiders amongst the fringe bidders. Second, the relationship between the bidders valuations is best described by the independent-private-values model. The justification for this is similar to the one presented in the last section for the softwood nonfringe sawmills. Third, the fringe bidders bid competitively throughout the sample period. Fourth, the bids submitted by the fringe sawmills are affected by the same factors as the nonfringe sawmills; I have discussed these in Section 7.

9 Conclusion

For the auctions conducted by the county of Simcoe, it seems reasonable to assume that the independent-private-values model describes the bidding behavior of the participating sawmills. The bidders are not identical; they exhibit asymmetries on account of technology, location, and frequency of participation. While the fringe firms bid competitively, the nonfringe firms seem to be coordinating their bidding strategies on the basis of their bidding experience in the first five years of the sample period.

Some support is provided by the data for aggressive/nonaggressive bidding strategies that characterize the bidding behavior of bidders with multi-unit demand facing budgetary restrictions or capacity constraints that has been discussed by Engelbrecht-Wiggans and Weber (1979); the evidence is however, not conclusive. The large differences in the winning bid and the second-highest bid noted by Engelbrecht-Wiggans and Weber (1979) could be due to asymmetries in bidders valuations. When bidding on subsequent sales in a year, sawmills also seem to learn from previous sales in that year in a manner similar to the multiple rounds of the PCS spectrum auctions. Neither the woodlots in a sale, nor the environment across sales is homogenous.

Three policy conclusions emerge from the analysis in this paper.

First, I observe that most sawmills target either softwood or hardwood on a woodlot that has both types of trees; I have pointed out earlier that on an average, 40% of the woodlots auctioned in a sale held by the county are mixed woodlots. Since one of the aims of the county of Simcoe is to ensure the viability of the forest industry, it may want to reconsider this practice of selling mixed woodlots. With resale not being allowed, the hardwood trees on the woodlot would be of marginal commercial value to a softwood sawmill, and the softwood trees of marginal commercial value to a hardwood sawmill.

Second, after 1994-95 the nonfringe softwood sawmills are targeting softwood woodlots which contain trees of a specific diameter. I also observe the county combining softwood trees of different diameters, which are at times from two different tracts, and selling them as one unit. Unlike Northern Ontario, the softwood from Southern Ontario is *not* being used to produce pulp and paper; the diameter of the softwood tree is irrelevant if pulp and paper is the final use for the harvested timber. A softwood firm in Southern Ontario that has orders for electricity poles will have no use for small diameter softwood trees. Hence following the arguments in the last point, the county of Simcoe may want to reconsider its policy of selling woodlots which have softwood trees of varying diameters.

Third, it is the fringe firms that are providing competition for the nonfringe firms. Most of the fringe firms have their sawmills outside the county of Simcoe; one of them has it's sawmill in Northern Ontario. In view of this, the county may want to add sawmills active outside the county of Simcoe to it's mailing list. Since these sawmills constitute potential bidders, adding them to the mailing list will make bidding in the county more competitive.

Two issues which need to be explored further. **First**, should the County be performing strategic aggregation of trees into "units" and using "size" to deter entry of the fringe sawmills. Second, how should the "size" of the "units" be determined in multiple sales in a year.

I conclude by saying that the analysis in this paper is suggestive. Detailed work on modelling the bidding strategies of the bidders in the manner described above will clarify further the bidding strategies and allow comparison of auctions forms and the manner in which woodlots should be put up for sale in an auction.

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Figure 1: Average Volume/ # of Trees

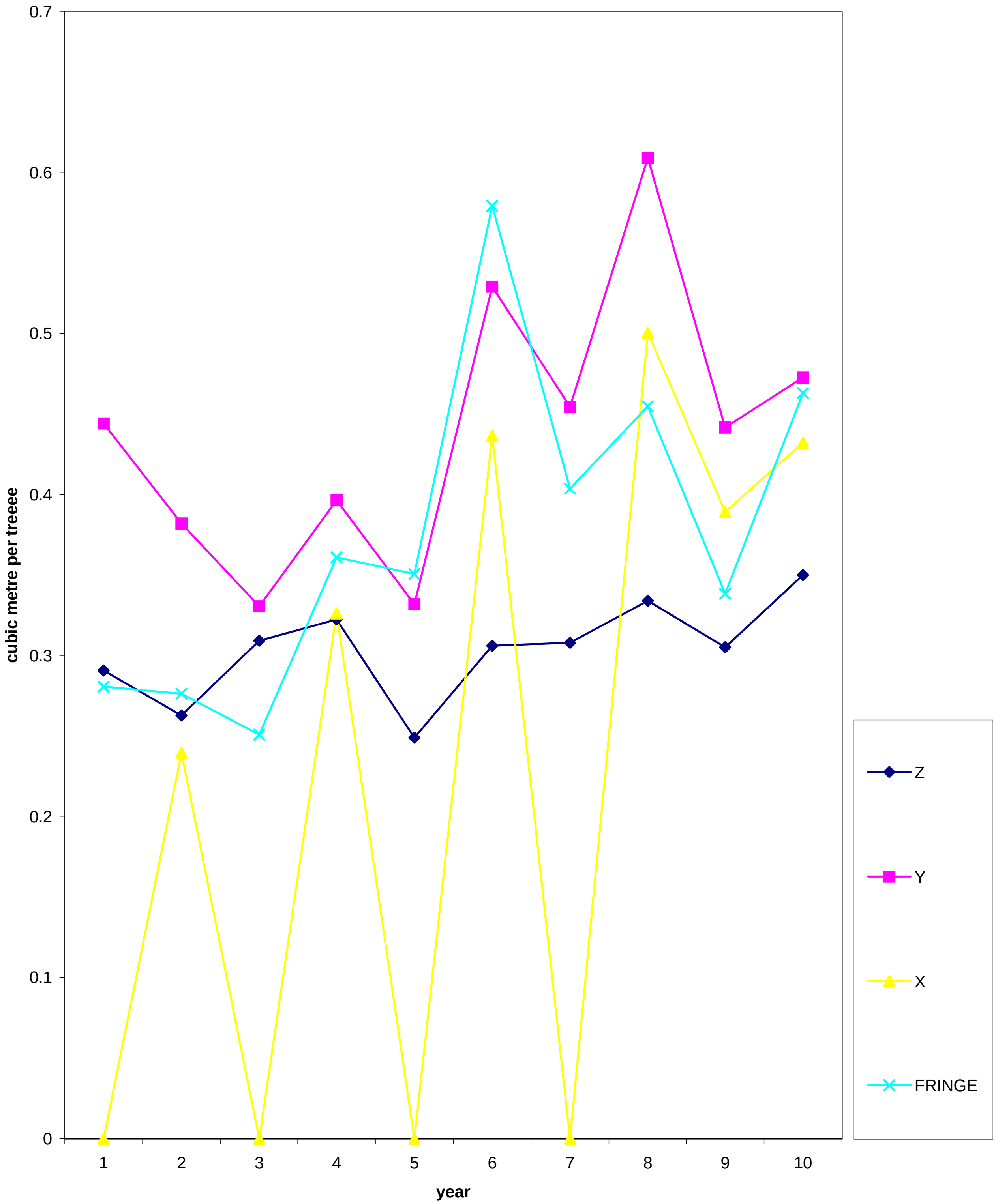


Figure 2: Real Bid/Volume/# Trees Across Years

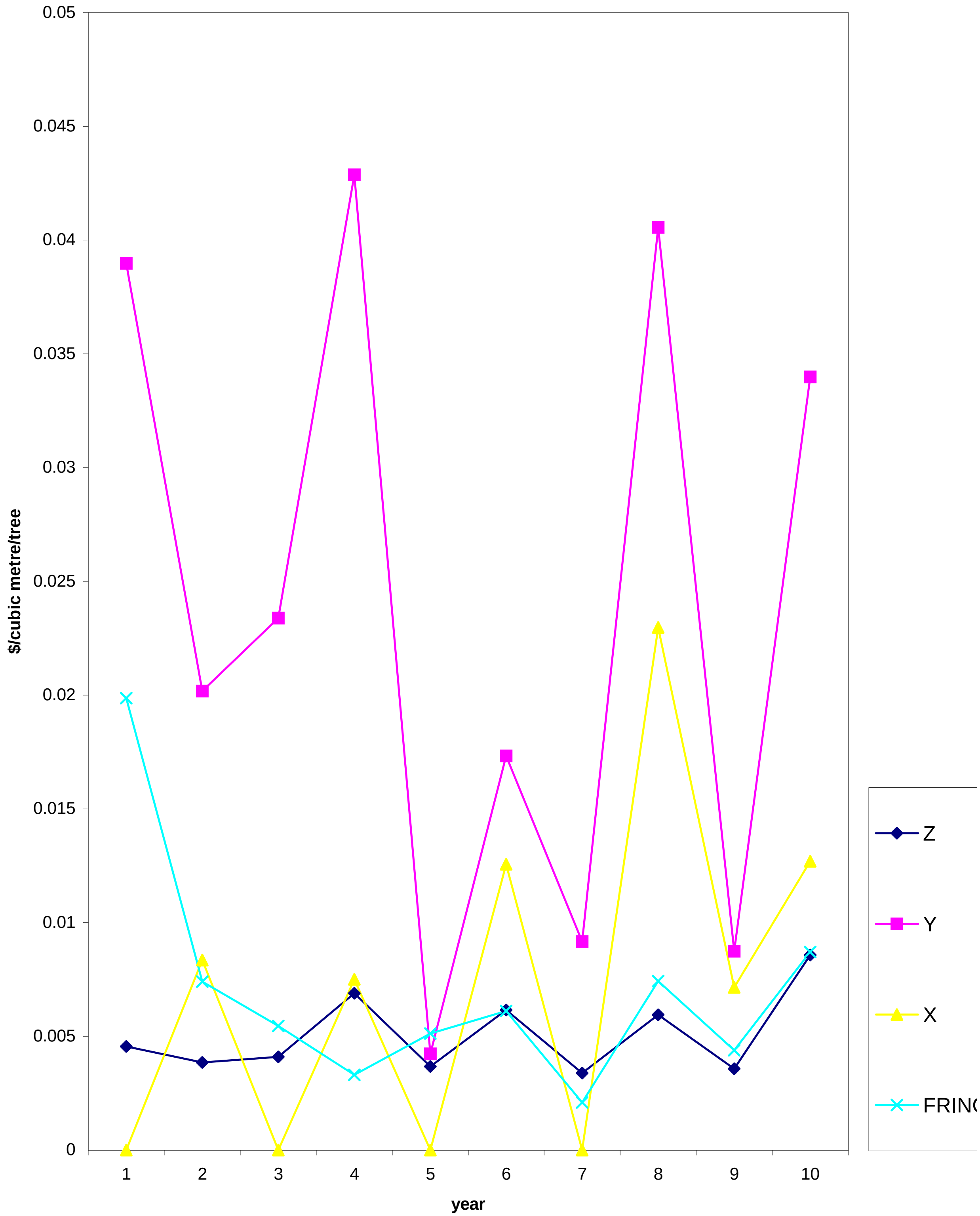


Figure 3: # of Bids and # Wins/# Bids Across Years

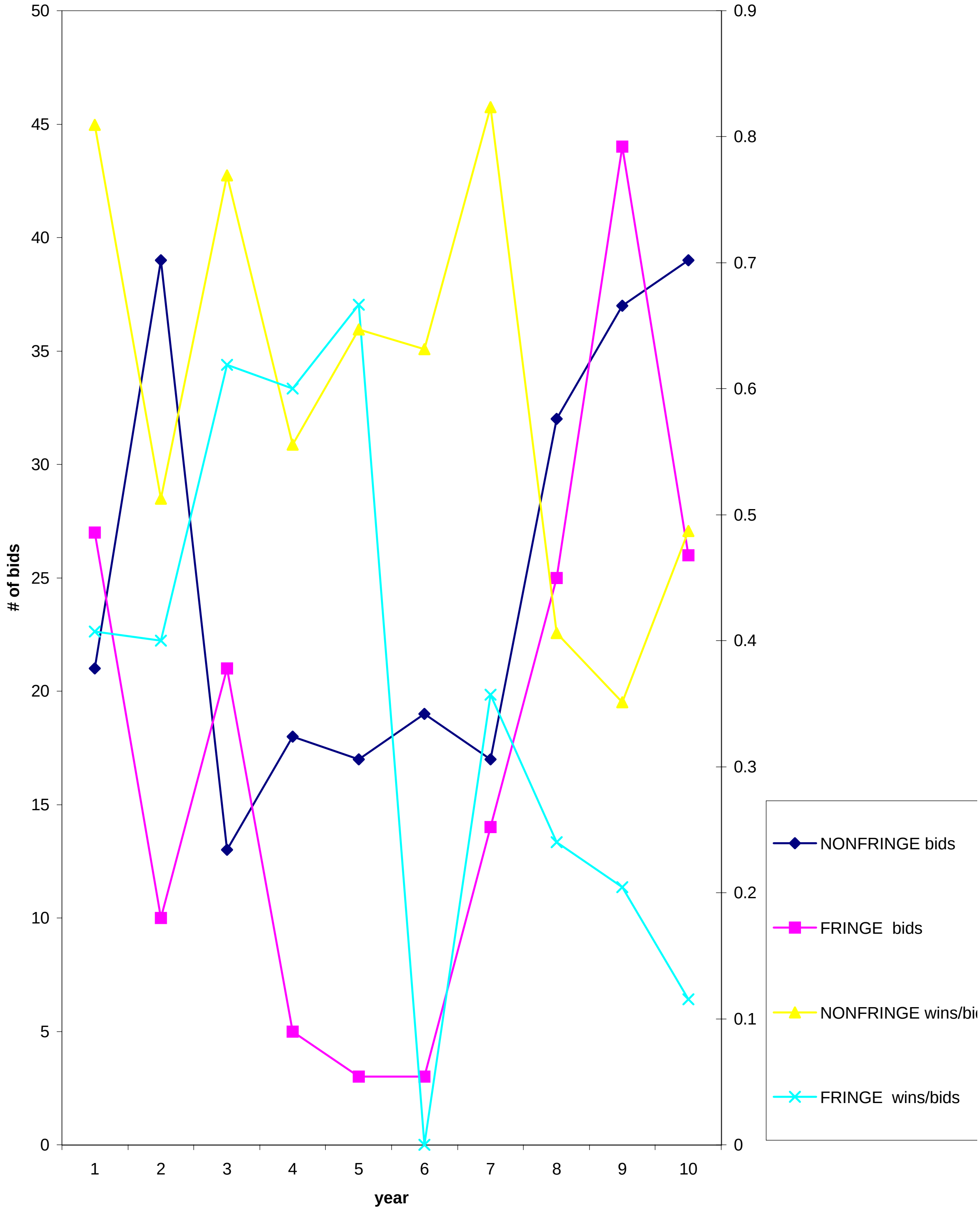


Figure 4: # of Bids and # of Wins/# of Bids Across Years

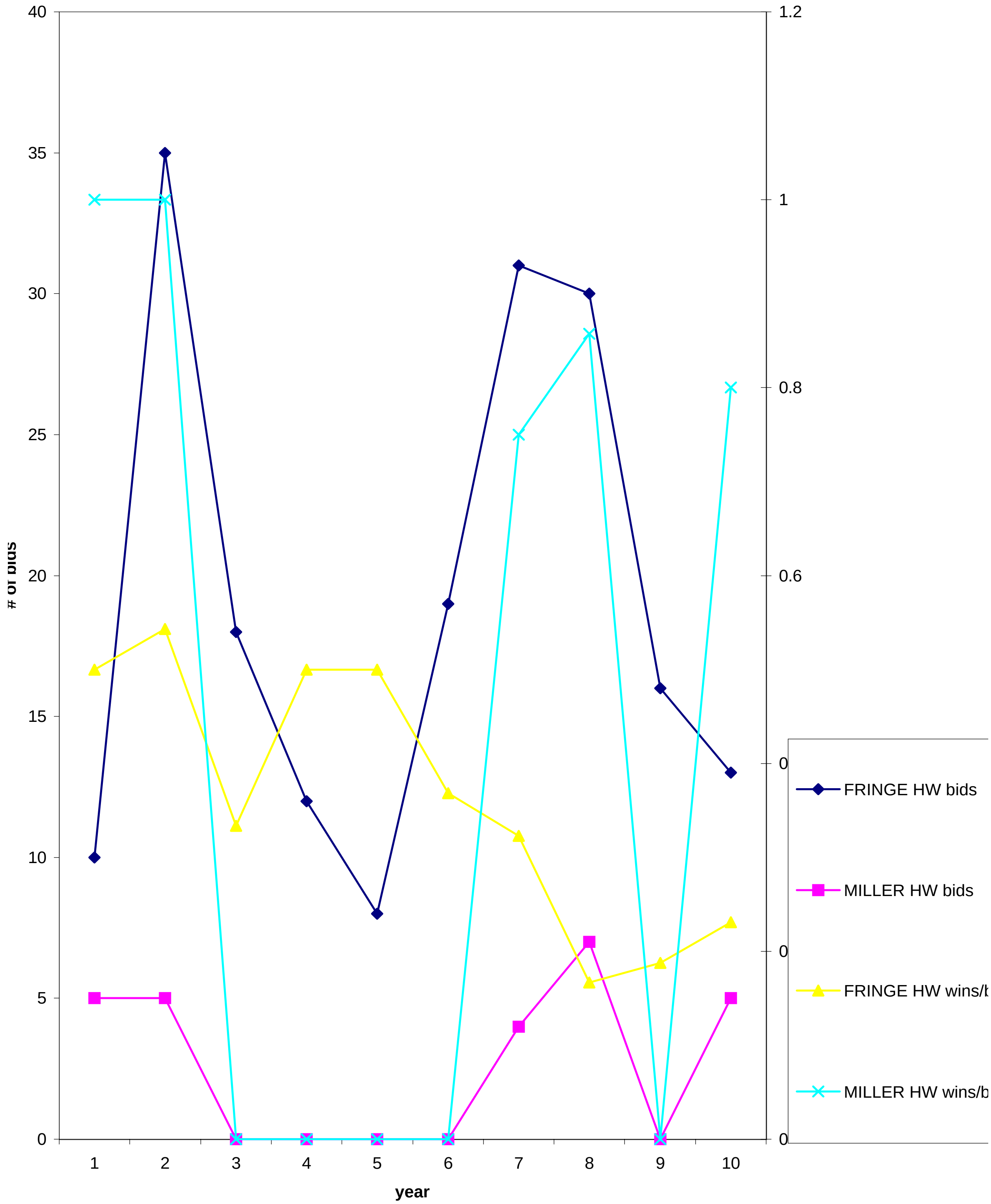
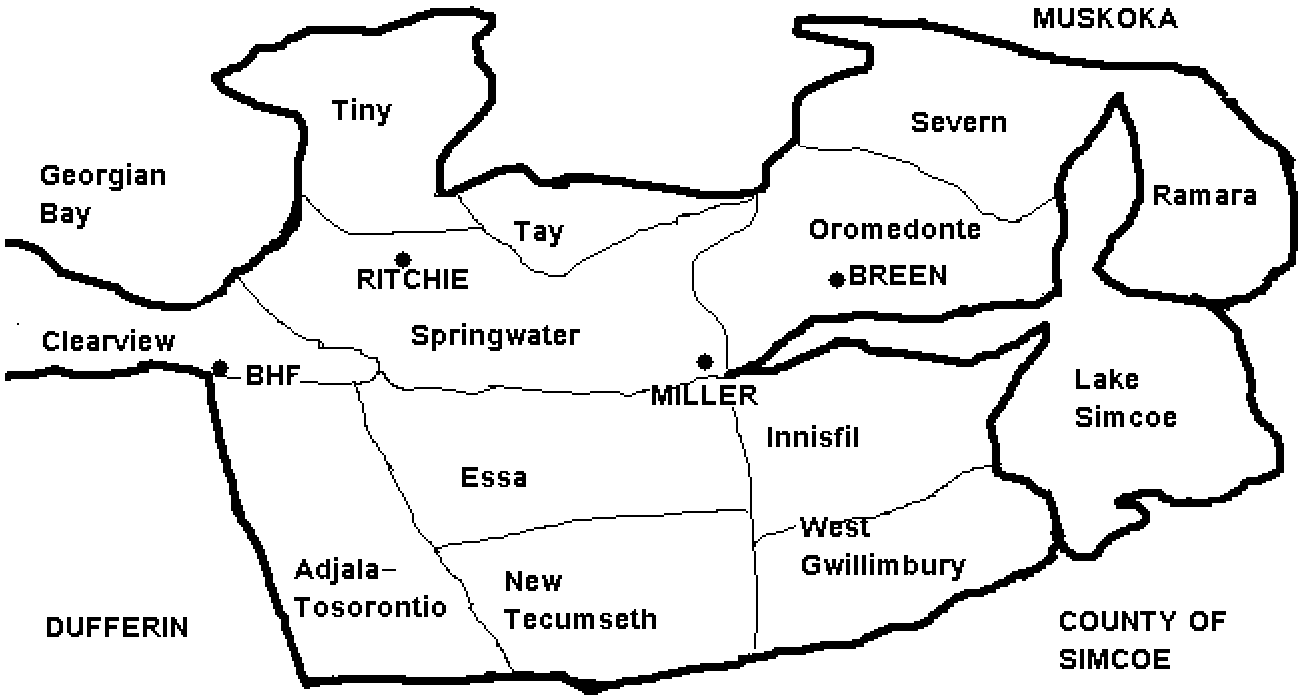


Figure 5: Map of Simcoe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Tiny
Georgian Bay
Severn
Ramara
Tay
Oromedonte
RITCHIE
BREEN
Springwater
Clearview
BHF
MILLER
Lake Simcoe
Innisfil
Essa
West Gwillimbury
Adjala-Tosorontio
New Tecumseth
DUFFERIN
COUNTY OF SIMCOE