Tacit Coordination in Southern Ontario Timber Auctions.*

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Abstract

This paper examines *tacit coordination* of bidding strategies by the three *nonfringe* sawmills in first-price, sealed-bid auctions conducted by the county of Simcoe in Southern Ontario for standing timber in the woodlots that it owns. Frequent participation enables a *nonfringe* sawmill to learn about the *type* of woodlots on which other nonfringe sawmills bid. As a result, conditional on a softwood lot being homogeneous, the *nonfringe* avoid competing with each other corresponding to a pure strategy equilibrium of a coordination game. Joint bidding is observed on heterogeneous woodlots. On jointly bid woodlots *tacit coordination* refers to the *nonfringe* bidders anticipating *nonfringe* competition perfectly; *ex post* a *nonfringe* bidder would appear to bid more aggressively if she is competing against a larger number of *nonfringe* bidders. This contrasts with mixed bidding strategies in a coordination game with *ex ante* uncertainty about *nonfringe* competition; *ex post* a *nonfringe* bidder's strategy would appear invariant with respect to potential *nonfringe* competition since *ex ante* she is unable to conjecture this potential competition perfectly. This distinction in the data is used to rule out mixed strategies on woodlots where joint bidding by the *nonfringe* bidders occurs.

Keywords: ASYMMETRIC, COORDINATION GAMES, FIRST-PRICE SEALED-BID, FRINGE, MULTI-UNIT.

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1 Introduction

An important issue from the perspective of a seller in designing an auction market is to discourage collusive bidding. Empirical papers that document the prevalence and profitability of collusion in auction markets have focussed on collusive practices that are *explicit* and *illegal*. Bidding practices of colluding firms are well documented since these firms have been convicted for bid-rigging. This paper examines *tacit* and *legal* coordination of bidding strategies by the three sawmills who bid frequently in first-price, sealed-bid auctions conducted by the county of Simcoe in Southern Ontario for standing timber in the woodlots that it owns.

Empirical work in auctions that relaxes the assumption of noncooperative bidding is limited. Porter and Zona (1993) in the context of procurement auctions for state highway construction contracts propose a bid rigging scheme in which all cartel members submit bids. One cartel member is a serious bidder and the remaining cartel members submit phony higher bids. Collusion is detected by noting that the while the lowest bid of a noncartel bidder is statistically indistinguishable from that of other noncartel bidders, the determinants of the low cartel bid differs from the higher cartel bids.

Baldwin, Marshall and Richard (1997) examine whether the price variation in timber sales held by the Forest Service in the Pacific Northwest is better explained by collusion or variations in supply conditions. The bid rigging scheme proposed by them is a is a pre-auction knockout round. In this round a "center" or the mechanism conducts a second-price auction amongst cartel members; the highest cartel member is instructed to bid the second-highest bid in the auction and remaining cartel members are instructed to bid zero. The Porter and Zona (1993) approach cannot be used to detect this bid rigging scheme for two reasons. First, it requires bidder specific data which is not available. Baldwin, Marshall and Richard have to rely on the winning price in the English auction and tract specific characteristics to detect the proposed bid rigging scheme. Second, the widespread geographical area covered by the auctions implies that different bidders participate in the auctions. The identity of these bidders in not known to the authors. Conditional on the coalition size and the number of tracts that are being sold, the proposed hypotheses imply a distribution for the winning bids that is a mixture of order statistics from the distribution of private signals of the bidders. Specifying a functional form for the latter and a reduced-form model for the coalition size and number of tracts, they compare the data likelihood across the proposed hypotheses; the collusion hypothesis has the highest likelihood.

Pesendorfer (2000) distinguishes between bid rigging schemes in the Texas and Florida school milk markets. Under both bid rigging schemes, the sole cartel member with the lowest cost bids in the buyer's auction. The *key* difference between the two cartels hinges on side-payments made by the cartel member with the lowest cost. In the weak cartel in Texas, no side-payments are made. In the strong cartel in Florida, prior to the buyer's auction a first-price auction is held amongst the colluding bidders; the lowest bid is equally spilt among the cartel members. The two bidding schemes have different implications for the market share of the colluding firms; the market share of a member in the weak cartel has a smaller variance than the market share of a member in the strong cartel.[1] This provides the test to distinguish between the two bidding mechanisms. However it is questionable as to why a cartel without side payments would operate in Texas in view of the results by McAfee and McMillan (1992) that a cartel with side payments is efficient. Pesendorfer (2000) proves that while any incentive compatible mechanism is not efficient with a finite number of contracts, it is almost efficient with a large number of contacts; this is the case in Texas. Pesendorfer (2000) also establishes the existence of cartels by distinguishing between the bidding behavior of cartel and non-cartel bidders. Again the Porter and Zona (1993) approach cannot be adopted since bidder specific costs are not observed in the data set. However the structural model makes two reduced-form predictions which can be tested on the data. First, the the non-cartel and cartel bidders bid differently;[2] specifically, the former bid more aggressively than the latter. Second, the distribution of cartel bids is first-order stochastically dominated by the distribution of non-cartel bids.

The papers above highlight that there is no unique test for detecting collusion; rather the testing procedure is idiosyncratic to the proposed bid rigging scheme. In general, a two-step approach is taken in these papers. The first step is to specify a collusive scheme and identify the colluding bidders on the basis of formally documented bid-rigging practices in the markets under study. The second step is to use a reduced-form approach to detect the proposed bidding scheme. This approach follows from the two key problems in identification of a structural model of cooperative bidding. The collusive scheme has to be identified and then conditional on the collusive scheme it has to be proved that an observationally equivalent noncooperative bidding model does not exist. Little is known about the equivalence of bidding strategies under different collusive arrangements. The equivalence of bidding patterns associated with noncooperative bidding equilibria and bid rotation have been noted by Zona (1986) and Lang and Rosenthal (1991).

I follow the approach taken in previous empirical work in detecting collusion in that conditional on the collusive scheme a reduced-form approach is adopted. *Unlike* the previous papers, specification of the collusive scheme is a non-trivial exercise in the County of Simcoe since bidders have neither been charged nor convicted of bid-rigging. Second, the collusive mechanism involves *tacit coordination* of bidding strategies by the three nonfringe bidders in the County of Simcoe rather than explicit formation of cartels with or without side-payments. *Nonfringe* refers to bidders who participate frequently in the auctions conducted by the county of Simcoe. Learning through their frequent participation, nonfringe bidders anticipate nonfringe competition perfectly. As a result, on homogeneous woodlots, *nonfringe* bidders avoid competing with each other by bidding on woodlots which have trees of different diameter corresponding to a pure strategy equilibrium of a coordination game. The coordination is *tacit* in that the bid of a nonfringe bidder depends only

[1] In essence, weak cartel members have to be compensated for no side payments through larger share of the contracts.

[2] There could either be *ex ante* asymmetries between the cartel and non-cartel bidders or asymmetries on account of the cartel scheme; the test does not distinguish between the two. Further, *ex ante* asymmetries between cartel and non-cartel bidders would not exist if the cartel was randomizing when selecting the member who would participate in the buyer's auction rather than the lowest cost cartel member.

on her valuation and the absence of transfer.[3]

The presence of heterogeneous woodlots or woodlots with trees of different diameter prompts joint bidding by the *nonfringe* bidders. Joint bidding could also be interpreted as mixed strategy of a coordination game with endogenous participation and *ex ante* uncertainty about *nonfringe* participation. The paper proposes a test to rule out these mixed strategies. The basic idea of the test is that in the *tacit coordination* game, since a *nonfringe* bidder anticipates *nonfringe* competition perfectly, *ex post* her bidding strategy would appear to change with *nonfringe competition*. She would bid more aggressively as competition from the *nonfringe* increases. In contrast, when playing mixed strategies of a coordination game with *ex ante* uncertainty about *nonfringe* competition, the bidding strategy of the nonfringe bidders will appear to be invariant with respect to nonfringe participation, *ex post*.

The auction mechanism and *tacit coordination* are described in section 2. A bidding model and the independent private-values assumption is justified in Section 3. A description of the data is given in Section 4. The hypothesis of *tacit coordination* is tested in Section 5. A test that rules out mixed strategies of a coordination game is performed in Section 6. Since a bidder can simultaneously bid on more than one woodlot in a sale, it may appear that a bidder valuations are not additive. Several reasons are given in Section 7 to show that there is no conclusive evidence of either synergies on account of superadditive valuations as in Krishna and Rosenthal (1996) and Marshall and Raiff (1996) nor aggressive-nonaggressive bidding on account of subadditive valuations described in Engelbrecht-Wiggins and Weber (1979). Finally, Section 8 concludes.

2 Description Of The Market

2.1 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 four, are held each year to sell the right to harvest the marked trees on these woodlots.[4] Details of each sale are announced *only prior* to a sale.

[3]This definition of *tacit* mechanism was first used by McAfee and McMillan (1992). However the frequent bidders will not bid the reserve price as in their paper due to bidder asymmetry.

[4]The aim of the County in conducting multiple 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 comparable to the multiple

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.[5] 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. Twenty five percent of the sealed bid submitted by the sawmill for a woodlot has to be deposited by the sawmill as down payment 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.

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 low. This is just 4% of the 339 woodlots that were auctioned across these years.

The woodlots auctioned in a sale are not homogeneous; they differ in terms of species, diameter and the number of trees. The bidders do not bid on each woodlot in a sale; rather participation is endogenous and linked to woodlot specific characteristics. This motivates a classification scheme for woodlots; this is described

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.

[5]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.

in Appendix A and B. Woodlots are classified broadly into primarily softwood lots and primarily hardwood lots depending on whether a major proportion of the volume of a woodlot is from softwood or hardwood species, respectively. Summary statistics are given in Table A.1, Appendix A.

Bidders are classified into insider-outsider, softwood-hardwood and fringe-nonfringe. The insider-outsider distinction is based on whether a bidder's sawmill is located inside or outside the county of Simcoe. The softwood-hardwood distinction is based on whether a bidders bids on softwood or hardwood lots. The fringe-nonfringe distinction is explained below. Table 1 summarizes this classification. 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.

Table 1
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	

The frequency with which sawmills participate in the auctions conducted by the County of Simcoe reveals asymmetries in bidder valuations and also provides the motive for the *tacit coordination* discussed in this paper. In Table 2, I have categorized the sawmills in terms of the number of bids they submit in the first half of the Table. The second column of the table gives the number of bidders 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, the third row indicates that 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. I notice ***sporadic*** participation by 98% of the sawmills. About 42% of the 109 participants in the auctions submit just one bid; another 56% submitted more than one but less than thirty bids. Three sawmills bid **consistently** throughout the sample period; these are the sawmills who submitted more than 30 bids. The former will be referred to as the *fringe* and the latter as the *nonfringe* sawmills. I will also identify these three *nonfringe* sawmills by X,Y, and Z. The fact that *nonfringe* bidders learn from their frequent participation is indicated by the hit rate which is the highest for the nonfringe bidders.

Table 2
Analysis by Number of Bids

Categories	# of Sawmills	# of Bids	# of Wins	$\frac{\#ofWins}{\#ofBids}$
1	46	46	12	0.26
2-10	51	169	47	0.28
11-30	9	178	83	0.47
30	3	251	138	0.55
X	1	65	28	0.35
Y	1	97	61	0.63
Z	1	102	57	0.56

Why do the *nonfringe* bid frequently in the auctions compared with the *fringe* sawmills ? *At least* two factors could explain this. First, all *fringe* bidders are outsiders since their sawmills are located outside the county of Simcoe. In contrast, two of the three nonfringe bidders, Y and Z are insiders in that their sawmills are located within the county of Simcoe while bidder X is an outsider. 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 in the second-half of Table 1 where the win/bid ratio of the outsider nonfringe bidder X is the lowest compared with the other nonfringe bidders. 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 the the nonfringe, outsider sawmill X to bid frequently the years she is "in".[6]

Second, the three nonfringe sawmills are softwood bidders.[7] The technology for harvesting softwood *vs* hardwood trees makes it feasible for softwood sawmills to bid frequently compared to hardwood sawmills. Hardwood trees typically have larger diameter than softwood trees. 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.

[6]For the first seven years in the sample, this sawmill bids every alternative year.

[7]The sample contains an approximately equal number of primarily hardwood and primarily softwood lots: 181 of the former and 198 of the latter. Hence the greater intensity with which the nonfringe bid on primarily softwood *vs* primarily hardwood lots cannot be explained by their being a larger number of woodlots of the former type.

2.2 The Coordination Mechanism

The meaning of *tacit coordination* of bidding strategies by the nonfringe firms is now explained.

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.[8] 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. Since volume per tree is a key variable that affects the submitted bid, this pattern gets repeated when I plot the average real bid/volume/number of trees for these three nonfringe sawmills and the fringe sawmills.[9] Hence, like Figure 1, after year 5 sawmill 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. It is as if on the basis of their bidding experience in the first four years the nonfringe sawmills are playing pure strategies of a coordination game which involves not bidding against each other.

Table 3
Payoffs in a Coordination Game

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

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 3, 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. 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, X and Z prefer woodlots with large, medium and small diameter softwood 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 coordinate their bidding strategies, competing against each other is a Pareto inferior bidding strategy for each of the three sawmills.

The coordination game in this paper has two additional features.

[8]The years 1994 and 1995 have been excluded from this sample since I have information only about the first auction for these two years. Since 20% of the bids submitted by Y are on primarily hardwood lots, and hardwood lots typically have trees with large diameters, the average V/T for Y pertains only to the primarily softwood lots that it bids on.

[9]Note that the peaks and the troughs in Figures 1 and 2 for all sawmills occur 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.

First, participation by both the fringe and nonfringe is endogenous. It is linked to woodlot specific characteristics. In a specific sale, sawmills will bid on certain woodlots with probability one and not bid on the others.

Second, nonfringe bidders anticipate perfectly nonfringe participation. That is, *ex ante* or prior to bidding, nonfringe participation on woodlots in a sale is known with certainty by nonfringe firms. This follows from the frequent participation by nonfringe firms which enable them to learn the woodlot specific characteristics that prompts participation from competing nonfringe sawmills. Conditional on softwood lots being homogeneous or of a single *type*,[10] a nonfringe sawmill will avoid bidding on woodlots which other nonfringe sawmills habitually bid on. Joint bidding by the nonfringe will be observed on heterogeneous woodlots. On these woodlots *tacit coordination* refers to nonfringe competition being common knowledge for nonfringe sawmill; nonfringe sawmills know with certainty the number of competing nonfringe bidders *ex ante* or prior to bidding.

The fringe bidders, on the other hand, may find it impossible to coordinate their bidding since a large number of them bid just once; the first row in Table 2 reveals that 46 sawmills bid just once. The ones who bid more than once, just go in and out without any systematic pattern. Figures 1 and 2 reveal that the fringe is not bidding on softwood lots of any specific *type* in terms of average volume per tree. This makes learning about the bidding patterns of competitors difficult. Reflecting this, the win/bid ratio in column 3 of Table 2 is the lowest for the fringe bidders.[11]

The coordination is tacit in that no explicit communication exists between the nonfringe bidders. Typical issue that have to be sorted out in an explicit collusive arrangement - sharing arrangement for the "spoils", enforcing the collusive arrangement, deterring entry into the collusive arrangement and punishment from the seller in case of detection - do not have to be addressed in the kind of tacit coordination discussed here. They *key* feature of the auction that facilitates the *tacit coordination* mechanism described is the regularity with which sales are organized by the County and frequent participation by a small subset on the mailing list of the County. These features enable both the seller and the frequent bidders to learn about woodlot specific characteristics targeted by the three nonfringe bidders and the fringe bidders in general. The frequent bidders use this learning to anticipate nonfringe competition perfectly. The seller uses this learning to ensure the availability, in each sale, of some *homogeneous* woodlots habitually targeted by the various bidders.

On ***softwood*** lots, while the nonfringe can *ex ante* anticipate nonfringe competition perfectly, this is not the case for fringe competition. In Figure 3 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

[10] *Type* or homogeneity of a woodlot is defined in terms of the diameter of the trees on a woodlot. A homogeneous woodlot will contain trees that have similar diameter or trees of a single *type*.

[11] The high win/bid ratio of the of the 9 fringe sawmills in the 11-30 category in Table 2 follows from these firms being hardwood firms.

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.

Of the three nonfringe sawmills, only nonfringe sawmill Y bids once in a while on large diameter ***hardwood*** lots. However on the hardwood lots it is not the case that 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 her 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, her bidding is so aggressive that she wins almost all woodlots on which she 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, there are *only* hardwood, fringe sawmills in my sample and ***no*** hardwood, nonfringe sawmill.

3 The Bidding Model

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. The harvesting cost incurred by bidder i, on woodlot j in the t-th sale will be indicated by $c^i_{j,t}$. $mp_{j,t}$ is the market price of timber available on woodlot j in sale t. The second component of a bidder's valuation is the demand that this bidder faces in the secondary market for processed lumber in the form of orders for processed lumber received by this bidder. $\eta^i_{j,t}$ 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:

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

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

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.

Typically, the common-values model has been assumed for bidders' valuations at timber auctions; this was the case in Haile (2000) and Athey and Levin(2000). In Haile (2000) the common and unknown component was the result of resale opportunities. Even if the value of the tract is known with certainty by a bidder prior to the resale round, the resale value is unknown in the auction-round. Haile argues that since the auction format in his paper is one of "scaled sales" where a winner's payment is based on the actual timber volumes and the payment is indexed to the timber prices at the time of harvest, there is neither uncertainty about the value of the tract nor the scope for private information about any common element in a bidder's valuation. Athey and Levine (2000) make a contrary case. Ignoring resale, the common and unknown component in "scaled sales" is the species composition of a tract. Private information about this common and unknown component is obtained by sawmills through independent "cruises" conducted by them. Unlike these two papers, Paarsch (1997) assumes an independent private-values model for bidders' valuations in "scaled sales" in British Columbia. The private component of a bidder's valuation is the bidder-specific harvesting cost.

The reasons for justifying a common-value model of bidder valuations by Haile and Athey and Levin do not apply for timber auctions in Southern Ontario. First, resale is forbidden. Second, bidders do not conduct their own cruises to gather private information about the "true" and unknown value of the tract. Rather the information provided by the County about the woodlot gives the bidders a fairly accurate idea about the "true" value of the tract. This follows from the seller participating in the auctions through a secret reserve price. The secret reserve is based on the information about the tract it provides to all bidders in the tender notice and is based on it's own cruise. Since the highest bid was rejected by the County in only 4% of the woodlots that it put up for sale, it seems reasonable to conclude that the County's tender information provides an accurate rather than a noisy signal of the tract value.

Several additional facts support the hypothesis there is little uncertainty about the common components of the value of timber on a woodlot or that bidders have private information about these common elements. The market price of lumber, $mp_{j,t}$, is known to all the bidders since it is based on past lumber prices and the bids submitted on similar woodlots in the past sales. A well documented cycle for lumber and timber industrial prices exists as well. The harvesting costs, $c^i_{j,t}$, are *standard* and *known* since road construction to reach the woodlots is not required.[12] Uncertainty about the value of timber on a woodlot on account of time lags in harvesting as in the "scaled sales" in the U.S. is not an issue in the auctions in Simcoe since the harvesting time is a year. Finally, bidders in the area of Simcoe do not bid to carry inventories. Rather these auctions are termed "fell and sell" auctions with bidders participating in the auctions in response to demand shocks in the market for processed lumber.[13] Orders for processed lumber, $\eta^i_{j,t}$, are private information of the bidder. These reasons make the assumption of private-values compelling.

It would seem that the private-values are correlated due to the harvesting cost and the fact that orders for processed lumber are related to the demand-supply shocks in the timber industry in general. Since harvesting costs are *known* and a reasonably well documented cycle exists for Canadian lumber and timber industrial price, the component which could cause correlation in valuations is nonstochastic. The assumption of independent private-values seems reasonable as a first approximation. In equation (2), the first component of bidders' valuation, $mp_{j,t} - c^i_{j,t}$ is nonstochastic. $\eta^i_{j,t}$, the orders for processed lumber is the stochastic component; it is assumed to be independently distributed.

[12]This is unlike Paarsch (1997) who assumes that harvesting costs are idiosyncratic and private to a bidder justifying the private-values model for bidders' valuations.

[13]An approximate figure quoted for inventories by the County is about 10% of the bidding volume in a year by the nonfringe. This is in contrast to counties in Northern Ontario who carry inventories to the extnet of 70% of the volume on which they bid.

4 Description Of The Data

My study focuses on the sales conducted by the county of Simcoe between the years 1987-1998. 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. 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 A.1 in Appendix A presents summary statistics.

On the basis of the discussion in the previous Sections, I assume the log-linear bidding rule in equation (3) below describes the equilibrium bidding behavior of *only* softwood firms in the sample. I consider only softwood firms because 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.

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

$\log(b^i_j)$ 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 4.[14]

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 cubic metre per 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.

$(\mathrm{TYPE})_{j,t}$ 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

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

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.

Table 4
Results from Regression in Equation (3)

Variable	Coefficient	Estimate	Standard Error	t-value (t^*)	Prob($t \geq \mid t^* \mid$)
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

$(\text{PTP})_{j,t}$ 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 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.[15] β_5 and $\beta_7 - \beta_6$ are the fringe-nonfringe difference in log bids of the outsider and the insider firms, respectively; these are analyzed in the next Section.

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,

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

bidder i expects to win in sale t. This variable is introduced to capture the effect of aggressive-nonaggressive bidding described by Engelbrecht-Wiggans and Weber (1979). In simultaneous auctions of multiple units with capacity constraints and no resale, bidders tend to bid aggressively on some units and less aggressively on others. The aggressive bidding is done to ensure that they win *at least* some units; the less aggressive bidding is done to ensure that too many units are not won in view of the existence of capacity constraints. Thus, if a bidder is expecting to win a large number of woodlots in a 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. A bidder will increase her bid by 0.05% for each additional woodlot that she wants to win. It is interesting to observe that the sign of the coefficient for the variable $(\text{NWINS})^i_{-jt}$ is positive indicating that the aggressive/nonaggressive bidding effect due to the the multi-unit aspect of the sales may be of secondary importance.[16] A possible explanation for the positive sign of the coefficient could be the *demand* effect. 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.

Finally, $(\text{CAPACITY})^i_{-t}$ is the number of woodlots won by bidder i in the sales held in the previous calendar 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 3 supporting this conjecture.

5 Testing for *Tacit Coordination* by the Nonfringe

As further evidence of the hypothesis that X, Y and Z are coordinating their bidding strategies after period 5 in the manner discussed in Section 2, 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.*

[16] A further discussion of this issue is given in Section 7.

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 processed lumber that is their private information. Hence I should observe the nonfringe firms bidding more aggressively than the fringe firms. I see in Table 3, 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*. 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. 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 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.[17]

Table 5
Results from Unrestricted Regression Prior to Coordination

Variable	Estimate	Standard Error	t-value (t^*)	Prob($t \geq \mid t^* \mid$)
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, $\beta_7, \epsilon^i_{j,t}$ replaced with β^{nc}_o, β^{nc}_5, β^{nc}_6, $\beta^{nc}_7, \epsilon^{i,nc}_{j,t}$, 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 she starts coordinating her bidding with the other two nonfringe sawmills. After year 5, when the three nonfringe

[17] The bidding strategy of the fringe firms will not change in response to the coordination by the nonfringe Thus, the insider-outsider difference in bids of fringe firms, $\beta_7 - \beta_5$, the expected bids of the insider and outsider fringe firms, $\beta_o + \beta_7$, and $\beta_o + \beta_5$, will be unchanged once coordination by the nonfringe commences.

sawmills coordinate their bidding strategies, the regression in equation (3) is run with β_o, β_5, β_6, $\beta_7, \epsilon^i_{j,t}$ replaced with β^{cr}_o, β^{cr}_5, β^{cr}_6, $\beta^{cr}_7, \epsilon^{i,cr}_{j,t}$, respectively. I have reported the results of these two regressions in Tables 5 and 6, respectively. The results confirm the conjectures made above about the differences in bids, prior to, and post coordination.

Table 6
Results from Unrestricted Regression Post Coordination

Variable	Estimate	Standard Error	t-value(t*)	Prob($t \geq \mid t^* \mid$)
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

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,[18]

$$H_o : \beta^{nc}_o = \beta^{cr}_o, \beta^{nc}_5 = \beta^{cr}_5, \beta^{nc}_6 = \beta^{cr}_6, \beta^{nc}_7 = \beta^{cr}_7. \quad (4)$$

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

6 Testing for Pure *vs* Mixed Strategies on Jointly Bid Woodlots

Supporting the *tacit coordination* hypothesis, a single nonfringe bidder is present in 50% of the 171 softwood auctions in the sample. However, contradicting the coordination hypothesis I also observe either 2 or 3 nonfringe bidders bidding together in 35% of the 171 softwood auctions. The woodlots on which joint bidding was observed are typical in terms of the observable characteristics: the woodlots are not located in the peripheral townships of the county of Simcoe; each woodlot has more than 2000 trees and volume per tree varies between 0.24-0.78 cubic metre per tree.

Joint bidding by the nonfringe would seem to support a hypothesis alternative to the pure strategy of the *tacit coordination* game. Joint bidding by the nonfringe could be interpreted as a mixed strategy equilibrium of a coordination game with nonfringe bidders being uncertain *ex ante* about the nonfringe competition they will face *ex post* after bidding transpires. The *nonfringe* would then randomize with respect to the woodlot *type* instead of bidding on woodlots of a single *type* leading to the joint bidding by the nonfringe bidders observed in the sample. This

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

may not be the case for timber auctions in Southern Ontario since joint bidding would be observed even if the nonfringe were playing pure strategies of the *tacit coordination* game whereby they target a single woodlot *type*. This follows from a significant number of woodlots in the sample being heterogeneous or containing trees of more than a single *type*. Of the 379 woodlots in the sample, while 44% and 20% of the woodlots contained exclusively softwood and hardwood trees, respectively, 36% of the woodlots contained both softwood and hardwood trees. Within woodlots containing exclusively softwood trees, there was significant variation in the diameter of the trees to be harvested on a woodlot. This is supported by the practice of the county in reporting only the average diameter of the trees to be harvested on a softwood lot in the tender notice, even if the trees on the woodlot belong to a single species.

Jointly bid woodlots provide a means to test whether the nonfringe bidders are playing pure strategies of the *tacit coordination* game or mixed strategies of a coordination game with *ex ante uncertainty* about nonfringe competition. *Tacit Coordination* on jointly bid woodlots refers to the nonfringe bidders anticipating nonfringe competition perfectly *ex ante* or prior to bidding. The basic idea of the test is that nonfringe play mixed strategies because the nonfringe competition they expect *ex ante*, prior to bidding, differs from the nonfringe competition *ex post*, after bidding transpires. This follows from a nonfringe bidder being unable to anticipate perfectly nonfringe competition. Thus even though *ex ante* a nonfringe bidder will bid more aggressively if she expects more nonfringe competition, *ex post* her bidding strategy would appear to be invariant to nonfringe competition. As a result, the woodlots won by this nonfringe bidder as a proportion of the woodlots on which she bids, will be invariant to the number of nonfringe bidders present in this auction *ex post*. In contrast, in the *tacit coordination* game, since a nonfringe bidder anticipates nonfringe competition perfectly, *ex post* her bidding strategy would change with nonfringe competition. Specifically, she would bid more aggressively, and as a result win a larger proportion of the auctions she participated in, with additional *ex post* nonfringe competition.

To conduct this test, I collect all the auctions in the sample with two nonfringe bidders; all nonfringe bidders are treated symmetrically.[19] This sub-sample of auctions is then partitioned into two depending on whether an additional nonfringe bidder was present in the sale or not. The presence of this additional nonfringe bidder in the sale is taken to be a proxy for nonfringe competition in the auction. This nonfringe competition is anticipated perfectly *ex ante* by the two nonfringe bidders present in the auction if the nonfringe bidders are playing pure strategies of the *tacit coordination* game. The win/bid ratio should be higher when an additional nonfringe bidder is present in the sale. On the other hand, if the two nonfringe bidders are playing mixed strategies of a coordination game with *ex ante* uncertainty about nonfringe competition, then the win/bid ratio for these two nonfringe bidder will remain unchanged when this additional nonfringe bidder was present in the sale compared to when she was not. An example illustrates these points. Suppose sawmills X and Y are present in an auction in the sub-sample of auctions

[19] There is no joint bidding in auctions with a single nonfringe bidder; hence they are not included in this sub-sample. A measure of nonfringe competition would not be available if auctions with all three nonfringe bidders was included in this sub-sample.

with two nonfringe bidders. If sawmill Z is present in the sale, then sawmills X and Y face competition from an additional nonfringe bidder. Sawmill Z is a proxy for this additional nonfringe competition. The conjecture is that if sawmills X and Y played mixed strategies of the coordination game with *ex ante* uncertainty about nonfringe competition, their bidding strategies and consequently their win/bid ratio would appear to be unchanged *ex post* whether sawmill Z was present in the sale or not. If they were playing pure strategies of the *tacit coordination* game, sawmills X and Y would bid more aggressively, *ex ante* when sawmill Z was present in the sale. Since *ex ante* they anticipate perfectly participation by sawmill Z, their win/bid ratio would be higher *ex post*, after bidding has transpired.

Table 7: Proportion of Wins in Auctions with Two Nonfringe Sawmills

Additional NF in Sale	Bids	Wins	Wins/Bids
0	44	19	0.43
1	66	35	0.55

An analysis of the sub-sample of auctions in which two nonfringe bidders were present is given in Table 6; there are 110 auctions in this sub-sample. The first column divides this sub-sample of auctions into two. In addition to the two nonfringe bidders present in the auction, a third nonfringe bidder could be absent or present in the sale to which this auction belongs; the first and second rows of the first column refer to these two scenarios, respectively. The second column indicates that there were 44 auctions in the sub-sample in which two nonfringe bidders were present in the auction but no nonfringe bidders was present in the corresponding sale. There were 66 auctions in which two nonfringe bidders were present in an auction and an additional nonfringe bidder was present in the corresponding sale. The third column gives the number of times a nonfringe bidders won the auction in the sub-sample of 110 auctions. For example, 19 of the 44 auctions in which two nonfringe bidders were present but no nonfringe bidder was present in the sale to which this auction belonged were won by a nonfringe bidder. The last column gives the win/bid ratio.

Since the wins/bids ratio has increased with the presence of an additional nonfringe bidder in the sale, it seems likely that the nonfringe sawmills are playing pure strategies of the *tacit coordination* game.

7 Additive Valuations in a Multi-Unit Sale

Since a sawmill can bid simultaneously on *multiple* woodlots in a sale, it could be the case that the valuation of a bidder who bids on more than one woodlot in a sale is either subadditive or superadditive. I give reasons below that the assumption of additive values seems reasonable for the woodlots won in a sale by a bidder in the auctions held in Simcoe.

Superadditive values arise due to increasing returns or synergies from a bidder winning multiple woodlots in a sale; Krishna and Rosenthal (1996) Marshall and Raiff (1997) characterize the equilibrium for simultaneous multi-unit second-price and first-price auctions with synergies, respectively. Synergies between woodlots in a sale in Simcoe could be present due to two reasons: geographic contiguity and a matching of a bidder's order in the secondary market. For example, if a sawmill had an order which matched the volume of timber available on two softwood lots being auctioned in a sale, then a bidder's valuation from winning the two woodlots would be greater than the sum of this bidder's value for the two woodlots. If these two woodlots were adjoining each other as well, then again the value of winning the two woodlots would be superadditive on account of geographical proximity. The County of Simcoe, in it's role as a seller, seems to be taking account of these synergies when aggregating trees to form woodlots in a sale. This follows from the woodlots in a sale being different in terms of the two *key* woodlot-specific characteristics targeted by the bidders: species in terms of the hardwood-softwood distinction and volume per tree.[20] Further, even though the county marks down trees to be harvested at the beginning of the year, it does not announce the details of the sales it will be conducting through the year till before the sale. It learns about the orders for processed lumber that a fringe/nonfringe sawmill faces from the bidding of this sawmill in a sale. It ensures that the bidders who are not able to fill their orders in one sale can do so in subsequent sales in the year.[21] Hence, a compelling case cannot be made for superadditive valuations.

A second possibility with multiple and simultaneous auctions of woodlots in a sale is that there could be decreasing returns to winning multiple woodlots in a sale. Engelbrecht-Wiggans and Weber (1979) describe an equilibrium in aggressive/nonaggressive strategies for a simultaneous but independent auction of *identical multiple* units, with budgetary restrictions or capacity constraints and *without* resale. The bidders are assumed to be risk-neutral, *identical* with independent private-values about the auctioned objects and subadditive valuation. The money left on the table or the spread between the winning and the second-highest bid in the Simcoe auctions is similar to the prediction of the equilibrium in aggressive/nonaggressive strategies. In Table A.1 in the Appendix 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.[22] 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. 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 bidders with sawmills outside

[20] Of the many observed woodlot-specific characteristics, the fact that these two were the most important becomes evident from Table B.1 in the Appendix B

[21] For example, there were several instances in the sample when I observed that a woodlot "similar" to the one a nonfringe bidders had bid but lost in a sale, available in the subsequent sale in the year.

[22] Hendricks, Porter and Boudreau (1987, p. 524) also note a similar spread in the OCS wildcat auctions.

the county bring in their own equipment to harvest the timber. The key point is that the sawmill bids less aggressively on these woodlots, expecting to win these woodlots if the other sawmills also bid unaggressively, and as a result win them at a bargain price.

The money left on the table would seem to support an equilibrium in aggressive/nonaggressive strategies in multi-unit auctions described by Engelbrecht-Wiggans and Weber (1979). Two *key* assumptions which deliver this equilibrium 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. The sign of the coefficient on the variable $(\text{NWINS})^i_{-jt}$, the number of auctions that a sawmill i wins in sale t *excluding* the current auction j in the regression in Section 4 also seems to support that the aggressive/nonaggressive bidding feature of simultaneous multi-unit auctions may not be the explanation for the large money left on the table.

8 Conclusion

This paper describes *tacit coordination* by the nonfringe bidders 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. Frequent participation enables a nonfringe bidder to learn about the woodlot specific characteristics that prompts participation from other nonfringe bidders. As a result, on homogeneous woodlots, they avoid competing with each other corresponding to a pure strategy equilibrium of a coordination game. Joint bidding by the nonfringe is observed on heterogeneous woodlots. On jointly bid woodlots *tacit coordination* refers to nonfringe competition being common knowledge for nonfringe bidders.

An issue not currently addressed in this paper or in the literature is the strategic aggregation by the seller of dissimilar sub-units to form a unit that is then auctioned off. This is a *key* feature of the auctions conducted by the County of Simcoe and of timber auctions in general. A woodlot or unit consists of heterogeneous sub-units in the form of trees of different *type* in terms of species or diameter. Aggregation of sub-units to form a unit is a critical issue that the seller has to address in designing the auction. At one extreme, the seller can design an auction in which she offers only homogeneous units or woodlots which consist of trees of a single *type*. In this set up there will be an incentive for bidders to coordinate their strategies by specializing in the processing of trees of a specific *type* with the gain to each bidder being the surplus generated on account of specialization. While this may be socially efficient, it is not optimal for the seller since gains from specialization are not passed on to the seller. This suggest the other extreme auction design which is socially inefficient: only heterogeneous units are sold and resale is forbidden. The bidders now do not specialize and have to compete with each other. In timber auctions in the United States a middle ground is followed; woodlots are heterogeneous but resale is allowed. Heterogeneity prevents bidders from coordinating their bidding strategies and they have to compete to win woodlots. But resale allows the bidders to specialize. In Southern Ontario, the seller offers a "mixed bag". While a large proportion of the woodlots are homogeneous, the number of heterogeneous woodlots is not insignificant. The frequent bidders coordinate on the homogeneous woodlots in that they do not compete with each other. But this coordination does not lead to specialization since the frequent bidders have to compete on the heterogeneous woodlots. Coordination does enable them to predict nonfringe competition perfectly on the heterogeneous woodlots. An interesting issue to be addressed in future research is a comparison, in terms of the seller's revenue and the social surplus, of the two auction mechanisms currently prevalent in Southern Onatrio and the United States.

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APPENDIX A: SUMMARY STATISTICS

Table A.1 lists the variables for which summary statistics are provided in Table A.2.[23]

Table A.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

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 mixedwood. 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.[24]

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

[23] 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.

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

that 20% of the bids submitted by Y are on large diameter hardwood lots.[25] 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 A2 presents summary statistics with this categorization. There are three points to note here.

Table A.2
SAMPLE DESCRIPTIVE STATISTICS BY SPECIES

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. Second, the average bid/m3/tree is higher on the hardwood lots than the softwood lots. 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.

APPENDIX B: CLASSIFICATION OF WOODLOTS

Categorization of woodlots is being done to ascertain whether sawmills target woodlots with specific characteristics. It has already been demonstrated that the three nonfringe sawmills bid on softwood lots with different diameter trees. The fact that of the 287 auctions in the sample the fringe and nonfringe compete on only 38% of the woodlots even though they participated in 75% and 63% of the woodlots respectively, indicates that fringe participation is linked to woodlot-specific characteristics as well.

Of the observable woodlot-specific characteristics, it appears that species in terms of hardwood-softwood and volume per tree provide a comprehensive categorization of woodlots in the sample. In Table B.1 the auctions in the sample have been classified by woodlot-specific characteristics and the number of nonfringe bidders. The column "0 NF" refers to auctions with *only* fringe bidders; NF indicates

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

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 been isolated in the paper. Classifying sawmills as hardwood *vs* softwood sawmills was prompted by the *type* of auction - hardwood or softwood - in which a sawmill participated.

Table B.1: 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

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 B.1 auctions are classified into Boundary *vs* Central auctions depending on the township in which the woodlot is located.[26] The fringe is participating in roughly the same

[26]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.

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% in the boundary as opposed to 33% in the center. 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; [27] 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.

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 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.

From the discussion above it appears that the fringe target hardwood trees compared to the nonfringe. Within softwood lots, the fringe targets woodlots with low volume of lumber which could be on account of either a small number of trees or small diameter.

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

Figure 1: Average Volume/ # of Trees

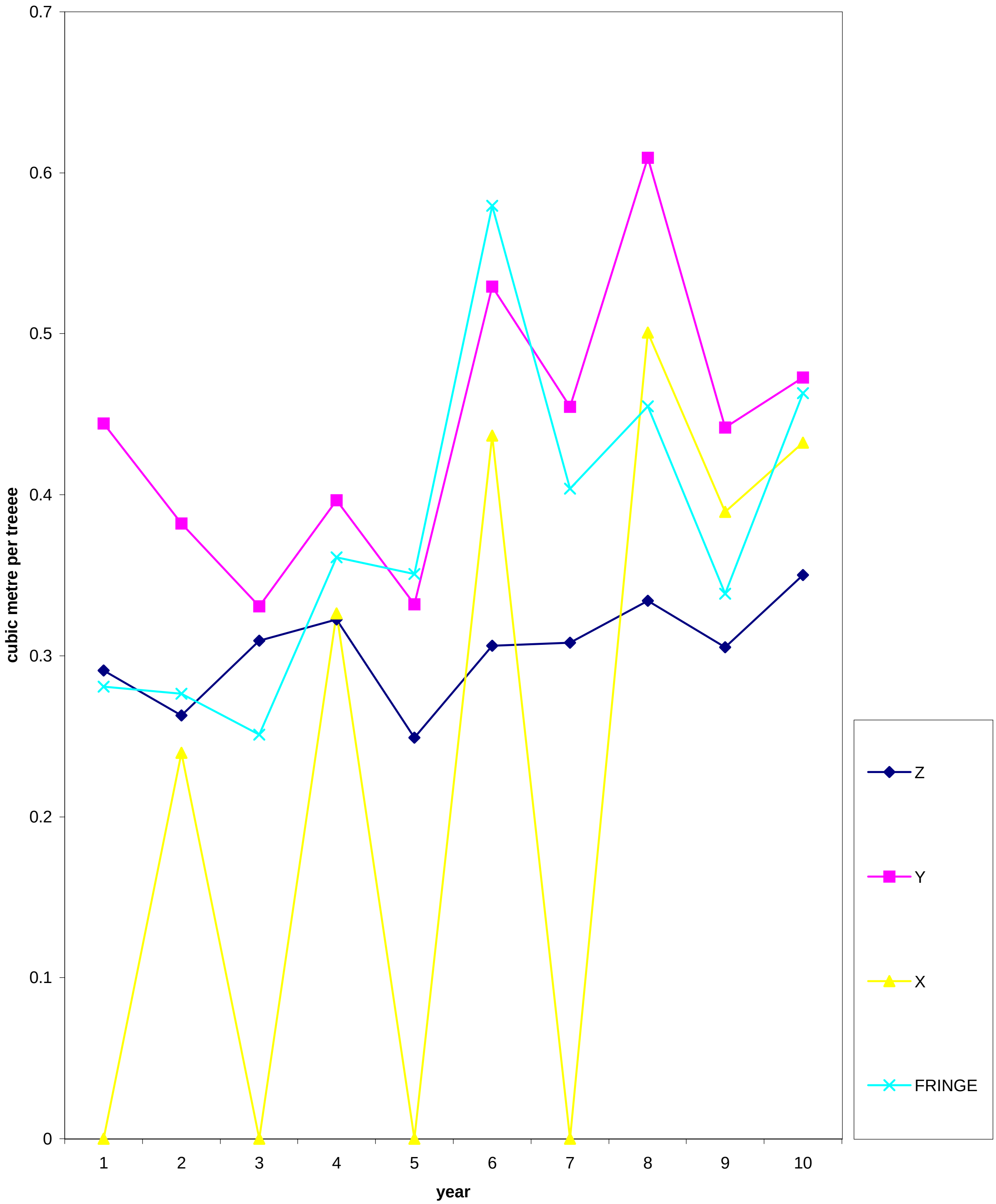

Figure 2: Real Bid/Volume/# Trees Across Years

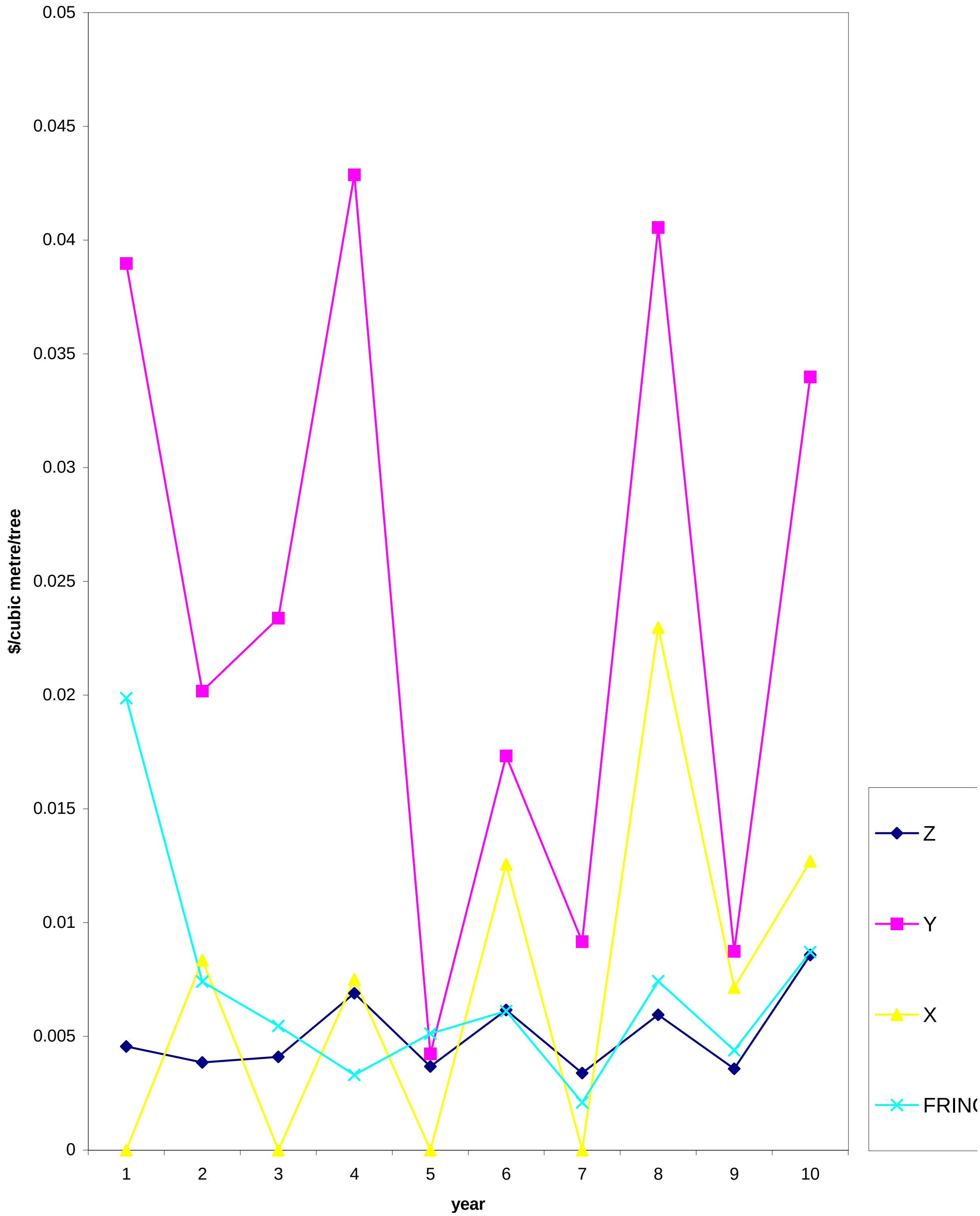

Figure 3: # of Bids and # Wins/# Bids Across Years

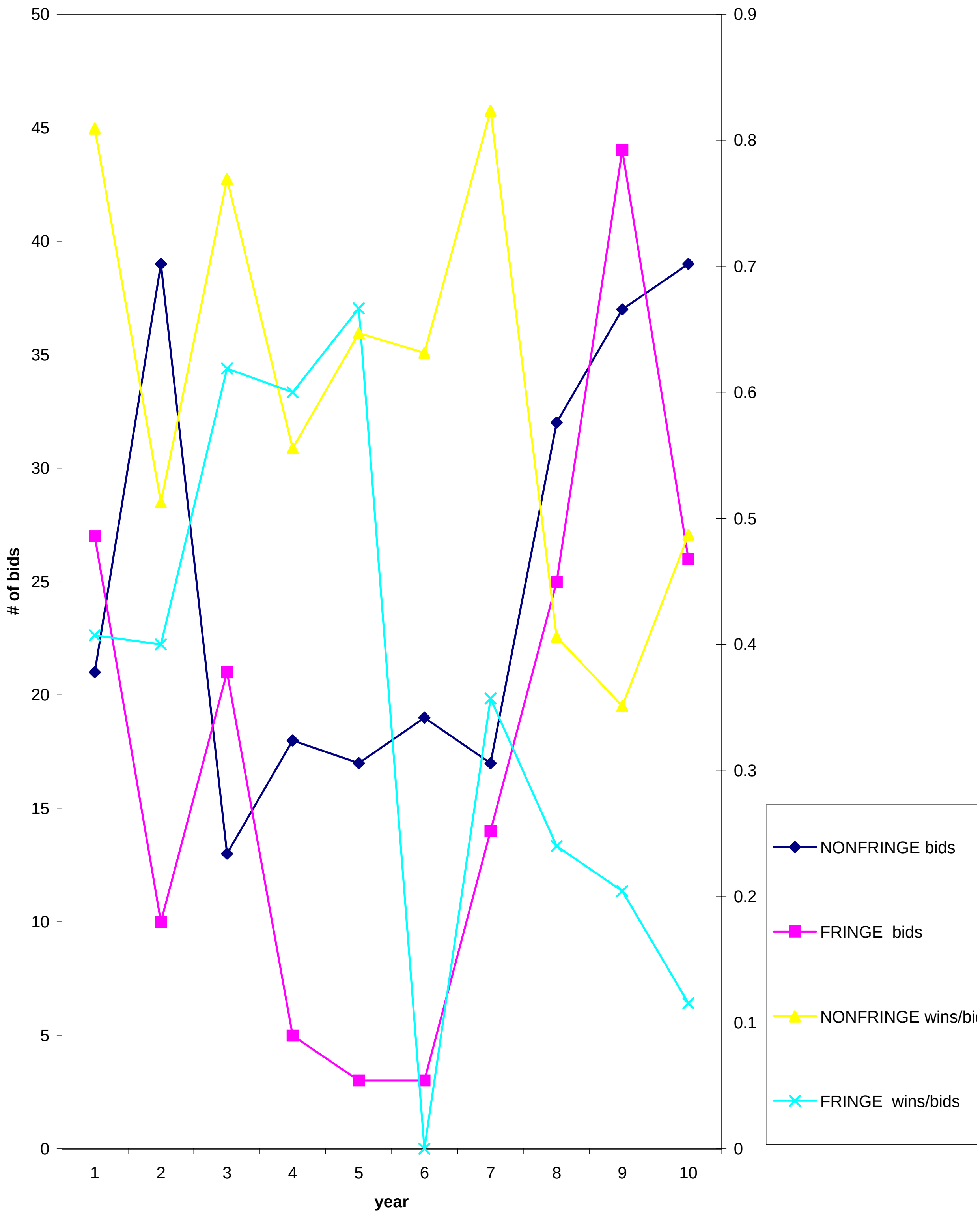

Figure 4: # of Bids and # of Wins/# of Bids Across Years

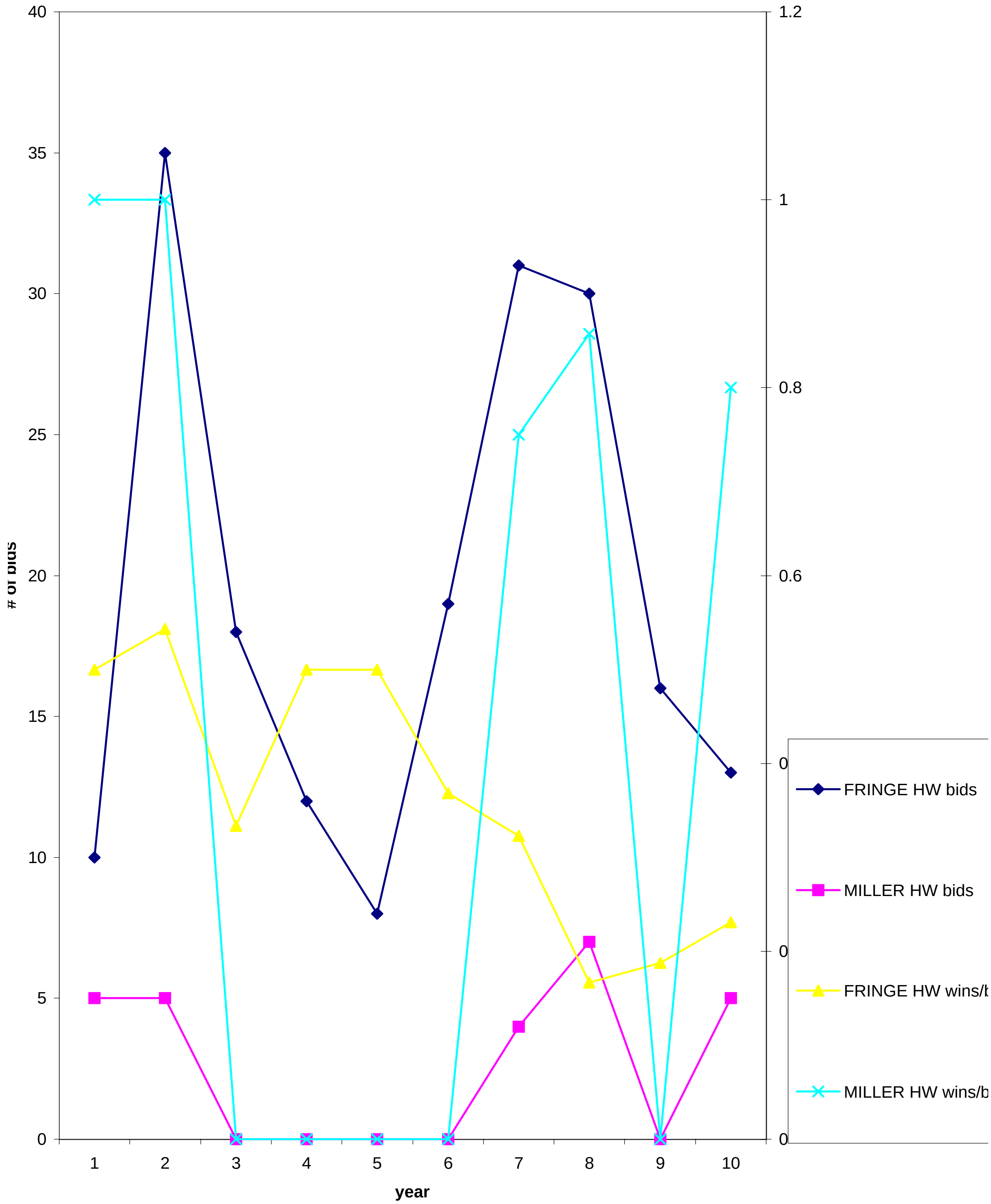

Figure 5: Map of Simcoe