Participation Screen for Collusion in a Simultaneous Multi-unit Procurement Auction

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7.5.2007 preliminary

Abstract

I propose two statistical tests to screen for collusion in a simultaneous multi-unit auction setting. I apply these tests to Helsinki school yard snow removal auctions. The behavior of two of the participating firms seems collusive. These two bidders seem to agree on territorial allocation of contracts.

1 Introduction

I propose two statistical tests to screen for collusion in an auction setting. Contrary to the existing literature, I concentrate only on the collusion that takes the form of territorial contract allocation. Therefore the tests are based only on the participation decision instead of the bid level. Moreover I argue that simultaneous multi-unit auction setting is particularly well suited for this approach.

Collusion is defined here as an explicit arrangement among a group of bidders that limits the competition between the participants. Collusion can take many forms in auctions. Typical methods include a territorial allocation mechanism and submitting phony bids. Hendricks and Porter (1989) argue that the detection of collusion is necessary case specific because the characteristics of collusive mechanism depend critically on the nature of the object beign auctioned, and on the particular auction rules. The empirical work needs to be tailored accordingly. The previous literature on detecting collusion in auctions has studied only phony bidding scenarios.

I present the participation condition, the idea of detecting the collusion and the econometric tests. Then I take these tests to a procurement auction data. I test whether the participation of one bidder affects the participation decision of other bidders. In the competitive setting the identity of competitors should not affect the participation decision, given that the auctioned contracts are identical and the bidders are symmetric. Porter and Zona (1999) propose a test based on the correlation of residuals of single equation participation choice models. They use it to detect phony bidding. They refer to (Kiefer 1982) as introducing this test to statistics literature. In addition to this simple testing method, I propose a more robust test. This is based on solving the simultaneous equations model of participation fully.

The central difficulty in detecting collusion is that similar market outcomes can be a result of either collusive or competetive behavior. Territorial allocation can be a result of either an explicit agreement or due to cost advantages that firms have in different areas. For example due to transaction costs, firms could decise to bid to only those markets that are near the location of their operations. With different locations, territorial allocation emerges as a competitive result. We get suspicious however if the territories overlap, but firms still systematically avoid bidding to same contracts. Unfortunately this can be again a result of competitive behavior if the contracts are heterogenious. Some firms may have costs advantages in some types of contracts. Therefore with heterogenous contracts and asymmetric bidders any kind of participation patterns may emerge in competitive setting. However if we can control for all the relevant bidder and contract heterogeneity, then the indentity of other participants should not affect the participation decision of any bidder in the competitive setting. This makes testing for collusion possible. I apply the methods to Helsinki school yard snow removal auctions held in the autumns of years 2003-2005. In graph 1. I present the spatial participation pattern in these auctions in year 2003. It marks on the city map the the schools that each bidder has participated on. The map shows that two bidders (A and K) seem to avoid each other. Moreover they systematically avoid each others in an overlapping geopraphical area, the city centre. This suggests collusive behavior in this market. This I put to test.

All the schools were auctioned at the same time. In contrast to structural econometric models of auctions, the simultaneous multi-unit nature of these auctions actually helps testing in this case. In sequential auctions, territorial allocation could exist as a competitive equilibrium even with symmetric bidders and contracts, if there are capacity constraints or decreasing returns to scale. In simultaneous auctions capacity constraints only constrain to how many auctions firms bid but not to which auctions. We can think of it as firms randomly submitting bids to contracts up to their capacity. Then it is highly unprobable that some firms systematically avoid each other. I also argue that in this particular case the larger participants in these auctions are not constrained by capacity. In sequantial auctions bidders condition their decisions on the outcomes of previous auctions, but in simultanous auctions the econometrian does not have to worry about any dynamic factors in the analysis. The harder sustainability of collusion typically evident in simultaneous setting is not an issue here because firms have other means to punish from deviation as discussed later.

The auction format is a first-price sealed-bid price-only procurement auction. The model is based on a participation condition in a situation where buyer posts a secret reserve price. This means that if a buyer can provide the service itself cheaper than the lowest bid, it will not accept the bids. Bidders participate in a given auction if their own costs of providing the service are low and their probability of winning is high. These depend on turn on the general market conditions and the buyer characteristics, the characteristics of a given contract and the characteristics of the bidder itself and it's competitors. In a competitive setting participation should not however depend on the identity of competitors, only their characteristics. In collusive setting the identity affects the participation decision. Controlling for observed characteristics the participation decision of two bidders affected each others decision to participate. Thus the behavior of these two firms is more consistent with collusive than competitive model. This result relies heavily on the assumption that there is no unobserved heterogeneity. In terms of Harrington (2005), this is a screening result, which means that I have identified this market as suspectible to collusion. This can also be though of as a verification of the cartel because the method by construct also identifies the exact model of collusion. This is not however sufficient for the prosecution of the colluding firms. Screening is useful in fairly quickly analysing the market to detect those where more attention should be put to find legal evidence.

This study is related to two different fields of empirical industrial organization literature. First is the detection of collusion. Second is the entry literature, as it is possible to think of this problem as an entry game with a single auction as an analog of a single market. Harrington (2005) provides a recent survey on detecting cartels. Levenstein and Suslov (2006) have also a recent survey on cartel studies but they do not deal with auctions nor the detection of cartels. Berry and Tamer (2007) provide a survey on empirical analysis of entry models.

Entry has been studied widely in empirical industrial organisation literature (e.g. Bresnahan and Reiss 1990 and 1991). Empirical models of entry in auctions have been considered by Athey et al. (2004), Bajari and Hortacsu (2003), Krasnokutskaya and Seim (2005), Li (2005) and Li and Zheng (2006). Athey et al. (2004) form a structural model that allows for heterogenous bidders, unobserved auction heterogeneity and models participation at the same time. They find evidence of mild degree of cooperative behavior in U.S. Forest Service sealed bid timber auctions when they compare open and sealed bid auctions. They exploit variation in auction format to assess the competetiveness. They also quantify the effects of collusion and find them significant. Bajari and Hortacsu (2003) use a structural model to study winner's curse and the effects of reserve price on seller revenue when entry is endogenous in eBay coin auctions. Krasnokutskaya and Seim (2005) analyze the effects of bid preference programs on participation in highway procurement. Li (2005) considers the structural estimation of first-price auctions with entry and binding reservation prices. Li and Zheng (2006) form a structural auction model with endogenous entry and uncertain number of actual bidders. They use it form counterfactuals on the effects of number of bidders on procurement costs in highway mowing auctions. The insights of these paper could help in analysing the costs of collusion. This counterfactual analysis is an ongoing work. Considering more classic entry games, Bajari et al. (2006) propose a method for estimating static games of incomplete information. They generalize the discrete choice models to allow for actions of a group of agents to be interdependent. I plan to use their method as further test for collusion among other things.

There has been some previous work on empirically detecting collusion in auctions. Hendricks and Porter (1989) have an early discussion on detecting collusion in auctions but do not present any method. Porter and Zona (1993) examine bidding in auctions for state highway construction contracts in order to determine whether bid rigging occurred. They find that the bids of noncartel firms, as well as their rank distribution, was related to cost measures whereas the rank distribution of higher cartel bids was not. They present two different analyses. One based on the level of bids and other on the rank of bids. They test differences between the behavior of cartel and non-cartel firms. They use rank distributions because they cannot control for contract characteristic. Porter and Zona (1999) examine the institutional details of school milk procurement process. They compare the bidding behavior of a group of firms to a control group and find them being different. They argue that behavior is consistent with collusion. The approach is similar to Porter and Zona (1993) though in this case the reduced form model of firm's bid level is estimated simultaneously with a probit specification for whether bid was submitted. They use likelihood ratio test to see whether the bids of the suspected cartel firms are determined differently than the bids of the control group. They also look whether the submission decision was correlated between the cartel firms. Their test based on submission decision is used in this paper. The idea of the papers by Porter and Zona is to use reduced form models to test whether bidder behavior is consistent with competition. Their 1999 paper requires prior information on which firms should be suspected of colluding. This information can be provided also by other screening methods.

Bajari and Ye (2003) introduce a general auction model with asymmetric bidders and independent private costs. They state the conditions that are both necessary and sufficient for a distribution of bids to be generated by a model with competitive bidding. They also discuss how to elicit a prior distribution over firm's structural cost parameters from industry experts and use this to compare collusive and competitive models. They apply their methodology to a data set of seal coat contracts. They use reduced form bid functions to test for conditional independence and exchangeability. The conditional independence means that conditional on the set of covariates observable to the firms, their bids are independently distributed. Exchangeability means that firm characteristics should enter the bid function in an symmetric way. The test of conditional independence is equivalent to testing that the OLS residuals to firm i's bid function are uncorrelated to residuals to firm j's bid function. The test of exchangeability is equivalent to testing whether the OLS slope coefficients of the bid function for the firms are the same. After they have identified the suspectible firms they use structural models to decide between the alternative models of industry equilibrium.

Some authors compare competitive and collusive models to determine which better fits the data. Among earlier of these studies are (Porter 1983) and (Ellison 1994) The general strategy is to specify structural competitive and collusive models of firms' bids and to estimate them using cost shifters. Baldwin, Marshall and Richard (1997) and Banerji and Meenakshi (2004) use this approach for oral ascending auctions. Bajari and Ye (2003) use it for first price sealed bid procurement auctions.

In contrast to most of the existing studies for detecting collusion this study does not utilise outside information about the possible colluders, like Porter and Zona (1999) or depend on observing the engineer estimates, like Bajari and Ye (2003). In that respect it may have more use as a screening and verification device for the competition authorities. The second testing approach is also more robust to unobserved heterogeneity than the methods proposed by Porter and Zona (1999) and the reduced form method by Bajari and Ye (2003). This approach can also be applied when there is no heterogeneity at all, unlike the structural approach by Bajari and Ye (2003). On the other hand the cases where bidders use territorial allocation scheme with overlapping territories may be limited.

2 Market

Harrington (2005) states that "it has been shown that cartel formation is more likely with fewer firms, more homogenous products and more stable demand". In this section I show that these are all true for the snow removal market under scrutiny. This section also explains the rules of the auction in question and gives a general description of the market.

In graph 1. I present the spatial participation pattern. It marks on the city map the schools that each bidder has participated on. Also the location of the known garages is marked there (bold and larger letters, Only one out of approximately 40 garages of firm K is known). Firms seem to participate more actively near their garages than further away. The map shows the bidders A and K seem to avoid each other. Moreover they systematicly avoid each others in an overlapping geopraphical area, as we can see at the lower left corner. Of the other bidders, bidder R submits bids to all but two contracts and the three small bidders, T, S and P, only few bids. This map is meant to validate our suspicions of collusive territorial allocation. Maps for years 2004 and 2005 are in the appendix 1 (to be added). It is interesting that in year 2005 the participation pattern does not imply collusive behavior anymore.

Graph 1. Bidder participation in school yard snow removal auctions in Helsinki 2003.

Starting from autumn 2003 the City of Helsinki has auctioned the snow removal services for school yards. All the schools are auctioned simultaneously. The bidders submit single sealed bids for four different type of services for each school. First service type consists of snow ploughing and sanding. Second service is the transportation of snow from the school to the snow dump. Third service is the transportation of sand from the school to the snow dump and the fourth is washing the yard. The last two services are needed only once every spring. Different services can be allocated to different firms within the same school. The lowest bid wins the given contract and the winner is paid their unit bid times the respective size of the contract. After the auction, all the bids are public knowledge. Thus all bidders detect deviators from collusive agreements easily. The bids are in unit costs. For example in the first service winner's bid in m^2 times the school yard size in m^2 is the payment per ploughing. Snow has to be ploughed every time there is more that 5 cm of snow on the ground. Typically bidders submitted bids to all of the services. But there are exceptions. For example one firm participated only to the snow transportation service and they bidded for all the schools. I consider only the bidding to the first service because it is the most important in monetary terms. For the purpose of this study the chosen service type does not matter. The amount of schools contracted differs from year to year. In year 2003 it was 153, in year 2004 37 schools and in 2005 65 schools. This number varied according to how much of the services the city wanted to provide itself. I restrict the discussion in this chapter to year 2003 because that is the year that I suspect that the collusion took place.

It states in the invitation to tender that "the buyer reserves the rights to transfer some of the contracts to be serviced by the city itself". This means that city announces that it has set a secret reserve price for the contract. Secret reserve price means that the city does not accept bids that are too high. In this case too high means a bid higher than the costs that city would incur by providing the service itself. It seems that this secret reserve price is binding for many firms in most auctions. In 2003 a total of six bidders participated in the snow ploughing and sanding services. Of the 153 contracts there were 2 with zero bidders, 85 with one bidder, 60 with two bidders, 5 with three bidders and 1 with four bidders. If the secret reserve price was not binding we would expect all the potential bidders that are not capacity constrained to submit a bid in all the auctions. The actual number of submitted bids can still change due to capacity constraints and different number of potential bidders in different areas of the city. Porter and Zona (1999) observe a similar distribution of actual bidders on their data set of school milk bidding. They suggest that small number of actual bidders indicates that "there may not be significant firm-specific information in the markets. If bidders knew their costs as well costs of the other potential suppliers, then under a set of standard assumptions either one or two bids would be observed. the low cost supplier would submit a bid just below the cost of the next-lowest-cost supplier, and the next-lowest supplier would be indifferent between bidding at its own cost and not bidding." In contrast to the markets analysed in Porter and Zona (1999), there is more uncertainty about costs of other bidders evident in this market. The bidders use somewhat different equiment, they can have different main activities and possibly efficiency differences. It is also inplausible that the asymmetries among bidders would be so large that it is common knowledge which will be the cost ordering of the bidders in all the auctions. I think the explanation of binding secret reserve price possibly joint with territorial allocation is more plausible. This is assuming that the three large bidders are not capacity constrained.

Snow removal is typically a secondary activity for the firms. The main activities of the three larger participants are construction, paving, delivery services and landscaping. The three smaller firms do real estate maintenance as their main activity. The common feature for all these firms is that they use the snow removal equipment for these main activies outside the winter period. Flambard and Perrigne (2006) argue that because snow removal is a secondary activity to supplement income, capacity constraints do not seem to be major issue in their auctions. For the Helsinki auctions this is probably true for the larger companies. On the other hand the smaller companies are typically one man firms with very limited amount of equipment. The three smaller firms only submit bids to from three to six auctions located near their office. Another reason to suspect that the large firms are not constrained by capacity is the fact that they have subcontracting deals with each others. Meaning that they have free capacity beyond what they win. These firms also participate to other snow removal auctions that the city holds. The secondary nature of the activity also acts as an entry barrier. No seller can enter just the snow removal activity alone. The required equipment is too expensive in relation to the industry's part-year nature for it to be profitable. On the other hand there are numerous construction firms in the area that already have the necessary equipment.

Flambard and Perrigne (2006) investigate the potential asymmetry among bidders in their study of snow removal contracts in Montreal. They find empirical evidence of asymmetry resulting from firm location, because in the urbanized part of the city the storage costs were prohibitive. Their assesment of most of the market conditions hold also for these snow removal contracts. The only difference being that in they study streets and I study schools. They argue that because of the equipment size and weather conditions, firms located far from the snow removal location will have to rent storage space for their equipment. This additional cost can induce some asymmetry among firms. They argue further that this asymmetry may prevent the least efficient firms from participating to the auction as their bids will not be competitive.

Market can be described by the nature of demand, the nature of production process and the nature of competitive interaction among seller. Demand for snow removal services is very inelastic. The weather is not affected by the price. And the conditions stated in the invitation to the tender about when the service should be provided do not depend on price. This property makes collusion more profitable because the increase in prices due to collusion does not reduce demand. The product is homogenous. There can be very little quality differences in snow removal. It is either removed or not. On the other hand the existence of reservation price makes the demand elastic. If cartel bids too high, the contract may not be awarded to anyone. Thus reservation prices reduce the incentives to collude. The production process can be different due to difference in snow removal equipment.

Besides the fairly inelastic demand there are also other characteristics in this market that may facilitate collusion. First is that firms compete only on price which simplifies cartel operations. Thus cartel needs to only coordinate participation or level of bids. Second is that publicly announcing all bids and bidder indentities makes it easier for the cartel to detect deviation. Markets are easily defined allowing assignment of territories. The set of participating firms is small and there are entry barriers making it possible to submit higher carter bids. Subcontracting is typical in this market. This provides an easy way to distribute the cartel rents and also faciliates direct communication and pretext for meetings of the cartel. The buyer suspects that some of the firms are colluding, but there is no legal outside evidence. On the other hand the simultaneous nature of these auctions makes it more difficult to sustain collusion. Bidders can punish from deviation only in the next year auction. On the other hand if the bidders meet in the other markets that they are active on, for example construction, they can possibly punish there. Also subcontracting deals allow a way to punish deviators.

As can be seen from the participation maps (graphs 1-3) the behavior of bidder A changes over time. In year 2005 it bids to seven same schools as bidder K whereas in year 2003 they never bidded to the same school. K bids generally to the same schools in 2005 as in 2003. Therefore we can conclude that it would have possible for A to compete with K also in year 2003 as I am not aware of any technology or location changes for A. This is further evidence for collusive behavior in 2003.

3 The participation model

Consider a procurement auction where N competitively behaving risk-neutral potential bidders bid for T contracts simultaneously. Bidders are allowed to submit only single sealed bids separately for each contract. Lowest bid wins a given contract. Seller posts a secret reserve price r before the bids are submitted. Secret reserve price is based on the buyer's ability to provide the service by itself. Thus it is not modelled as a strategic choice. r is drawn from a commonly known distribution $G(r|a_t, z_t)$ with support $[\underline{r_t}, \bar{r_t}]$. a_t is a vector of buyer's characteristics that affect the costs that buyer has in producing the service by itself. Buyer has it's own snow removal equipment. a_t can include for example the distance from nearest buyer's garage to a given school. z_t is a vector of contract characteristics like school yard size and shape. Bidders and contracts are asymmetric only in a sense that bidder i draws costs C_{it} in auction t independently from distribution $F(|x_{it}, z_t)$. x_{it} is a vector of bidder characteristics which may differ across auctions. This conditional symmetry is an essential assumption for this screening method. It implies that after controlling for x_{it}'s and z_t, bidders and auctions can be treated as symmetric. This also requires the assumption that there is no unobserved heterogeneity. With these assumptions, identity is irrelevant in competetive setting. Bidders' strategies consist of pair (y, β) where y is the decision to submit a bid and β is the amount bidded. If bidder wins an auction it receives utility $U_{it} = b_{it} - c_{it}$.

Let $C_{(1:N_{-i}),t}$ denote the lowest costs among i's potential opponents in auction t. With optimally chosen U_{it}, bidder i submits a bid to auction t if c_{it} is below the screening level c^*_{it}.

$$(1) \qquad c^*_{it}(x_{it}, x_{-it}, z_t, N_t, \bar{r_t}) = \sup\{c : (U_{it}|C_{it} = c)\Pr(C_{(1:N_{-i}),t} > c) \geq 0, c < \bar{r_t}\}.$$

This means that the threshold value is the largest such cost that fulfills the condition that expected profits are nonnegative and costs are below the upper bound of reservation price. To put it more simply bidder submits a bid if it can get positive profits with positive probability of winning and bid being accepted. The screening level depends on the direct cost factors, that is x_{it} and z_t, the factors that affect the probability of winning, that is N_t and $x_{(1:N_{-i}),t}$ and on the factors that affect the reservation price, that is a_t. This formulation requires the assumption that there are no cost synergies between contracts. If there were, in this simultaneous multi-unit setting the screening level would depend on the bidders probability of winning other contracts as well. The screening level should be modelled then with respect to sets of contracts. In multi-unit setting, the structural estimation of latent costs is not possible as shown by Cantillon and Pesendorfer (2006). However it is still possible to construct a reduced form model of participation.

Bidder i submits a bid to auction t if $y_{it} = c^*_{it} - c_{it} > 0$. y_{it} is a latent variable that depends on bidder's own characteristics, it's most cost efficient competitor's characteristics, contract characteristics, number of potential bidders and buyer's characteristics. We do observe $y^*_{it} = 1$ if bidder did submit a bid and $y^*_{it} = 0$ if it did not. In competetive setting we can model participation separately for each firm i with following equation.

$$(2) \qquad y_{it} = f(\theta, x_{it}, x_{-it}, , z_t, N_t, a_t).$$

Now θ denotes the parameters of the model. Next I consider a collusive model. Assume that some firms agree not to compete with each other. In this case their collusion takes the form of territorial allocation. They agree not bid on the same contracts. They negotiate privately before the auction on which contracts they each bid. Other firms behave in a competetive way. Denote the colluding firms by $j = 1, ..., J$ and competetive firms by $i = J+1, ..., N$. The screening level for collusive firms is denoted by c^*_{jt}. $x_{(1:N_{-(1..J)}),t}$ denotes the characteristics of bidder j's competitive competitor that has the lowest costs. I assume that competitive firms are unaware of the collusion. They still participate following equation (2).

$$(3) \qquad c^*_{jt}(x_{jt}, x_{-(1,...,J)}, z_t, N_t, \bar{r_t}) = \begin{matrix} \sup\{c{:}(U_{jt}|C_{jt}{=}c)\Pr(C_{(1:N_{-(1,...,J)}),t}{>}c){\geq}0, c{\leq}\bar{r_t}\}, \text{ if } y^*_{-j\neq i,t}{=}0 \\ 0 \qquad\qquad\qquad\qquad\qquad\qquad , \text{ if } y^*_{-j\neq i,t}{=}1 \end{matrix}.$$

Equation (3) states the fact that the behavior of colluding firms is dependent on the agreed allocation. Firms do not participate in the auction if one of their fellow colluders does participate. If the contract has been allocated to bidder j, then it participates if it's cost are below the screening level, taken into account the fact that bidder faces competition only from noncolluding firms. The participation decision for collusive firm's can be modelled with following system of equations.

$$(4) \qquad y_{1t} = f_1(\theta_1, x_{-(1,...,J),t}, x_{1t}, z_t, N_t, a_t, y^*_{-j\neq 1,t})$$

$$...$$

$$y_{Jt} = f_J(\theta_J, x_{-(1,...,J),t}, x_{Jt}, z_t, N_t, a_t, y^*_{-j\neq J,t})$$

The only difference with the competitive model is that now we include the participation decisions of other bidders. Therefore conditional on all relevant characteristics, other bidder's decision should not affect participation decision on competitive setting. If they do, bidders collude. This forms the basis of testing. Observing all relevant characteristics is essential here. We also need to impose structure on the participation equations to be able to estimate them.

4 Testing for collusion

First we need to assume that observed characteristics enter linearly to the participation models. Then for competitive bidders, the parameter vectors α_i, β_i, γ_i, δ_i and λ_i, $i = J+1, ..., N$, of the system of equations (5) can be estimated with some univariate discrete choice model for each firm separately. This is possible because there is no endogeneity.

$$(5) \qquad \begin{aligned} y_{J+1,t} &= x'_{-(J+1),t}\alpha_{J+1} + x'_{J+1,t}\beta_{J+1} + z'_t\gamma_{J+1} + N'_t\delta_{J+1} + a'_t\lambda_{J+1} + \varepsilon_{J+1,t} \\ &... \\ y_{Nt} &= x'_{-N_t,t}\alpha_N + x'_{Nt}\beta_N + z'_t\gamma_N + N'_t\delta_N + a'_t\lambda_N + \varepsilon_{Nt} \end{aligned}$$

For collusive bidders, the parameter vectors α_j, β_j, γ_j, δ_j, λ_j and η_j, $j = 1, ..., J$, of the system of equations (6) need to be estimated jointly because of the endogeneity problem. The dichotomous response variables are included as explanatory variables in the other equations. A bivariate simultaneous probit model with endogenous regressors is fortunately very easy to estimate. As Greene (1998) states: "in the bivariate probit model, unlike in the linear simultaneous equations model, if the two dependent variables are jointly determined, we just put each other on the right-hand side of the other equation and proceed as if there were no simultaneity problem". A multivariate model is more challenging. Therefore the estimations are conducted pairwise.

$$(6) \qquad \begin{aligned} y_{1t} &= x'_{-(1,...,J),t}\alpha_1 + x'_{1t}\beta_1 + z'_t\gamma_1 + N'_t\delta_1 + a'_t\lambda_1 + y^{*\prime}_{-j\neq 1,t}\eta_1 + \varepsilon_{1t} \\ &... \\ y_{Jt} &= x'_{-(1,...,J),t}\alpha_J + x'_{Jt}\beta_J + z'_t\gamma_J + N'_t\delta_J + a'_t\lambda_J + y^{*\prime}_{-j\neq J,t}\eta_J + \varepsilon_{Jt} \end{aligned}$$

We do not know ex ante which firms belong to collusive group and which to competetive group. Therefore we replace $x_{-(1,...,J),t}$ with x_{-jt} in equation (6) in the estimation. Now we are interested in whether the estimates of vector η_j are statistically significant. The sign is negative if there is territorial allocation scheme and and can be positive if bidders submit phony bids. We can construct following hyphothesis with null as the competitive behavior. This is the first test for collusion. If the null hyphothesis is rejected, firms collude. This test is new.

(7) H_0: $\eta_i = 0$ for all $i = 1, ..., N$
H_1: $\eta_i \neq 0$ for some $i = 1, ..., N$.

Fortunately we are not interested in any of the other estimates. Therefore we can construct a simpler test where we do not need to estimate the entire system. It is sufficient for testing to estimate each competitive equation separately with probit and then test whether the residuals are pairwise correlated. If the Spearman correlation is negative and statistically significant we can conclude that we are missing some variable from the estimation that affects both bidders negatively and significantly. If we have no other missing variables this is the identity variable. Thus we can conclude collusive behavior with territorial allocation for these bidders. This is the the second test for collusion. The benefit of this test is that it requires less observations. But it is even less robust with respect to missing variables than the first test. A similar test would be that of exogenous bivariate probit model with test for correlation of the error term.

(7) H_0: $Corr(\varepsilon_{it}, \varepsilon_{jt}) = 0$ for all $i, j = 1, ..., N$ and $i \neq j$.
H_1: $Corr(\varepsilon_{it}, \varepsilon_{jt}) \neq 0$ for some $i, j = 1, ..., N$ and $i \neq j$.

This second method was proposed by Porter and Zona (1999). They use it as a part of their methodology to detect phony bidding. They detect positive correlation and thus conclude phony bidding. In contrast to this study they utilise a priori knowledge to form a control group and a test group.

5 Problems and remedies

The one central problem in these tests is the unobserved heterogeneity. With respect to the second test, Porter and Zona (1999) state that "the test statistics may also reject the null hyphothesis of independent action if an important variable was omitted from the (control group) probit model that affects these firms similarly". If the test is used to detect phony bidding, i.e. positive correlation, as Porter and Zona

(1999) did we are more worried about missing variables that would induce some bidders to bid for the same schools or for them to avoid the same schools. These would cause residuals with same sign and thus positive correlation. In territorial allocation situation we are more worried about missing variables that would cause one bidder to avoid bidding for some schools and engourage the other to bid for them. With that kind of missing variable it would seem that these firms avoid each other with no reason. This would cause residuals with opposite sign and thus negative correlation. This we would interpret as collusion. The second testing approach is robust to missing variables with similar effects on the participation of the firms but not robust to missing variables with different effect on the potential participants. In the first tests, the question is about how missing variables affect the parameter of interest. In both cases the same problem remains to some extend.

Porter and Zona (1999) also say that "this test has little power to reject the null under an effective territorial allocation conspiracy, if there are no complementary bids, because we might not observe bids from ring members in the same district in the same year". This argument is probably the reason why their test has never before been used in the literature to detect territorial allocation. Fortunately in this data the firms have overlapping territories. Thus this simple test is feasible in this application as long as enough bidder characteristics are observed.

Entry literature (e.g. Bresnahan and Reiss 1990 and 1991) note the problem of multiplicity of equilibria in simultaneous entry games. In simultaneous two firm game they show that if one firm gets positive expected monopoly profits and another firm negative expected duopoly profits the equilibrium is monopolistic. However the identity of the monopoly firm is not uniquely determined. Auctions are simultaneous games. Sequential auctions are about making sequentially decisions on many simultaneous games whereas simultaneous auctions are about making simultaneous decisions on many simultaneous games. Sequential auctions have potentially more equilibria ex ante because decisions are conditional on the results of the previous auctions. On the other hand this multiplicity of equilibria allows us to rule out actions that look out like collusion evolving implicitly. On the other hand it poses problems to estimation. The observed characteristics might not have one-to-one mapping on the participation probabilities. In an auction setting the existence of multiple equilibria is driven by entry costs. If preparing and submitting the bid is costless, then entry decisions of symmetric bidders are based only on beating the reservation price. There is little reason to suspect that bid preparation includes large costs for the firms in these markets because the bidding process is very simple and they have previous experience from providing the service under contract. Moreover, the reduced form econometric approach does not need to assume a given equilibrium behavior. In needs just the assumption that the observables enter the participation decision in a similar way regardless of the equilibrium. Bajari et al. (2007) propose a method to empirically analyse the equilibrium selection in discrete games of complete information.

Job rotation is a similar phenomenon to territorial allocation. In a sequential auction setting job rotation can exist either as a result of collusion or as a result of efficient outcome of a competitive bidding process when capacity constraints or decreasing returns to scale matter (Hendricks and Porter 1989). This makes detection of collusion more difficult in that setting. In contrast to sequential auction where winners of previous auctions are observed, in simultaneous auction the bidders do not observe how much capacity is already committed when making a decision to participate in a given auction. Thus there is no backlog. In a simultaneous setting capacity constraints or decreasing returns to scale affect only the total number of auctions that seller participates in. If there is uncertainty about other bidders costs competitive bidding should not result in the case where certain bidders systematically avoid each other. Also in sequantial auctions, the bidders may signal their preferences to other bidders more easily than in simultaneous auction. Territorial allocation can be a result of competitive behavior when there are large observable cost differences among bidders. But if these differences are controlled for we should not observe that identity in itself matters in a competetive setting.

6 Data and modelling choices

The data is a cross section of 258 auctions with 335 bids submitted. 28 auctions did not receive any bids, of which 19 where held in 2004. Ten bidders participated in these auctions. Six in 2003, three in 2004 and six in 2005. Three small firms exited the market after 2003 and three entered in 2005. The participation decisions of bidders are described in table 1. along with bid levels. It shows the number of bids submitted, number of contracts won, number of contracts won when facing competition and bid level information for each bidder. It also shows to which city areas a given bidder submitted bids and in which years the bidder submitted any bids. Only three players submitted bids every year. By looking at the map we notice that only A and K avoid each other in the same city area. Therefore I conduct the tests only for the bidders A and K. Moreover, bidder R submitted too many bids in the year it participated and bidders T,S, H and O too few bids to be of any use in analysis of discrete choice models. There is too little variation in their decisions to use the tests for them even if I wanted to.

Table 1. Descriptive statistics for the bidders in years 2003-2005. Participation and bids.

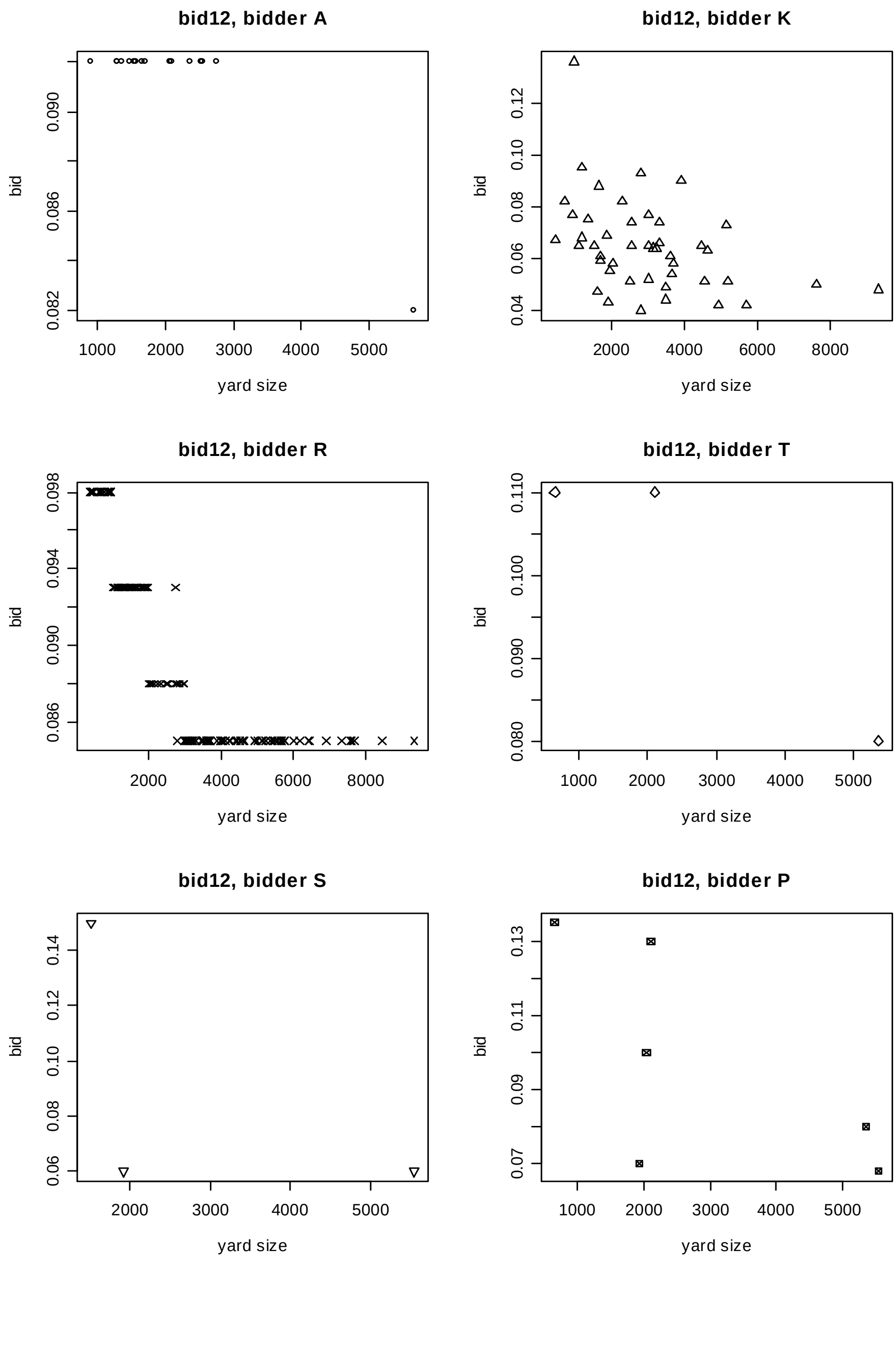
	A	K	R	T	S	P	H	J	O
# of bids	42	98	151	3	3	16	1	19	2
# wins	33	89	97	1	1	4	1	2	2
# of wins|com	16	66	12	1	1	1	0	0	2
mean bid	0,097	0,071	0,089	0,100	0,090	0,107	0,050	0,103	0,097
sd bid	0,005	0,020	0,005	0,017	0,052	0,021	NA	0,022	0,018
min bid	0,082	0,040	0,085	0,080	0,060	0,068	0,050	0,071	0,084
max bid	0,110	0,156	0,980	0,110	0,150	0,135	0,050	0,140	0,110
South(centre)	Yes	Yes	Yes	No	No	No	Yes	No	No
Northwest	Yes	Yes	Yes	Yes	Yes	Yes	No	No	No
North	No	Yes	Yes	No	No	No	No	Yes	Yes
East	No	Yes	Yes	No	Yes	No	No	No	No
Year 03	Yes	Yes	Yes	Yes	Yes	Yes	No	No	No
Year 04	Yes	Yes	No	No	No	Yes	No	No	No
Year 05	Yes	Yes	No	No	No	Yes	Yes	Yes	Yes

The data includes information on contract characteristics and bidder characteristics.Contract characteristics include the school yard size and some measures of it's shape or "tighness" that intend to capture how difficult it it to plough the yard. These are the number of walls or fences that surround the.yard, the number of permanent obstacles like trees or small buildings in the yard and dummy for whether the yard includes tight spaces. The shape variables are obtained by looking at the 1:1250 -maps of the school areas. Contract characteristics also include the distance to the schools from the City's garages to account for changes in the secret reservation price. The information on the bidders is very limited. Bidders did not agree to be interviewed. They only answered few short questions. The most important variable that we are interested in is the location of bidder garages. We could use that to calculate the distances from garages to the contracted schools. I do not have this information for the bidder K, because that is a joint organization of over 40 different small companies. That organization did not provide the information on the location or identity of the actual firms bidding for each school. The location is also missing for bidder J. Thus we need to construct a proxy variable for distance. I also use four area dummies in the analysis to capture the strength in larger area around the school. These dummies also capture the possible changes in the number of potential bidders.

To proxy distance, I construct a variable called "sact" - subjective activity. First I counted a variable "ofsix" - how many of the six nearest schools of a given school a given bidder submitted a bid in a given year. I formed an index out of this that gains a value one for the highest number a given bidder had, two for the second highest and so on up to seven in case bidder had all the values from zero to six the "ofsix" variable. Note that different bidders can both have value one in "sact" with different values of "ofsix". This variable captures not only the distance, but the overall costs of the bidder in the close proximity of the given school. There is a possible endogeneity problem with this proxy. Bidder might have or might not have bidded to some of the near schools due to collusion instead of cost conditions. Experimenting with different proxies for distance and using distance for those firms that it observed for does not change the results of the tests. When explaining the distance with the "sact" proxy for bidder A, R^2 is about 0.5 for year 2005 and about 0,3 for year 2003. Correlation is significantly positive for both years. These facts imply that the proxy is valid and that endogeneity problem is not necessary significant.

Graph 2. shows scatter plots of bids in relation to school yard size for each bidder separately. It is also informative about participation with respect to yard size. Bidder A participated in smaller auctions than other bidders. This is probably because they operate only in the centre of the city where yards are smaller. But in can also be because they specialise in smaller yards due to their different equipment. We note that unit bids are decreasing in yard size, implying economies of scale. These seem to be decreasing. This is why I include yard size and it's square in the probit analysis of participation. Both were significant in the OLS analysis of bids (not reported).

Graph 2. Scatter plots of bids and school yard size for each bidder separately for snow ploughing and sanding contract (bid 1 + bid 2) in year 2003.



7 Results

7.1 Test 1

I am able to conduct this test only for the joint data with all the years included. This is because the model does not identify for the year 2003 alone, because there is not a single observation where both $y_1 = 1$ and $y_2 = 1$. In year 2004 there is one such observation and in year 2005 seven. For the 2005 data there are too few observations for it to used alone while I could include all the controls that I want. Even with the joint data I have to make compromises with respect to controls. I leave out the bidder characteristic for all but the three bidders that were present in all the years. Single equations probit estimation show that these omitted variables are not important. I am also able to use only one area dummy instead of three.

Table 2. Results of the bivariate probit estimations with endogenous regressors.

	Bidder A		Bidder K	
	Estimate	P-value	Estimate	P-value
constant	+		+	***
cd	-	*	+	
ys	-		+	
ys^2	+		-	
w	+		+	
o	+	*	-	
s	+		+	
t03	reference group		reference group	
t04	-		-	
t05	+	***	+	****
sactA	-	***	-	
sactK	-		-	****
sactP	-		-	
Area S	+	***	+	
Area NW				
Area N	reference group		reference group	
Area E				
yA	response		-	****
yK	-	****	response	

Unit of observation is school. n = 258. "cd" is the distance from the nearest City garage. "ys" is the yard size and "ys^2" its square. "w" is the number of walls surrounding the yard, "o" the number of obstacles in the yard and "s" a dummy for yard including tight areas. "t03 - t05" are the year dummies and "Area X" the area dummies. "sacti" is the subjective activity of bidder i. "*" means 10 % significance level, "**" means 5 % significance level, "***" means 1 % significance level and "****" means 0,1 % significance level.

Contract characteristics seem not be very important for either of the firms. A seems to bid more to schools with many obstacles in the yard. This is line with the fact that they have small equipment that is best suited for difficult yards. Surprisingly A seems to bid more to school which are close to City's garages i.e those which should have lower reserve price. This may be due to the fact the City has more garages in the centre area where A also mostly operates. Both bidders are more active in year 2005 than before. As seen below, this supports the conclusion that collusion lasted only the year 2003. Another axplanation is that the firms started to submit phony bids. Bidder's own cost proxy is very important with the expected sign but competitor's proxies are not. As also known from the map, bidder A operates most in the south area of the city. The collusion test is significant at 0,1 % level. Note that the null hyphothesis of competition is rejected even though the joint data is used. Due to limations in the data I cannot check whether the result is robust to different model specifications. This result should be robust to missing variables that are not correlated with the participation decision of the other bidder. These should not include own bidder characteristics but may include contract characteristics.

7.2 Test 2

I estimate the probit models separately for bidders A and K. First I estimate the model for year 2003 alone and then use the same joint data as in the first test. I use the same controls as before. Again the subjective acticity variable is significant for both bidders and has the expected sign. For the 2003 data this is the only significant variable in addition to City's garages for bidder A. Garage variable probably captures some of the area effect for A. Bidder K seems to get returns to scale from yard size. Results are similar to those of the test one with slight changes. The residuals of these probit models were negatively correlated for the two bidders. This correlation is significant for the 2003 data. This implies collusion in the year 2003 but not in 2004-2005. When using more refined area dummies the correlation is no longer significant even for the 2003 data. I also conducted this test with smaller control set separately for year 2005 and 2003. Then the residual correlation for 2005 was positive and not significant for 2005 and negative and significant at every standard level for 2003. "sact" variable is not significant for any of the omitted bidders but including them to the model with many area dummies makes the negative residual correlation again significant for 2003. This show that this test is not robust to model specification nor to missing variables. The result should be robust to symmetric missing variables but not to asymmetric missing variables. These may include both contract and bidder characteristics.

Table 3. Results of the single equations probit estimations and the residual correlation test.

	2003				2003-2005			
	Bidder A		Bidder K		Bidder A		Bidder K	
	Estimate	P-value	Estimate	P-value	Estimate	P-value	Estimate	P-value
constant	+		+		+		+	
cd	-	**	-		-	****	+	
ys	-		+		-		+	*
ys^2	-		-		+		-	
w	-		-		+		+	
o	+		+		+		-	
s	+		+		+	**	+	
t03					reference group		reference group	
t04	NA		NA		-		-	
t05					+	***	+	**
sactA	-	***	+		-	****	+	
sactK	-		-	**	-	*	-	****
sactP	-		-		-		-	
Area S	+		+		+	***	+	
Area NW								
Area N	reference group		reference group		reference group		reference group	
Area E								
Log lik	-11,3		-86,2		-25,9		-142	
AIC	44,5		194		77,8		310	
Spearman's corr	-0,192				-0,070			
p-value	**							

8 Conclusions

I find evidence of collusion in Helsinki school yard snow removal auctions. Two bidders seem to participate in contract allocation scheme. The collusive regime seems to last only one year. This conclusion is supported by market conditions, spatial properties and the results of a statistical test. There are two possibilities of model misspecification. The testing approach may not be valid if the bidders are not conditionally symmetric. The test may also give wrong results if there are missing variables that affect the bidders participation decisions. This result seems to validate closer legal study to support the prosecution of these two companies. This test can be applied to screen for collusion in other auction markets as well. This test is more plausible if two conditions are met. Firstly, the auctions should be simultaneous. Secondly, the collusion has to take the form of bid rotation or territorial or contract allocation scheme. And the allocation has to overlap with respect to the important variable. For example the geographic territory. Unfortunately these conditions are somewhat restrictive.

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