Design, Implementation, and Outcome inCombinatorial Public Procurement Auctions An Empirical Analysis[♣]

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Abstract

Combinatorial procurement auctions enable suppliers to express potential cost synergies in their package bids. In this paper it is explored how bidders respond to the option to submit package bids. The rules of the game vary over the combinatorial procurement auctions studied in terms of restriction on the number of contracts awarded to one and the same bidder, the option to express capacity constraints and restrictions on how many packages the bidders are allowed to submit. In addition to this is bidder behaviour with respect to the likelihood of winning a contract given the number of packages submitted, type of bidders, and contracts bid on explored.

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1. Introduction

In recent years, combinatorial auctions have been applied in a number of Swedish public tenders of multi-unit contracts. Besides the submission of bids on individual contracts (stand-alone bids), bidders have in these tenders also been allowed to submit bids on arbitrarily packages of contracts. The pricing mechanism has been the first-price rule, which in some cases has been modified to also include other qualitative criteria in the awarding of contracts, i.e., the principle of the most economically advantageous bid. The main advantage with combinatorial auctions is that the mechanism enables bidders to offer discounts in case they are allocated a bundle of contracts. That is, they are not exposed to the risk of winning to few contracts. Hence, the buyer may exploit suppliers' cost synergies of winning multiple contracts and thereby reduce his own costs. In addition to allowing the submission of bids on packages of contracts, bidders have in most of these Swedish combinatorial public procurement auctions also been allowed to express limitations in their capacities. In an addendum to the stand-alone bids on individual contracts, the bidders had the option to state the maximum volume that they could accept in case a too large volume would be awarded. This constraint upon volume could be expressed in terms of maximum number of contracts awarded or maximum awarded contract value or a physical volume inherent in the contracts (m2,tons, km etc). Such an optional constraint may potentially increase the number of competitive bids from bidders with limited capacity since they will not be exposed to the risk of winning to many contracts. To sum up, both these two types of conditional bids – bids on packages and "bids" declaring a constraint upon awarded volume – have the potential of both lowering the procurer's cost and increase efficiency.

Although there is quite a large literature on combinatorial auctions, the number of empirical studies on bidding behavior in combinatorial procurement auctions implemented in the field.

The latter format is seen as an alternative to a non-combinatorial mechanism as it enables suppliers to express synergies across bundles of contracts, which mitigates the exposure problem (Pekeč and Rothkopf, 2003) and putatively has the potential to both lower the procurer's cost and enhance efficiency.In this paper, the design, implementation and the outcome from a number of combinatorial public procurement auctions of various services are analysed. The analysis is empirical and elaborative without the ambition to tackle the inherent complex bidding strategy problem.

Combinatorial auctions can be very complex. Beside the buyer's inherent potential computational problem in determining the winner in a combinatorial auction (Nisan, 2006),the auction mechanism is also strategically very complicated. Although the literature on combinatorial auctions is relative extensive, the number of studies based on field data is scarce. One explanation is that this mechanism due to its complexity rarely is applied in public procurement, albeit being increasingly applied in industrial procurement (Bichler et.al. 2009). Therefore there is a lack of evidence of to what extent bidders use the option to submit packages. In the combinatorial public procurement auctions studied here, bidders placed simultaneously both stand-alone bids on single heterogeneous contracts and bids on various packages of these contracts. Any bid in a package had be followed by a stand- alone bid. Consequently, not only did a bidder compete against other bidders stand-alone and combinatorial bids, thebidder's stand-alone bids are also competing with his own combination bids and vice versa. As such the degree of complexity in a combinatorial auction islikely increasing in the number of separate contracts. The aim of this paper is to empirically explore the design, implementation and the outcome from 13 combinatorial public procurement auctions of four different services carried out in Sweden during the period 2003-2010.The rules of the game varyacross the combinatorial procurement auctions studied in terms of (i) restriction on the number of contracts awarded to one and the same bidder, (ii) the option to express capacity constraints and (iii) restrictions on how many packages the bidders were allowed to submit. In addition to this, we study the likelihood of a bidder winning at least one contract and proportions of contracts won, respectively, as explained by the number of stand-alone and combinatorial bids submitted.Besides the differences in design the type of bidder, local or global will also be controlled for.

The outline of our paper is as follows. Section 2 includes the related literature. The auctions and a simple theoretical model will be presented in Sections 3 followed by the empirical analysis in Section 4. The results are discussed in Section 5 and Section 6 concludes the paper.

2. Previous studies

Combinatorial auctions have received substantial attention in recent years, in both practice and theory (e.g. De Vries and Vohra, 2003; Epstein et al., 2004; Sheffi, 2004; Cantillon and Pesendorfer, 2006; Cramton et al., 2006; Abrache et al., 2007). Also, there is quite a large amount of literature analyzing the strategic implications of combinatorial bidding and how to design combinatorial bidding. A number studies consider the Vickrey-Clarke-Groves (VCG) mechanism (e.g. Krishna and Rosentahl, 1996; Holzman and Monderer, 2004; Yokoo et al., 2004; Ausubel and Milgrom, 2006; Chew and Serizawa, 2007). Relatively little is however, known about equilibrium bidding strategies in environments of heterogeneous multiple items. The ambition with the current paper is to contribute to the understanding of combinatorial auctions in such an environment.

In the presence of synergies across items or contracts, the effect upon revenues or cost when allowing bidders to submit combination bids has been assessed in a number of experimental studies (see Chernomaz and Levin, 2012, for a list of some previous experiments) and field data (Lunander and Lundberg, 2012a; 2012b). Chernomaz and Levin (2012) find evidence of the threshold problem regardless of the level of synergies to cause the combinatorial auction rule to generate lower revenues to the seller than the separate auction. Theoutcome from their experiments indicate that the theory qualitatively is consistent with the observed behaviour: the stronger the synergies, the better performance of the combinatorial auction in terms of efficiency; the seller's revenue is higher under separate auctions than under the combinatorial auctions, irrespectively of the size of the induced synergies.

Theoretical evidence is found in Krishna and Rosenthal (1996) who have shown that the simultaneous sealed-bid second-price auction with two objects and a single global bidder due to "overbidding" outperforms a corresponding combinatorial auction when synergies are present.[1]Maskin and Riley (2000) show that in a first-price auction, the equilibrium bid distribution of the "strong" bidder (the global bidder) stochastically dominates that of the "weak" bidder (the local bidder). A similar result is found in Kagel and Levin (2005), in which they derive and analyze bidding behaviour in a sealed-bid uniform price auction when synergies are present. They find that bidders with multi-unit demand have, for some intervals of values, an incentive to submit bids above their valuation.

Cantillon and Pesendorfer (2006) refer to the results obtained in McAfee et al. (1989) and show that the presence of a combination bid does not necessarily indicate that the bidding firm is facing synergies. The submission of a combination bid can be equally motivated by strategic price discrimination. Cantillon and Pesendorfer conclude that the welfare consequences of first-price combinatorial procurement auctions are an open empirical

[1]Overbidding is a situation where a bidder bids above her value, facing the possibility of a loss ex post.

question. However, the more bidders' unit costs are negatively correlated in the number of contracts won, the more likely it is that the combination bids reflect synergies across contracts rather than strategic price discrimination.

Given the data from these tenders, the questions analyzed are to what extent do suppliers use the option to submit combinatorial bids and are contracts allocated more to packages bids rather than to stand-alone bids?

3. The auctions and design issues

The empirical analysis in this paper is based on Swedish public procurements of four different public services;internal regular cleaning services, road resurfacing, bus routes, and provision of nursing home care for the elderly. These procurement auctions were all organized as simultaneous combinatorial auctions and the contracts within each auction are in one or several dimensions heterogeneous. The auctions vary in their design even for the same type of service. Discussed below are some general design issues related to combinatorial procurement, followed by a presentation of the design of the procurements studied here.An overview of the design of the procurements studied here is provided in Table 1.

3.1 Dead Lock

To make sure that there will be no "dead-lock" when allocating the contracts, a bidder can be obligated to place a stand-alone bid for every contract included in one or several package bids. Following Lunander and Lundberg (2012b) this can be illustrated with an example. Assume that the procurement auction consists of three contracts (C1, C2, C3).Assume further that two bidders submit each a package bid. The first bidder bids a package of {C1, C2} and the second bidder bids for package {C2,C3}. As both bidders have included C2 in their package there will be an unsolved allocation of contracts (the dead lock). The solution to this problem is to require that there should be a stand-alone bid for every contract that is part of any package of contracts. In all of the auctions studied here this was required.

3.2 Predatory bidding

Another strategy that may be used by global bidders is to submit excessively high stand-alone bids with the aim to shut out local bidders from the competition. Let us again illustrate this with an example. Assume that the bids from the local bidders, in contrast to a global bidder, will not cover on all contracts (e.g. capacity constraints) then the global bidder may apply predatory bidding in the form of extremely high stand-alone bids on every contract in a packagebid which comprises all contracts in the tender. This will imply a very high discount and will effectively prevent its package bids from being outperformed by its own stand-alone bids in combination with the bids from the local bidders.

One way to deal with this problem is to restrict the number of contracts allowed in a package. This is preferable if the procurer lacks information about which of the contracts the local bidders are likely to refrain bidding for.[2] Another option is to restrict the size of the maximum discount allowed in a package bids. This creates incentives for the global bidder to submit lower stand-alone bids. The obvious drawback with both options is that the procurer may not be able to fully exploit potentially substantial synergies in large package bids. Restrictions of this kind are applied in seven of the 13 procurements studied here. The bidders were however free to choose which contracts to combine in a package.

3.3 Option to Express Capacity constraints

The option for the bidders to express capacity constraints can be used to increase the bidders' ability to bid on many contracts without the risk of being allocated more contracts than they

[2] If the procurer has such information these contracts can preferable be procured in a separate procurement auction.

can handle in terms of capacity. Another reason to apply capacity constraints are that it can reduce the risk for collusion as it makes it harder for potential bidders to divide the market.

Bidders can be allowed to express their capacity in terms of number contracts or size of contracts in terms of value or volume. In the data studied here capacity constraints in formof quantity or value is found in five out of the 13 procurements.

3.4Award restrictions

If the procuring authority for some reason fear a future declining market it can use award restrictions. As such it can seek to ensure that there is more than one potential bidder in future procurements. This can be motivated if the procuring authority is a dominant buyer but it most likely comes to the price of higher costs since the bidders' opportunity to express synergies is reduced.[3]The first procurement of internal regular cleaning services is the only procurement in the data where the design included an award restriction.

3.5Lowest price or EMAT

Being a part of the European Union (EU) Swedish procuring entities have to follow the EU procurement directives (2004/17/EC and 2004/18/EC). As such there is a choice between two award principles. Contracts can either be awarded based on price only and then takes the form of the standard first-price sealed bid auction. Optional contacts can be awarded based on the principle of economically most advantageous tender (EMAT). The lowest price principle (LP) can of course be combined with technical specifications, mandatory requirements and contract conditions that target quality dimensions. This is also the case for EMAT but in addition, bids are at least two-dimensional and evaluation is based on both price and one or several quality dimensions. The choice of principle is made on the procurement level so the same principle applies for all contracts auctioned in one and the same procurement. EMAT is applied in eight

[3]This is a rule that is not unique for the combinatorial mechanism.

of the procurements in our data. See e.g. Verdeaux (2003), Chen (2008), Mateus et al (2010), Telgen and Schotanus (2010) and Bergman and Lundberg (2011) for more on scoring rules and the principle of EMAT.

The procurements studied varied in other dimensions such as quality requirements and contract period but these are not considered in detail as dummy variables for type of service procured will be used in the empirical analysis. When relevant, the standard errors will be adjusted for clusters where each procurement auction represents a cluster.

3.6 Overview of the procurements studied

The empirical analysis builds on bid level data from 13 different procurement auctions of four different types of public services; internal regular cleaning services, road pavement, bus routes, and provision nursing home care for the elderly. The timing of the procurement auctions goes between 2003 and 2010. The number of contracts auctioned in one and the same procurement range between 4 (elderly care) and 42 (internal cleaning services). Bidders were free to compose the packages in terms of which objects to include in a combinatorial bid. This is a difference to e.g. the procurements of bus routes in London studied by Cantillon and Pesendorfer (2006).

As displayed in Table 1 all of the procurements studied here applied a design that prevented the dead lock problem, that is, bids on packages had to be followed by stand-alone bids. In seven out of the 13 procurements prevention of predatory pricing was applied. The bidders had the opportunity to express capacity constraints in five of the procurements. The capacity constrain could either be expressed in quantity terms (Q) or in terms of total value of contact (V). Quantity capacity constraints is the mainly design, given that capacity constraints are used. A restriction on the maximum number of contracts that could be awarded to one bidder was only present in one of the auctions (internal cleaning services) and the maximum number of contracts that could be awarded to one bidder was three out of seven. Contracts were awarded based on the lowest price principle in five procurements.

The procurements of internal regular cleaning services were performed by three different procuring entities in Sweden. The first two (Cleaning 1 and 2 in Table 1) were organized by two municipalities in mid-Sweden. The third one was organized by the Swedish Social Insurance Agency and consisted of all its local offices.

The six road pavement procurements were organized by the Swedish Road Administration (SRA) and more specifically the mid-Sweden area. As displayed in Table 1 the SRA set a limit as to the maximum number of contracts to have in a package bid. In addition to this there was also an upper limit on the maximum discount in a package bid. For the first three years the discount was 20 percent and then lowered to 10 percent for the next three years.

The bus route procurements include one procurement auction from the Värmland region and two procurements from the Skåne region. Potential suppliers could freely compose package bids and in addition they could declare the maximum overall volume they were willing to undertake. In the Värmland procurement the potential suppliers could express their capacity constraint in terms of the number of kilometers and in the Skåne procurements it was expressed in terms of number of available buses.

The procurement of nursing home care for the elderly was organized by a municipality in the north of Sweden (Östersund). Two of the contracts were excluded from being a part of a package bid and there was an upper limit on the discount set to five percent. Potential suppliers could express capacity constraints by indicating the maximum number of contracts they were willing to undertake.

Table 1. Overview of the design of the procurement auctions studied.

Type of service	Year	Number of contracts	Dead lock prevention	Predatory pricing prevention (Restricted number of contracts)	Capacity constraints (Q for quantity and V for value)	Award restriction	Evaluation principle
Cleaning 1	2005	7	Yes	Yes (3)	Yes (Q)	Yes (3)	LP
Cleaning 2	2006	9	Yes	No	Yes (V)	No	EMAT
Cleaning 3	2007	42	Yes	No	No	No	EMAT
Road 1	2005	17	Yes	Yes (5)	No	No	EMAT
Road 2	2006	8	Yes	Yes (4)	No	No	EMAT
Road 3	2007	9	Yes	No	No	No	EMAT
Road 4	2008	9	Yes	Yes (3)	No	No	EMAT
Road 5	2009	7	Yes	Yes (3)	No	No	EMAT
Road 6	2010	9	Yes	Yes (5)	No	No	LP
Bus1	2003	34	Yes	No	Yes (Q)	No	LP
Bus 2	2003	6	Yes	No	Yes (Q)	No	LP
Bus 3	2004	12	Yes	No	Yes (Q)	No	EMAT
Care	2008	4	Yes	Yes (3)	No	No	LP

Table 2. Outcome and contract allocation by type of service.

Service	No of contracts	No of bidders	No of global bidders	No of bidders submitting a package	No of single bids			No of packages			No of winners			No of allocated contracts	
					Min	Max	Mean	Min	Max	Mean	All (uniquefirms)	By singlebids	By packagebids	By singlebids	By packagebids
Cleaning	58	33	3	16	1	42	8.93	1	56	11.14	7	4	3	10	48
Cleaning 1	7	6	2	5	3	7	5.86	10	56	29.00	3	1	2	1	6
Cleaning 2	9	14	2	6	4	9	8.57	1	8	3.00	3	3	0	9	0
Cleaning 3	42	21	3	11	1	42	10.91	1	25	7.45	1	0	1	0	42
Road	58	9	4	7	1	17	7.95	1	33	11.00	5	1	5	13	45
Road 1	17	8	4	6	5	17	14.29	10	33	18.83	5	4	4	5	12
Road 2	8	8	4	7	2	8	6.00	1	14	6.00	2	2	2	2	6
Road 3	8	6	4	6	3	9	7.17	2	30	10.50	3	1	3	1	7
Road 4	9	5	4	4	4	9	7.20	3	17	10.50	3	2	3	2	7
Road 5	7	6	4	4	1	7	5.33	2	26	8.75	3	1	3	2	5
Road 6	9	5	4	2	3	9	7.00	2	22	12.00	3	1	2	1	8
Bus	52	29	3	13	1	33	5.61	1	31	5.47	16	11	6	28	26
Bus 1	34	22	3	8	1	33	5.41	1	31	9.14	11	11	2	23	11
Bus 2	6	8	2	7	1	6	3.63	1	8	2.71	4	3	1	3	3
Bus 3	12	6	2	5	5	12	9.00	1	8	4.20	4	0	4	0	12
Care	4	6	3	2	2	4	4.00	2	2	2.00	2	1	1	2	2

The outcomes of the auctions are displayed in Table 2. The main focus of this paper is how the bidders respond to the design of the combinatorial auction and number of packages submitted. As such prices (bids) are not included in Table 2.[4] In total 78 unique firms are identified in the data and 33 of them are observed in the cleaning service data, 9 in the road pavement data, 29 in the bus route data, and 6 in the procurements of nursing home care for the elderly. All in all some of these 78 unique bidders participated in more than one procurement (1.6 procurements on average) giving a total of 123 observations on the firm level.

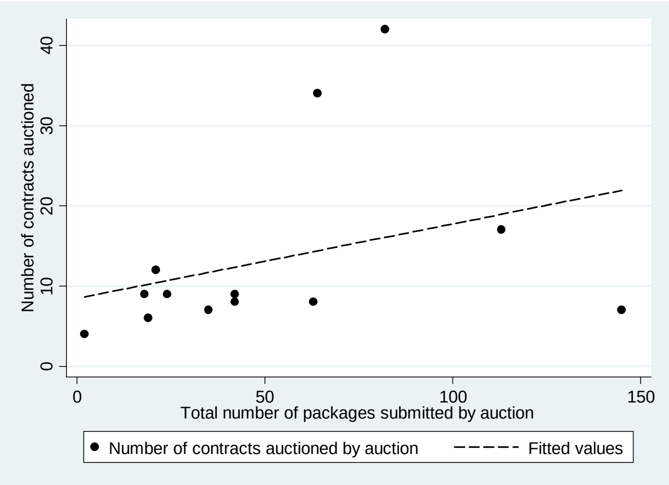
The number of bidders varies substantially within and over the type of services procured. Within the cleaning service procurements the number of bidders varies between six and 21, and overall it varies between five and 29. Note that the number of bidders figure regards the number of bidders on the procurement level which can differ from the number of bidders on each contract.Following the work of Chernomatz and Levin (2011), Kagel and Levin (2005), Maskin and Riley (2000), and Krishna and Rosenthal (1996) bidders are identified as global or local. Global bidders are firms that operate nationwide in contrast to local bidders who typically are identified as small and medium sized firms. The internal cleaning service and bus route procurements are the most fragmented with an overall share of global bidders from 14.29 percent (cleaning) and 13.64 percent (bus) to 33.33 percent (the same figure for both markets). The largest dominance of global bidders in terms of participation is found in the procurements of road pavement where they in two of the procurements represent 80 percent of the bidders.

Bidders submit on average between 2 and 29 packages (see Table 2). The maximum number of combinations can be found in one of the cleaning service procurements. A total of 56 combination bids were submitted on the 7 contracts included in the procurement.The lowest

[4] See Lunander and Lundberg (2012b) for an overview of discounts and price levels.

number of packages submitted is found in the procurement of nursing home care for the elderly. This is also the procurement where the number of auctioned contracts is the lowest. The relationship between the numbers of contracts auctioned in one and the same procurement and the number of package bids submitted is illustrated in Figure 1. There is an indication of a positive relationship between the total number of packages submitted and the number of contracts auctioned in one and the same procurement.

Figure 1. Scatter plot of number of contracts auctioned and total number of packages submitted by auction, N = 13.



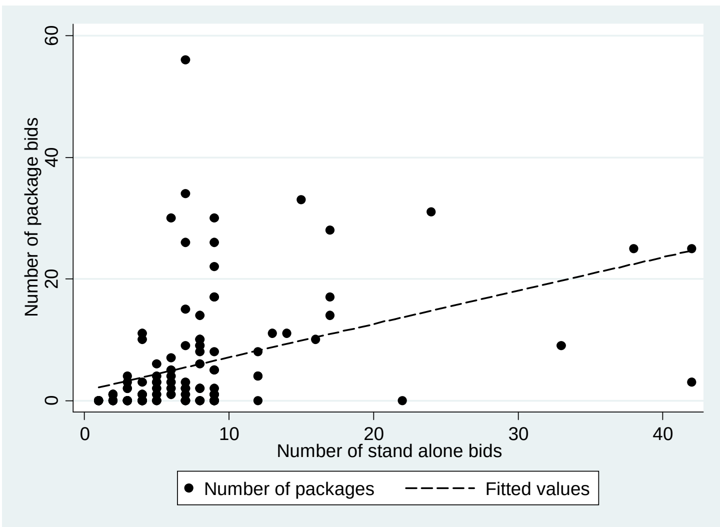
The distribution of the number of submitted package bids is displayed in Table 3 and evidently there is an overrepresentation of bidders submitting no package bids or only one package bid.Note that one bidder can submit several combinations in one and the same procurement. This explains why the product of the first column and the frequency column exceeds 123. Also, a bidder submitting no combinatorial bid in one of the procurements can submit one or several packages in other procurements. The proportion of zeros is almost 40 percent and adding the ones makes more than half of the sample. The distribution has a relative long right tail and 10 percent of the observations exceed 30 packages. This will have implications for the empirical analysis.

Table 3. Frequencies for the number of combinations.

No of Combinations	Freq.	Percent	Cum.	No of Combinations	Freq.	Percent	Cum.
0	49	39.84	39.84	14	2	1.63	86.99
1	15	12.20	52.03	15	1	0.81	87.80
2	9	7.32	59.35	17	3	2.44	90.24
3	7	5.69	65.04	22	1	0.81	91.06
4	5	4.07	69.11	25	2	1.63	92.68
5	3	2.44	71.54	26	2	1.63	94.31
6	2	1.63	73.17	28	1	0.81	95.12
7	1	0.81	73.98	30	2	1.63	96.75
8	3	2.44	76.42	31	1	0.81	97.56
9	4	3.25	79.67	33	1	0.81	98.37
10	4	3.25	82.93	34	1	0.81	99.19
11	3	2.44	85.37	56	1	0.81	100.00
				Total	123	100.00	

The average number of submitted stand-alone bids in relation the average number of submitted packages indicates a relative large variation among bidders in their composition of packages. As displayed in Figure 2 there is indication of a positive correlation between the number of package bids and stand-alone bids submitted.

Figure 2. Scatter plot of the number of package bids and stand-alone bids submitted (N = 123) by each bidder in the 13 procurements.



Package bidding seems to be a key to success since a clear majority of all contracts are allocated based on the package bids. The exception is one of the cleaning service procurements in which all contracts were allocated based on stand-alone bids. The average proportion of contracts won per bidder is according to the figures in Table 4 11 percent. The average proportion of contacts allocated based on stand-alone bids and combinatorial bids are 4 and 6 percent, respectively. The same figures but distributed on the 49 winners in the data translate to 27 percent of the contracts overall, 10 percent based on stand-alone bids and 16 percent based on combinatorial bids. According to the descriptive statistics global bidders are to a greater extent than local firms awarded contracts based on combinatorial bids while this relationship is the opposite for awards based on stand-alone bids.

Table 4. Descriptive statistics, proportion of contracts won by all bidders and by winning bidders, respectively.

Variable	Obs.	Mean	Std. Dev.	Min	Max
All bidders					
All bids	123	0.11	0.19	0.00	1
Stand-alone bids	123	0.04	0.10	0.00	0.67
Combinatorial bids	123	0.06	0.16	0.00	1
Winning bidders					
All bids	49	0.27	0.21	0.03	1
Stand-alone bids	49	0.10	0.13	0.00	0.67
Combinatorial bids	49	0.16	0.23	0.00	1
All bidders Global firms					
All bids	41	0.17	0.22	0	1
Stand-alone bids	41	0.04	0.06	0	0.18
Combinatorial bids	41	0.13	0.23	0	1
Winning bidders Global firms					
All bids	23	0.30	0.22	0.06	1
Stand-alone bids	23	0.07	0.07	0	0.18
Combinatorial bids	23	0.23	0.26	0	1
All bidders Local firms					
All bids	82	0.07	0.15	0	0.71
Stand-alone bids	82	0.04	0.11	0	0.67
Combinatorial bids	82	0.03	0.11	0	0.71
Winning bidders Local firms					
All bids	26	0.23	0.20	0.03	0.71

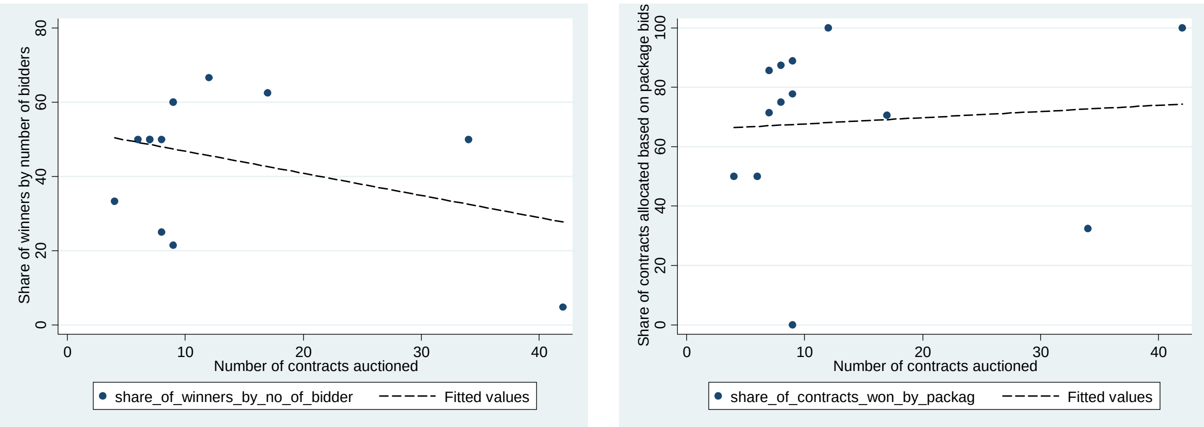
Stand-alone bids	26	0.13	0.17	0	0.67
Combinatorial bids	26	0.10	0.18	0	0.71

Based on Figure 3and the left graph the distribution of winners seems not to be correlated with the number of contracts auctioned. If something, the number of contracts and distribution of winners is negatively correlated. Further, based on the right graph in the same figure there is visually no clear relationship between the shares of contracts allocated based on package bids and the total number of contracts that were auctioned in one and the same procurement.

Figure 3. Allocation of contracts, *N*=13.

Share of winners by contracts and number of contracts auctioned

Share of contracts allocated based on package bids and number of contracts auctioned



4. Empirical analysis

The strongest incentive for a procurer to apply the traditional approach, that is to divide a procurement auction into separate contracts with parallel bidding on each contract, is that few suppliers – or sometimes none of them – would have the capacity to complete the assignment if aggregated into one larger contract. Dividing the large contract into smaller contracts is believed to increase the competition from small and medium-sized suppliers with limited capacity. This is advantageous for both the supplier and the procurer as long as the supplier's costs for undertaking one or more of the parts of the procurement are independent of how many contracts they are awarded: that is to say, if the supplier's unit price per contract is nearly constant up to a certain volume.

When simultaneously bidding on several contracts takes place, a supplier's cost for fulfilling a specific part of the tender can depend on the number and volume of the contracts awarded. In such a situation, a supplier choosing to bid on several contracts of the tender faces more complex strategies than in the cases where the costs of different contracts are independent of each other. It now becomes decisive how, and to what extent, the supplier has an opportunity in the bidding process to convey that the supplier's costs, and consequently the prices offered, depend on how much of the tender the supplier is awarded.

Here, the decision of potential bidders to enter an auction or not is assumed to be a function of the design of the auction in terms predatory pricing prevention, presence of capacity constraints and award restriction (*design*). It is also a function of the number of contracts auctioned in one and the same procurement (*contracts*), award principle (*emat*), the expected number of competing bidders (*competition*), and if the potential bidder is a global or local bidder (*type*) and some other procurement and contracts characteristics (*Q*). A potential bidder *i*:s decision to enter a procurement auction is a function

(1) $[Entry_{ai} = f(design]_a, contracts_a, period_a, extension_a, emat_a, type_i, Q_a)$

A potential bidder *i* will enter auction *a*if the expected profit from doing so is non-negative, that is:

(2) $Exp(\pi_{ai}) \geq \mathbf{0}$

or expressed in another way, if the expected profit from doing so (π_{1ai}) increases the profit from not doing so (π_{0ai}):

(3) $Exp(\pi_{1ai}) \geq Exp(\pi_{0ai})$ or

(4) $\Pr[\varepsilon_{1ai} - \varepsilon_{0ai}] < x'_{ai}(\beta_1 - \beta_0)$

Here, *x* is a vector of the variables that are assumed to effect the expected profit and thereby the entry decision as well as the decision which contracts to bid on and how many and which combination bids to submit.

More specifically, the expected profit is assumed to be a function of the number of stand-alone bids submitted (*standalone*), the number of combinations submitted (*comb*), the size of the combinations submitted (*size comb*), the cost for completing the contracts (*c*), and the degree of competition (*competition*).

(5) $Exp(\pi_{1}ai) = f(standalone_{1}ai, comb_{1}ai, size\ comb_{1}ai, c_{1}ai)[Prob\ i\ wins|competition$

The same variables as in expression (5) will also affect the likelihood of bidder*i* to be a winner in procurement auction *a*.

The aim of this paper is to explore empirically bidder behavior in terms of the determinants of the number of combinations submitted conditional on that the entry decision is made. Further, the analysis will also include the determinants of the probability of bidder *i* being a winner. The analysis will be performed in an elaborative manner without the ambition to solve the complex bidding strategy problem. In doing so bidders are assumed to first decide to enter the procurement or not. Secondly, bidders are assumed to identify the individual contracts they are interested in. After that, they are assumed to decide if they will settle with submitting stand-alone bids only or include all or some of the contracts in packages. Given that a bidder has decided to submit packages it has to decide the number of packages and the composition of each package.

Given that we observe bidders who have decided to enter at least one combinatorial auction we explore the determinants of the number of submitted packages, the effect of the behavior of bidder *i* in procurement *a* on the probability that bidder *i* is an overall winner in procurement *a*, winner with at least one package bid, or winner with at least one stand-alone bid. Further, the share of contracts won by bidder *i*in procurement is estimated using variables the describe bidder behavior and procurement characteristics.

Here, the number of combination bids submitted by bidder *i* in procurement auction *a*, y_{ai}, is a count dependent variable that is: $y_{ai} \in Y_0 = \{0,1,2,,...\}$. Since over-dispersion is quite common when the outcome is a count the negative binomial model will be used, although results from Poisson and ordinary least square regression also will be presented. The density function for the negative binomial regression model is

(6) $f(y_{ai}) = \frac{\Gamma(y_{ai} + \varphi_{ai})}{\Gamma(\varphi_{ai})\Gamma(y_{ai} + 1)} \left(\frac{\varphi_{ai}}{\lambda_{ai} + \varphi_{ai}}\right)^{\varphi_{ai}} \left(\frac{\lambda_{ai}}{\lambda_{ai} + \varphi_{ai}}\right)^{y_{ai}}$ and

(7) $\lambda_{ai} = \exp(x_{ai}' \beta$) and

(8) $\varphi_{ai} = \left(\frac{1}{\alpha}\right)\lambda_{ai}^{k}$ where

Γ is the Gamma distribution, $\alpha > 0$ is an over-dispersion parameter and *k* is an arbitrary constant. The mean is $E[y_{ai}|x_{ai}] = \lambda_{ai}$ and the variance is $Var(y_{ai}|x_{ai}) = \lambda_{ai} + \alpha\lambda_{ai}^{(2-k)}$. Here *k* will be set to zero. If $\alpha=0$ the model is the Poisson model. Two different specifications of *x* will be used:

$$x_{ai} = x1_{ai} = (Comp, stand - alone, contracts, design, emat, type, global)$$

$$x_{ai} = x2_{ai} = (Comp, stand - alone, contracts, design, emat, type, global, I1, I2)$$

That is, the probability of an event (the number of combination bids submitted) is estimated using the degree of competition, the number of stand-alone bids submitted in procurement *a*, the number of contracts auctioned in procurement *a*, the design as described by two variables; a dummy variable if a predatory pricing prevention rule is used (yes = 1) and a dummy variable that takes the value one if there is some rule that allows bidders to express capacity constraints and a dummy variable that takes the value one if bids are evaluated according to some scoring rule under the EMAT principle. In addition to this a dummy variables for the type of service procured (nursing home care for the elderly care is the reference category) and a dummy variable that takes the value on if the bidder is a global bidder is included. The second specification follows the first but with two additional variables. Here, a potential firm type effect of the design of the auction is explored with two interaction variables, *I1* is an interaction variable between global and the predatory pricing dummy variable and *I2* is an interaction variable between global and the capacity constraint dummy variable.

Based on the distribution of number of combinatorial bids submitted illustrated in Table 3 we should expect over-dispersion in the dependent variable.Following Cameron and Trivedi (1990; 1998) we test for over-dispersion by an auxiliary regression of the generated dependent variable $\frac{\{(Comb - \hat{\mu})^2 - comb\}}{\hat{\mu}}$ on $\hat{\mu}$ excluding the constant and then perform a *t*-test of $\hat{\mu} = 0$.

The probability that a bidder *i*is a winner in procurement auction *a* is estimated according to:

$$\text{(9)} \quad \Pr[i\ wins|x3_{ai}] = \Lambda(\beta' x3_{ai}) = \frac{\exp(\beta' x3_{ai})}{1 + \exp(\beta' x3_{ai})}$$

andΛ is the cumulative distribution function. Here, *x3* includes variables for the degree of competition, the number of contracts auctioned, number of stand-alone and combinatorial bids, respectively, submitted in auction *a* by bidder *i*, and type of firm (global firm or not). With a correlation coefficient of 0.41 the inclusion of the number of combinatorial and stand-alone submitted by the same bidder in the same procurement is unproblematic. Procurement characteristics are also included as controls. These are evaluation method (*emat*) and type of service procured (elderly care is the reference category). Expression (9) is estimated using three different specifications of the event variable. First the probability that bidder *i* is a winner in a procurement auction *a*, is estimated without the type of bid (stand-alone of package bid) considered. Second, the probability that bidder *i* is a winner in procurement *a*, with at least one package bid is estimated and finally the probability that *i* wins in *a* with at least one stand-alone bid is estimated.

With the ambition to better describe the path to success without consideration of the ranking or the relative monetary size of the bid (stand-alone or package) the probability of the share of contracts won, overall, by combinatorial bids and by stand-alone bids is also estimated.

The determinants of share of contracts won is treated as proportions data and the dependent variable is the proportion of contracts won, overall, with package bids, or stand-alone bids respectively. The hypothesis to be tested is then that the share of contracts won by bidder *i* in procurement auction *a* is positively affected by the number of package and stand-alone bids submitted.The relationship between bidder behavior and the share of contracts won is explored with the minimum chi squared estimator (MCSE) which is generated with weighted least square. The inverse of the logistic function is

(10) $$\frac{\log p_{ai}}{1-p_{ai}} = \alpha + x4'_{ai}\beta_i + \omega'_{ai}\gamma_{ai} + \varepsilon_{ai}$$ where

(11) $$E[\varepsilon_{ai}] = 0 \text{ and} VAR[\varepsilon_{ai}] = \frac{1}{contracts_{ai}p_{ai}(1-p_{ai})}$$

where p_{ai} is the number of contracts won by bidder $i$in auction $a$in relation to the total number of contracts auctioned in auction$a$ and $p_{ai} \in [0,1]$and$x4$ is a vector that includes the number of combination bids and stand-alone bids submitted and a dummy variable for global bidders. The estimation of equation (10) is performed in two steps. The first step generates predicted probabilities equal to

(12) $$\widehat{p}_{ai} = \frac{\exp\left(\widehat{\alpha} + x4'_{ai}\widehat{\beta}_i + \omega'^{j}_{ai}\widehat{\gamma}_{ai}\right)}{1+\exp\left(\widehat{\alpha} + x4'_{ai}\widehat{\beta}_i + \omega'^{j}_{ai}\widehat{\gamma}_{ai}\right)}$$ where

(13) $$\omega_{\downarrow}ai^{\uparrow}j = \Pr[Y_{\downarrow}ai^{\uparrow}j = j | x_{\downarrow}ai \dashv]$$

is the estimated probability that bidder i wins a contract in auction a. Expression (13) is in turn are used to generate the analytic weights (the estimated variances)

(14) $$\omega^{j}_{ai} = \frac{1}{contracts_{ai}\widehat{\Lambda}_{ai}\left(1-\widehat{\Lambda}_{ai}\right)}.$$

Here the logit model is applied and $\Lambda(\cdot)$ is the logistic cumulative distribution function.[5] The second step proceeds with estimation of equation (13) based on the analytic weights generated

[5] The probit model can also be applied and the estimated variance is then $w_i = (\hat{\Phi}_i(1-\hat{\Phi}_i))/n_i\hat{\phi}_i$ where Φ is the standard normal cumulative distribution function.

in the first step by equation (14). The use of analytic weights is due to that the weights are dependent on unknown parameters. See Greene (2003).

5. Results

Negative binomial estimation results from the regression on the number of combinatorial bids submitted using the two specifications presented above are presented in Table 5. For comparison results from ordinary least square regression is also included as well as the outcome from the Poisson regression although it according to the test is clear evidence of over-dispersion which suggests that the results from the negative binominal to be trusted. The standard errors are adjusted for 78 clusters in firm.

Primarily the results of negative binomial regression will be commented upon, starting with the specification in which the interaction variables are not included (two first columns under each estimation approach).

According to the findings the number of packages submitted is negatively affected by the number of bidders on the procurement level. Based on the positive and on the 7 percent level significant coefficient for global firms a cautious interpretation is that the number of combinations submitted is positively affected by the number of global firms participating and that a higher number of bidders is mainly explained by the entrance of small and medium sized firms.

The design of the combinatorial auction seems to have no impact on the number of combinatorial bids submitted since none of the coefficients for capacity constraints or predatory bidding is significant. The award method matters for the number of combinations submitted.

The probability of a higher number of combination bids submitted is lower when the bids are evaluated according to some scoring rule under the principle of EMAT. It could be that understanding the scoring rule is complex enough (meaning higher transaction costs) which limits the bidder's willingness to bid package bids in terms of number of combinatorial bids submitted when this principle is applied.

As one can expect the number of contracts (or objects) auctioned in one and the same procurement has a positive and significant effect on the number combinatorial bids submitted. Further, a higher number of combinatorial bids submitted are expected when the number of stand-alone bids is high.

All things equal, the coefficients for the type of service procured suggest the probability of a higher number of combination bids to be more likely in procurements of road pavement compared to nursing home care for the elderly.

The findings are in general stable for the type of regression method and specification used. There is one important exception and that is the coefficient for the type of firm. Thecoefficient for *Global* is positive and significant but only in the negative binomial regression without the interaction terms. The effect is lost when the interaction between capacity constraints and type of firm and predatory pricing prevention and type of firm are included in the model. There is however no firm type specific effect of the design of the auction. None of these coefficients are significant.

The results from the logit regressions are presented in Table 6. The first three columns represents the results when the probability that bidder *i* is a winner in procurement auction *a*is estimated. The three following columns represents the findings when the probability of winning with one or several combination bids is estimated and finally the three last columns to the right represent the estimation of the probability of winning with at least one stand-alone bid. Note that the standard errors are adjusted for the 13 clusters in procurement auction.

Somewhat surprisingly the only significant effect from competition is found in the estimation of the probability of winning with a stand-alone bid and the direction of the effect is also somewhat surprising, the more bidders the higher the probability of winning with a stand-alone bid. One additional bidder leads to relative odds of winning that are 1.23 times what they were before the increase in competition degree. Also, the marginal effect of increased competition corresponds to a 0.03 higher probability of winning with a stand-alone bid.

Table 5. Results.The dependent variable is the number of combinations. Standard errors are adjusted for 78 clusters in firm.

	OLS				Poisson				Negative binomial			
Variable	Coef.	t	Coef.	t	Coef.	z	Coef.	Z	Coef.	z	Coef.	z
Competition	-1.50	-3.18	-1.46	-3.52	-0.21	-4.35	-0.20	-4.24	-0.21	-3.76	-0.21	-4.13
Contracts	0.78	3.35	0.77	3.57	0.10	3.25	0.10	3.22	0.08	2.33	0.08	2.54
Capacityconstraints	14.73	2.89	15.31	3.00	2.44	3.49	2.73	3.57	0.82	0.88	0.74	0.93
Predatory pricing prevention	0.13	0.05	2.83	0.59	-0.11	-0.50	0.35	0.76	-0.06	-0.17	0.01	0.03
Emat (yes=1)	-6.13	-2.20	-5.40	-2.25	-0.62	-2.55	-0.52	-2.05	-0.89	-2.43	-0.89	-2.58
No ofsinglebids	0.50	3.04	0.42	2.25	0.08	4.66	0.07	2.60	0.11	3.13	0.11	3.09
Eldelrycare							Reference					
Bus	-11.99	-2.26	-9.33	-1.78	-0.14	-0.13	-0.01	-0.01	1.68	1.34	1.66	1.55
Cleaning service	-0.09	-0.02	1.91	0.34	1.39	1.49	1.37	1.38	2.97	2.91	2.94	2.89
Road pavement	8.38	2.79	7.90	2.78	3.12	4.55	3.08	4.52	3.35	5.34	3.36	5.05
Global (yes=1)	1.16	0.52	6.60	1.13	0.19	0.63	0.95	1.38	0.57	2.12	0.24	0.43
Global * Capacityconstraint	-	-	-6.53	-1.13	-	-	-0.66	-1.45	-	-	0.24	0.43
Global * Predatory pricing	-	-	-4.41	-0.77	-	-	-0.62	-1.14	-	-	-0.12	-0.28
Constant	3.64	1.26	0.58	0.16	-0.79	-1.22	-1.37	-1.84	-1.06	-1.47	-1.03	-1.59
Lnalpha									0.34		0.33	
Alpha									1.40		1.40	
Numberof obs		123		123		123		123		123		123
F(10,77), F(12,77) or Wald Chi2(10), (12)		12.50		18.63		210.44		223.63		137.87		192.42
Prob> F		0.00		0.00		0.00		0.00		0.00		0.00
R-squared		0.43		0.44		0.43		0.44				
Log pseudolikelihood						-483.87		-476.39		-278.92		-278.77
t-test over-dispersion						4.40		3.58				

According to our findings the probability of being a winner overall or a winner with a stand-alone bid is negatively affected by the number of contracts auctioned in one and the same procurement. This has however no effect on the probability of being a winner with a package bid. Looking at the odds ratio, a one-unit increase in the number of contracts leads to the relative odds of winning or winning with at least one stand-alone bid that are 0.92 and 0.89 times what they were before the increase, respectively. A one unit increase in the number of contracts auctioned in the same procurement leads to a 0.02 decrease in the probability of winning.

The number of combination bids submitted by a bidder has according to our findings no significant effect on the probability of being a winner or a winner with a stand-alone bid. There is on the 6 percent level a positive and significant effect on the probability of being a winner with a combination bid from the number of combination bids submitted.

Compared to the reference category for type of service, nursing home care for the elderly it is all things equal, a little bit more difficult to win in procurements of cleaning services but easier in procurements of bus routes or road pavement. All three coefficients for the type of service indicate tougher winning opportunities with a combination bid for all type of services compared to the reference category. The odds ratios indicate greater changes in odds for winning overall than winning with a package bid. The pattern for the probability of winning with a stand-alone bid is the same as the pattern for the overall winning probability.

If we allow ourselves to play with the idea that a firm in the bus industry could instead make a bid in a tender for nursing home care for the elderly increases the probability of winning by 0.36 while the probability of winning at least one stand-alone bid increases with 0.23.The same conjecture applied to the asphalt companies show a similar pattern. A shift of business from internal cleaning services to nursing home care for the elderly would lead to a 0.31 decrease in the probability of winning with at least one combinatorial bid.

Table 6. Results, logistic regression. Estimated coefficients, odds ratio and marginal effect. Marginal effects are evaluated at the mean. Standard errors are adjusted for 13 clusters in procurement auction.

Dependent	Winner			Winner by combination			Winner by stand-alone bid		
Variable	Coef.	*z*	Odds ratio	Coef.	*z*	Odds ratio	Coef.	*z*	Odds ratio
Competition	0.07	1.05	1.07	-0.11	-1.36	0.89	0.21	2.39	1.23
Contracts	-0.07	-1.84	0.92	-0.02	-0.33	0.98	-0.11	-2.34	0.89
Emat (yes=1)	-0.26	-0.58	0.77	-0.02	-0.02	0.98	-0.55	-1.28	0.58
No of stand-alone bids	0.06	1.65	1.06	0.09	1.19	1.10	0.06	1.41	1.07
No of combinations	0.06	1.64	1.06	0.09	1.90	1.09	-0.01	-0.50	0.99
Elderly					Reference				
Bus	1.60	3.36	4.97	-3.15	-1.93	0.04	1.52	4.77	4.57
Cleaning service	-0.78	-1.24	0.46	-5.50	-2.72	0.00	-0.39	-0.46	0.68
Road pavement	1.09	1.65	2.99	-3.40	-1.74	0.03	1.75	3.53	5.76
Global	0.07	0.13	1.08	-0.17	-0.28	0.85	0.33	0.44	1.39
Constant	-1.42	-4.01	0.24	2.51	1.95	12.25	-3.03	-6.29	0.05
Correctly classified (%)			70.73			86.99			78.05
Number of obs			123			123			123
Wald chi2(9)			189.73			214.86			870.03
Prob> chi2			0.00			0.00			0.00
Pseudo R2			0.21			0.39			0.13
Log Pseudolikelihood			-65.70			-42.38			-59.15
Marginal effects									
Competition	0.02	1.09		-0.01	-1.13		0.03	3.24	
Contracts	-0.02	-1.97		-0.00	-0.35		-0.02	-3.16	
Emat (yes=1)	-0.06	-0.58		-0.00	-0.02		-0.08	-1.22	
No of stand-alone bids	0.01	1.67		0.01	1.70		0.01	1.40	
No of combinations	0.01	1.67		0.01	1.56		-0.00	-0.49	
Elderly					Reference				
Bus	0.36	3.36		-0.31	-1.44		0.23	4.13	
Cleaning service	-0.18	-1.27		-0.54	-1.90		-0.06	-0.48	
Road pavement	0.25	1.65		-0.34	-1.32		0.26	2.83	
Global	0.02	0.13		-0.02	-0.30		0.05	0.44	

There is no significant difference found between global and local firms in their opportunities to win at least one contract overall, win with at least one combinatorial bid or at least one stand-alone bid.

Although the method for bid evaluation, lowest price or EMAT had an impact on the bidder behavior in terms of the number of combination bids submitted it has no significant effect on the overall probability of winning, winning with a package or a stand-alone bid. This is expected, the award method should not, all things equal, have an effect on the winning odds, but as it is a characteristic of the procurement it is included in the model.

The pseudo R^2 values, probability values and percentage of correctly classified events suggest the models to be fairly accurate with the highest explanatory power and percentage of correct classifications for the model where the probability of winning with a combination bid is estimated.

The results from the regression of the determinants of the share of contracts won, won by combinatorial bids and stand-alone bids, respectively, are presented in Table 7. The degree of competition has a negative and significant effect on the share of contracts won overall and share of contracts won by stand-alone bids but no significant effect is found with respect to combinatorial bids. Overall the marginal effect (-0.19) is significant. On a ten percent level the share of contracts won and won with combinatorial bids are positively affected by the number of combinatorial bids submitted. The marginal effects are also significant. The number of combinatorial bids submitted has no bearing on the proportion of contracts won by stand-alone bids.

The probability of winning with at least one package is negatively related to the number of stand-alone bids submitted. The marginal effect on the probability of increased share of contracts won by combinatorial bids of submitting one additional stand-alone bid is 0.25.

Table 7. Results, Weighted least square regression. Estimated coefficients, odds ratio and marginal effect.Marginal effects are evaluated at the mean.

Dependent	Share of contracts won			Share won by combination			Share won by stand-alone		
Variable	Coef.	*t*	Odds ratio	Coef.	*t*	Odds ratio	Coef.	*t*	Odds ratio
Competition	-0.08	-3.84	0.92	0	-0.12	1.00	-0.08	-3.04	0.9
No of stand-alone bids	0.01	0.33	1.01	-0.12	-2.65	0.89	0.01	0.42	1.01
No of combinations	0.02	1.94	1.02	0.02	1.81	1.02	0.02	1.13	1.03
Global	0.08	0.28	1.09	0.45	1.43	1.58	-0.33	-0.82	0.72
Constant	-0.90	-2.67	0.41	-0.46	-1.16	0.63	-1.12	-2.82	0.32
Number of obs			48			30			38
F(4,43);(4,25);(4,33)			7.66			3.39			3.12
Prob F>0			0.00			0.02			0.03
R2 adj			0.36			0.25			0.19
Marginal effects									
Competition	-0.19	-3.65		-0.01	-0.12		-0.14	-0.56	
No of stand-alone bids	0.02	0.34		0.25	-2.55		0.02	0.41	
No of combinations	0.06	1.92		0.05	1.81		0.05	1.13	
Global	0.19	0.28		0.95	1.43		-0.60	-0.83	

There is no significant difference between global and local bidders with respect to the probability of winning a greater proportion of the contracts, overall, by package bids or stand-alone bids.

The adjusted R^2 values and probability values suggest the models to be reasonably well specified.

6. Summary and Conclusions

In this paper bidder behavior in terms of determinants of the number of combinatorial bids submitted is empirically explored. The analysis is based on data on 13 multi-object public procurement auctions of four different services organized by Swedish procuring authorities. The analysis is elaborative without the ambition to solve the complex bidding strategy problem but with the aim of contributing to the understanding of the same. In the auctions studied bidders had the opportunity to alongside stand-alone bids submit combinatorial bids. Any bid in a package had to be followed by a stand-alone bid. Simultaneous bidding was applied. The auctions vary in their design with respect to rules governing e.g. restrictions on the number of objects that was allowed in a package and opportunity to express capacity constraints. Based on the data the questions analyzed are to what extent potential supplier use the option to submit combinatorial bids and if the allocation of contracts can be explained with the composition of stand-alone and combinatorial bids. Besides the design of the different auctions the type of bidder, global or local was also controlled for.

According to our findings the degree of competition has a negative impact on the number of combinatorial bids submitted. This is most likely explained by the fact that an increase in competition degree dominated by additional local firms entering the auctions. Local firms are, namely, found to a lesser degree than global firms submit combinatorial bids. More combinatorial bids are more likely in auctions with a greater number of contracts auctioned. Bidders that submit many stand-alone bids are more likely to also submit many combinatorial bids. This is a result that might seem trivial, but bidders were free to compose the packages and the same set of objects can constitute a large number of different packages where the bidder vary those in the package included object specific prices. The design of the auction in terms of option to express capacity constraints and predatory pricing prevention has no significant effect on the number of packages submitted.

The findings also give at hand that the probability of becoming a winner overall or a winner with at least one stand-alone bid is negatively related to the number of contracts included in the auction. The probability of being a winner with at least one package bid is higher the greater number of packages submitted. The share of contracts won overall or by stand-alone bids by a bidder is also negatively related to the degree of competition. A higher number of combinatorial bids submitted the more likely is the bidder to win a larger share of the contracts overall and by combination bids. There is also evidence of that a higher number of stand-alone bid submitted is associated with a lower proportion of contracts allocated based on combinatorial bids.

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