JEL: D44, H57

Do Combinatorial Procurement Auctions Lower Cost?

- An Empirical Analysis of Public Procurement of Multiple Contracts

Anders Lunander
Sofia Lundberg*

April 2011

Abstract

Combinatorial procurement auctions enable suppliers to pass their potential cost synergies on to the procuring entity and may therefore lead to lower costs and enhance efficiency. However, bidders might find it profitable to inflate their stand-alone bids in order to favour their package bids. Using data from standard and combinatorial procurement auctions, we find that bids on individual contracts in simultaneous standard auctions without the option to submit package bids are significantly lower than the corresponding stand-alone bids in combinatorial auctions. Further, no significant difference in procurer's cost as explained by auction format is found.

*Anders Lunander, Swedish Business School, Örebro University, SE-701 82 Örebro, Sweden, e-mail: anders.lunander@oru.se
Sofia Lundberg, Department of Economics, Umeå University, SE-901 87 Umeå, Sweden, e-mail: sofia.lundberg@econ.umu.se
The authors would like to thank Mats Bergman and Per-Olov Marklund, participants of seminars at the Departments of Economics at Umeå and Uppsala Universities, and participants at the IPPC 2008 (Amsterdam), and EARIE 2009 (Slovenia) conferences for valuable comments. We also wish to thank Trade Extensions for providing us the combinatorial bid data. Financial support from the Swedish Competition Authority is gratefully acknowledged.

1. Introduction

Auctions in which bidders are allowed to submit bids on combinations (or packages) of contracts 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). Combinatorial procurement auctions are increasingly being employed in both the private and public sector as an alternative to simultaneous auctions of individual contracts. The mechanism 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.

However, combinatorial auctions are very complex. Beside the inherent potential computational problem in determining the winner in a combinatorial auction (Nisan, 2006), the auction mechanism is also strategically very complicated. When first–price combinatorial procurement auctions are practiced, bidders generally place both stand-alone bids on single contracts and bids on various packages of contracts. This implies that a bidder's stand-alone bids also will be competing with his combination bids. Hence, bidders might find it profitable to inflate their stand-alone bids, or refrain from submitting any, in order to increase the probability of winning with their combination bids. Therefore, an observed difference between the sum of a bidder's stand-alone bids on a particular set of contracts and his combination bid for the same set of contracts does not necessarily reflect the size of the underlying cost synergy.

In this paper we empirically study bidding behaviour in first-price public procurement auctions of single and multiple contracts, where bidders in some of the multi contract auctions also have had the option to submit bids on combinations of contracts. In the combinatorial auctions studied, suppliers were free to bid for any combination of contracts but there had to be a

submitted stand-alone bid for every contract being part of any combination.[1] The same set of bidders is found in standard auctions where contracts are auctioned as single items only. As such we can compare the behaviour of the bidders for two different auction rules: package bidding allowed and not allowed, and evaluate the extent to which the package bid discount really reflects a cost reduction for the procuring entity. The procurement auctions studied consist of internal regular cleaning contracts. We argue that cost synergies across contracts are the motivation for the observed combination bids.

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 experiment studies (see Chernomaz and Levin, 2011 for a list of some previous experiments). However, relatively few studies have provided equilibrium bidding strategies in environments of heterogeneous multiple items. Krishna and Rosenthal (1996) show that a simultaneous auction outperforms a corresponding combinatorial auction when synergies are present in a sealed-bid second-price auction, with two objects and a single global bidder. The reason for this is that the global bidder engages in "overbidding", i.e. bids above his/her value, facing the possibility of a loss *ex post*. 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. Chernomaz and Levin (2011) analyze a simple bidding environment in a first-price sealed bid model where a single item is auctioned off in each of two markets. In every market there is a bidder with unit demand (local bidder) who bids against s single bidder demanding one unit in each market (global bidder). They show that the first-price

[1] One reason for restricting bidders to place stand-alone bids on those contracts included in one or several combination bids, is to avoid a dead-lock problem, i.e., overlapping winning bids, when determining the winner(s).

combinatorial auction, regardless of the level of synergies, generates lower revenues to the seller than does the separate auction. The reason is a pervasive threshold problem. Local bidders have to coordinate their single bids in order to outbid the combination bid from the global bidder (the threshold value), which gives rise to a free riding problem. Therefore, the local bidders are expected to bid less aggressively in a combinatorial auction than they do in two separate auctions. Their experimental results indicate that the theory qualitatively is in line 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.

It should be pointed out, that even in the absence of any cost synergies, there are still incentives for at bidder to submit a combination bid which is lower than the sum of the stand-alone bids for corresponding contracts. Referring to the literature on multi-product monopoly pricing (e.g. McAffe et al. (1989)), Cantillon and Pesendorfer (2007), show that a combination bid in a first-price auction can be profitable for the same reason why the multi-product monopolist finds price discrimination profitable. In their model with one unit auctioned out in two markets, Chernomaz and Levin (2011) derive a unique equilibrium where the global bidder submits only a combination bid for the two items, even though stand-alone bids are allowed. However, this result likely hinges on the fact that the values of the global bidder in their model are perfectly positive correlated across the two markets. Under the assumption that combination bids is motivated by strategic pricing rather than by the presence of (strong) synergies Chernomaz and Levin (2011) show that the expected efficiency is higher if the items are auctioned off in two separate auctions. As the synergies reaches a significant level, an auction allowing for combination bids will eventually outperform the separate auctions in terms of efficiency.

Given the presence of cost synergies in a multi contract auction environment there seems to be few reasons -- if any -- to believe that the stand-alone bids in a first-price combinatorial procurement auction on a set of individual contracts are identical to the bids submitted on the same set of contracts in a first-price auction without the option to bid on packages. Due to aggressive bidding on individual contracts in the simultaneous format and to inflated stand-alone bids in the combinatorial format, the bids on single items are likely to be higher in the combinatorial format than in the non-combinatorial format. Therefore, the observed package discounts are likely to overstate the real cost savings – if any – of allowing for combinatorial bids in a multi contract environment. Here, we empirically explore this idea by comparing observed bidding behaviour in procurement auctions – single contract auctions as well as simultaneous auctions (standard auctions henceforth) – with that in combinatorial procurement auctions (combinatorial auctions henceforth). However, we also compare bidding behaviour in standard multi item auctions and standard single item auctions to refine the effect of multiple contracts upon the bid level. Three hypotheses are tested. The first is that the bid level decreases with increases in the number of contracts due to the more aggressive bidding in a multiple contract environment than in a single contract environment, *c.p*. Hence, we assess the extent to which the bid level in standard auctions is affected by the number of contracts auctioned. The second hypothesis is that the stand-alone bids in combinatorial auctions do not reflect the contra factual case, i.e. that stand alone bids are significantly higher. To test this, we assess whether stand-alone bids in combinatorial auctions are identical to bids submitted in standard auctions. Thirdly, we evaluate differences in procurement cost across auction formats. Making use of the winning bids in both combinatorial and standard auctions, we test the null hypothesis that both auction formats generate identical procurement costs.

Our empirical study is based on a dataset consisting of single bids in standard auctions (single- and multiple-contracts) and stand-alone bids and package bids in combinatorial auctions. The bids originate from public procurement of an identical service, internal regular cleaning service contracts, with an identical set of bidding firms in both the standard and combinatorial auctions. Hence, the data include information about bids submitted in both combinatorial and standard auctions, allowing us to assess the true cost savings putatively realised by applying package bidding. To our knowledge, this study is the first to compare observed bidding behaviour in procurement auctions both with and without the option to submit package bids, contingent upon firm identity.

The main findings are that, when controlling for firm identity and other characteristics: (*i*) the bid level in standard auctions decreases with increases in the number of contracts auctioned; (*ii*) the stand-alone bids in the combinatorial auctions are significantly higher than the bids in standard auctions. Regarding differences in procurement cost, we do not find any significant difference in winning bids that can be attributed to differences in the format of auctions of multiple contracts.

The paper is organized as follows. In Section 2, we very briefly describe different types of combinatorial public procurement auctions that we are aware of having been applied in Sweden in recent years. Section 2 also includes a description of the design of three specific combinatorial auctions and the standard auctions from which our data originate. The full dataset, empirical analysis and results are presented in Section 3. Section 4 concludes the paper. Additional figures and tables are presented in the Appendix.

2. Combinatorial Public Procurement Auctions in Sweden

Since the enforcement of EU procurement directives in Sweden in 1994, public procurement auctions have been held on a regular basis and, as in most OECD countries, the contracts awarded in them account for a substantial part of the national economy (ca. 15 percent of the gross national product.[2] Public procurement auctions in Sweden are regulated by legislation (following the EU directives)[3] stipulating that bids must be sealed, and the contract(s) awarded either to the bidder who submits the lowest bid, or (when criteria other than price are also important), the bidder who is considered to have submitted the most economically advantageous bid (or tender).[4] Irrespective of the award criteria, the winning bidder is paid in accordance with his/her bid.

The procurement auctions may be either single-contract auctions or involve multiple contracts. In the latter case the auctions are simultaneous and traditionally separate bids are placed on the different contracts auctioned in one and the same tender. The opportunity to submit bids on public contracts is announced by a "call for tenders" and the announcement is accompanied by detailed descriptions of the services to be performed and the conditions to be stipulated in the contracts.

In Sweden, combinatorial auctions have been used relatively scarcely in public procurement auctions of multiple contracts, but there is a growing interest in the mechanism. Examples are found in the procurement of bus routes, road resurfacing, elderly care and internal regular cleaning services. The generally applied mechanism has been a first-price procurement auction with an option to bid on packages of contracts. In most of these auctions the contracts

[2] See the Swedish Competition Authority (www.kkv.se)
[3] Directives 2004/17/EC and 2004/18/EC
[4] Note that awarding contracts according to the principle of the lowest bid does not exclude the option to consider quality dimensions. Mandatory quality criteria can be stipulated in combination with the lowest bid principle.

have been more or less substitutes. The design of the combinatorial auctions has varied in terms of the restrictions imposed on bidding. In general, to avoid dead-lock problems, bidders have been obliged to submit a stand-alone bid for every contract that make up a package bid.

2.1 Auctions of Cleaning Services

The empirical analysis in this paper is based on data from sealed bid public procurement auctions of internal regular cleaning services in Sweden. The auctions had the character of first-price sealed bid auctions and were organized either as single-contract or multi-contract auctions. The combinatorial auctions were first-price sealed bid auctions held in 2005, 2006 and 2007. The standard auction data originate from auctions held in the periods 1992 to 1998 and 2006 to 2007. We have identified the same set of bidding firms in all sub-samples considered here. This enables us to compare the bidding behaviour of the same firms, submitting all types of bids, across auction mechanisms, and thus robustly compare bidding behaviour in auctions with different designs (combinatorial versus non-combinatorial), including one or several contracts (single contract versus multi-contract auctions). Before describing the full dataset, the design of the three combinatorial auctions is briefly reviewed.

2.1.1 Combinatorial Auctions

One of the combinatorial procurement auctions were held in 2005 and another in 2006 (designated auctions A and B, respectively). In both of these cases the procuring entity was a local government. Auctions A and B were for nine and seven separate contracts, with total areas to be cleaned of 105,000 m^2 and 400,000 m^2, respectively. The premises to be cleaned were either public offices or public schools. In both auctions bidders were free to submit bids on any bundle of contracts, and bidders had to submit a stand-alone bid for every contract included in a

package bid. In auction A, a bidding firm could, in addition to the various bids, declare the maximum area in terms of m^2 it could accept being contracted for if it was awarded too many contracts. In auction B, a firm could express its capacity constraint by stating the maximum contract sum it could be awarded. In auction A, 14 firms participated. Almost every firm placed a stand-alone bid on each of the nine contracts. Six firms submitted package bids of various sizes, from a two-contract bundle up to a nine-contract bundle. The total number of package bids was 54, of which 35 were submitted by a single firm. The discounts in the package bids ranged from 2 to 9 percent. No firm declared a constraint on the maximum number of square metres it could clean. All the winning bids were stand-alone bids. In auction B there were six bidders, and the maximum number of contracts allowed in a package bid was three. All the bidding firms, except one, placed stand-alone bids on each of the seven contracts, and four of the six participating firms submitted 104 package bids in total. The discount in these package bids ranged from 2 to 6 percent. Again, no bidder placed a bid declaring a constrained capacity. Two firms were each allocated three contracts and one firm was awarded one contract. As shown in figures A1 and A2 in the Appendix, for both types of bids the offered price declined with increases in the number of square metres to be cleaned.

The third combinatorial procurement auction examined (designated auction C) was organised by the Swedish Social Insurance Agency, a national agency with local representation throughout the country, in 2007. Forty-two separate contracts to provide regular cleaning services in all of the agency's local offices in Sweden were offered for sale. Each contract was to clean one or more offices in the same geographical area, and the total area to be cleaned was about 445,000 m^2. Unlike combinatorial auctions A and B, both of which were local government auctions, combinatorial auction C was a nationwide auction. The number of bidders in this auction was 22. Three firms submitted only stand-alone bids on each of the 42 contracts. Eight

firms submitted a total of 69 package bids. Two of these firms also submitted, among several other package bids, a package bid on all 42 contracts. One of the nationwide firms was awarded all 42 contracts through one package bid. Again, the stand-alone bids and package bids declined with increases in contract size, suggesting the presence of synergies. Hence, as shown in figure A3 in the Appendix, the offered price per square metre decreased with increases in volume for both the stand-alone and package bids. Stand-alone bids and winning bids from auctions A, B and C are included in the data in order to analyse the presence of bid inflation and cost differences attributable to differences in auction format.

As indicated by the scatter-plots in figures A1-A6, (and later in this paper also statistically tested), the bidders' offered price is decreasing in the number of square metres to be cleaned. Hence, there are reasons to believe that the package bids are motivated by significant cost synergies.[5]

3. Empirical Analysis

3.1 The Data and the Standard Auctions

As outlined above, the bids used to compare the stand-alone and winning bids from the combinatorial auctions originate from single and multi-contract public procurement auctions of cleaning services, organized by local governments and government authorities. We refer to these bids as single bids. The data were acquired from two surveys. The first covers the time period 1992 to 1998 and includes 362 contracts. The second covers 2006 and 2007 and includes 30

[5] In personal contacts with some of the bidding firms, we have been told that there are cost advantages of winning larger contracts. A larger contracts means more personnel but at a diminishing ratio. Also, the branch suffers from relatively high frequency of sick leaves. The nature of the work makes people get back and shoulder pain. Because the cleaning contracts are very close substitutes, firms with more employees can easier replace those who are on sick leave than firms with fewer employees can do. At least for larger firms, the flexibility to move personnel from one contract to another contract is increasing in the number of contracts.

contracts. We also use solely the winning bids in this dataset to compare the difference in procurement costs across the auction formats.

The bid level dataset consists of bids from cleaning firms that participated in auctions with both formats, i.e. they submitted single bids in standard auctions and at least one package bid in a combinatorial auction. Bids from firms that only participated in one type of auction are excluded from this analysis. In total, 13 firms satisfied the criteria for including their bids. In all, the dataset includes 1,185 bids submitted on 450 sealed-bid internal regular cleaning service contracts auctioned in 96 procurement auctions. The winning bid data comprise winning bids on the 450 contracts. The contracts were fixed price contracts for cleaning public premises that were either schools or offices. The dataset is based on submitted bids – a matter of open public record – requested from the procuring entities, which have also provided us with the documentation related to the calls for tenders. The majority of the bids (80 percent) in the dataset have been collected from standard auctions of single contracts or standard auctions of multiple contracts. Descriptive statistics for the annual bids in SEK per square metre to be cleaned (at the 1994 price level) together with contract, auction and bidding environment characteristics, can be found in table 1, and correlations among these variables in table A1 in the Appendix.

As displayed in table 1, the average bid was 10 percent higher in the standard auction format than the average bid in the combinatorial format. Decomposing the data for the two types of premises, we see that there is a significant difference in mean values across formats, due to differences in the bidding for offices.[6] There is also a notable difference in winning bids between auction formats; on average, not allowing for package bidding cost 33 percent more.

[6] There is no significant difference in mean values for schools.

Table 1. Descriptive statistics

Sample	*N*	Mean	Minimum	Maximum	Standard deviation
All auctions					
Bid per square metre (SEK)	1185	100.62	21.08	488.11	42.26
-public schools (percent)	811	103.57	21.08	488.11	40.90
-public offices (percent)	377	94.69	22.65	412.54	44.33
Square metres (contract level)	450	5735.35	68	79334	9021.83
Number of bids (contract level)	450	6.9	1	37	3.94
Number of contracts (procurement level)	96	5.38	1	42	8.11
Winning bid per square metre (SEK)	450	101.06	22.83	412.59	41.62
Standard procurement auctions					
Bid per square metre (SEK)	973	102.47	21.07	488.11	45.48
- public schools	752	102.95	21.08	488.11	41.96
- public offices	221	100.84	22.65	412.54	55.90
Square metres (contract level)	392	4171.08	68	42329	4974.81.
Number of bids (contract level)	392	6.98	1	37	3.92
Number of contracts (procurement level)	93	4.29	1	29	7.28
Winning bid per square metre (SEK)	392	104.44	22.83	412.59	43.16
Combinatorial procurement auctions					
Bid per square metre (SEK)	212	92.16	60.30	169.04	20.07
- public schools	59	111.48	73.27	169.04	22.18
- public offices	159	84.71	60.30	129.61	13.07
Square metres (contract level)	58	16307.66	807	79334	18461.35
Number of bids (contract level)	58	5.71	2	14	3.97
Number of contracts (procurement level)	3	19.3	7	42	19.66
Winning bid per square metre (SEK)	58	78.26	51.36	126.12	16.08
Bidding environment characteristics					
Population density (population per square metre)	1185	321.42	1.20	4228.20	675.75
Unemployment rate, in percent	1185	7.06	1.2	13.96	3.17
Left wing proportion of seats in local council, in percent	1185	44.97	13	67	12.14

The average contract specified 5,735.35 square metres to be cleaned, and a majority of the premises were schools (68 percent). Approximately five contracts were auctioned, on average, in the same procurement. The degree of competition in these auctions was fairly high; the average

number of bidders was about seven with a slightly lower degree of competition in the combinatorial auctions (5.7) compared to the standard auctions (6.9).

3.2 Empirical Setting and Results

In order to empirically analyse the extent to which package discounts in combinatorial bids reflect a true cost reduction for the procuring entity, we apply three tests. In the first test we only make use of the data from standard auctions, to investigate if the bid level, in terms of submitted price per square metre to be cleaned, is affected by the number of contracts auctioned in the same tender process. This will determine whether firms bid more aggressively in standard auctions of multiple contracts than in standard auctions of single contracts. Intuitively, we expect to find lower bids when the number of contracts in a tender is increased due to aggressive bidding on individual contracts. In our second test we include the stand-alone bids from the combinatorial auctions, to assess whether the stand-alone bids submitted in the combinatorial auctions are identical to bids on individual contracts in standard auctions. For reasons mentioned in the introduction, we conjecture that stand-alone bids in the combinatorial format are likely to be higher than those submitted in standard auctions. Finally, using only the winning bids in the dataset, the third test analyses whether the procurement cost differs across auction format.

3.2.1 Test of Bidding Behaviour and of Procurement Cost

Bidding behaviour is empirically tested here using the annual bids (i) per square metre at the 1994 price level (SEK) as the dependent variable (logarithmically transformed since the annual bid per square metre is a unitary measure). A dummy variable, *FORMAT*, is used in two of the tests to control for the type of auction – standard or combinatorial - the bids originate from. The logarithm of the number of contracts in each auction is captured by the variable *CONTRACT*,

the size of each contract is defined as the logarithm of the number of square metres to be cleaned, *SQM*.[7] A dummy variable for the type of premises takes the value one if the premises is a school (*SCHOOL*) and zero otherwise. The degree of competition (*COMP*) is measured as the logarithm of the observed number of bidders in each auction. By including dummy variables for the six most frequently bidding firms we control for bidder identity (*FIRMj*, where *j=A,…, F*). These six firms operate on a national or regional basis. Smaller, essentially locally operating firms constitute the reference category. As an alternative to using firm dummy variables we control for cluster where firm identity defines the cluster.

In addition, since the auctions took place in different areas of Sweden, differences in cost structure and preferences are accounted for by controlling for unemployment rate (*UNEMP*), population density (*DENSITY*), and the proportion of seats in the local council assigned to the left wing (*LEFT*). These variables are also expressed as logarithmic values. Cleaning services are personnel-intensive and thus their costs are mainly driven by wages, which are expected to be lower when the unemployment rate is high, but higher in more densely populated areas. The following regression equation is applied in the first test (*test I*):

$$(1) \qquad y_i = \alpha_i + \beta_1 CONTRACTS_i + \beta_2 SQM_i + \beta_3 COMP_i + \beta_4 SCHOOL_i + \beta_{5j} \sum_{j=A}^{F} FIRMj_i + \beta_6 UNEMP_i + \beta_7 DENS_i + \beta_8 LEFT_i + \varepsilon_i.$$

while the equation applied to test our second and third hypotheses (*tests II and III, respectively*) includes a dummy variable to control for the auction mechanism:

[7] The data indicates that the bid level mainly is driven by the size of the contracts. A regression analysis, where only the number of square meters is used as an explanatory variable, shows that the variation in contract sizes alone can explain 94 percent of the variation in bids.

(2) $$y_i = \alpha_i + \beta_1 FORMAT_i + \beta_2 CONTRACTS_i + \beta_3 SQM_i + \beta_4 COMP + \beta_5 SCHOOL_i + \beta_{6j} \sum_{j=A}^{F} FIRMj_i + \beta_7 UNEMP_i + \beta_8 DENS_i + \beta_9 LEFT_i + \varepsilon_i.$$

The dummy variable *FORMAT* takes the value 1 if the bid originates from a standard auction. Equations (1) and (2) are solved by ordinary least square regression with White-correction for heteroscedasticity.

3.2.2 Results

The regression results from all tests are presented in table 2. The results of the first test, *test I*, indicate that the null hypothesis that the submitted price on an individual contract is unaffected by the number of contracts auctioned in the same tender process should be rejected. The results indicate that the bid per square metre decreases as the number of contracts auctioned in one and the same procurement increases.

Table 2. Estimation results (t-ratio in parentheses)

Variable	*Test I*	*Test II*	*Test III*
Format		-0.17 (-4.12)	-0.06 (-0.75)
Number of contracts	-0.004 (-7.54)	-0.04 (-4.81)	-0.05(-3.73)
Square metre	-0.09 (-7.36)	-0.09 (-7.85)	-0.11 (-6.85)
Competition	-0.06 (-2.27)	-0.04 (-1.62)	-0.08 (-2.44)
School	0.24 (6.88)	0.25 (8.64)	0.38 (7.67)
FIRM A	-0.10 (-1.93)	-0.11 (-3.12)	-
FIRM B	-0.07 (-1.27)	-0.09 (-2.31)	-
FIRM C	-0.30 (-3.61)	-0.26 (-3.95)	-
FIRM D	-0.08 (-1.48)	-0.07 (-2.01)	-
FIRM E	-0.07 (-1.24)	-0.06 (-1.46)	-
FIRM F	-0.21 (-3.02)	-0.19 (-3.35)	-
Unemployment rate	-0.05 (-1.33)	-0.06 (-1.54)	-0.04 (-0.69)
Population density	0.02 (1.90)	0.02 (2.08)	0.00 (0.18)
Leftwing	-0.25 (-4.31)	-0.18 (-3.53)	-0.45 (5.76)
Constant	6.38 (27.16)	0.14 (37.36)	5.16 (26.07)
N	973	1185	450
R^2	0.16	0.16	0.31
F(7, 955), F(14, 1170), F(8, 441)	14.84	15.93	43.52
Mean VIF	2.19	2.32	2.08

Our second test, *test II,* indicates that the null hypothesis that stand-alone bids and single bids submitted in standard auctions are identical should also be rejected. The estimate of the variable *FORMAT* supports our conjecture that bids on individual contracts in combinatorial auctions are higher than corresponding bids in standard auctions.

Further, the general impression from all three tests is that the correlation coefficient for the relationship between *COMP* and bid price is significantly negative (albeit more weakly significant according to the second test than Tests *I* and *III*), i.e. bids decrease with increases in the number of bidders, in accordance with previous findings based on an extended set of the data used in this study.[8] In addition, the results show that the size of the contracts, in terms of square metres to be cleaned, has a significant negative impact on the bids per square metre, indicating the presence of economies of scale. The coefficient for the number of square metres to be cleaned per contract is also negative and significant. The results also indicate that scale effects are present not only in terms of the number of contracts, but also within contracts, and that schools are more expensive to clean than offices, most likely due to differences in needs and quality demands. The outcome of the three tests for the firm identity coefficients varies, but the impression is that larger firms generally submit lower bids than local firms. Another finding is that the bidding environment affects, to some extent, the size of the bids. The coefficients for the population density in the area, and the proportion of seats in the local council held by the left wing are negative and significant, while the unemployment rate seems to have no effect on the bids (except according to test *II*).

[8] Lundberg (2005) finds bids to decrease with increases in the number of bidders in an empirical study in which all bids, from which the data in this study is a sub-sample, generated in standard auctions, are used.

The outcome of test II also indicates that the significant difference between the stand-alone bids in the combinatorial auctions and the bids in the standard auctions is due not only to aggressive bidding in the multi-contract environment in standard auctions, but also to inflated stand-alone bids in the combinatorial auctions.[9] These findings are robust for controlling for firm identity clusters (see Table A2 in the Appendix).

The null hypothesis that procurement costs are identical across auction mechanisms (*test III*) cannot be rejected. Hence, our data do not provide significant evidence that the use of a combinatorial auction lowers procurement costs. This might be due to the fact that the observed discounts in the package bids are offset by the inflated stand-alone bids.

As displayed in table 2, the explanatory power of the models is reasonably good. In addition, using total bids per contract, instead of bids per square metre, in equations (1) and (2) leads to the same conclusions as those based on the findings from all three tests, and the explanatory power of the models then rises to 92-94 percent. For the square metre coefficient, high *t*-values and positive coefficients are found. Clearly (and not surprisingly) therefore, the number of square metres to be cleaned is a very strong predictor of the total bid. The estimation results can be found in table A3 (Appendix).

4. Summary and Conclusions

This paper has empirically investigated two related aspects of first-price combinatorial procurement auctions. The first question raised is to what extent the bids on individual contracts in a combinatorial auction – the stand-alone bids – differ from the bids on individual contracts in auctions with no option to place bids on packages of contracts. Referring to the present

[9] A similar comparison of the stand-alone bids from the combinatorial auctions with the bids from auctions of single contracts, i.e., excluding any potential effect of multi-contract bidding behavior in the standard auction from the analysis, confirms the finding of inflated stand-alone bids.

theoretical guidance we have found concerning sealed bid combinatorial first-auction – albeit not precisely modelling the bidding environment of the auctions from which we have collected the data - we predict the stand-alone bids to be higher than the bids on individual contracts in standard auctions for two reasons. First, in order to favour a package bid in a combinatorial auction, bidders inflate their stand-alone bids on those contracts making up the package bid. Secondly, given synergies across contracts, bidders submit a lower bid on each individual contract in a multi-contract non-combination auction than they do in a single contract auction. The second question raised is whether the procurement cost in a combinatorial auction format is different from that in a standard auction format.

Based on data from Swedish procurement auctions of cleaning services, we find that stand-alone bids in the combinatorial auctions are higher than bids in the standard auctions. This difference seems to be merely due to inflated stand-alone bids in the combinatorial auctions rather than aggressive bidding in the standard auctions of multiple contracts. In addition, the data indicate that the use of combinatorial auctions does not significantly lower the procurement cost. The increase in the stand-alone bids seems to offset the discounts expressed in the package bids.

A policy implication of the conclusions drawn in our study is that one needs to be careful when interpreting the size of the package discounts in first-price combinatorial auctions. Even if package bids are motivated by synergies, and thus have the potential to lower the procurer's cost, the observed package discount overstates the actual cost reduction of a combinatorial auction.

References

Abrache, J., T.G. Crainic, M. Gendreau and M. Rekik. "Combinatorial Auctions." *Annals of Operations Research,* 2007, 153(1), 131-164.

Cantillon, E., and M. Pesendorfer, "Combination Bidding in Multi-Unit Auctions," CEPR Discussion Papers 6083, 2007, C.E.P.R. Discussion Papers.

Cantillon, E., and M. Pesendorfer. "Auctioning Bus Routes: The London Experience." in *Combinatorial Auctions* edit by Cramton, P., Y. Shoham, and R. Steinberg, The MIT Press, Cambridge, USA, 2006, 573-591.

Chernomaz, K., and Levin, D. "Efficiency and Synergy in a Multi-Unit Auction with and without Package Bidding: an Experimental Study." Working paper, *Social Science Research Network (SSRN),* (2011)

Cramton, P.; Y. Shoham, and R. Steinberg. *Combinatorial Auctions* The MIT Press, Cambridge, USA, 2006.

De Vries, S., and V. R. Vohra. "Combinatorial Auctions: A Survey" *INFORMS Journal on Computing*, 15(3), 284-309.

Directive 2004/17/EC of the European Parliament and of the Council of 31 March 2004 coordinating the procurement procedures of entities operating in the water, energy, transport and postal services sectors (30.04.2004).

Directive 2004/18/EC of the European Parliament and of the Council of 31 March 2004 on the coordination of procedures for the award of public works contracts, public supply contracts and public service contracts (30.04.2004).

Epstein, R.; L. Henriquez, J. Catalán, G. Y. Weintraub, C. Martínez, and F. Espejo, "A Combinatorial Auction Improves School Meals in Chile: A Case of OR in Developing Countries." *International Transactions in Operational Research*, 2004, 11(6), 593-612.

Kagel, J. H., and D. Levin. "Multi-unit Demand Auctuions with Synergies: Behaviour in

Sealed-bid Versus Ascending-bid Uniform-price Auctions." *Games and Economic Behavior*, 2005, 53(2), 170-207.

Krishna V., and R. W. Rosentahl. "Simultaneous Auctions with Synergies." *Games and Economic Behavior*, 1996, 17(1), 1-31.

Lundberg, S. "Auction Formats and Award Rules in Swedish Procurement Auctions." *Rivista di Politica Economica*, 2005, 96(1-2), 91-116.

McAfee, R. P., J. McMillan, and M. D. Whinston. "Multiproduct Monopoly, Commodity Bundling, and Correlation of Values." *Quarterly Journal of Economics*, 1989, 104(2), 371-383.

Nisan, N. "Bidding Languages for Combinatorial Auctions." in *Combinatorial Auctions* edit by Cramton, P., Y. Shoham, and R. Steinberg, The MIT Press, Cambridge, USA, 2006, 215-232.

Pekeč, A. and M. H. Rothkopf. "Combinatorial Auction Design." *Management Science*, 2003, 49(11), 1485-1153.

Sheffi, Y. "Combinatorial Auctions in the Procurement of Transportation Services." *Interfaces*, 2004, 34(4), 245-252.

Appendix

Figure A1. Stand-alone and package bids/m2 in auction A (SEK)

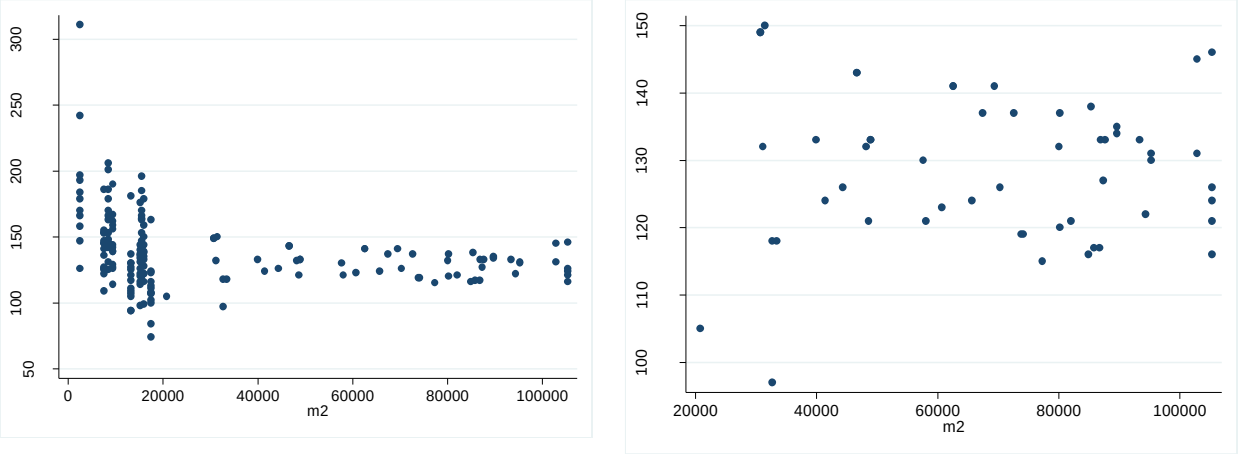

Figure A2. Stand-alone and package bids/m2 in auction B (SEK)

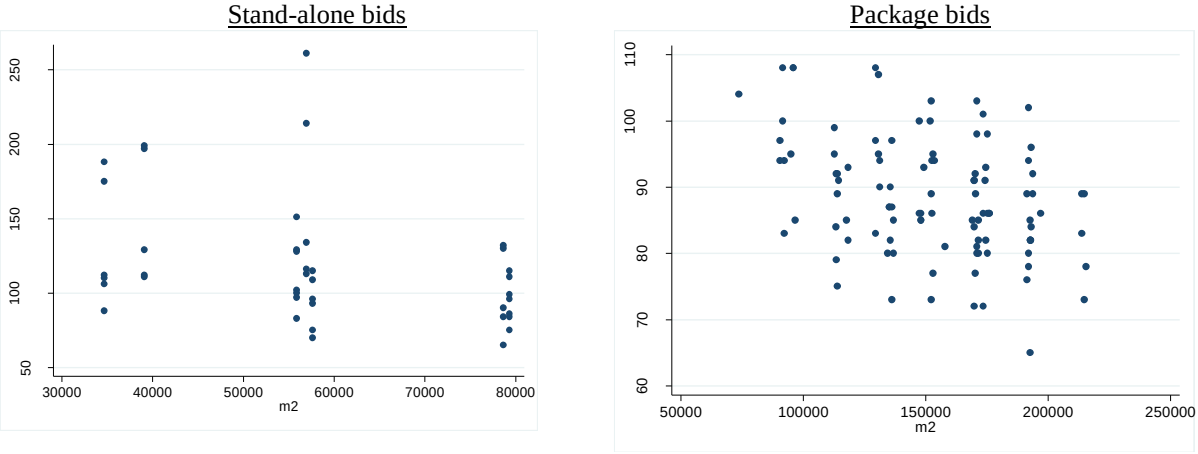

Figure A3. Stand-alone and package bids/m2 in auction C (SEK)

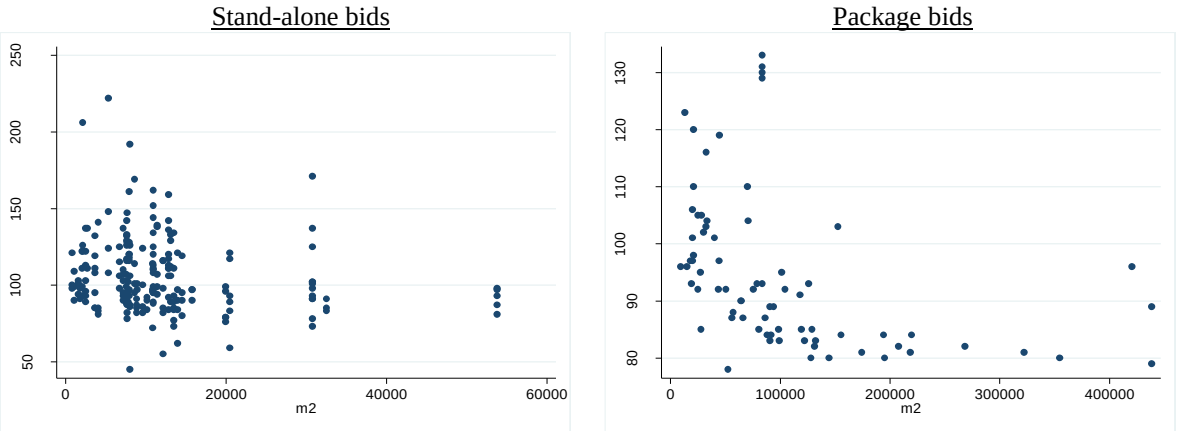

Table A1. Correlation matrix

	Contract	*Competiton*	*Format*	*Sqm*	*School*	*Office*
Contract	1.00					

Competition	-0.09	1.00				
Format	-0.27	0.12	1.00			
Sqm	-0.07	-0.04	-0.49	1.00		
School	-0.28	-0.05	0.42	-0.02	1.00	
Office	0.28	-0.12	-0.42	0.02	1.00	1.00

Table A2. Estimation results – standard errors adjusted for 13 clusters in firm identity (t-ratio in parentheses)

Variable	*Test I*	*Test II*
Format		-0.21 (-8.21)
Number of contracts	-0.04(-4.05)	-0.05 (-5.07)
Square meter	-0.10 (-6.16)	-0.10 (-7.13)
Competition	-0.05 (-0.96)	-0.03 (-0.64)
School	0.23 (5.24)	0.25 (5.65)
Unemployment rate	-0.05 (-1.01)	-0.04 (-1.11)
Population density	0.02 (1.79)	0.02 (1.51)
Leftwing	-0.18 (-2.45)	-0.16 (-2.81)
Constant	5.96 (16.07)	5.13 (1.79)
N	973	1185
R^2	0.12	0.14
F(7, 10)/F(8, 13)	212.15	189.74
Mean VIF	1.75	2.26

Table A3. Estimation results – dependent variable "Total Bid", annual price in SEK (t-ratio in parentheses)

Variable	*Test I*	*Test II*	*Test III*
Format		-0.17 (-4.12)	-0.06 (-0.75)
Number of contracts	-0.13(-3.36)	-0.04 (-4.81)	-0.05 (-3.73)
Square meter	0.91 (65.03)	0.90 (73.41)	0.89(53.89)
Competition	-0.05 (-1.99)	-0.04 (-1.62)	-0.08 (-2.44)
School	0.25 (6.98)	0.25 (8.64)	0.38 (7.67)
FIRM A	-0.12 (-2.33)	-0.11 (-3.12)	-
FIRM B	-0.07 (-1-29)	-0.09 (-2.31)	-
FIRM C	-0.34 (-4.00)	-0.26 (-3.95)	-
FIRM D	-0.10 (-1.89)	-0.07 (-2.01)	-
FIRM E	-0.10 (-1.68)	-0.06 (-1.46)	-
FIRM F	-0.23 (-3.23)	-0.19 (-3.35)	-
Unemployment rate	-0.07 (-1.55)	-0.06 (-1.54)	-0.04 (-0.69)
Population density	0.02 (2.16)	0.02 (2.08)	0.00 (0.18)
Leftwing	-0.23 (-3.79)	-0.18 (-3.53)	-0.45 (5.76)
Constant	6.28 (25.54)	5.24 (37.48)	5.16 (26.07)
N	973	1188	450
R^2	0.92	0.94	0.93
F(13, 959, F(14, 1173), F(8, 441)	464.50	1011.43	43.52
Mean VIF	2.51	2.32	2.08