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Taking the Lab to the Field: Experimental Tests of Alternative Mechanisms to Procure Multiple Contracts

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**Taking the Lab to the Field:
Experimental Tests of
Alternative Mechanisms to
Procure Multiple Contracts**
Anders Lunander and Jan-Eric Nilsson
NOTA DI LAVORO 28.2003

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Taking the Lab to the Field: Experimental Tests of Alternative Mechanisms to Procure Multiple Contracts

Summary

The first part of the paper reports the results from a sequence of laboratory experiments comparing the bidding behavior for multiple contracts in three different sealed bid auction mechanisms; first-price simultaneous, first-price sequential and first-price combinatorial bidding. The design of the experiment is based on experiences from a public procurement auction of road markings in Sweden. Bidders are asymmetric in their cost functions; some exhibit decreasing average costs of winning more than one contract, whereas other bidders have increasing average cost functions. The combinatorial bidding mechanism is demonstrated to be most efficient. The second part of the paper describes how the lab experiment was followed up by a field test of a combinatorial procurement auction of road markings.

Keywords: Multiple units, non-constant costs, asymmetric redemption values, alternative procurement mechanisms

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1. INTRODUCTION

Using the standard first-price sealed bid auction, Sweden's National Road Administration (henceforth the Road Administration) annually awards some 60 contracts for the updating of road markings on national roads, subsequently referred to as road painting: Firms are invited to submit a bid on each contract, prior to an announced point in time. The bids on each contract are then evaluated separately and independently, and the firm submitting the lowest bid on a certain contract is awarded it, the same or another firm submitting the lowest bid on another is awarded that contract and so on. We consider this as a number of simultaneous auctions for identical, or at least very similar, objects.

Previous analyses of the bidding in these procurement auctions have demonstrated that there are two types of bidders for the contracts; 'large' and 'small' (Eklöf & Lunander (1999)). In the present paper, we conjecture that large suppliers submitting bids on more than one contract have decreasing average costs (synergies) in the number of contracts they win. A firm with synergies across combinations of contracts is then exposed to the risk of failing to acquire some contracts of a package, thereby ending up being paid less than its cost for executing the set of won contracts. To curb this risk, the firm may submit less aggressive bids, which then generates a risk that the lowest-cost supplier is not awarded the contracts. If a large firm still wins all contracts in the bundle, it may then earn supranormal profits.

Furthermore, we conjecture that because of capacity constraints, small bidders have increasing average costs in the number of contracts they are awarded. For this reason, small firms may also submit less aggressive bids or may abstain from bidding on some contracts to avoid the risk of ending up with more jobs than they have the capacity to carry out. This

jeopardizes the small firms' possibility to stay in business and makes it difficult for new ones to enter, which is harmful for the competitive pressure in the industry at large.

One way of reducing the exposure problem for the procurer would be to substitute the standard sealed-bid mechanism for a simultaneous multiple round (SMR) auction with the opportunity for bid withdrawal or the option to submit package bids. The former type of auction was used in connection with the allocation of spectrum licenses in the United States (cf. Cramton (1997), Milgrom (1998), CRA (1998), Cybernomics, Inc (2000a)). The first use of combinatorial bidding for spectrum licenses in the US is scheduled to 2003; see www.fcc.gov. In the presence of synergies across contracts, the SMR auction format may generate higher efficiency and higher revenue (lower procurement cost) than a simultaneous one-shot auction of independent units, at least if the items that are sold have significant common value components. Despite the fact that public procurement represents about 20% of GDP within the OECD countries, innovative auction designs are not often observed in this area. One reason is that the bidding procedure in public procurement auctions is regulated by rules restricting bidding to a one shot sealed-bid procedure, which do not allow for iterative bidding.¹ The use of a one-shot procedure is also known to reduce the risk of collusion between bidders.

Using data from both a lab and a field experiment, the purpose of this paper is to explore the efficiency and revenue generation qualities of two sealed-bid alternatives in relation to the standard procedure to award contracts for multiple units; the standard approach is subsequently referred to as *simultaneous* bidding. Under the *sequential* bidding mechanism,

¹ Article XIII:1-3 of the Agreement on Government Procurement (WTO) states that "the opportunities that may be given to tenderers to correct unintentional errors of form between the opening of tenders and the awarding of the contract shall not be permitted to give rise to any discriminatory practice," and that "all tenders solicited

firms are allowed to observe the outcome of bidding on the first contract before submitting bids on the second, and so on. The benefit of the sequential approach would be to provide information about the outcome of one contest before bidders submit bids on the next. With *combinatorial* bidding, firms are allowed to submit bids also on packages of contracts in a simultaneous first-price sealed bid setting which is another way of reducing the uncertainty that comes with multiple bids and eliminate the exposure problem.²

Theory provides limited guidance as to general predictions concerning revenue and efficiency ranking of multi-unit auction mechanisms, when some bidders have economies and other diseconomies in the number of contracts they are awarded. Within the independent private values model, Krishna and Rosenthal (1996) compare the revenues in a second-price sealed-bid environment where objects are auctioned out simultaneously with package bids and a sequential auction. Given their parameterization of the distribution of bidders' values, the number of global (large) and local (small) bidders and the number of objects auctioned, they show that both the 'standard' simultaneous and the sequential auctions yield higher revenue than does the combinatorial auction, at least when there is only one global bidder. This is due to the more aggressive bidding by the global bidder in order to exploit synergies under the standard bidding format. By submitting bids on separate contracts, which are above the valuation for each separate contract, the bidder makes a loss in case he wins only a fraction of the contracts. This risk of a negative profit is compensated by the global bidders' gains in case of winning all contracts.

shall be received and opened under procedures and conditions guaranteeing the regularity of the openings.”

² Combinatorial bidding can differ considerably and the lab and field experiments reported here only represent two simple versions of this much more general mechanism.

Several experimental studies have, however, arrived at an opposite revenue ranking. Ledyard *et al.* (1997), and Bykowsky *et al.* (1998) demonstrate that a combinatorial bidding mechanism dominates other mechanisms, both in revenues and efficiency. In a laboratory environment, Cybernomics, Inc (2000b) compares the performance of two multiple round auctions, one without (SMR) and one allowing for package bids (combinatorial). The combinatorial auction generates higher efficiency but lower revenues than the auction without packages bids, the reason being that bidders in the SMR auction make losses because of failed contract aggregations. Further, field applications of procurement auctions where suppliers have had the option to submit bids on bundles of contracts, have generated substantial savings in procurement costs [see Ledyard *et al.* (2000) (transportation services), and Trade Extensions (2001) (wooden packaging material)].

In contrast to the above references, the ‘small’ or ‘local’ bidders in our experimental testbed are assumed to have decreasing returns to scale in the number of contracts. While there are results indicating that with only small firms taking part in the auction, it is in the procurer’s interest that the contracts are auctioned out sequentially and not simultaneously [see Engelbrecht-Wiggans and Weber (1979), Lang and Rosenthal (1991) and Ungern-Sternberg (1991)], we know less about the combination of small and large bidders. In the absence of clear theoretical predictions, we have difficulties in benchmarking the results and the results reported below therefore rely on a systematic comparison of outcomes from mechanisms for the lab experiment.

The outline of the paper is the following. Section 2 describes the process of a real governmental procurement auction, constituting the basis from which the present paper’s lab and field experiments have grown. The lab experiment, its design and results, are presented in

section 3, the subsequent field experiment is reported in section 4 and section 5 concludes.

2. THE PROCUREMENT AUCTIONS OF ROAD MARKINGS IN SWEDEN

Every year, the Road Administration contracts firms for the maintenance of road markings.

Each of the seven regional offices of the Administration is responsible for the procurement of such services in the counties (being between two and five) under its rule. In each county, there are often two or three separate classes of contracts which are all very similar in nature; up to a linear transformation, painting a road in one place using a certain technique is very similar to this same activity, or a different technical version of it, undertaken elsewhere. In total, there are 50-60 contracts auctioned out, each valid for one year at a time. Between 1993-98, the Road Administration spent an annual average of SEK 100 million (USD 10 million) on the procurement of road painting.

The procurement process is identical across regions. Each contract is awarded by means of a first-price sealed bid auction and all contracts within the region have the same bidding deadline. Bids on one contract are evaluated independently of the bids submitted on any other contract. A bid consists of a set of prices (price per meter) for various types of road marking lines. The competitive bid is then computed as a weighted average of these separate prices; the weight attached to each individual price is common knowledge. Bidding on packages is not allowed. The periods of time required for evaluating the bids in all regions fully or partially overlap,³ and the procurement of road markings may thus be described as 50-60 first-price sealed bid auctions, run simultaneously and independently.

³ In 1999, the number of overlapping auctions was 53 out of a total of 55.

About eight firms are active in bidding for the contracts. Two of them are relatively large and operate in most counties, whereas the others are more or less local, operating in adjacent counties only. The two large firms win about 50% of the contracts. During the period 1993-1999, on average 4.7 bids were submitted on each contract.

Minutes from the procurement auctions provide examples of firms that – except for submitting bids for each of the contracts – have also made offers with either a discount on a bundle (a large firm has, for instance, made an offer to lower its bid on two adjacent contracts by 5%, given that is awarded both) or with restrictions on the number of contracts the firm can fulfill, given that it wins “too many”. One motive given by the Road Administration for not taking these side-bids and restrictions into account is the computational problem of finding the optimal cost minimizing allocation.

3. THE LAB EXPERIMENT

Based on the above elements of the real-life process, we have designed a lab experiment with the purpose of comparing three bidding mechanisms to procure multiple units provided by bidders with induced non-constant costs. Each experimental session consisted of a series of auction periods where three identical contracts, *A*, *B* and *C* were subject to bidding. Five subjects participated in each session, two of *type 1* and three of *type 2*. The subjects’ costs of fulfilling the fictitious contracts were randomly determined in each period, according to procedures described below, and they made profit by winning one or several contracts. In each period, the low bidder(s) made a profit equal to his (their) low bid(s) less his (their) induced cost of the contract(s); other subjects earned nothing.

Prior to bidding in each period p , the two bidders of *type 1* faced a cost c_i^p ($i=1,2$) randomly and independently drawn from the uniform distribution $[200,300]$, one for each bidder.

Similarly, the three bidders of *type 2* faced a cost c_j^p ($j=3,4,5$) drawn from the uniform distribution $[160,220]$. The superscript p ($p= 1... 15$) denotes that the same set of randomly generated costs, c_i^p and c_j^p was used for each session.

The production costs of the two *type 1* bidders were decreasing in the number of contracts, with identical scale parameters for the two bidders. If a bidder won one of the contracts in the period, his cost equaled c_i^p (cf. table 1). If the same bidder won two contracts in the same period, the cost decreased to $0.9 \times c_i^p$ per contract and if he won all three contracts, the unit cost was $0.8 \times c_i^p$. The three *type 2* bidders faced an increasing unit cost function, again with identical scale parameters across bidders. The cost was equal to c_j^p if winning one of the contracts, winning two contracts in the same period made the cost increase to $1.1 \times c_j^p$ and, finally, winning all three contracts, the unit cost was $1.2 \times c_j^p$.

The purpose of this design was to mimic the observed number and size composition of bidders. First, it is difficult to believe that entrepreneurs would continue to be of different sizes if there were no real reasons for this; the presence of scale (dis-) economies being one such reason. Second, it would have been feasible to represent ‘small’ entrepreneurs with constant-cost functions. Such bidders, however, often want to restrict the number of contracts they can win, one possible reason being that they have capacity restrictions, here modeled as increasing costs. The random draw for the small bidders (*type 2*) then had to be made from a different support than that of the large bidders (*type 1*). If the cost for both types had been

drawn from the same distribution, then the chances for *type 2* of winning any contract would have been small, given the number of contracts auctioned out and the size of the scale parameters.

Table 1. Induced costs for bidders of type 1 and type 2.

	<i>Type 1</i>	<i>Type 2</i>
Number of bidders	2	3
Support $[c_{i,j}, \bar{c}_{i,j}]$	$[200, 300]_i$	$[160, 220]_j$
Average cost for one contract (A, B or C)	c_i	c_j
Average cost for two contracts (AB, AC or BC)	$0.9 \times c_i$	$1.1 \times c_j$
Average cost for three contracts (ABC)	$0.8 \times c_i$	$1.2 \times c_j$

When arriving at the lab, each subject was randomly assigned to be either *type 1* or *type 2* and remained the same type throughout the session. A show-up fee of SEK 100 was paid.⁴ In addition, each bidder was provided with SEK 50 for the purse, meaning that bids generating losses were accepted up to a deficit of this amount. The first five bidding periods made use of an exchange rate of SEK 0.5 for each experimental currency unit, the next five periods had a one-to-one exchange rate and the final five periods paid SEK 3 for each experimental currency unit. In addition, bidders did not have to carry the losses from the first five periods with them. These design aspects were used to reduce the risk of having to terminate a session before the participants had understood the logic of the game.

The contents of table 1 were common knowledge prior to bidding, meaning that bidders knew their own valuation and type, the distribution from which the valuations of the others were drawn, and the number of bidders of each type. A session was initiated with two shorter training periods. The subjects were students from the business administration and economics programs at Uppsala University and Dalarna University. Each session took up to two hours to

conclude. Earnings ranged from the guaranteed amount up to SEK 400. The treatment variable was the auction mechanism with the following three one-shot bidding mechanisms being tested.

Simultaneous first-price sealed bid. In each period, the subjects submitted bids simultaneously for all three contracts. The bids on one contract were evaluated independently of the bids on the others, and the contract was awarded to the lowest bidder on that contract. In order to avoid an ordering effect (always place the highest/lowest bid in the first empty field on the screen), the three contracts were displayed on the screen in a randomized order; sometimes *A, B, C*, on other occasions *B, A, C*, etc. After each period, the winner(s) and the winning bids were reported to everyone and the profits reported to those who were awarded a contract.

Sequential first-price sealed bid. Subjects submitted bids in a sequential order for the three contracts; the assignment of the first contract (contract *A*) was reported prior to bidding for the second contract (contract *B*), and the assignment of the second contract was reported prior to bidding for the third. It was not announced whether a contract had been awarded to a small or a large bidder. When all contracts had been awarded, the winner(s) was (were) informed about his (their) profits.

Combinatorial first-price sealed bid. In addition to placing separate and independent bids for contracts *A, B* and *C*, subjects were also allowed – but not required – to place bids on all other combinations of contracts. Each subject could therefore submit seven bids; one on each single

⁴ The exchange rate during the fall of 1999 was about SEK 8 for each \$US.

contract and bids on packages AB , AC , BC and ABC .⁵ The winning combination was the combination of bids on the three contracts yielding the lowest procurement cost. Subjects part of the winning combination were awarded their contract(s) and their profit equaled their bid(s) less their cost for the number of contract(s) won.

4. EXPERIMENTAL RESULTS

Nine experimental sessions were conducted, each mechanism replicated in three sessions, where each session consisted of 12 or 15 periods (cf. table 2).

Table 2. Number of periods performed across mechanisms

Bidding mechanism		
Simultaneous	Sequential	Combinatorial
12	12	12
12	15	15
15	15	15
39	42	42

One way of measuring efficiency under the three mechanisms is to take the ratio between the lowest induced cost of fulfilling the three contracts and the induced cost for the winner(s). We have, however, applied a normalized efficiency measure taking the level of drawn costs into account. The efficiency measure is defined in (1).

$$E = 1 - \frac{A - M}{N - M} \quad (1)$$

A is the actual costs for the winners of fulfilling contracts, M is the lowest induced cost of fulfillment and N is the expected induced cost of a random allocation. For each period, N is computed as the total sum of the induced cost of all possible allocations of the three contracts

⁵ The bidders were also told that they could only win all three contracts on the ABC package bid, not on a combination of the three separate bids on contracts A , B and C , or a two-plus-one combination. In the same way, a two-pair could only be awarded by a bid on this two-pair, not from a combination of two single-contract bids. These restrictions were introduced in order to avoid bidders accidentally placing bids on singletons or two-plus-one combinations that made them win contracts at bids below costs, which was a real risk in view of the non-

among the five bidders, taking the economies and diseconomies of scale into account. This sum is then divided by the number of possible allocations, which are (5^3) 125.

Table 3 shows the average and median efficiency for the three mechanisms. We apply a Wilcoxon rank test to test for significant differences in efficiency across mechanisms, given identical periods. Table 4 demonstrates that the combinatorial mechanism generated fully efficient allocations in 28 periods out of 42 and is significantly more efficient than the other two mechanisms.

Table 3. Efficiency Across Mechanisms

	<u>Mechanism</u>		
	Simultaneous	Sequential	Combinatorial
Average efficiency	0.70	0.68	0.91
Median efficiency	0.66	0.68	1.00
# observations	39	42	42

Table 4. Wilcoxon matched-pairs signed-rank tests of efficiency

	<i>z-statistics</i>	<i>N</i>
Simultaneous = Sequential	-0.45	39
Simultaneous = Combinatorial	-3.28	39
Sequential = Combinatorial	-3.64	42

Next, we compare the procurer’s cost under each mechanism. One complication in this is that bidders have now and then incurred losses, i.e. been awarded contracts with bids below their costs, in various periods of all three mechanisms. In 15 periods out of 39, the simultaneous mechanism has generated losses for at least one bidder, the sequential mechanism in 10 out of 42 while the combinatorial mechanism resulted in losses in only 2 (early periods) out of 42.

linearities in costs.

To take the impact of such behavior into account when comparing the procurement costs in pairs for identical periods across mechanisms, we apply the Wilcoxon rank-test both to all possible pairs of identical periods, irrespective of outcome, and all possible pairs of identical periods in which the winner(s) did not make a loss.

Table 5 demonstrates that the combinatorial mechanism generates significantly lower procurement costs than the other two mechanisms. By only considering periods with no losses, the average reduction in procurement costs of using the combinatorial mechanism increases from 2-3% to 4%. This is due to the decreasing effect of the winners' incurred losses on the procurer's cost within the simultaneous and the sequential mechanisms.

Table 5. Wilcoxon matched-pairs signed-rank tests of procurer's cost

Tested pair	<i>z</i> -statistics	<u>All periods</u>			<u>Periods with no losses</u>		
		<i>n</i>	Relative difference	<i>z</i> -statistics	<i>n</i>	Relative difference	
Cost _{Simultaneous} = Cost _{Sequential}	0.47	39	0.008	0.22	14	-0.001	
Cost _{Simultaneous} = Cost _{Combinatorial}	3.08	39	0.028	3.05	22	0.041	
Cost _{Sequential} = Cost _{Combinatorial}	2.74	42	0.022	3.49	21	0.037	

Table 6 compares the outcome of an efficient allocation with the observed allocation of contracts to bidders of *type 1* and *type 2*, respectively. Given our random draw from the two distributions of costs, an efficient allocation would have about 50 % of the contracts awarded to each type. The observed allocation of contracts to each type of bidder in the combinatorial mechanism almost coincides with the efficient allocation. In contrast, an average *type 2* bidder won a larger number of contracts under the sequential than under the other two mechanisms.

Table 6. Efficient and observed relative allocation of contracts to each type

Bidder	Efficient allocation	Simultaneous	<u>Mechanism</u>	
			Sequential	Combinatorial
<i>Type 1</i>	52%	34%	23%	49%
<i>Type 2</i>	48%	66%	77%	51%

Finally, there is reason to ask whether our conclusions regarding (relative) efficiency and revenue generation qualities materialize for the right reasons, or if the results emanate from some arbitrary or unknown underlying process. To test for this, we have formulated a set of conjectures regarding the individually rational bidding behavior of subjects of the respective type under each mechanism. The overall conclusion is that observed behavior periods can indeed be seen to be rational, at least under the simultaneous and the combinatorial mechanisms. Some deviations from what we expected to find under the sequential mechanism could possibly be explained by the fact that subjects were not informed about whether the first contract was awarded to a large or small bidder, which was also the case when contract two was awarded. This might have confused bidders somewhat; to economize on space, the analysis is placed in an appendix.

5. THE FIELD TEST

The results from the lab experiment were reported to the Road Administration in September 2000, and it was decided to make a field test of combinatorial bidding when procuring road paintings in 2001. The agency did not want to let all 50-60 contracts be auctioned out simultaneously in a nationwide first-price sealed bid combinatorial auction. Instead, it restricted combinatorial bidding to be partially implemented in two of its regions, the procedure for contracts in the remaining five regions being left unchanged. Software for

evaluating a possibly complex set of combinatorial data was programmed by Trade Extensions. The software could, in principle, deal with any types of bids, both package bids and so-called XOR bids. We first present the bidding rules of the field test and the results at large (in subsection 5.1) and also try to understand what savings, if any, the Road Administration actually made from the test (5.2).

5.1 BIDDING RULES AND RESULTS

The number of contracts subject to bidding was nine and ten, respectively, in the two choice regions. Half of the contracts in each region were relatively small, with the cost of carrying out a small contract being about a sixth compared to the other contracts. Firms were not allowed to submit bids on own-formed bundles of contracts. Instead, prior to bidding, the Road Administration specified which – and in one region how many – of the contracts could be included in a package bid. The agency feared that if firms were allowed to submit bids on the whole sample or various combinatorial bids on arbitrary sub samples, there was a risk that larger firms would “take it all” with one aggressive combinatorial bid. For unexplained reasons, it was stipulated that a firm submitting a combinatorial bid also had to tender a single separate bid for each of the contracts included in the combination. We comment on these aspects of the field test below. In addition, firms were given the opportunity to declare how many contracts they could accept in case they were awarded more contracts than they had the capacity to fulfill.

Nine separate contracts were advertised in *Region Middle*. Firms could submit an arbitrary number of combinatorial bids for a specified sub sample of four contracts. In table 7, bold letters represent contracts that could be included in a combinatorial bid. A firm submitting a bid for contracts C1, C2, D1 and D2 and ticking the C1-C2 combination with a discount of

five would then reduce its price by 5% if awarded this pair.

Table 7. Contracts auctioned out in Region Middle.

Contract	Single bid (SEK)	Comb. Bid 1 (mark with √)	Comb. bid 2 (mark with √)	Comb.bid n (mark with √)
T1				
T2				
D1				
D2				
E2				
C1				
C2				
U1				
U2				
	Discount in %			

Contracts numbered “1” are large, and contracts numbered “2” are small contracts.

Five firms took part in the bidding in this region. One of them submitted separate bids on *CI*, *UI*, *DI* and *TI* with the restriction that it could take two contracts at most; this bidder won no contract. Only one of the bidders, here labeled *CLE*, used the option to submit a combinatorial bid on two of the four contracts that could be included, *UI* and *CI*. Table 8 displays *CLE*’s separate bids and the two-combinatorial bid on these two contracts. The discount was 2% of the sum of the single bids, meaning that the combinatorial bid was about SEK 142 000 lower than the sum of the two single bids on the same contracts.

Table 8. *CLE*’s Bids in Region Middle, thousand SEK

Contract	Lowest stand-alone bids	Combinatorial bid (2 % discount)	Lowest bids including discount for package
C1	2 722	√	2 668
C2	602		602
U1	4 383	√	4 295
U2	804		804
Sum of winning bids	8 511		8 369

It turned out that this firm had also submitted the lowest single separate bids on each of the

nine contracts; the combinatorial bid made no difference for the outcome of the contest.⁶ Ten contracts were awarded in *Region West*. Three of these were open to combinatorial bidding (cf. bold letters in table 9). Firms could only submit two-contract package bids, that is, a firm could submit three combinatorial bids at most.

Table 9. Contracts auctioned out in Region West

Contract	Single Bid (SEK)	Combinatorial bid 1	Combinatorial bid 2	Combinatorial bid 1
H1		✓	✓	
H2				
G1		✓		✓
G2				
V1			✓	✓
V2				
M1				
M2				
K1				
K2				
	Discount in %			

Five firms took part in the bidding also in Region West, two of which submitted combinatorial bids. One firm chose to submit all three possible two-contract combinatorial bids, each with a discount of 3%, whereas the other firm submitted one combinatorial bid with a 3.5% discount. The former firm, again *CLE*, won seven of the ten contracts in the region, including the three contracts *H1*, *G1* and *V1*. As can be seen from table 10, the combination yielding the lowest cost is the package bid on (*H1+G1*), together with the single bid on *V1* (with a total cost of SEK 4 415 000). The difference between this sum and the sum of the separate bids on the three contracts (column one) amounts to 96 000 SEK. In the same way as in Region Middle, the combinatorial bids did not affect the allocation of contracts; *CLE* would also have won the seven contracts without them.

⁶ The table does not include the outcome of the bidding on the other five contracts since they could not be included in the combinatorial bid.

Table 10. CLE's Bids in Region West, thousand SEK

.Contract	Lowest separate bid	Combinatorial bid H1+ G1 (3 % discount)	Combinatorial bid H1+ (3 % discount)	bid V1 V1+ (3 % discount)	bid G1
H1	1 372	1 331	1 331		
G1	1 849	1 794			1 794
V1	1 290	(1 290)	1 252		1 252
Sum	4 511				
Winning sum		4 415			

5.2 DID THE FIELD TEST SAVE MONEY FOR THE ROAD ADMINISTRATION?

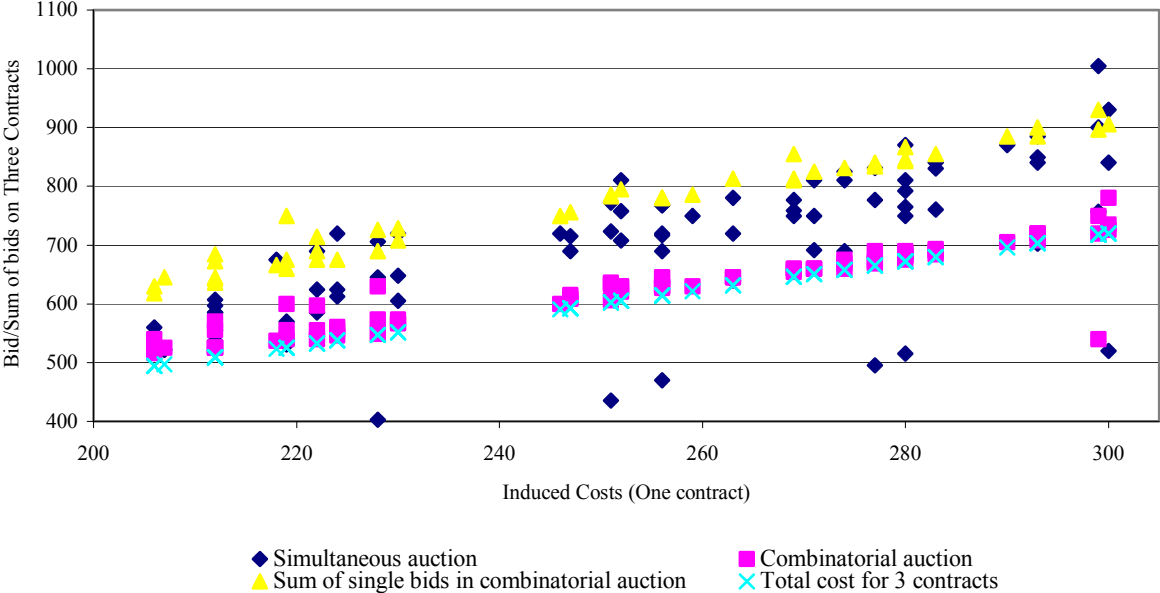
An important question is whether the option to submit package bids made the Road Administration save any money. This is certainly the case if a firm's bid on each of the contracts included in a package, mirrors the bid the firm would have submitted in an auction without combinatorial bids; if so, the Road Administration saved SEK 238 000. There are, however, grounds for calling this into question.

First, Krishna and Rosenthal (1996) show that when bidders face increasing returns of winning multiple objects, the separate bids on each object in a (second-price) sealed bid auction do not coincide with the corresponding bids in a (second-price) sealed bid auction without package bidding. In the former case, the bidder's dominant strategy is to bid his value for the single objects as well for the bundle. In the absence of package bidding, the bidder would optimally, in equilibrium, submit a bid on each object that is above his value. If similar results held for first-price auctions, the single bids in the auction without combinatorial bidding would be lower than the corresponding separate bids in an auction allowing for package bids. This result is at least valid when there are a few bidders only.

Second, by considering the behavior of *type 1* bidders in the lab experiment, we get

indications that this may indeed be the case. Figure 1 plots the observed behavior of *type 1* bidders against their induced values. Diamonds indicate the bid-sum of the three separate bids on contracts *A*, *B* and *C* in the simultaneous auction with no package bids, triangles show the bid-sum of the separate bids on contracts *A*, *B* and *C* in the combinatorial setting and the quadrants illustrate the package bids in the same auction.

Figure 1. Bidding behavior for bidders with decreasing costs in simultaneous and combinatorial auctions.



The total cost of winning all three contracts for each induced value is marked with a cross. Markings below the crosses indicate that individuals have been bidding below their induced costs.⁷ Figure 1 therefore indicates that bids in the simultaneous auction that does not allow for package bids are lower than the corresponding separate bids when allowing for package bids.⁸

Third, we also have field observations supporting the hypothesis that there is a difference

⁷ It should be noted that a number of individuals in the combinatorial auction did not submit a separate bid on each of the three contracts, thus only bidding on the ABC-package.

between the single bids on each contract in a first-price auction that allows for package bids and not, respectively. Table 11 shows *CLE*'s bids in the different counties in Region Middle and Region West over the period 1998-2001.⁹ During the period 1998-2000, *CLE* submitted identical sets of prices across the four Region Middle counties. For the year 2001, the firm seems to have abandoned this strategy, instead submitting different sets of prices across the counties. The highest bids in 2001 were submitted for those contracts that could be included in a package bid.

Table 11. *CLE*'s submitted bids (SEK) for a specific type of road marking line across counties 1998-2000

(a) Region Middle					(b) Region West					
Contract					Contract					
Year	T1	D1	CI	UI	Year	HI	GI	VI	M1	K1
1998	9.13	9.13	9.13	9.13	1998	9.45	8.8	8.8	9.45	9.65
1999	9.45	9.45	9.45	9.45	1999	10.2	9.5	9.5	10.2	-
2000	6.40	6.40	6.40	-	2000	6.8	6.8	6.8	9.5	-
2001	5.85	5.90	5.90	6.00	2001	7.25	7.1	6.8	6.6	6.6

CLE exhibits a similar bidding pattern in Region West. In previous years, it has submitted a set of prices for contracts *HI*, *GI* and *VI* that have not been higher than the bids for the other contracts. When *CLE* is then given the option to submit package bids, each bid combining two of the contracts *HI*, *GI* and *VI*, the firm raises its single bids on these contracts above the prices on the other two contracts (*M1* and *K1*), which cannot be included in a package bid.

To sum up, theoretical predictions, the lab experiment and our field data indicate that the separate bids on contracts, which are also involved in a package bid, do not reflect the separate bids that would have been submitted in a world without package bids. Therefore, it is hard to estimate if and to what extent the Road Administration reduced their procurement cost

⁸ This result also shows up when comparing the regression results for *type 1* in tables A1 and A3 (appendix).
⁹ The numbers in the table denote the bid/price *CLE* charges for painting one meter of road marking, a line

by letting firms submit package bids within the first-price sealed bid auction.¹⁰

6. SUMMARY

The research reported in this paper focuses on the fact that procurement auctions may involve contracts for a large number of similar activities, each contract – except for up to a linear transformation – being very similar to others. Based on the observed outcome of the procurement processes conducted in the last few years, it is clear that two categories of entrepreneurs, here referred to as ‘large’ and ‘small’, are awarded contracts.

Using an experimental testbed, we have demonstrated that efficiency may suffer from employing the standard, one shot, sealed bid procurement process under these circumstances. The experiments also show that efficiency is enhanced and procurement costs reduced by admitting for combination bids within the standard simultaneous mechanism. The results are based on a particular way of modeling bidders; they have economies and diseconomies in the number of contracts awarded and their costs are drawn from different supports. Moreover, one specific way of designing combination bidding has been tested while combinations may take on a number of different forms. Generalizations from our results should be drawn with these facts in mind.

Furthermore, the lab experiment was based on induced private values (costs), whereas the cost of the bidding firms in the field may, to some extent, be uncertain and affiliated. For all firms, it is somewhat more difficult and more costly to paint roads in bad weather, but, prior

which is 10 cm wide and 3 mm thick.

¹⁰ As an illustration, if we make the assumption that, in the absence of package bids, *CLE* would have submitted the same set of prices for *CI* and *UI* as it did for contract *TI*, that is, 5,85, in Region Middle, then the Road Administration would have obtained a lower procurement cost than with package bids.

to bidding, no firm knows what the weather will be during the ‘painting season’. An open bidding mechanism, where bidders can, to some extent, observe each other’s behavior, may therefore affect the firms’ perceptions of their true cost of fulfilling the contracts and, hence, the Administration’s procurement cost.¹¹ This points towards the possible benefits of a SMR auction format, which also allows for package bids.

Based on the experimental results, we suggested that the Road Administration should test combinatorial bidding and such a test has also been undertaken, albeit with many restrictions. Two regions out of seven tried out versions of combinatorial bidding on a restricted number of contracts. Firms could submit bid combinations on only a few of the contracts, and they were also permitted to place an upper limit on the number of contracts they could accept; this is a way of giving, in particular small firms, the possibility of participating in the bidding for many contracts while not risking to win ‘too many’. Despite the restrictions, this first trial saw in total 6 bids out of 32 being submitted in one way or another, making use of the possibility to submit combinational bids, and it was also these bids that won the contracts in question. However, we have not been able to establish whether the Road Administration actually made any financial saving from the trial.

Throughout the trials, the agency feared that the possibility to submit combinatorial bids would make it easier for a large firm to win a large number of contracts, thereby jeopardizing the industry’s long run competitive pressure. Our data in combination with theoretical results by Krishna & Rosenthal (1996) confirm that this may be a risk, at least if there is only a small number of ‘large’ bidders. Even with modest scale economies, it takes a certain competitive pressure amongst the large firms to avoid this pitfall, at least when the number of contracts is

¹¹ For a discussion on how individuals’ beliefs about costs and characteristics may be related to elicitation

large.

One way around the problem could be to require bidders to submit both package and stand-alone bids, a restriction imposed by the Road Administration officials. The chance that bids from small firms can be combined with the stand-alone bids of large operators would then be greater. This could indeed be countered if large firms submit stand-alone bids that are very large, precisely in order to avoid this obvious threat. A possible complementary restriction would then be to put an upper limit on the discount, i.e. that it could not exceed, say, 5-10% of the stand-alone bid. If anything, this demonstrates the importance of being careful in designing the details of any new method for handling age-old problems.

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Appendix

Analysis of individual bidding behavior

Conjectures under Simultaneous Bidding

The average bid of *type 1* (*type 2*) bidders is below (above) the induced cost in order to increase the chance of winning all projects (reduce the risk of winning all projects at too low bids). There is no systematic difference between bids on projects *A*, *B* and *C*. To test the conjectures, we estimate equation (A1)

$$BID_{i,k} = \beta_1 COST_i + \beta_2 D_i^B + \beta_3 D_i^C + \varepsilon_i \quad (A1)$$

where $i = 1, 2$ (*type 1*), $i = 3, 4, 5$ (*type 2*) and $k = A, B, C$. The dependent variable, BID_i , is the bid on a specific contract, $COST$ denotes the induced cost of winning a single contract and the two dummies D^B and D^C take the value 1 if the dependent variable reflects a bid on contract *B* and contract *C*, respectively. The regression results summarized in table A1 confirm these conjectures. On average, large bidders place bids five percent below the cost while small bidders add 18 percent to the cost on an average bid. Neither dummy variable coefficient is significant, indicating that bidders, given their type, placed identical bids on the three contracts.

Table A1: Bidding behavior across types – simultaneous auction

Variable	Type 1		Type 2	
	All periods	Period >5	All periods	Period >5
<i>COST</i>	0,95* (0,009)	0,95* (0,009)	1,18* (0,019)	1,18* (0,025)
D^B	-3,25 (3,14)	-0,72 (3,25)	5,78 (5,18)	5,34 (6,88)
D^C	-1,44 (3,19)	-0,65 (3,32)	2,14 (5,17)	-0,20 (6,88)
<i>N</i>	228	140	350	216

Standard error in parentheses, *significant at the (at least) 5 % level

Conjectures under Sequential Bidding

The average bid of *type 1* (*type 2*) is below (above) the induced cost in order to increase (reduce) the chance of winning all contracts. *Type 1* bidders then reduce their bids after having won a contract and without a win they increase their bids. *Type 2* bidders increase their bids after having won a contract, and without a win, they do not change their bidding behavior. To test the conjectures, we estimate equation (A2). The five dummy variables are used to represent the outcomes as given below and the regression results are summarized in table A2.

$$BID_{i,k} = \beta_1 COST_i + \beta_2 D_i^1 + \beta_3 D_i^2 + \beta_4 D_i^3 + \beta_5 D_i^4 + \beta_6 D_i^5 + \varepsilon_i \quad (A2)$$

$D^1 = 1$ if bid on *B* when *A* is won

$D^2 = 1$ if bid on *B* when *A* is NOT won

$D^3 = 1$ if bid on *C* when *A* OR *B* is won

$D^4 = 1$ if bid on *C* when *A* AND *B* is won

$D^5 = 1$ if bid on *C* when neither *A* nor *B* is won

Table A2: Bidding behavior across types – sequential auction

Variable	Type 1		Type 2	
	All periods	Period >5	All periods	Period >5
<i>COST</i>	0,91*	0,93*	1,04*	1,04*
	(0,008)	(0,006)	(0,004)	(0,004)
D^1	-9,74	-10,37*	22,63*	24,63*
	(6,73)	(4,56)	(1,60)	(1,63)
D^2	3,79	7,28*	-2,32*	-1,73
	(3,03)	(2,24)	(1,17)	(1,16)
D^3	-6,66	-1,38	23,90*	28,31*
	(6,17)	(4,56)	(1,51)	(1,5)
D^4	-13,87	-15,33*	54,15*	55,62*
	(8,90)	(5,93)	(2,52)	(2,62)
D^5	17,71*	18,21*	-4,49*	-3,87*
	(3,20)	(2,39)	(1,27)	(1,28)
<i>N</i>	258	168	405	270

Standard error in parentheses, *significant at the (at least) 5 % level

Considering the behavior of *type 2* it is clear that the conjecture regarding D^5 is not confirmed by data. If these bidders have not won any item before, they seem to change their bidding

behavior in the last round. This could possibly be a result of subjects not being informed about whether a *type 1* or *type 2* bidder had been awarded previous contracts. In other respects, our conjectures are not contradicted by observed behavior, however.

Conjectures under Combinatorial Bidding

Under this mechanism, up to seven bids from each bidder were received. For our purpose, this is partially redundant information since a bid on the single project *A* in all respects provides the same information as a bid on the single project *B*, which once more is the same as the bid on a single project *C*; no bidder will be awarded more than one contract based on the singleton-bids. The same argument is relevant for bids on two-pairs. The seven observations have therefore been boiled down to three: (i) the bidder's lowest bid on singletons *A*, *B* and *C*; (ii) the bidder's lowest bid on two-pairs *AB*, *AC* and *BC* (divided by two to allow for comparison with the induced cost); (iii) the bidder's bid on *ABC* (divided by three).

We conjecture that the average *type 1* bidder does not submit a singleton bid below his induced cost, and that his two combination and three combinations bids reflect the decreasing average cost of winning two and three contracts. The three bids of the average *type 2* bidder on varying numbers of contracts will exhibit his increasing average cost. The following equation is estimated for the two types of bidders, within the combinatorial mechanism

$$BID_{i,k} = \beta_1 COST_i + \beta_2 D_i^1 + \beta_3 D_i^2 + \varepsilon_i \quad . \quad (A3)$$

The subscript *k* indicates whether *BID* is the bidder's (lowest) singleton bid, his (lowest) combinatorial bid on two contracts or his three-contract combinatorial bid. *COST_i* is the bidder's induced cost of winning a single contract. The dummy variables *D¹* and *D²* take on

the value 1 if *BID* is a two-contract combinatorial bid and the three-contract combinatorial bid, respectively. The regression results are presented in table A3.

For both types, the singleton bids are very close to their induced cost. The option to submit combinatorial bids on packages of two and three enables the *type 1* bidder to bid a lower average price for two and three contracts. The average *type 2* bidder exhibits the inverse behavior, that is, bidding a higher average price for the two- and three-contract combinations in order to compensate for his increasing average cost of winning more than one contract.

Table A3: Bidding behavior across types – combinatorial auction

Variable	<i>Type 1</i>		<i>Type 2</i>	
	All periods	Period >5	All periods	Period >5
<i>Cost</i>	1,00* (0,005)	1,00* (0,005)	1,03* (0,004)	1,02* (0,003)
<i>D¹</i>	-21,02* (1,69)	-20,09* (1,72)	17,94* (1,07)	18,31* (0,98)
<i>D²</i>	-45,55* (1,66)	-43,07* (1,68)	36,27* (1,12)	37,99* (1,02)
<i>N</i>	205	131	327	207

Standard error in parentheses, *significant at the (at least) 5 % level

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