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DIFFERENT DESIGN – DIFFERENT COST: AN EMPIRICAL ANALYSIS OF COMBINATORIAL PUBLIC PROCUREMENT BIDDING OF ROAD MAINTENANCE

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ABSTRACT. This paper is an empirical analysis of first-price sealed-bid procurement auctions in Sweden, with and without combinatorial bidding. The data comprises procurement auctions of identical contracts (road resurfacing) with identical bidders conducted under the same time period (2009-2011) in two different regions in Sweden. Given the comparison of the suppliers' offered price per tons of asphalt, we cannot reject the hypothesis of identical distribution of standalone bids generated in both types of auction. The distribution of package bids within the combinatorial format is significantly lower than the distribution of standalone bids within the non-combinatorial format, suggesting substantial cost reduction of allowing package bidding. Also, within the combinatorial format, our analysis of data indicates higher costs when packages are predetermined by the purchaser rather than chosen freely by the suppliers.

INTRODUCTION

Combinatorial bidding has been applied in a number of public procurement auctions in Sweden for the last ten years. The contracts have comprised both goods and services. Overall, the bidding mechanism has been the first-price sealed-bid format in which the supplier can offer a discount if awarded a package of contracts,

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pre-determined by the purchaser or arbitrarily chosen by the supplier. In many of these auctions, a supplier also had the option to express limitations in her capacity to fulfill more that a certain number of contracts auctioned out. In an addendum to her stand-alone bids on single contracts, the supplier could state that she was only prepared to accept a maximum number of contracts, contracts up to a given maximum contract value or contracts up to a given maximum physical volume. The combinatorial mechanism has the advantage that it enables both smaller and larger suppliers to bid more competitively on more contracts without being exposed to the risk of winning too few or too many contracts. Hence, the mechanism has the potential to both lower the price paid by the procuring authority and enhance efficiency.[1]

Within the first-price sealed-bid format, the purchaser may for various reasons impose restrictions upon the bidding procedure when combinatorial bids are allowed. Firstly, a supplier is often required to place a standalone bid for every contract included in one or several combinatorial bids. The reason is to avoid a potential unsolvable allocation of contracts (the dead-lock problem).

Secondly, in order to reduce suppliers' incentives to engage in "predatory bidding", the purchaser may limit the size of the maximum discount allowed in a combinatorial bids. A salient feature with combinatorial bidding is that a supplier's standalone bid for a specific contract, that also is part of one or several combinatorial bids, may compete against the supplier's own combinatorial bids. By placing extremely high standalone bids on those contracts, in combination with a combinatorial bid implying a very high discount, say 80 to 90 percent, a (global) supplier effectively blocks his standalone bids to be part of any winning combination. In this way, a global supplier may try to shut out those local suppliers, that to a large extend only submit standalone bids, from the competition. Setting a limit on the maximum discount forces the global supplier to place relatively low standalone bids if he wishes to bid aggressively with his combinatorial bids. As a result, the competitiveness of the standalone bids of others is strengthened. Thirdly, the purchaser may restrict the maximum number of contracts allowed to enter in a combinatorial bid in order to reduce the competitive power of global bidders *vis-a-vis* local bidders. The obvious potential drawback with the restrictions aiming to reduce the power of global bidders is that the purchaser may not be able to fully exploit potentially substantial synergies in large combinations.

In this paper we try to empirically assess the effects on bidding behavior within a first-price sealed-bid combinatorial auction in two dimensions. Firstly, we compare the bids generated in a non-combinatorial format with the bids generated in a combinatorial format. Secondly, within the combinatorial format, we analyze to what extent bidding behavior is affected when the purchaser predetermines the packages allowed to bid for, instead of letting the suppliers themselves decide the composition of packages. The data analyzed in the paper is collected from public procurement of road resurfacing in Sweden. The Swedish Road Administration (SRA) has used combinatorial first-price sealed-bid auctions to a greater or lessere extent in various regions of Sweden when procuring asphalt since 2001. Here we make use of the observed bids from the yearly procurement of asphalt in two Swedish regions, Region A and Region B henceforth for the years 2009-2011.[2] Within each region, multiple asphalt contracts were procured simultaneously, but independently across the regions. In Region A combinatorial bidding was not allowed during the period, whereas in Region B suppliers had the option to bid on packages of contracts. However, in the latter region, the SRA constrained the maximum number of contracts allowed to be included in any combinatorial bid. In the procurement of contracts 2009-2010, suppliers were free to place a bid on any arbitrary combination of contracts as long as the total number of contracts included in a combinatorial bid did not exceed the maximum number allowed. In the year 2011 this constraint was sharpened. The SRA then specified which packages of contracts one would be allowed to bid for.

In our paper we investigate whether the change in the bidding constraint on combinatorial bidding has had any effect upon bidding behavior. The procured services, resurfacing of national roads, are very homogeneous across the two regions and across the three years, and almost the same set of bidding firms are found in the data. To some extent, our analysis resembles the analysis of data from a field experiment. Our treatment variable “level of package constraint” has three outcomes; (i) no combinatorial bids allowed; (ii) bids allowed only on predetermined packages; (iii) free package bidding. Our analysis shows that the bidders offer lower prices per ton of asphalt when combinatorial bidding is optional but these gains are reduced when the packages are predetermined by the purchaser.

The paper is organized as follows. In section 2 we refer to some related results on bidding behavior in first-price sealed-bid auctions of multiple units. Section 3 presents the data and the bidding environment from which the data is collected. In section 4 we compare the distribution of bids across bidding format. Section 5 contains a comparison of the distribution of bids within the combinatorial format, generated under two different constraints concerning the maximum size of a package. Section 6 concludes.

RELATED LITERATURE

The study of combinatorial auctions has increased rapidly during the last decade. Due to the interdisciplinary nature of combinatorial auctions, various aspects of the mechanism have been in focus.[3]From the computer scientists' and mathematicians' perspective, central issues of combinatorial auctions have been the winner determination problem and the bidding language. Economists have been more devoted to investigate the economic properties of combinatorial auctions, but the game theoretic complexity of these auctions has made it difficult to derive general predictions concerning behavior and revenue ranking similar to what has been achieved in single object auctions. Nevertheless, there exists a number of experimental studies exploring the differences across bidding mechanisms in a heterogeneous multi-object environment. The general picture in these experiments is that combinatorial bidding generates higher revenues and higher efficiency than other mechanisms do in the presence of synergies across objects.[4] However, the few theoretical contributions there are, providing equilibrium strategies in multi-unit auctions, indicate that combinatorial bidding is inferior to simultaneous auctions in terms of revenues to the seller. A related work to our study is Chernomaz and Levin (2012). They analytically and experimentally analyzed bidding strategies for two types of bidding rules within a first-price sealed-bid auction, with two local bidders and one global bidder, where one object is for sale in each of two markets.[5] In their model, the local bidders demand only one object each, whereas the global bidder demands both objects, that is, in each of the two markets two bidders are active: a local bidder and the global bidder. Under the first rule -

the separate rule - bids are submitted simultaneously and the outcome in one market is determined independently of the outcome in the other market. Under the second rule - the package rule - the global bidder places a package bid for both objects. The outcome in each market is then determined by considering the bids in both markets. In their experiment, the package rule is tested in two ways: (1) the global bidder is allowed to only place a cross-market package bid for the two objects; (2) in addition to the package bid, the global bidders is allowed to submit a standalone bid in each market. In their stripped-down model Chernomaz and Levin showed that the package rule generates lower expected revenues to the seller than does the separate rule.[6]The reason is that the combinatorial mechanism introduces free-riding incentives for local bidders which make them bid less aggressively than they do in two separate auctions. Also, it is shown that a global bidder is better of by setting her standalone bids to zero, i.e., submitting only the package bid. The experimental results indicate that their derived predictions are consistent with observed behavior. However, within the package rule, revenues are only lower when the global bidder is not allowed to place standalone bids on the individual items. When this constraint is relaxed, then the reversed result is obtained: package bidding generates higher revenues than does separate bidding.

There exist a relatively large number of empirical studies on the use of combinatorial procurement auction, especially on how the mechanism has been implemented in the procurement of transportation services (see for example De Vries et al. ,2003; Sheffi, 2004; Cantillon et al., 2006; Epstein et al., 2011; Lunander & Lundberg, 2012a, for various surveys.) A general impression of these studies is that the adoption of combinatorial bidding has been fruitful and has lowered procurement cost. However, the number of empirical studies comparing bidding behavior in procurement auctions with and without package bidding is limited. Lunander and Lundberg (2012b) analyzed data from first-price sealed-bid procurement auctions of Swedish public cleaning contracts, where firms in some of the auctions have had the option to bid on packages of contracts. They found that bids on individual contracts in simultaneous, non-combinatorial auctions are lower than the corresponding standalone bids in combinatorial auctions. Further, they found no significant differences in costs across the bidding mechanisms.

THE PROCUREMENT PROCESS AND THE DATA

Every year the SRA contracts firms for asphalt resurfacing within its different regions. Asphalt resurfacing in Sweden is characterized by a relatively high degree of homogeneity with different suppliers offering similar quality and performance. Most suppliers operate over the whole of Sweden and submit tenders for contracts in all regions. Contracts are mostly awarded on the basis of price alone. The number of contracts auctioned out in the regions varies across years and regions. In most regions, bids on each contract are evaluated independently, but in two of the regions, the SRA has allowed to some extent for combinatorial bids since 2001. There has never been an option for suppliers to submit bids on bundles of contracts across regions. The data collected for this study is taken from two, partly adjacent regions situated in the middle of Sweden. Combinatorial bidding has been allowed only in one of the regions (region B) but not in the other region (region A).

About two months before the bidding deadline in a specific region, the SRA publishes a tender request document. Besides the formal conditions, the document contains information about the demanded volume of asphalt, the dimensions of the roads to be resurfaced, the number of road signs to be replaced, provision for new water drainage pipes, etc. The bid is then submitted as the supplier's total price for carrying out the contracts(s). In order to compare the bids across contracts, regions and years, we divided the bids on a contract by the volume of demanded asphalt for that particular contract. Table 1 provides the summary statistics of our data.

Although all contracts *de facto* more or less differ in various ways (volume of asphalt to be re-laid, differences in the types of side-work to be carried out, etc), we observed that the variation in submitted bids to a very large extent can be explained by the variation in the volume of asphalt only. The relation between the bids and the size of the contacts is estimated in Equation 1:

$$\ln\left(\text{standalonebid}_{\text{i,j}}\right) = \alpha + \beta_1 \times \ln Ton_j + \beta_2 \times D_{\text{Region B}} + \beta_3 D_{2010} + \beta_4 \times D_{2011} + \varepsilon_{i,j} \qquad (1)$$

Where the superscripts *i* and *j* denote the supplier *i* bidding for contract *j*.

TABLE 1
Descriptive Statistics (Euro per Ton Asphalt, 2010 Prices)

	Region A			Region B		
	2009	2010	2011	2009	2010	2011
Number of contracts	6	4	10	7	9	8
Volume (tones of asphalt)	137,287	84,002	189,192	253,695	251,214	201,109
Number of bidders	4	4	5	6	6	5
Number of stand-alone bids	19	15	40	32	35	31
Bid (€/ton) average	67.04	98.47	96.92	81.45	91.44	88.94
std. dev	10.90	11.85	16.05	24.62	17.17	13.39
min-max	48-86	77-115	77-147	41-145	72-152	68-115
Number of package bids	-	-	-	16	43	12
Bid (€/ton) average	-	-	-	67.75	81,93	87.31
std. dev	-	-	-	17.95	4,00	5,23
min-max	-	-	-	47-114	73-92	79-97

The estimation results presented in Table 2 indicate that almost 90% of the variation in the stand-alone bids is explained by variation in contract size, that is, tons of asphalt, when using dummies to control for location (Region) and time (Year). Hence, the potential loss of information by transforming the observed bids into offered prices per ton of asphalt can be neglected.

The estimation result in Table 2 also reveals that there is no significant effect on standalone bids across regions but there exists a

TABLE 2
Estimation Results: Total Bids

Variable	Coefficient	t-ratio
Ton	0.806	33.90
Region B	0.047	1.69
Year 2010	0.183	5.30
Year 2011	0.177	5.46
α	6.24	25.95
n = 172, r^2 = 0.89		

real price effect across years. The offered real prices are substantially higher for 2010 and 2011 when compared to 2009. Running the same regression where year 2010 is replaced with year 2009 does not indicate that there is a real effect on prices between years 2010 and 2011.

ESTIMATED DIFFERENCES IN BIDDING BEHAVIOR ACROSS MECHANISMS

Standalone Bids and Bidding Mechanism

As discussed above, there is an incentive for a supplier, who submits a package bid for a set of contracts, to increase his standalone bids for the same set of contracts. This increase reduces the risk that his standalone bids, together with the bids of others, will outperform the supplier's own package bid. Given that the variation in contracts sizes (tons of asphalt) to a large extent explains the variation in bids, and that almost identical suppliers bid in both regions, we may regard an observed difference in bids across the two regions as being the result of using different bidding mechanisms, that is, a treatment effect. For that reasons, we rename the dummy variable *Region* to *Format*, which indicates the use of the combinatorial format. The results in Table 2 show that we cannot reject the hypothesis of identical standalone bids across regions, that is, the predicted increase of the standalone bids due to package bidding is not supported by data. Dividing each standalone bid by the corresponding tons of asphalt and re-estimating Equation 1, we see in Table 3 that the bid per ton is decreasing in contract size, which suggests synergies in the number of tons won.[7]

TABLE 3
Estimation Results: Stand-Alone Bids per Ton

Variable	Coefficient	t-ratio
Ton	-0.193	-8.13
Format	0.047	1.69
Year 2010	0.183	5.30
Year 2011	0.177	5.46
α	6.24	25.95
n = 172, r^2 = 0.44		

The estimated non-significant difference in standalone bids across bidding formats differs from the results obtained in Lunander and Lundberg (2012b) who observed higher standalone bids when package bidding was an option.

The Impact of Allowing Package Bidding

In this section we compare the bids per unit generated in the non-combinatorial mechanism with the package bids per unit generated in the combinatorial format. Again, the dummy variable *Format* in equation 2 captures the difference in the average offered price per ton across the mechanisms.

$$ln\left(bid\ \ per\ ton\right)_i = \alpha + \beta_1 \times Format\ + \beta_2 D_{2010}\ + \beta_3 \times D_{2011}\ + \varepsilon_i \quad (2)$$

The results in Table 4 show that the distribution of offered prices per ton asphalt is significantly lower when the combinatorial mechanism is applied. To illustrate the differences across auction mechanisms without having to consider the year effects, we compared the distributions of the unit bids for the year 2010 in two separate t-tests. The plotted bids in Figure 1 shows that the bids in the non-combinatorial format and the standalone bids in the combinatorial format are clustered on a higher price level than the package unit prices are.

The t-tests in Table 5 confirm the differences in distributions. The average offered price (Euro/ton) within the combinatorial format is about 10% lower than the corresponding price from the non-combinatorial mechanism.

TABLE 4
Standalone Bids and Package Bids

Variable	Coefficient	t-ratio
Format	-0.100	-3.78
Year 2010	0.290	9.22
Year 2011	0.328	10.33
α	4.234	156.89
n = 145, r^2 = 0.51		

FIGURE 1
Standalone Bids and Package Bids in 2010, Both Regions

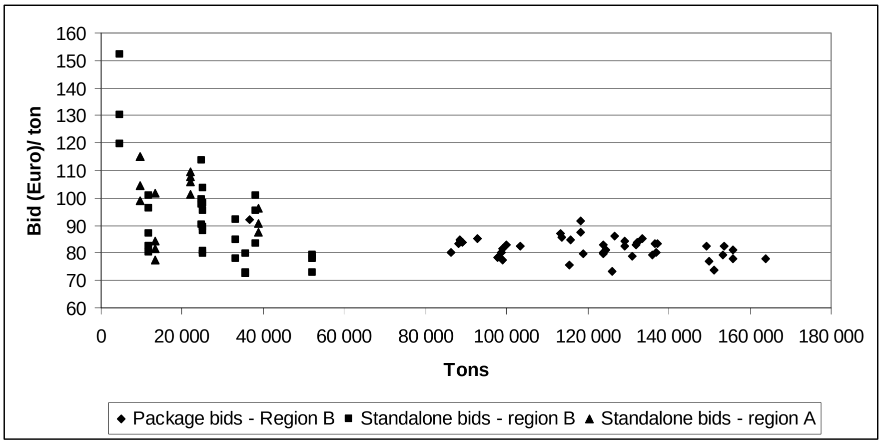


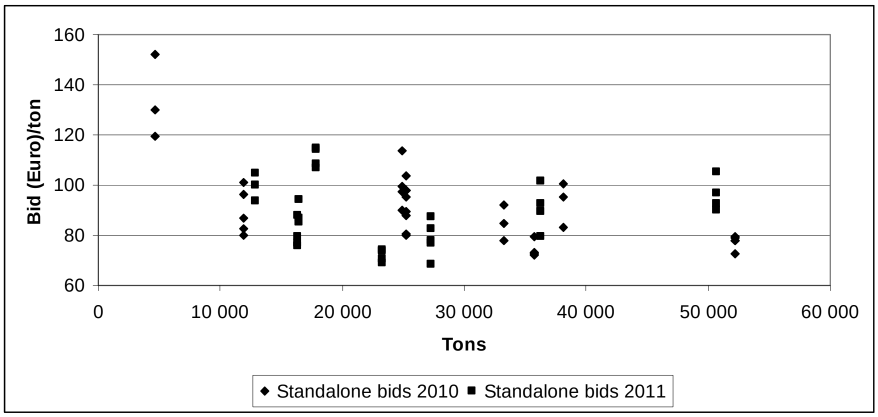
TABLE 5
t-Tests of Distribution of Bids (Euro/Ton)

	Bids, non-combinatorial auction	Stand-alone bids, combinatorial auction	Bids, non-Combinatorial auction	Package bids, combinatorial auction
Mean	97.08	91.44	97.08	81.93
Std dev	11.11	17.17	11.11	4
N	15	35	15	43
t-test	1.17		7.72	

ESTIMATED DIFFERENCES IN BIDDING BEHAVIOR WITHIN A MECHANISM

The analysis above focused on the data generated in first-price sealed-bid auctions with and without package bidding. We have estimated the impact on bidding behavior when bidders are exposed to different auction mechanisms. Below we compared observed bidding behavior within the same auction mechanism.

FIGURE 2
Stand-alone Bids in Region B, 2010-2011



The design of the combinatorial mechanism used in 2009 and in 2010 in region B differed slightly from that applied in 2011 (Figure 2).

For the years 2009-2010 suppliers were free to bid on any combination of contracts as long as the total number of contracts making up the package did not exceed 3 contracts in 2009 and 5 contracts in 2010. In 2011 the packages were predetermined by the purchaser. There were six packages and the largest package contained three contracts. Figure 3 shows our plotting of the standalone bids for both years. The plot indicates decreasing unit bid in the number of tons, but no systematic differences in bid level between the years.

Regression Equation 3 was used to test the hypothesis of identical distribution of standalone bids generated under the two package rules applied. The dummy variable *Constrained* is used to denote the bids generated under the constrained combinatorial mechanism with pre-determined packages.

$$ln(standalonebid\ per ton)_{i,j} = \alpha + \beta_1 \times \ln ton_j + \beta_2 \times Constrained + \varepsilon_{i,j} \qquad (3)$$

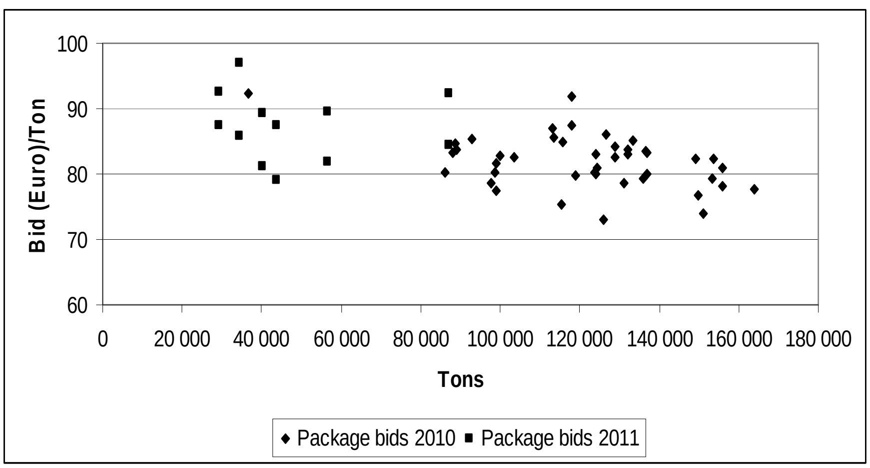
The estimation result in Table 6 shows that we cannot reject the hypothesis of identically distributed standalone bids under the two types of package bidding design.

TABLE 6
Distribution of Stand-alone Bids 2010-2011

Variable	Coefficient	t-ratio
Ton	-0.139	-4.48
Constrained	-0.026	-0.74
α	5.906	18.78
n = 66, r^2 = 0.25		

Looking at the distribution of the package bids across the two designs of the combinatorial auction, we observed a significant difference. The plot in Figure 3 indicates higher offered package prices per ton asphalt when the packages are predetermined rather than when they are allowed to be chosen arbitrarily by the suppliers.

FIGURE 3
Package Bids under Different Bidding Constraints



A t-test rejects the hypothesis of equally distributed package bids. Our data suggests that the suppliers offered 6% lower prices when they were free to choose their own combinations of contracts rather than when they were predetermined by the purchaser.

TABLE 7
Package Bids and Type of Design

Variable	*n*	*Mean*	*Std. error*
Package bid, unconstrained design	43	81.93	4.00
Package bid, constrained design	12	87.31	5.23
t-ratio		-3.85	

CONCLUSION

Using data from first price sealed-bid procurement auctions with and without package bidding, we have found empirical evidence that allowing for package bids, in a bidding environment characterized by synergies, generates lower bids than does the non-package mechanism. Our findings are in line with a number of previous experimental and empirical studies. The comparison of bids from the non-combinatorial format with the standalone bids from the combinatorial format shows no significant difference, suggesting non-increased standalone bids in the combinatorial mechanism. Also, our analysis of data shows that the suppliers are willing to offer lower prices if they are allowed to make up their own packages instead of having them predetermined. In our study, the purchaser imposed a number of restrictions on the bidding behavior, such as demanding a standalone bid for every contract included in one or several combinatorial bids, limiting both the size of the maximum discount and the maximum number of contracts allowed to have in a package. To what extent our results are driven by those restrictions is difficult to assess. However, given the theoretical predictions derived by Chernomaz and Levin (2012) and the observed outcome in their experiments, we believe from a policy maker's point of view, that those restrictions are more or less necessary to impose in order to achieve a desired result. Otherwise, the implementation of a combinatorial procurement auction may lead to the opening of Pandora's box.

ACKNOWLEDGMENTS

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NOTES

1. See Lunander and Lundberg (2012) for a review of the design, implementation and of the outcome from a number of combinatorial first-price public procurement auctions carried out in Sweden during the period 2003-2010.
2. Region Mälardalen (A) and Region Mitt (B).
3. See Cramton et al. (2006) for a comprehensive work on combinatorial auctions.
4. See Chernomaz and Levin (2012) for a summary of some previous experiments.
5. See also Krishna and Rosenthal (1996) who analyze bidding behavior in a sealed bid, second-price price auction with and without package bids.
6. A similar result is derived by Krishna and Rosenthal (1996) in a second-price sealed bid auction.
7. In figures A1-A3 (appendix) we have, for each year, plotted bids per ton as a function of number of tons.

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APPENDIX

FIGURE A1
Stand-alone Bids 2009

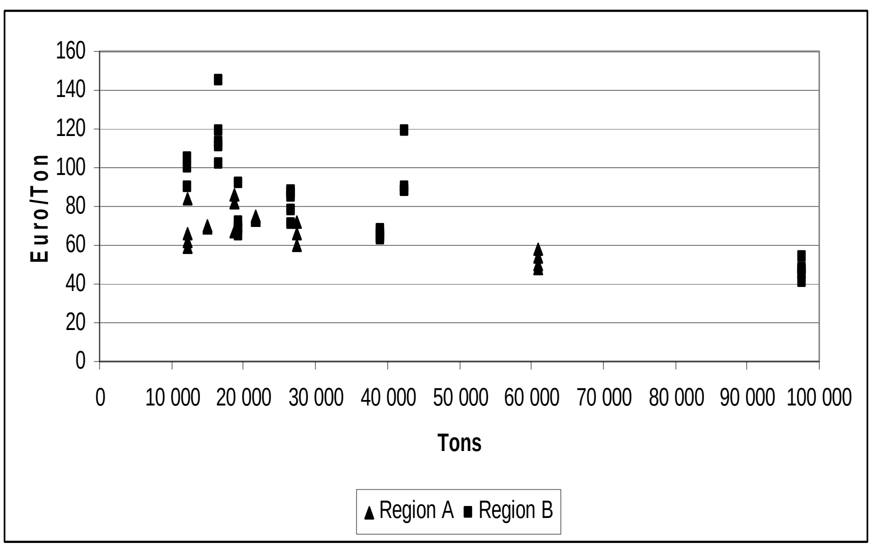

FIGURE A2
Stand-alone Bids 2010

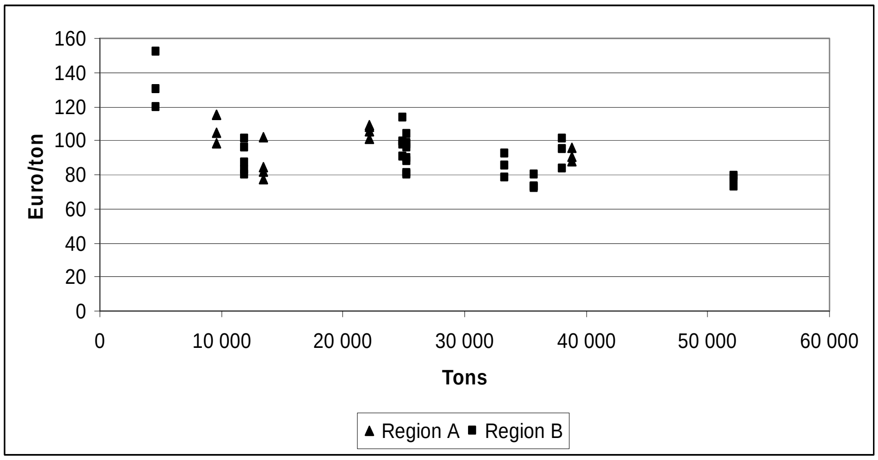

FIGURE A3
Stand-alone Bids 2011