



## Detection of anomalous bids in procurement auctions

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### ARTICLE INFO

#### Article history:

Received 4 October 2007

Received in revised form 4 August 2008

Accepted 24 August 2008

Available online 3 September 2008

#### Keywords:

Procurement

Auctions

Anomalous bids

Statistical detection algorithms

### ABSTRACT

Procurement auctions may be affected by abnormally low bids, whose acceptance may have negative consequences on the auctioneer. A method, based on the average submitted bid, is considered to detect such anomalous bids and aid the auctioneer in the possible rejection decision. Analytical expressions or simulation results are provided for the detection probability and for the false alarm probability. The performances heavily depend on the number of tenderers and on the dispersion of bid values. Both performance indices improve as the number of tenderers grows and generally degrade as the dispersion grows. The presence of multiple anomalous bids leads to a significant worsening of the performance, while courtesy bids raise both the false alarm probability and the detection probability. The use of the average-bid criterion, though officially endorsed in national legislations, is therefore recommended as a strongly precautionary criterion, i.e. when the need to avoid anomalous bids is considered much more relevant than the costs associated to deeper investigation of anomalous bids or to the erroneous rejection of regular bids.

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### 1. Introduction

Procurement of goods, services, or public works is often accomplished by reverse auctions, where suppliers provide their competitive biddings to a buyer [7,8]. Each supplier indicates the minimum price at which it is willing to undertake the work or provide the goods/services. Through this competition auctions appear as an effective way of reducing prices for the buyer. Since the assignment is typically awarded to the supplier providing the lowest bid, each tenderer is spurred to provide the lowest possible bid, taking into account the expected level of competition and its expected rate of return (we assume anyway that competitors are not informed of the bids of one another, which could lead to forms of cheating as described in [27]). However, in some circumstances the behaviour of the tenderer may deviate from these guidelines. For example, it may be in desperate need of obtaining a contract, though it may turn into a financial loss. Or it may aim at ousting a potential competitor (the phenomenon of predatory bidding [1]). In some cases it may even present a non-competitive bid, i.e. a bid just a bit higher than the expected competitors so to have a very small probability of winning (the phenomenon of cover pricing), with the aim of staying in favour with the auctioneer by showing interest in the auction (hence such bids are also known as courtesy bids) [31]. In all these cases the tenderer presents an anomalous bid, whose value has been set by a line of

reasoning different from that of regular competitors. Such anomalous bids represent a distortion in the regular execution of an auction. In particular, abnormally low bids, leading to awarding the contract to a supplier that could end up not providing the goods/services, are a cause of deep concern and have come to the attention of the European Union [13]. The negative consequences on the auctioneer's activity can be avoided if the anomalous bids are detected and their submitters subject to a deeper investigation, hence the need for a criterion to identify anomalous bids and support the auctioneer in the rejection decision. Decision support systems are an established tool to aid the auctioneer in auction operations such as this [25].

In the statistical literature observations that stand outside the bulk of the data (a characteristic common to both abnormally low bids and courtesy bids) are typically designated as outliers. Many statistical tests have been proposed for the general problem of identifying and removing outliers. Two surveys of such methods can be found in [2] and [34], while the most prominent one is described in the seminal paper by Grubbs [16,35]. In addition, some tests have been devised for the specific purpose of detecting bids due to cover pricing (i.e. abnormally high) and have been examined e.g. in [19,30,31,33]. Instead a number of schemes, typically different from the ones above mentioned, have been introduced in the grey literature for the detection of abnormally low bids. Examples are the national regulations in Spain [20,21], Italy [28], Germany, and Turkey [37]. However, the introduction of these schemes has not been accompanied by a proper evaluation of their performances, namely of their capability to detect anomalous bids without declaring as anomalous otherwise regular bids (which we may call a false alarm).

In this paper we provide analytical expressions and simulation results for two performance indices of detection schemes: the

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detection probability and the false alarm probability. We focus on a class of detection schemes for abnormally low bids (hereafter we will use the generic term of anomalous bids), based on the use of the average bid. A particular version of such scheme has been officially adopted by public bodies in Spain and Italy. Its relevance lies in its official endorsement, though it has so far escaped a proper evaluation. Some background information on procurement auctions is provided in Section 2, while the average-bid detection scheme itself is described in Section 5. The reference model for the bid distribution needed to perform our evaluation is provided in Section 3, while the performance indices are defined in Section 4. The evaluation is finally conducted in Sections 6 (detection probability) and 7 (false alarm probability) for the case of a single anomalous bid. The case of multiple anomalous bids is instead studied in Section 8. In addition, the influence of the presence of courtesy bids (abnormally high) on the detection of abnormally low bids is evaluated in Section 9.

## 2. Procurement auctions and anomalous bids

Auctions (actually reverse auctions) are now an established means of accomplishing procurement activities as opposed to negotiation or direct purchasing through catalogs [8]. In reverse auctions all tenderers provide their bid, indicating the minimum price at which they are willing to provide the goods or services up for auction. A number of auction formats have been devised, differing essentially for the way the auction is conducted and for the way the contract is awarded [17]. A well established format in procurement auctions is the sealed bid tendering, where all tenders are made known at the same time (for the purpose of this paper the terms tender and bid, and analogously tenderer and bidder, are considered synonymous). When the auction is based on price considerations only (e.g. because the required characteristics of the item up for auction have been well defined and are therefore not a discriminant among different tenders) the contract is generally awarded to the tenderer submitting the lowest bid. Each bidder is then induced to submit the lowest bid it can under its financial constraints (e.g. a minimum expected rate of return for its activities) and considering the expected competition from the other tenderers. The natural incentive to submit the lowest possible bid can however turn into an anomalous behaviour when the tendering company submits too low a bid. Such anomalous bids have received a considerable attention in the latest years, due to the distortion they introduce in the procurement activities. A precise definition has also been attempted by the European Union, according to which a tender is assumed to be abnormally low if the following two conditions are met at the same time [13]:

- i. In the light of the client's preliminary estimate and of all the tenders submitted, the tender seems to be abnormally low by not providing a margin for a normal level of profit;
- ii. The tenderer cannot explain its price on the basis of the economy of the construction method, or the technical solution chosen, or the exceptionally favourable conditions available to the tenderer, or the originality of the work proposed.

Several researchers have examined the reasons for such behaviour [1,5,10]. A list of possible reasons is reported below:

- i. The bidder underestimates its cost (due to irrationality or bad performance of its budgeting department);
- ii. The bidder expects to renegotiate the contract later, e.g. when it is too costly for the auctioneer to replace the winning company;
- iii. The bidder's financial conditions are very bad, leading it to use the awarded contract as a bridging opportunity (just surviving and waiting for better times), since the company's possible losses are upper bounded by the possibility of going bankrupt;
- iv. The bidder may aim at ousting a competitor (a.k.a. predatory bidding).

If the procurement procedure allows so, the bidder, after submitting its bid, could recognize its mistake leading to an excessively low bid and revise its bid accordingly. A procedure including such second stage adjustment of bids has been proposed in [36]. Such mechanism, lying halfway between the sealed bid auction and the multiple rounds involved in a descending or ascending auction, doesn't seem to have been widely adopted and is not further considered here.

Whatever the reason for the abnormally low bid the contracting authority shall typically act in two stages, first examining the distribution of bid values (and maybe comparing them with an expected cost basis) in order to detect the presence of anomalous bids, and then performing a deeper investigation of the tender labelled as anomalous. The second stage analysis will say if that bid is reasonable, i.e. supported by the actual operating conditioning of the tendering company, and lead to reject it if that's not the case. Such two-stage strategy is actually suggested by Article 55 of 2004 EU Directive [11], according to which "the contracting authority shall, before it may reject those tenders, request in writing details of the constituent elements of the tender which it considers relevant." As an alternative to such reactive strategy, the auctioneer could have the auction preceded by a prequalification phase, where prospective bidders are screened for the purpose of eliminating those that don't appear sufficiently reliable to perform the work if awarded the contract. Such prequalification may be conducted by looking e.g. at the size and reputation of contractors, or at their previous participation at similar contests. However, if (as it happens) the prices requested in previously submitted bids are a screening variable, the prequalification may result in those contractors submitting higher prices being eliminated rather than those submitting too low bids [9]. In the following we will not consider the presence of a prequalification phase.

## 3. Bid distribution models

For the purpose of defining and evaluating any statistical detection criterion we are compelled to use a working model for the distribution of bid values.

A simple model for distribution of costs rather than bid values is provided by Calveras [5], right in the context of abnormally low bids. In that model all the bidders have the same cost structure, so that the cost  $C_p$  of the project under auction is made of two components: a deterministic one, which represents the knowledge common to all the tenderers, plus a random component

$$C_p = c + s. \quad (1)$$

The random component  $s$  is modelled by a Bernoulli distribution: it takes the value  $-k_G$  with probability  $1-p$  and the value  $k_B$  otherwise. In order to result in positive bids the condition  $c > k_G$  must of course hold. The overall cost is therefore again Bernoullian, with expected value

$$E[C_p] = (1-p)(c-k_G) + p(c+k_B) = c + p(k_B + k_G) - k_G. \quad (2)$$

Though the proposed distribution is asymmetric, a symmetric version, where  $k_B = k_G$ , has also been proposed by the same authors in [4].

Starting from this cost model, a model can be derived for the bids by multiplying the cost by an expected rate of return, leading again to a Bernoulli model.

In a recent paper, in the context of an auction directed to a mass market rather than a procurement auction, the following larger set of probability models has been considered [23]:

- Uniform;
- Triangular;
- Gaussian;
- Exponential;
- Pareto.

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