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A rank-and-compare algorithm to detect abnormally low bids in procurement auctions

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ABSTRACT

Detecting abnormally low bids in procurement auctions is a recognized problem, since their acceptance could result in the winner not being able to provide the service or work awarded by the auction, which is a significant risk for the auctioneer. A rank-and-compare algorithm is considered to detect such anomalous bids and help auctioneers in achieving an effective rejection decision. Analytical expressions and simulation results are provided for the detection probability, as well as for the false alarm probability. The suggested range of application of the detection algorithm leaves out the cases of many tenderers (more than 20) and quite dispersed bids (coefficient of variation larger than 0.15). An increase in the number of tenderers leads to contrasting effects, since both the false alarm probability and the detection probability are reduced. If the bids are spread over a large range, we have instead a double negative effect, with more false alarms and less detections. The presence of multiple anomalous bids worsens the performance of the algorithm as well. On the other hand, the method is quite robust to the presence of courtesy bids.

1. Introduction

Auctions are a widespread tool for the assignment step in the procurement process (Dimitri et al. 2006, Banker and Mitra 2007, Sardinha et al. 2009). Traditionally, procurement is accomplished primarily through electronic means, and represents now a major example of B2B e-commerce activities (Davila et al. 2003, Subramaniam and Shaw 2002). Electronic procurement auctions can boast advantages that go beyond mere cost savings and include improvements in the cycle time, enhancement of quality, and rationalization of the supply base (Amelinckx et al. 2008), which can be further enhanced by incorporating quality negotiations in the procurement mechanism (Huang et al. 2011). In procurement auctions, a customer (e.g., the government or a company) asks potential suppliers to submit their own bids to provide some specified goods and services. Each bid comes with the price the supplier will charge the customer for the provision of those goods and services. Procurement auctions represent an instance of reverse auctions, since we have a single buyer and multiple sellers. In direct auctions the seller manages the auction and seeks to maximize its profit by choosing the buyer submitting the highest bid; in procurement auctions the buyer manages the auction and seeks to minimize its expense by choosing the seller submitting the lowest bid. It is generally assumed that each prospective seller submits a bid as small as possible, but compatible with its own costs and expected rate of return.

However, bidders may deviate from this rational behavior, and submit bids termed in the literature as *anomalous*. Namely, they may submit bids that are either too small or too high when compared to the bidders' costs and expected rate of return.

The former case is known as the phenomenon of *abnormally low bids*; it has been recognized since long and has spurred the European Union to signal it (EUWG 1999). A number of reasons may exist for such anomalous behavior: the bidder may be in desperate need of a contract, though it may turn into a financial loss; it may lack experience in auctions; it may miscalculate its costs and the rate of return needed to repay its funding sources (Gunduz and Karacan 2009). In other cases, it may deliberately submit a low bid to oust a competitor, either to protect its position in the market or to enter a new market (Alexandersson and Hultén 2006, Alexandersson and Hultén 2007). Such a behavior is known as *predatory bidding*, and represents an instance of the well known phenomenon of predatory pricing (Kobayashi 2008), applied to the context of auctions.

At the same time, bidders could submit bids that are too high with respect to what is expected to win the auction. Such phenomenon has been known for a long time as well (McCaffer 1976, Whittaker 1970). Again, a number of reasons may be considered

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for this behavior: the buyer may have little interest in the contract for sale, or lack the resources and skills to properly submit a suitable bid, or submit just to remain considered for future sales (Skitmore 2002). The resulting bids are often named *courtesy bids*.

Though both courtesy bids and abnormally low bids represent an anomalous behavior, the assignment and pricing procedures in procurement auctions are actually altered just by the latter. In fact, since the contract is awarded to the lowest bid, and courtesy bids are not expected to be the lowest ones, their presence does not change the final outcome of the auction. On the other hand, abnormally low bids will often result the lowest in the set of submitted bids and declared winners. Since abnormally low bids are associated, either deliberately or not, to slashed rates of return or even to prices lower than costs, the business deriving from winning an auction through submitting an abnormally low bid may not be sustainable, and the awarded contract may not be honored in the end.

Some mechanisms have been proposed in the literature to prevent the manipulation of auctions. For example, in Porter et al. (2008) an assignment mechanism is proposed that offers a contract to the winning tenderer, but the payment is contingent on whether the task is completed, so reducing the risk for the auctioneer. Another mechanism is proposed by Ramchurn et al. (2009) that takes into account the probability that the contractor actually completes the project and its reputation. In Chen et al. (2010), the assignment includes a penalty to be paid by the contractor if the project does not meet the requirements, and that penalty, proposed by each bidder, is used to rank the tenders. On the other hand, the notion that bidders may cheat may alter the strategies followed by other bidders; the resulting equilibrium strategies have been studied by Porter and Shoham (2005).

Here we consider the case where a plain first price (in this case, the lowest price) mechanism is in place. And, rather than through a preventive mechanism, anomalous bids are detected when they take place. Even in the case of assignment mechanisms aiming at avoiding the probability of success of anomalous tenders, a subsequent phase where surviving anomalous tenders are detected may help in further reducing the risk associated to anomalous behavior.

For those reasons, abnormally low bids should be detected, and the reasons behind them investigated to assess whether they derive from a true competitive advantage or just from situations such as those described above. It is commonly accepted that the rejection of bids cannot be performed in an automated way, but an algorithm is needed to detect suspicious bids and submit them to a thorough investigation. The detection algorithm has therefore to act in the framework of a decision support system, an established tool to aid the auctioneer in auction operations such as this (Papazoglou and Tsalgatidou 2000).

In Statistics, observations that stand outside the bulk of data (i.e., either too small or too large) are named outliers. Hence, both abnormally low bids and courtesy bids could be classified as outliers. Many tests have been proposed in the statistical literature to identify and remove outliers. An excellent book on outliers detection is that by Barnett and Lewis (1994), and good surveys are in Beckman and Cook (1983) and Tietjen (1986); prominent techniques are also described in the seminal paper by Grubbs (1950). In addition, some tests have been devised for the specific purpose of detecting bids due to cover pricing (McCaffer and Pettitt 1976, Skitmore 2002). A number of specific schemes, typically different from the ones above mentioned, have been introduced in public documents for the detection of abnormally low bids. Examples are the national regulations in Spain (Ministerio de Hacienda de España 2000, Ministerio de Hacienda de España 2001), Italy (Presidente della Repubblica Italiana 2006), Germany, and Turkey (Zanza 2004). The introduction of such schemes has not been generally 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 name a false alarm). However, a special class of such schemes, adopted in Spain and Italy, and based on the deviation of the abnormally low bid from the average bid, has been evaluated by Conti and Naldi (2008). It has been shown that its performance heavily depends on the number of tenderers and on the dispersion of bid values, therefore calling for caution in the use of that average-bid criterion, and for a careful choice of the parameter setting the detection threshold.

A new class of detection algorithms has been proposed for abnormally low bids, based on a preliminary sorting of the bids and on the comparison of the lowest bid with the second lowest bid. A particular instance of this algorithm has been incorporated in the German law (Zanza 2004). We name the general form of this class the *rank-and-compare* algorithm; the single instances of the class differ for the value assigned to a single parameter (the *Maximum Allowed Deviation*), which acts as a scaling factor for the detection threshold. Though applied in a real context, this class of algorithms has not been examined thoroughly, to the best of the authors' knowledge. In Engel (2005), the criterion has been dismissed through the qualitative consideration that bidders anticipating to be excluded would raise their bids to alter the auction's outcome. On the other hand, in Decarolis (2009), an alternative assignment scheme has been proposed to solve the problem of anomalous bids without resorting to statistical detection algorithms. No quantitative evaluation of the rank-and-compare algorithm has been accomplished so far. It can appear strange that a procedure found its way in the national legislation without having been thoroughly examined. However, a detection algorithm based on order statistics, such as the one we examine in this paper, could be expected to be robust with respect to outliers, certainly more than average-based algorithms. That may have been the rationale for its adoption. After its adoption, the German Federal Procurement Agency (BESCHA) has not released data on the effectiveness of that procedure. So, we miss both a theoretical and an empirical evaluation of rank-and-compare algorithms. We aim to fill that gap, by providing a quantitative evaluation of its performance.

In this paper, we examine this new class of rank-and-compare algorithms. The main results we provide are listed below.

(a) Analytical expressions for both the false alarm probability and the detection probability, when a single abnormally low bid is present;
(b) Simulation results for the detection probability under multiple abnormally low bids;
(c) Simulation results for the false alarm and detection probability when courtesy bids are present in addition to abnormally low bids.

On the basis of the above mentioned results, we show that:

(i) the false alarm probability is unaffected by the presence of multiple abnormally low bids;
(ii) the Maximum Allowed Deviation has to be controlled to very low values (e.g., 10%) to have acceptable values of the detection probability;
(iii) the detection performance degrades gradually as the number of participants grows;
(iv) the algorithm is relatively robust with respect to the presence of courtesy bids.

The paper is organized as follows. In Section 2, we define the probability model for abnormally low bids. The algorithm we are going to examine is described in Section 3. Its evaluation is accomplished in Section 5, after defining both the performance parameters and the evaluation scenarios in Section 4. The evaluation framework follows that already established in Conti and Naldi