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# Detection of collusion in government procurement auctions

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ABSTRACT

Research on bidder collusion in procurement auctions is reasonably successful in unveiling the mechanisms of collusion among the bidders. But it is relatively weak in forwarding effective practical methods of collusion detection before the winner is declared, because they presuppose the knowledge of collusion in specific auctions. Past studies, however, point out the need for working with bid price-to-reserve price ratios rather than bid prices or winning bid prices, to be free from the problem of heteroscedasticity. They also draw an important inference that the set of collusive data are significantly different from the set of competitive data. On the basis of these basic facts, the current paper outlines a seven-step approach to collusion detection. The approach makes rudimentary statistical analysis of bid price-to-reserve price ratios for all the bidders. The analysis comprises tests of equality of means, medians and variance and tests of skewness, autocorrelation and normality of the ratios. It divides the ratios into two significantly different clusters. The cluster with the higher mean and variance values of the ratios corresponds to collusive bidding with the other cluster corresponding to competitive bidding. The paper proposes the construction of a process control chart to detect occurrence of collusion in an auction immediately after the price bids are opened. The approach is illustrated by applying it to data from procurement auctions for construction projects in a State Department of the Republic of India.

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## 1. Introduction

Government departments procure a large variety and number of goods and services in order to carry out their normal operational responsibilities and to implement various plans and policies. Government procurement typically accounts for 10–15% of GDP for economically developed countries (Global Trade Negotiations, 2006), and up to as much as 20% of GDP in countries like India (Srivastava, 2006). Government departments outsource their required works and services through various methods such as open-cry auctions, competitive bidding through Request for Quotation (RFQ), and agreement through negotiation (Padhi and Mohapatra, 2010). Of these, competitive bidding through RFQ, also called the sealed-bid auction, is the most frequently used method, where government invites a sealed technical and financial bid from each contractor against each project. In such an auction, bidders compete with one another by quoting low bid price to outbid their rivals and win the projects (Marshall and Marx, 2007). This is also the only method used by government departments in India to select contractors to award construction projects (CPWD Works Manual, 2003; Padhi and Mohapatra, 2010).

Corruption, collusion, and tender fixing are the major concerns of auctions (Blume and Heidhues, 2006; Menezes and Monteiro, 2006; Bolotova et al., 2008). Also several studies (for example, Porter and Zona, 1993, 1999; Pesendorfer, 2000; Connor, 2001; Leyton-Brown et al., 2002; Bajari and Summers, 2002; Skrzypacz and Hopenhayn, 2004; Porter, 2005; Harrington and Chen, 2006; Marshall and Marx, 2007; Kagel and Levin, 2008; Ishii, 2009) have confirmed that bidders form cartels in procurement auctions to increase bid price and clinch contracts at the cost of the auctioneers.

Thus, in general, procurements in government departments are beset with many weaknesses. Some of the major weaknesses that are acknowledged in the literature are the following:

- Lack of transparency in the award of work contracts is common in government departments (Gupta and Jana, 2003; Liao et al., 2003; Mitra and Gupta, 2007).
- Excessive state intervention, favouritism towards the local contractors, and discrimination in awarding contracts create problems in the tender awarding process (Carayannis and Popescu, 2005).
- Procurement in government is usually associated with corruption, scandal, and abuse of public resources (McAfee and McMillan, 1992; Mougeot and Naegelen, 2005; Liao et al., 2003; Mitra and Gupta, 2007; Sharma, 2007).
- Many studies have confirmed that bidders form cartels in procurement auctions to increase bid price and clinch contracts at the cost of the auctioneers (for example, Porter and

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Zona, 1993, 1999; Bajari and Summers, 2002; Porter, 2005; Harrington and Chen, 2006; Marshall and Marx, 2007; Ishii, 2009).

### 1.1. Broad approaches to collusion detection

Several methods are proposed in the literature to detect collusion. They use different types of information and use different techniques. The types of information used in the collusion detection methods are the following:

- Bid price (Lang and Rosenthal, 1991; Baldwin et al., 1997; Aoyagi, 2003; Lengwiler and Wolfstetter, 2006; Harrington, 2005; Abrantes-Metz et al., 2006; Marshalla and Marx, 2007; Bolotova et al., 2008).
- Winning bid price (Lundberg, 2005; Brosig and Reiß, 2007).
- Bid price-to-reserve price ratio (Ishii, 2009).
- Winning bid price-to-reserve price ratio and non-price attributes like distance, utilized capacity and experience of the winning bidder, free capacity of the rivals, and minimum distance of the rival firms (Porter and Zona, 1993, 1999; Pesendorfer, 2000; Bajari and Summers, 2002; Bajari and Ye, 2003; Skrzypacz and Hopenhayn, 2004; Kagel and Levin, 2008).
- Winner (Lang and Rosenthal, 1991).

The methods proposed in the literature for collusion detection range from parametric tests (Lang and Rosenthal, 1991; Baldwin et al., 1997; Bolotova et al., 2008) and non-parametric tests (Lundberg, 2005; Brosig and Reiß, 2007) to data mining (Lengwiler and Wolfstetter, 2006), game-theoretic modelling (Aoyagi, 2003; Paarsch et al., 2006; Marshalla and Marx, 2007; Rasmusen, 2007), and econometrics modelling (Porter and Zona, 1993, 1999; Pesendorfer, 2000; Bajari and Summers, 2002; Bajari and Ye, 2003; Bolotova et al., 2008).

The broad approaches to collusion detection can be summarized as follows:

- The bid price data are collected for a number of procurement auctions.
- The bid price data for those auctions that are proven to be collusive in the past are separated from the others, thus forming two sets of data.
- Parametric and non-parametric tests are applied to each set of bid price data.
- Data mining techniques are applied to detect cyclicity of winners and price behaviour of winners in auctions in geographically dispersed locations.
- Game theoretic models derive the conditions of higher payoffs for collusive bids compared to competitive bids.
- Econometric models, the most comprehensive models so far, regress winning bid price-to-reserve price ratio with five non-price attributes (distance, utilized capacity and experience of the winning bidder, free capacity of the rivals, and minimum of the distances of the rival firms from the project site) and develop two conditions (those of normality of residuals and plausibility of directions of regression coefficients) that should hold for competitive bidding; violation of either condition is indicative of presence of collusive bidding.

All the above-mentioned models have one thing in common; they derive important features of competitive bidding, and show that one or more of these features are absent in collusive bids. For example, game theoretic models show that competitive bids follow normal distribution and that collusive bid prices are non-normal and have a higher level of mean compared to the mean value of competitive bid price. Among the parametric tests is the test of equality of variances of competitive and collusive bid price data, resulting in a property that collusive bid prices have higher variance compared to competitive bid prices. Data mining models look for cyclicity of winners and for the presence or absence of autocorrelations in the time-series data on winning bids—its absence indicating competitive bidding and presence collusive bidding.

### 1.2. Weaknesses of the available collusion detection methods

The above-stated approaches, thus, bring out and use important features of competitive bid prices—normality of distribution, lack of autocorrelations, and low mean and low variance. The approaches use these features to distinguish competitive bid price data set from the collusive data set. These contributions of the approaches notwithstanding, the approaches suffer from a common set of difficulties:

1. Econometric models, as also the data mining approaches, suffer from excessive effort required to collect data on many attributes other than the bid price data.
2. The approaches that are based on only bid prices suffer from the problem of heteroscedasticity, when they are applied to the differing sizes of projects being auctioned.
3. These approaches (barring only those that use parametric and non-parametric tests) are not very simple to apply in practice, being very sophisticated mathematically.
4. To validate the approaches, the past works have generally used data for those auctions in which the bidders had been found to be collusive (on the basis of publicity by media and external agencies and subsequent legal proceedings), and have compared the bid prices of these auctions with those from other auctions to find significant differences. These approaches are, thus, like a post-mortem analysis of collusive bid data.
5. A related difficulty, and the most important research gap in the area of collusion detection, is the lack of power of these approaches to indicate the presence of collusion in the absence of knowledge about the nature of bid price in an ongoing auction. What is of utmost practical use is to be able to detect the presence of collusion after the bids are obtained in an auction but before the winner is declared.

In view of the non-availability of a practical method of collusion detection, this paper seeks to answer the following research question: *How to develop a simple, practical method of detecting collusion in the absence of a prior knowledge of bidder collusion*?

### 1.3. Contributions of the paper

In this paper, we suggest a simple approach, based on rudimentary statistical tests on the winning bid price-to-reserve price ratios, to detect collusion. The seven-step approach requires dividing the ratios into two significantly different clusters. The cluster with higher mean and median, higher variance, negative skewness, and significant autocorrelations correspond to collusive bidding, whereas the other cluster corresponds to competitive bidding.

The approach is illustrated by applying it to data on bid price-to-reserve price ratios corresponding to procurement auctions for construction projects in a State Department of the Republic of India. We have demonstrated that this approach renders comparable results with those obtained with the method proposed by Bajari and Summers (2002) and Ishii (2009). The simplicity of the

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