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Application of Association Analysis to Detect Collusive Behaviour in Public Tenders

Abstract: The purpose of this study is to examine the conditions required for the application of association analysis in the identification of the collusive behaviour of contractors in public tenders. It also focuses on determining the values of the confidence and lift measures that will describe the rules specific to a tender cartel. Worldwide research has aimed to develop effective and easy-to-use screening tests to identify cartel cases in public procurement. The recent research focuses on price (its distribution, variance, range) and classifiers allowing for detection of contractors whose mode of operation deviates from that commonly observed. This study follows the direction of current research. The main results of the study include the confirmation of the applicability of the method for the detection of colluding entities and the determination of the value of the confidence and lift measures specific to cartel cases. The policymakers, law enforcement agencies, contracting authorities and competitors of the cartels can use the proposed method to eliminate or at least to limit the scale of the problem. The main shortcoming of the application of the results is the inability to apply them to cartels pursuing an avoidance strategy. Further research will be conducted to develop a conceptual application of association analysis to all cartel strategies.

Keywords: association analysis, bid-rigging, cartel detection

JEL: L41, C40

1. Introduction

Contractors in public tenders can adopt two primary strategies. The first is competition to win the contract. The competitive process of bidding involves offering conditions of sale of goods or services, including price or quality, which are more attractive than the competitor's offer. The implementation of this strategy entails a degree of uncertainty as to what bid the competitor will make. This uncertainty is the foundation of the competitive gameplay, providing the customer with the best possible purchase opportunity. The other form of action in the bidding market is collusive behaviour, also called a bidding cartel, bid-rigging or collusion. The essence of this strategy is to coordinate the behaviour towards the contracting authority by two or more contractors. Most often, it takes the form of a joint arrangement of the conditions of bids. As a result, the parties to such an agreement (from now on also referred to as cartelists) achieve a higher price than would result from free competitive play. A higher price translates into a higher profit for the contractor. The costs of such behaviour are passed on to buyers. In the case of public tenders – to the taxpayers. Due to the damage caused to consumer welfare, bidding collusion is prohibited by law and fought by law enforcement authorities.

The number of bidding cartels identified in Poland from January 2003 to May 2017 is around 250 cases¹, resulting in slightly more than 16 cases per year. Taking into account that the average number of public tenders during that period was 223,356², the fraction of detected bid riggings is less than 0.01% of the total number of tenders. In light of recent studies, such a result seems to be significantly lower than expected. Based on the data from the Finnish market, estimation shows that in a free market economy the probability of forming a cartel is somewhere between 0.2 and 0.3 (Hyytinen, Steen, Toivanen, 2018: 208). Similar conclusions can be drawn from the observation of the American public procurement market. According to the Association of Certified Fraud Examiners, about 35% of the analysed cases were affected by corruption (ACFE, 2016). Therefore, even if the studies mentioned above refer to the broader aspect of cartel and corruption phenomena within the public procurement market, the observed number of identified bid-rigging cases in Poland should be resulting in significantly more than 16 cases per year. Hence, the first factor indicating the benefit of research in this area is the higher detectability of collusion. What should be borne in mind is that bid-rigging usually leads to an increase in prices. Higher costs of supplies, services or works, are ultimately borne by the taxpayers. According to the OECD, the estimated savings from eliminating such collusion are close to 20% of the contract value (OECD,

1 Own analysis of the decisions of the antitrust authority. It should be noted that the investigations conducted by the President of the Office for Competition and Consumer Protection started on average 1,274 days later than the actual date of the collusion (with a median of 940 days).

2 Based on the annual reports of the President of the Public Procurement Office for 2007–2019.

2016). Taking into account the value of the Polish public procurement market, the taxpayers could save as much as several billion zlotys per year if bidding collusion could be successfully eliminated.

One of the main reasons for the low rate of revealed bid-rigging is the deficiency of a versatile and easy to use tool for screening the public procurement market³. The lack of a coherent database containing the essential parameters of bids submitted in tenders is also an area of concern (Harrington, 2008; OCCP, 2014; Fazeikas, Tóth, 2016). The former constitutes the foundation of this study. The primary motivation for the analysis was to propose a practical tool that allows for identifying contractors whose actions resemble the collusive-like cooperation. Law enforcement agencies, contracting authorities, and most importantly – other market players competing with fraudulent contractors (from now on, also referred to as cartels) could use this intuitive and straightforward tool. It is also essential to ensure that the screening method is based on publicly available data. Otherwise, some of the shareholders mentioned above would not benefit from the possibility of examining questionable cases.

Given the observations above, the following research hypotheses have been adopted:

H1: association analysis allows for the identification of cases of bidding collusion.

The analysis will be carried out ex-post and based on historical data on identified bidding cartels. Due to the specific nature of association analysis, its results will allow for concretising the arrangements for tendering. Therefore, it will be possible to verify two detailed hypotheses:

H1a: The value of *confidence* is closer to 100% for the rules concerning the cartel.

H1b: If bid-rigging occurs, and the colluding parties are active during the tender (they make an offer), the value of *lift* for the rules concerning conspirators is higher than 100%.

The analysis was performed using Statistica, version 13.3 – Data Mining, module SAL (Sequence, Association and Link Analysis).

2. Literature review

In this section, we will review the existing academic literature examining cartels. Furthermore, we will study methods used to identify bid-rigging at the moment. We will start by analysing the concept of a cartel.

³ The other are a lack of coherent and open database regarding details about contractors (including their identification), their bids and contracting authorities' decisions other than awarding the procurement, especially the decisions on excluding bidders from the procedure.

2.1. Concept of collusive behaviour

The primary objective of a cartel is to make an extra profit by increasing the price above the competitive level. For this reason, the law, both Polish and European⁴, forbids such cooperation. In a competitive environment, any price increase is limited by the buyers' preferences. Assuming a high degree of substitution between the offered products, an attempt to increase the price in a competitive market will result in a shift of demand to a cheaper seller. In such conditions, increasing prices above the competitive level means a loss of sales, and as a result, a loss of a market share. Therefore, to reduce the risk of losing the market share, the profit-oriented seller has a strong incentive to agree on a market strategy with a competitor. Such an agreement will allow both to apply a high price strategy while preventing the loss of sales. The smaller the number of competitors, the more effective such action will be.

The concept of the cartel is usually linked to the markets with an oligopolistic structure (Tirole, 1988; Cabral, 2000). Let us examine the reasons for such an approach. First of all, successful collusion requires at least two entities willing to act together. Secondly, the number of market players is limited – it has been proven that the more competitors there are in the market⁵, the smaller the impact on prices and output of each rival individually (Gabaix et al., 2016). What is more, any form of competition against the cartel, both actual or potential, jeopardises its aims (Harrington, 2006). So if there is a competitor who offers better conditions than the cartel (i.e. lower prices), they will be able to take over the market. In such a situation, the collusive parties will not only lose unfair profits but may also be pushed out of the market altogether. Church and Ware (2000) argue that internal competition is also a threat to the cartel. Each member of the cartel has a strong incentive to cheat the others for the same reasons described above. Therefore, for the sake of achieving its primary objective, the cartel has to supervise the activities of its members.

When it comes to protecting its interest, the cartel does so by building a network of links connecting as many aspects of its members' activities as possible (Church, Ware, 2000). McGowan (2010) argues that a typical cartel builds trust or forces dependency between cartelists⁶ concerning critical elements of their daily business. Cartel management usually introduces a disciplinary mechanism based

4 See Article 101 of the Treaty and Article 6 of the Competition Protection Act.

5 This means that there are also no entry/exit barriers in the market and the goods offered are close substitutes.

6 In some types of cartels, for instance, where parties involved in the collusion are strongly interdependent (family cartels, close business, strategic or organisational relations), a lack of trust may not be an issue in terms of stability of conspiracy. In such cases, compliance with the agreed strategy is controlled and managed by the most powerful party.

on monitoring their activities. Such a mechanism provides a full range of unavoidable, severe penalties for withdrawal from the agreement. For this reason, a lack of market transparency is considered to be an incentive to creating and maintaining a conspiracy (Cabral, 2000). Collusion is sound and stable when its members are equally sensitive to the threat of punishment in the case of deviation. For this reason, colluding partners usually are comparable in terms of production capacity, market share or cost structure (Cabral, 2000).

2.2. Strategies of the collusion

According to the OECD's report, the four basic strategies adopted by bidding cartels are as follows: cover bidding, bid suppression, bid rotation, and market allocation (OECD, 2016). The cover bidding strategy (also known as courtesy bidding) relies on the agreement that a given conspirator (the designated bidder) wins the tender, while the others submit higher bids or place offers that will undoubtedly be rejected by the buyer for other reasons⁷. The second type of cartel is called bid suppression and occurs when colluding parties decide that only the designated bidder will make an offer, while others refrain from bidding or withdraw their bids before the contract is awarded. The third scenario employed by bidding cartels is called the rotation of bids and involves the winning of subsequent bids by the colluding entities following a predetermined order. The fourth game plan – the market allocation – is the strategy similar to the bid suppression, although it ties colluding parties more broadly. When implementing this form of cooperation, conspirators appoint among themselves an operator who will have the exclusive right to bid for the contract in a given geographical area or a given type of product or to apply for a contract for a particular type of authority. The examples of collusive practices mentioned above do not create an exhaustive list of possible actions taken by fraudulent bidders, but these are the ones which occur most frequently (OECD, 2016).

The strategies of collusion briefly described above show that the success of a bidding cartel requires complete cooperation between the conspiring parties. The stability of such a cartel depends on the full-scale implementation of a pre-agreed game plan. For example, if the designated bidder submits a bid, other conspirators ought to submit less attractive offers or refrain from submitting bids at all. Hence, the behaviour of the cartelists should follow a specific pattern. Such a pattern can be described, e.g. by the relation of *if* → *then*. Given the characteristics of the cartel, recurring and nonrandom winnings or losses within the group of companies are expected.

7 For example, because of the failure to comply with the procedural requirements.

2.3. Identification of bid-rigging

Due to the confidential nature of bidding collusion, its detection is not a trivial task. Firstly, the conspirators usually do not discuss their actions or strategies openly⁸ and keep their agreements confidential. Secondly, it is rare for such deals to be written down in the form of a contract. Usually, it is some kind of gentleman's agreement. Hence, the contracting authorities, law enforcement agencies⁹ and, most importantly, the competitors do not have any direct evidence of a bidding cartel. Therefore, signs of collusion can only be found during the analysis of the events occurring during the tender procedures. It may involve, for example, participation by a group of contractors in the same tenders, unusual frequency of winnings by a given bidder, frequent withdrawals of offers, atypical differences in bids within a group of contractors. The information obtained in this way may lead to finding particular contractors guilty of participating in collusion. The possibility of opening a case shall then be determined by the availability of the data and the possibility of claiming on the basis thereof. The standard of proof is determined by the experience of the competition authority or the court. For example, the absence of a reasonable explanation of the behaviour from two or more contractors other than collusion may be sufficient to find them guilty of an infringement (The President of the OCCP, 2017).

The research into bid-rigging cartels suggests two main methods of detection: a structural one and a behavioural one (Abrantes-Metz et al., 2006; Harrington, 2008; Imhof, Karagök, Rutz, 2016). The structural method of detection uses the characteristics of the market, its structure and dynamics, barriers to entry, as well as demand and supply characteristics. It focuses on the conditions that are conducive to the existence of a collusive arrangement identified in the first part of this study. The behavioural method of detection uses the attributes of the bidders and their behaviour in the market. It emphasises identifying the contractors' practices consistent with the behaviour of a cartel participant.

The structural approach to cartel investigation can be described as a traditional way of detecting collusion (Shaik et al., 2012). Suspicious results of tenders are assessed by analysing the structure of supply and its dynamics over a given period, the countervailing power of purchasers, the substitutability of the prod-

8 Although there are cases where cartelists announce their strategy to the public. As in 2002, when Art Marketing Syndicate S.A., Europlakat Polska Sp. z o.o., Ströer Polska Sp. z o.o. and Outdoor Promocja Plakatu Sp. z o.o. announced a uniform minimum price for their services (lease of advertising space on billboards) at a press conference (see Decision of the OCCP N° RPZ-21/2002 of 22.10.2002).

9 Cartel members can avoid sanctions under the leniency procedure. In return for providing evidence of the existence of the cartel, they are granted total or partial immunity (Competition Protection Act, 2007, para. 106)

ucts offered, the impact of entry or exit barriers on any potential competition, total production and capacity, and the life cycle phase of the product concerned (Cabral, 2000). This method can be used as a tool to identify markets which are prone to collusive behaviour.

In contrast, the behavioural method places the entrepreneur at the centre of any investigation. For this research, it is of particular interest to determine the way entrepreneurs operate. Are they an active or a passive participant in public procurement, how often do they win, with whom do they cooperate most often, and whether we can observe any other significant changes in the way they act in the market. The behavioural analysis, when used to investigate any potential bid-rigging, pays attention to several price-related statistics such as its variation, the relative difference between prices (Abrantes-Metz et al., 2006; Mena-Labarthe, 2012; Imhof, 2017), mark-ups distribution (Bajari, Ye, 2003), distribution of bids, frequency and independence in the bidding process (Porter, Zona, 1997), or intensity of competition (Fazekas, Tóth, 2016; Huber, Imhof, 2018). The primary purpose of such an examination is to determine the contractors' pattern of conduct. If a deviation from the expected behaviour occurs, it constitutes the grounds for an in-depth analysis. The example of such an application is demonstrating the existence of collusive behaviour. Based on changes in price variance in the market of pharmaceuticals in Mexico, its suppliers were charged with participation in the collusion (Mena-Labarthe, 2012). More advanced statistical methods are also used. Morozov and Podkolzina (2013) attempted to use cluster analysis to study data from road construction tenders in the Novosibirsk region of Russia. Another work worth mentioning is the study on road construction tenders in Switzerland (Imhof, 2017). In this work, the author presented the application of price distribution to reveal atypical observations in the population. Both the Swiss and Russian research focused on a relatively narrow segment of the market. Most comprehensively, the problem of screening tests is presented in the report on the effectiveness of the Swedish antitrust authority in fighting collusion (Fazekas, Tóth, 2016). The authors present several innovative ideas on the possibility of using statistical methods to examine the public procurement market across the entire contract spectrum, including the use of Benford law, analysis of cyclicity of winnings, missing contractors and network analysis.

3. Association analysis in the identification of bid-rigging

The characteristics of cartels show that conspirators prefer to act together and cooperate on multiple procurements as often as possible rather than engage in ad hoc collaboration. The *if-then* formula can be used to describe the strategies they

use (for example, if one has been appointed as the winner, the others make less attractive bids). Taking that into account, the first pattern we should expect in the case of collusion is an increased frequency of bids for the same contract by a pair (or a group) of companies. Alternatively, we can see these companies avoiding each other in subsequent proceedings. These two types of behaviour will be adequate for the four collusive bidding strategies mentioned above.

Given the above, the use of association analysis seems justified. Association analysis is a data mining technique aimed at establishing relations between items in a given set, especially in large data sets (Agrawal, Imieliński, Swami, 1993). It should be noted that a dataset used to search for the signs of collusion is likely to contain at least several hundred thousands of records. For example, in 2019, there were 141,023 contracts awarded in Poland (PPO, 2019). Therefore, the database covering two or more years will consist of proportionately more observations. The main problem that can be solved by employing association analysis is determining the links between the items in the dataset – for example, the relationships between contractors taking part in public tenders. In order to apply the method mentioned above, we assume that the database consists of tenders (a single tender is a subset), and tenders are composed of individual contractors who have submitted bids in a given tender (a contractor is then an item of the subset). In the simplest terms, each relation that happens between two contractors constitutes a rule. For example, if contractors A and B bids in a given tender, the rule is described as $(A \rightarrow B)$. Only the rules indicating the possibility of implementing one of the cartel strategies will be interesting for the analysis. The significance of the rule (its strength) will be determined by the parameters of support, confidence and lift. Parameters of support and confidence are considered fundamental for describing the strength of a rule (Hand, Mannila, Smyth, 2005; Osowski, 2013).

The value of support defines how often a given subset occurs in a set of transactions.

$$\text{support}(X \rightarrow Y) = \frac{\sigma(X \cup Y)}{N}, \quad (1)$$

where X and Y are the elements of the subset (say contractors), $\sigma(X \cup Y)$ is the number of occurrences of the subset containing both elements (contractors), and N is the total number of subsets.

The confidence parameter defines the frequency of occurrence of a given item (say X) in the subset containing already the other item of interest (contractor Y).

$$\text{confidence}(X \rightarrow Y) = \frac{\sigma(X \cup Y)}{\sigma(X)}, \quad (2)$$

where X and Y are the elements of the subset, $\sigma(X \cup Y)$ is the number of occurrences of the subset containing both elements, and $\sigma(X)$ is the total number of subsets containing X . The lift value is the third measure indicated in the literature (Tan et al., 2019). In some studies, the parameter of lift is presented as a diagnostic indicator of association – the measure of interest (Osowski, 2013)¹⁰. The value of lift defines the ratio of observed confidence to expected confidence.

$$\text{lift}(X \rightarrow Y) = \frac{\sigma(X \cup Y)}{\sigma(X)\sigma(Y)}. \quad (3)$$

If the numerator and denominator of this fraction are equal, then the presence of X and Y in the subset is an independent event. Otherwise, it means an increased probability of Y being in the subset if X is already there. In terms of analysis provided, the value of lift higher than 1.0 (100%) suggests that both contractors were present in the subset of tenders more often than expected. On the other hand, the value of lift less than 1.0 means that this situation occurs less frequently than expected.

A strong rule distinguishes contractors whose behaviour (acting together or avoiding each other) will differ from the expected. Therefore, these rules should allow for the contractors linked by bid-rigging-like relations to be identified.

The search for rules of interest takes place in two main stages (Osowski, 2013). In the beginning, it is required to search for sufficiently frequent rules. Then, the set of such rules is limited to those that have the expected levels of confidence and lift. The cut-off value of these parameters is adopted based on data characteristics and the nature of the examined phenomenon. It should be noted that in large sets, the number of potential rules can be high ($2^k - 1$ possible subsets, given k for the number of elements in a dataset). It is therefore required to limit the number of subsets that will be subject to further classification. This problem is usually solved by identifying frequent sets first, and then building association rules on that basis (Hand, Mannila, Smyth, 2005).

The concept of the use of association analysis to detect collusion has so far been examined to a limited extent. A research gap exists when it comes to applying association analysis to the study of collusive behaviour in a broadly defined public procurement market. The author has found only three studies on the application of this method in the scenario outlined above. In 2016, Ziarko explored solely the theoretical possibility of applying association analysis to detect collusive behaviour in the public procurement market (Ziarko, 2016). In the study conducted by Foremny and Anysz, the use of association analysis was described as a marker of collusion in the road construction sector (Foremny, Anysz, 2018). Finally, in their 2019 research, Anysz and Foremny used association analysis to build a classifier based

10 In the context of this study, it is not crucial to define precisely the role of this indicator.

on a neural network (Anysz, Foremny, 2019). They aimed to identify contractors displaying characteristics of collusive behaviour. Fazekas and Tóth also studied the concept of using network analysis to assess the risk of collusive bidding in Sweden (Fazekas, Tóth, 2016). The analysis presented in their report is conceptually similar to the one which is proposed in this article.

4. Analysis of Polish bid-rigging cases

In this section, we will present the source of the data used and provide the results of the analysis.

4.1. Data

The data used in this analysis were collected from the 67 publicly available administrative decisions of the President of the Office for Competition and Consumer Protection (from now on also referred to as the OCCP). The analysis involved 323 tenders conducted from January 2003 to May 2017, spread across about 30 different categories¹¹ of the subject of the contract. If a given contract was divided into lots, each lot was considered as a separate tender (subset). Two decisions¹² were excluded from the study due to the secrecy of relevant information in their content (details of offers) or a lack of information allowing for the reconstruction of essential elements of the process. The tenders under examination involved 589 contractors, 191 of whom were suspected of participating in bid-rigging. As a result of the OCCP's investigations, 137 of them were found guilty. The charges against the remaining 54 contractors were dismissed.

The primary purpose of the analysis is to verify whether association analysis is an appropriate method for identifying bid-rigging to be applied to a diverse range of tenders, without limitation to a single market segment. If the answer to the first question is positive, the value for each measure of a strong rule has to be determined. This result will enable us to deduce the contractors whose activities were collusive.

11 For example: winter roads and bridges maintenance services, cleaning services for institutional customers, construction and renovation of residential buildings, roads and paths, transport services, running the Road Information Point, supply of rabies vaccines, forest management services, solid waste disposal services.

12 The decision of the President of the OCCP N° RKT-46/2013 of 16.12.2013 and the decision of the President of the OCCP N° RLU-30/2007 of 17.07.2007.

4.2. Results

The process of developing the model was divided into two stages. The first stage of analysis aimed to check whether the tested method generated rules that could be used as a foundation for further analysis (H1 hypothesis). After that, the H1a and H1b hypotheses were verified.

The first stage was to check whether it would be possible to generate rules consisting of only members of bidding cartels. For this purpose, the minimum values of the support ($support(X \rightarrow Y) \geq 0.3\%$) and confidence ($confidence(X \rightarrow Y) \geq 10\%$) were adopted. It should be noted that the software imposed a minimum value of the support, taking into account the processing capabilities of hardware used in the analysis.

With these assumptions, the model generated 51,118 rules, out of which, 12,041 rules included only the entrepreneurs who were found guilty of bid-rigging. That group covered 60.6% of all cartelists in the database. The remaining 39.4% of 12,041 were the contractors who formed a cartel in only one tender (the value of support for these rules was below the adopted level) or who pursued a single bidding strategy or who colluded in a very sophisticated way (via consortium or through controlling the cartel without participating directly in its operations). The results presented above argue in favour of the primary research hypothesis (H1).

In order to verify the detailed hypotheses (H1a and H1b), the rules are divided into two groups – the first one includes rules consisting of contractors that were not involved in cartel behaviour (G1)¹³, and the other includes rules concerning at least one cartelist (G0). After the split, 10,185 rules fall into G1, while G0 contains 40,933 rules. Both groups differ in terms of distribution. The minimum confidence level in both groups is similar (11.11–11.54), and the maximum value of it (100.00) is the same in both cases. The differences between the groups are noticeable concerning the mean value and the first and second quantile. The mean value for G0 (85.90) was 25% higher than for G1 (68.58). The first 25% of observations and the median in both groups also differ significantly (G1: Q1 = 40.00, Me = 66.67; G0: Q1 = 66.67, Me = 100.00). The value of confidence for the majority of rules in G0 is 100.00. In both cases, the dominant value was 100, with 47% of observations in G0 and 72% in G1. The details on the distribution of the confidence in both groups are shown in the table below (Table 1).

13 This group also includes entrepreneurs suspected of participating in the collusion but cleared of charges in the course of the investigation conducted by the President of the OCCP.

Table 1. Distribution of confidence – groups G0 and G1 (in %)

Group	N	Minimum	Q1	Mean	Median	Q3	Maximum
G1 no cartelists	10,185	11.54	40.00	68.58	66.67	100.00	100.00
G0 at least one cartelist	40,933	11.11	66.67	85.90	100.00	100.00	100.00

Source: own elaboration

Regarding the results described above, it can be assumed that the distribution of the value of confidence in both groups G0 and G1 supports the H1a hypothesis. The parameter of confidence reaches a higher value regarding rules containing one or more cartelists than in the case of rules consisting exclusively of fair playing contractors. It proves that this measure can be used as an indicator of the risk of collusive behaviour in public tenders. Such an indicator can prove especially useful to identify contractors for further in-depth analysis.

The hypothesis H1b was verified similarly. While the value of lift reaches the same maximum value of 235.00 in both G1 and G0 groups, differences are noticeable in terms of the minimum and average values. The lowest value of lift in group G0 is more than twice as high as in group G1. Almost 80% of rules in G0 have the value of lift higher than 100.00. While in G1, that is the case for only 44.1% of them. The other distribution measures are presented in the table below (Table 2).

Table 2. Distribution of lift – groups G0 and G1 (in %)

Group	N	Minimum	Q1	Mean	Median	Q3	Maximum
G1 no cartelists	10,185	3.16	18.08	95.68	44.76	156.67	235.00
G0 at least one cartelist	40,933	8.25	117.50	168.01	156.67	235.00	235.00

Source: own elaboration

The results have shown that the rules with high values of the lift parameter indicate the collusion. This result supports the second research hypothesis (H1b) – the measure of lift can be used to identify companies whose behaviour is consistent with the theory of collusive bidding.

5. Discussion and conclusions

There is a widespread demand for a method to detect tender conspiracies. The low detectability of collusive behaviour in procurement contracts in Poland and the demands formulated in scientific studies from other countries point to the need to develop a practical and easy-to-apply method to detect cartels. The first part of this study looked at the results of the Polish competition authority's efforts to detect collusive behaviour. Amongst a number of studies looking into collusive behaviour in the public procurement market, it is worth highlighting research carried out

in Russia, Switzerland and Sweden (Morozow, Podklozina, 2013; Fazekas, Tóth, 2016; Imhof, 2017). These studies all argue in favour of a universal tool for identifying bidding cartels. Furthermore, this research paper discusses the first empirical work, conducted by Anysz and Foremny (2019) on the application of association analysis to identify collusive behaviour. The results of the study presented in this work allow us to conclude that the set of methods for the identification of tender collusion can be enriched with the analysis of associations. The aim of this work has been achieved – conditions for the use of association analysis have been examined and the research hypotheses have been confirmed.

One of the limitations of the association analysis method is the small number of interactions between contractors, for example, in the case of the first tender in which the cartel operates. Due to a lack of relevant data, it was also not possible to analyse the strategies of avoiding direct competition. However, it should be assumed that in this type of cooperation, the analytical framework adopted in this work will have to be fundamentally changed. The challenge for using the method of association analysis, as well as other methods used for comprehensive analysis, will be employing them in sectors with a high concentration of competition (two or three competitors). The method discussed in this article may then give false-positive results – it may signal the risk of a cartel, while the intensification of relations between competitors results from the specific structure of the market.

It is planned to continue with the research on the subject. In particular, in areas where the withdrawal strategy (or avoidance strategy) is employed. It is also interesting to take into account the analysis of other variables, in particular, those characterising the contracting authority, the conduct of the contractor during the tender (a refusal to sign the contract and a direct or indirect withdrawal of the offer), and the case when cooperation takes place within the consortium. A potential new direction of analysis may also be to estimate the impact of bidding cartels on prices in other tenders within the same category.

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References

- Abrantes-Metz R. M., Froeb L. M., Geweke J., Taylor C. T. (2006), *A variance screen for collusion*, “International Journal of Industrial Organization”, vol. 24, pp. 467–486, <https://doi.org/10.1016/j.ijindorg.2005.10.003>
- ACFE (2016), *Report to the Nations on Occupational Fraud and Abuse 2016*, Association of Certified Fraud Examiners, Austin.
- Agrawal R., Imieliński T., Swami A. (1993), *Mining Association Rules Between Sets of Items in Large Databases*, “ACM SIGMOD Record”, vol. 22, pp. 207–216, <https://doi.org/10.1145/170036.170072>
- Anysz H., Foremny A. (2019), *Analityczne metody detekcji zmw przetargowych w budownictwie*, XI Konferencja Stowarzyszenia Kosztorysantów Budowlanych. Koniunktura i jej wpływ na ceny robót budowlanych, Warsaw, 21–22 March 2019.
- Bajari P., Ye L. (2003), *Deciding Between Competition and Collusion*, “Review of Economics & Statistics”, vol. 85, pp. 971–989.
- Cabral L.M.B. (2000), *Introduction to Industrial Organization*, 1st ed., Massachusetts Institute of Technology, Cambridge.
- Church J., Ware R. (2000), *Industrial Organization: A Strategic Approach*, McGraw-Hill Publishing Co., International Edition.
- Competition Protection Act (2007), Act of 16 February 2007 on Competition and Consumer Protection, Competition Law, 2007, Journal of Laws of 2007, N° 50, item 331, with subsequent changes.
- Fazekas M., Tóth B. (2016), *Assessing the potential for detecting collusion in Swedish public procurement*, Konkurrensverket, Stockholm.
- Foremny A., Anysz H. (2018), *The collusion detection in public procurements – selected methods applied for the road construction industry in Poland*, MATEC Web of Conferences, vol. 219, <https://doi.org/10.1051/mateconf/201821904002>
- Gabaix X., Laibson D., Li D., Li H., Resnick S., Vries C.G. de (2016), *The impact of competition on prices with numerous firms*, “Journal of Economic Theory”, vol. 165, pp. 1–24, <https://doi.org/10.1016/j.jet.2016.04.001>
- Hand D., Mannila H., Smyth P. (2005), *Eksploracja danych*, Wydawnictwa Naukowo-Techniczne, Warszawa.
- Harrington J.E. (2006), *How Do Cartels Operate?*, “Foundations and Trends in Microeconomics”, vol. 2, pp. 1–105, <https://doi.org/10.1561/07000000021>
- Harrington J.E. (2008), *Detecting Cartels*, [in:] P. Buccirossi (ed.), *Handbook of Antitrust Economics*. Massachusetts Institute of Technology, Cambridge, pp. 213–258.
- Huber M., Imhof D. (2018), *Machine Learning with Screens for Detecting Bid-Rigging Cartels*, Working Papers SES University of Fribourg, vol. 494.
- Hyytinen A., Steen F., Toivanen O. (2018), *Cartels uncovered*, “American Economic Journal: Microeconomics”, vol. 10, issue 4, pp. 190–222, <https://doi.org/10.1257/mic.20160326>
- Imhof D. (2017), *Simple Statistical Screens to Detect Bid Rigging*, Working Papers SES, University of Fribourg, vol. 484.
- Imhof D., Karagök Y., Rutz S. (2016), *Screening for bid rigging-does it work?*, Working Papers SES, University of Fribourg, vol. 468.
- McGowan L. (2010), *The Antitrust Revolution in Europe. Exploring the European Commission's Cartel Policy*, Edward Elgar Publishing Limited, Cheltenham – Northampton.
- Mena-Labarthe C. (2012), *Mexican Experience in Screens for Bid-Rigging*, “CPI Antitrust Chronicle”, no. 1, pp. 1–8.



- Morozov I., Podkolzina E. (2013), *Collusion Detection in Procurement Auctions*, Basic Research Program. Working Papers. Series: Economics (WP BRP 25/EC/2013), National Research University Higher School of Economics, Moscow, pp. 118–129.
- OCCP (2014), *Polityka konkurencji na lata 2014–2018*, UOKiK, Warszawa.
- OECD (2016), *Fighting bid rigging in public procurement*, Report on implementing the OECD Recommendation, Daf/Comp(2009)1/Final.
- Osowski S. (2013), *Metody i narzędzia eksploracji danych*, Wydawnictwo BTC, Legionowo.
- Porter R.H., Zona D.J. (1997), *Ohio School Milk Markets. An Analysis of Bidding (No. 6037)*, NBER Working Paper Series, no. 6037, National Bureau of Economic Research, Cambridge, <https://doi.org/10.1360/zd-2013-43-6-1064>
- PPO (2019), The annual report of the President of the Public Procurement Office for 2019.
- Shaik S., Allen A.J., Edwards S., Harris J. (2012), *Market Structure. Conduct Performance Hypothesis Revisited Using Stochastic Frontier Efficiency Analysis*, “Journal of the Transportation Research Forum”, vol. 48, issue 3, pp. 3–18, <http://doi.org/10.22004/ag.econ.207141>
- Tan P.-N., Steinbach M., Karpatne A., Kumar V. (2019), *Introduction to Data Mining*, 2nd ed., Pearson, New York.
- The President of the OCCP (2007), Decision N° RLU–30/2007 of 17.07.2007.
- The President of the OCCP (2013), Decision N° RKT–46/2013 of 16.12.2013.
- The President of the OCCP (2017), Decision N° RŁO–8/2017 of 28.12.2017.
- Tirole J. (1988), *The Theory of Industrial Organization*, Massachusetts Institute of Technology, Cambridge.
- Ziarko Ł. (2016), *Eksploracja danych w identyfikacji praktyk antykonkurencyjnych*, [in:] A. Fornalczyk, T. Skoczny (eds.), *Economic of Competition Protection. Vertical Restraints*, University of Warsaw, Warsaw, pp. 273–291.

Zastosowanie analizy asocjacji w wykrywaniu zmów w przetargach publicznych

Streszczenie: Celem niniejszego artykułu jest zbadanie warunków niezbędnych do zastosowania analizy asocjacji w wykrywaniu zmów zawieranych przez wykonawców zamówień publicznych. Koncentruje się ono na określeniu wartości parametrów zaufania (*confidence*) oraz podniesienia (*lift*), charakteryzujących reguły asocjacyjne właściwe dla zachowania się uczestników umowy przetargowej. Aktualnie prowadzone na świecie badania ukierunkowane są na opracowanie względnie łatwych w użyciu narzędzi, pozwalających na skuteczne ujawnianie przypadków karteli przetargowych. Podejmowane dotychczas próby ich opracowania skupiały się na analizie cen (rozkład, wariancja, rozstęp) oraz klasyfikatorach pozwalających na wykrycie wykonawców, których zachowanie w procedurze przetargowej odbiega od powszechnie obserwowanego. Analiza prezentowana w niniejszym artykule wpisuje się w ten kierunek badań. Do głównych wniosków z przeprowadzonej analizy zalicza się: potwierdzenie możliwości zastosowania analizy asocjacji do wykrywania zmów przetargowych oraz określenie wartości miar zaufania i podniesienia do identyfikacji podmiotów działających w sposób typowy dla karteli. Zaproponowana metoda może zostać zastosowana przez organy ochrony prawa, zamawiających oraz konkurentów, w celu wyeliminowania lub przynajmniej ograniczenia skali występowania porozumień przetargowych. Główną, zidentyfikowaną wadą proponowanej metody jest brak możliwości zastosowania do karteli realizujących strategię unikania konkurencji. Planowane jest prowadzenie badań ukierunkowanych na rozwinięcie użyteczności proponowanej metody na wszystkie strategie możliwe do zastosowania przez uczestników umowy.

Słowa kluczowe: analiza asocjacji, zmowa przetargowa, wykrywanie karteli

JEL: L41, C40

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