EKONOMIA I PRAWO. ECONOMICS AND LAW
Volume 21, Issue 3, September 2022
p-ISSN 1898-2255, e-ISSN 2392-1625
www.economicsandlaw.pl

ORIGINAL ARTICLE
received 15.12.2021; revised 10.09.2022; accepted 30.09.2022
Citation: Ziarko, Ł. (2022). Statistical methods as a tool to identify bid-rigging: the case of local authorities. *Ekonomia i Prawo. Economics and Law*, 21(3), 655–669.
https://doi.org/10.12775/EiP.2022.035.

Statistical methods as a tool to identify bid-rigging: the case of local authorities

ŁUKASZ ZIARKO

University of Lodz, Faculty of Economics and Sociology, Department of Economic and Social Statistics, ul. Rewolucji 1905, 41/43, 90-214 Lodz, Poland
lukasz.ziarko@uni.lodz.pl
orcid.org/0000-0002-9726-5552

Abstract

Motivation: Disclosure of bid-rigging is not a trivial process. The main difficulty lies in the secrecy of such an agreement. Also, the signals of collusion can be ambiguous. It, therefore, appears that only a tiny percentage of such collusive agreements are disclosed. Of the disclosed conspiracies, a significant proportion was identified due to information from contracting authorities. We have a catalogue of indicators for collusion, and statistical methods are particularly effective. What is the role of statistical methods in revealing bid-rigging? What determines their use in practice? In order to answer these questions, a questionnaire study was carried out. The survey covered local government units — the dominating group of contracting authorities.

Aim: The research aimed to identify the factors characterising local government units that foster statistical methods as a standard bid evaluation tool.

Results: The survey results indicate that using a statistical method as standard practice in the process of bids evaluation is related to the level of staff's professional expertise, the size of the procurement team and the size of the local authority. Concerning the risk of collusive bidding, respondents recognise it but believe that it does not significantly impact the achievement of procurement policy objectives. Despite a sense of responsibility for combating bid-rigging, respondents are reluctant to use statistical methods on a daily basis.

Keywords: *public procurement; local authorities; bid-rigging; screening methods*
JEL: H57; L41; C00

1. Introduction

Bid rigging is a term used to describe a publicly undisclosed cartel-like agreement that aims to influence the outcome of a public procurement procedure. In a competitive environment, suppliers try to develop an offer that is better than their rivals. Hence, the essence of the competition process is derived from the entrepreneur's uncertainty about his competitor's behaviour. Uncertainty is key to the efficient use of taxpayers' money for public procurement. The colluding parties seek to influence the procurement process and ultimately achieve a monopoly profit by eliminating it. Bid-rigging strategies usually involve price-fixing or market sharing.

The effects of collusion can be very severe on public welfare, which is why collusive tendering is forbidden by law. Price increases resulting from bid-rigging are passed through the contracting authority to the taxpayer. Japanese Fair Trade Commission (OECD, 2012, p. 2) estimates these costs to be at 20 per cent of the overall tender price, while others indicate them to be between 16 and 33 per cent (Froeb et al., 1993, p. 421; McMillan, 1991, p. 211). Analysis conducted in Poland shows that the increased cost placed on the contracting authority due to bid-rigging can be as high as 40 per cent (Anysz et al., 2014, p. 115). It is worth noting that OECD countries spend on average 15 per cent of their GDP on public procurement purchases (OECD, 2016, p. 49). In Poland, in 2020, there were slightly more than 135 thousand tenders, with a total value of PLN 183.5 billion, equalling 7.9 per cent of the country's GDP.

In Poland, the authority responsible for legal actions against anti-competitive behaviour, including bid-rigging, is the President of Competition and Consumer Protection (the OCCP). Between June 2004 and the end of 2020, the competition authority had initiated only slightly over 100 antitrust proceedings concerning accusations of collusive tendering in 550 cases. About 40 per cent of cases were launched based on the information gathered and passed on by the local authorities and their subsidiaries. Thus these institutions constitute the largest group of contracting authorities initiating the proceedings before the OCCP. Therefore, local authorities can be seen as the key players in initiating the process of disclosing collusive tendering behaviour.

Statistical methods can be the most practical and easy-to-use tools of analysis aimed at uncovering bid rigging. However, the analysis of the decisions of the President of the OCCP shows that their application is moderately popular. This paper will analyse the factors stimulating the application of statistical methods by local authorities in uncovering the collusive tendering cases. The research hypothesis assumes that applying these methods depends on the authority's knowledge, experience, and labour resources.

2. Literature review

All the above considerations allow us to ask whether local authorities could use statistical methods to analyse public procurement tender offers and evaluate bid-rigging risk. The OECD (2013, pp. 263–271) report includes a primary classification of cartel identification methods. The report results from a collaboration between academic researchers, practitioners (Abrantes-Metz, 2013, pp. 223–246; Kovacic, 2013, pp. 247–255; Schinkel, 2013, pp. 257–262) and consumer and competition protection agencies. The suggestion of division has its roots in the work of Hüschelrath (2010) and the International Competition Network (2012).

The first classification level distinguishes between reactive (ex-post, reactive) and proactive (ex-ante, proactive) methods. The first group includes leniency programmes and incentives for whistleblowers or promoting compliance programmes among companies. The second group includes economic research (including screening), case study analysis by competition authorities, market intelligence and inter-institutional cooperation. What should be emphasised, after Harrington (2008, pp. 214–215), the aim of using screening programmes is not so much to prove collusion as to provide arguments justifying an in-depth investigation of specific conduct or contractors.

Among screening methods, Bejger (2016, p. 238) and Imhof et al. (2016, p. 3) distinguish between structural methods and behavioural methods. Structural methods aim to estimate the probability of collusion based on the structural characteristics of the market, its concentration, asymmetry, scale and importance of entry and exit barriers, demand and supply features.

Behavioural analyses aim to examine entrepreneurs' behaviour in the competition for public contracts. Based on the results of behavioural studies, attempt to answer whether the analysed entrepreneurial activity corresponds to the behaviour that can be expected in a competitive market or the opposite. The OECD (2013, p. 6) report point out that the two direct collusion signals mentioned in the studies to assess contractors' behaviour include an unusual way of operating or low activity level.

The experience of competition authorities as presented in the literature (e.g. Abrantes-Metz, 2013; Fazekas & Tóth, 2016; Imhof et al., 2016) shows that the use of simple methods of analysis is particularly effective. Such methods are based on publicly available data and allow the survey to be conducted without advanced, specialised statistical or econometric knowledge. The contracting authority or the contractor can easily carry out the survey, i.e. the entities that can catch the signal of collusion as soon as possible after its implementation.

Behavioural methods for uncovering cartels focus on price and sales. In this context, it is worth noting that one of the characteristic effects of collusion, which is relatively easy to capture, is the low volatility of prices offered by cartel participants (Abrantes-Metz et al., 2006, p. 484; Bejger, 2016, p. 245; Harrington, 2008, p. 242; Imhof, 2017, p. 8; Korczyński, 2018, pp. 33–46). Such

price distribution is seen in the conditions present at the forming stage of cartels and their stability. Korczynski (Korczyński, 2018, pp. 33–46) offers a comprehensive literature review of this area and a systematisation of the causes of low price volatility in the case of collusion. The study of price volatility can thus estimate the beginning and end of a collusive period (Abrantes-Metz, 2013, p. 28; Bejger, 2010, p. 9; Harrington, 2008, p. 242).

Literature on the application of behavioural methods in identifying collusive behaviour shows that the vast majority of research deals with the problem of cartels within a single market. The markets studied have included, among others, food products — frozen fish, fruit (Abrantes-Metz et al., 2006) and fuel (Abrantes-Metz et al., 2006; Ragazzo, 2012), financial instruments — LIBOR rates (Abrantes-Metz et al., 2011), road construction (Anysz & Foremny, 2019; Imhof, 2017; Morozov & Podkolzina, 2011; 2013), or pharmaceutical products: lysine, vitamins (Bolotova et al., 2011) and hospital drugs (Estrada & Vazquez, 2013; Mena-Labarthe, 2012). In contrast, studies that attempt a comprehensive approach to analysing the public procurement system for collusion are rare. Fazeskas and Tóth study for Konkurrensverket, the Swedish antitrust authority, is an inspiring example (Fazekas & Tóth, 2016).

Among the markers (commonly described as flags or indicators) of the risk of collusive bidding discussed in the literature, the measures of descriptive statistics are worth noting. These are easy to apply and include indicators based on the price level, measures of price dispersion and skewness. Within the former group, the measures of price equality and the relative difference between lowest and second-lowest bid prices seem particularly useful (Fazekas & Tóth, 2016, pp. 67–69). The measures of deviation, which are of particular interest encompass the coefficient of variation (e.g. Abrantes-Metz et al., 2006, p. 468; Mena-Labarthe, 2012, p. 5), the relative price distance (Imhof et al., 2016, pp. 11–12), the bid price range (Anysz & Foremny, 2019, pp. 142–143; Fazekas & Tóth, 2016, pp. 71–73). The moment-based measure of skewness is helpful when studying price asymmetry (see Huber & Imhof, 2018, pp. 11–12).

In addition, the possible application of behavioural markers of collusive bidding also requires a rudimentary knowledge of the basic collusion strategies. These include courtesy bidding submitting incomplete bids, rotating and withdrawing submitted bids, and limiting bids. Characteristics of the different strategies are outlined in the works of Dorabialski and Jóźwiak-Górny (2017), Jurczyk (2012), OECD (2012), Wensink and de Vet (2013).

Experience in examining bids is the third factor that has a crucial impact on the ability to identify illegal activities of contractors. Considering the conditions of the Polish public procurement system and based on the experience of the national competition authority, a list of factors indicating an increased likelihood of a bid-rigging has been developed. Dorabialski and Jóźwiak-Górny (2017, pp. 27–30) presented nearly 30 features of bids and contractors' behaviour, indicating an increased risk of collusion. These features include uncovering similarities in rival's offers, establishing links between contractors (family,

capital), observing changes in contractors' behaviour over time or their activity during the tender procedure. This compilation has formed an annexe to the annual activity reports of the President of the Public Procurement Office in two consecutive years (UZP, 2019; 2020). Verification of these factors requires, on the one hand, experience in the area of examining offers, and on the other hand, the commitment of the contracting authority's resources (time, work) to carry out activities that often go beyond the simple selection of the most economically advantageous bid.

It is important to note that the contracting authority is required to exclude from the proceedings the contractor whose tender was submitted as a result of collusion (Public Procurement Law, 2019). However, the regulations do not contain a detailed catalogue of activities that the contracting authority would be obliged to perform in this type of investigation. Thus, the contracting authority's ability to uncover collusion will depend on the competence of the persons conducting the proceedings, including precisely their experience and knowledge.

3. Methods

The data source for this analysis is a questionnaire entitled *Tender agreements in the perspective of the contracting authorities in the Polish public procurement system*. The survey aimed to collect and then synthesise information on evaluating the phenomenon of collusive tendering by local authorities in Poland.

The survey was conducted between 18 May and 10 July 2021 under access to public information. The author's questionnaire for the survey included questions concerning respondents' assessments and opinions on the phenomenon of collusive tendering and the state of local government units' knowledge of selected issues related to this problem. The questionnaire consisted of 44 questions, 39 of which were directly related to the phenomenon of bid-rigging.

The statistical units of study were local authorities. Two factors dictated the choice of population. Firstly, the analysis of the decision of the President of the Office of the Competition and Consumer Protection shows that local government units (together with their subordinate units) accounted for nearly 60% of the contracting authorities affected by the problem of collusive tendering revealed in 2005–2020. Secondly, according to the data from the President of the Public Procurement Office, they constitute the most numerous group among all categories of contracting authorities, accounting for approx. 30% of the total number of contracting authorities in the Polish public procurement system (see: annual reports of the President of the Public Procurement Office 2008–2021).

The study used a Mixed Mode Design approach. The primary technique for conducting the study was CAWI (Computer-Assisted Web Interview), an online questionnaire interview. Additionally, respondents could choose to participate in the study using the CASI (Computer Assisted Self Interviewing) or PSAQ (Paper Self-Administered Questionnaires) technique. This approach

makes it possible to limit the problem of the so-called suitability of the survey technique (Sztabiński & Żmijewska-Jędrzejczyk, 2012, p. 34). The simultaneous use of two techniques for collecting information gave respondents how to participate in the survey. The approach adopted allowed for the reduction of non-response error and coverage error. Some of the institutions participating in the survey implemented various types of restrictions on the freedom of Internet use by its employees, e.g. in undertaking interaction with sources located outside the internal network of the institution (websites, platforms dedicated to conducting online surveys), or downloading files from unauthorised sources from the Internet, or even attachments to e-mail correspondence). The advantage of the simultaneous Mixed Mode Design adopted in the survey is that it gives the respondent a greater sense of self-determination by allowing them to choose the form of participation in the survey.

The survey questionnaire was available online (in the MS Forms application). A link to it was also sent by e-mail from the e-mail address dedicated to this study. An editable version of the questionnaire was attached to the message, possibly sending the answers in traditional or electronic correspondence.

The request for answers to the questions contained in the questionnaire was sent to all local government units at the municipality, poviat and voivodeship levels and Warsaw districts of the capital (due to the different status of these units) making up a group of 2 825 recipients (see Table 1). During the whole survey period, respondents could contact the researcher by phone or e-mail. The achieved response rate at the average level of 79 per cent confirmed that the research approach employed in the investigation was the right choice.

The index of similarity of structure (Grzelak, 2017, p. 23) is 98.6 per cent, indicating that the structure of the sample consisting of the responses obtained is very similar to that of the population.

A chi-square independence test and logistic regression will analyse the results. The Chi-square independence test enables the assessment of interdependencies between characteristics, predominantly when one of them is expressed on a nominal scale (Szymczak, 2020, p. 121). Thus, its application allows verifying the hypothesis on the relationship between the surveyed entities and their preferences regarding statistical methods.

Logistic regression is one method that enables the creation of interdependence models between a dependent variable and an independent variable or variables. It is particularly applicable to the analysis of cases in which the dependent variable is dichotomous, i.e. it takes one of two values indicating the occurrence or absence of the analysed phenomenon (Hosmer & Lemeshow, 2000, p. 1). The result of logistic regression analysis estimates the probability of the occurrence of the phenomenon under study depending on the value of one or more explanatory variables (risk factors), both qualitative and quantitative. This measure will be used to examine the impact of factors characterising respondents on the likelihood of their use of statistical methods in the evaluation of offers by local government units.

Statistical analysis was performed using IBM SPSS (IBM Corp. Released 2020. IBM SPSS Statistics for Windows, Version 27.0. Armonk, NY: IBM Corp).

4. Results

Respondents' answers indicate that statistical methods in analysing offers are not particularly popular among them. One in five contracting authorities declare that they use statistical price analysis as standard practice at the bid evaluation stage (they always or almost always use it). Hence, statistical analysis of prices cannot be regarded as a preferred solution, so its impact on preventing bid rigging seems weak. In addition, 17 per cent of the respondents declare that they do not use this type of analysis in their practice.

The research hypothesis assumed a relationship between the willingness of local government units to use statistical methods in the analysis of offers and the available labour resources, along with the knowledge and experience of persons conducting public procurement procedures. On this basis, six characteristics of respondents were identified, which may be related to the research phenomenon These include:

- number of FTEs in the procurement unit (average for the last five years) (X1);
- participation in training focused on fighting bid-rigging (X2);
- participation as a party in administrative or judicial proceedings concerning an alleged bid-rigging conspiracy (X3);
- existence of the bid-rigging prevention unit within the organisation (X4);
- assessment of the impact of bid-rigging on the ability to implement a public procurement policy (X5);
- assessment of the risk of bid-rigging in the public procurement system in Poland (X6).

Furthermore, three additional factors were established, which might differentiate respondents in terms of organisations and the scale of their procurement:

- average annual per capita expenditure over the period 2015–2019 (variants of the variable set as the 25th, 50th, 75th quantile) (X7);
- the type of local authority (X8);
- the population of the local government unit (variants of the variable set as the 20th, 40th, 60th and 80th quantile) (X9).

The verification of the research hypothesis was divided into two stages. The first stage shows which variables identify local government units, which treat statistical analysis of offers as a standard activity integral to the public procurement procedure. The study in this regard will be carried out using the chi-square independence test. In the next step, using logistic regression, the probability of treating statistical methods as a standard tool for evaluating offers for individual variants of the extracted characteristics will be estimated.

Among the nine features characterising local government units in the analysed aspect, four were found to be differentiating in terms of the inclination to treat statistical methods as a standard bid evaluation tool: average number of FTEs in the procurement unit (n=2,177), participation in training on the fighting of bid-rigging (n=2182), the type of local government unit (n=2,184) and its population (n=2,177) (see Table 2). Each of them is statistically significantly ($p<0.001$ in each case) related to using statistical methods in the practice of the unit implementing public procurement procedures. However, the relationship is weak (Cramér's V does not exceed 0.132 in any case).

There is an evident interdependence between the average number of FTEs working in the procurement unit and the percentage of entities applying statistical methods. It ranges from 14.8 per cent in the case of entities with no FTEs dedicated to public procurement to a maximum of 33.3 per cent in the group of entities employing six or more people. Similarly, in the case of institutions taking advantage of training dedicated to combating collusive tendering, the percentage of those applying the discussed methods (23.3%) is six percentage points higher than in the second group of entities (17.1%). An analogous relation is observed with an increase in the population of local government units and their type. Against this background, rural municipalities (17.1% treat statistical methods as a standard assessment tool) and units below 4,852 inhabitants (13.6%) stand out. A higher percentage of entities using the discussed methods is observable in the case of Districts of Warsaw and voivodships (35.7% and 58.3%, respectively) and local government units with the highest population (27.3%)

Among the characteristics not interdependent with the studied phenomenon, the variable describing the collusive tendering scale (n=2072) deserves particular attention. The study results indicate that an increase in the risk of collusion is not accompanied by a higher propensity to use statistical methods in evaluating offers. It is also interesting to note the lack of association between the use of the methods in question and the experience of participating in administrative (before the OCCP) or judicial proceedings (n=2184). The analysis of the competition authority's decision-making practice provides information on the applicability of statistical methods in identifying collusive bidding. The distribution of answers concerning assessing the impact of bid-rigging on the ability to implement public procurement policy is also intriguing.

The vast majority of respondents, as many as 80 per cent, believe that bid-rigging does not significantly threaten the ability of institutions to implement public procurement policy. Another 16 per cent believe that this threat can be described as moderate. These results are surprising as respondents (n=2,225) identify themselves as one of the three groups of actors responsible for combating collusive tendering. As many as 60% of them defined the contracting authorities, the OCCP and law enforcement as key players in this process. Approximately one-third of survey participants pointed to the President of the Public Procurement Office and competitive bidders as responsible for

combating collusion. These results provide a promising starting point for in-depth research on the normative and practical aspects of the role of contracting authorities in identifying collusive bidding.

Logistic regression was used to estimate the probability of using statistical price analysis methods as standard practice. The outcome variable uses statistical methods of price analysis as standard practice (y=1). Variables significantly related to the phenomenon under study were selected as risk factors (see Table 3).

The model (n=2,168) was estimated using backward stepwise elimination process (likelihood ratio). The final model was obtained in the second step.

Based on the results of the Omnibus Test of Model Coefficients (χ^2=64.696, df=12, p<0.001) and Hosmer–Lemeshow Test (χ^2 2=13.034, df=8, p<0.111), the quality of the estimation can be assessed at a satisfactory level. However, the model is not a good classifier, as indicated by the low percentage of correct true negative's classifications (0%).

Of the four risk factors significantly interdependent with the phenomenon under consideration, the type of local authority was unrelated to the likelihood of using statistical methods in bid evaluation (p=0.182).

In the case of FTEs, statistically significant differences occurred between the reference group (6 FTEs and above) and two, with zero and one FTEs dedicated to public procurement tasks. Such local authorities were 2.4 and 2 times less likely to use statistical methods in their bid evaluation than the reference group.

Concerning the variable indicating training in combating collusive tendering, the probability of applying statistical methods by entities that did not organise this type of training was 1.4 times lower than in the institutions training their employees.

As far as the population of the local government unit is concerned, the probability of using statistical methods in the three groups with the lowest number of inhabitants (up to 4,852, 4,853–7,166 and 7,167–11,585 persons) was lower by 1.4–2.1 times compared to the group of units with a population exceeding 28,071.

5. Conclusion

Bid-rigging poses a severe risk to the efficiency of public spending. Considering the size of the public procurement market and the estimated effects of collusive practices, taxpayers may have to bear substantial costs resulting from price increases caused by rigging cartels. The demand structure on the public procurement market and the decision-making practice of the OCCP indicate the critical role of local government units in combating bid-rigging. What is more, the survey shows that the local government units confirm this view. The literature review shows that economic analyses are particularly effective in fighting col-

lusion. These include using basic measures of descriptive statistics to examine bids.

This study was based on a survey conducted among local government units. Data gathered allowed to examine local government units' inclination to use statistical methods as a standard method of bids assessment.

Out of nine factors characterising local government units, four were significantly related to treating statistical methods as a standard method of offer evaluation. These are the average number of full-time employees in organisational units implementing public procurement, training in combating collusive tendering, the type of local government unit and its population.

Three of the above significantly impact the likelihood of using statistical methods as standard practice in tender evaluation. A 2–2.5 times higher likelihood of their application can be observed in units with a large number of FTEs (6 or more) compared to institutions where the number of FTEs does not exceed 1. Moreover, they are 1.4 times more likely to be applied in units whose employees have received training in identifying collusive tendering. Finally, statistical methods are 1.4–2.1 times greater likely to be used in institutions with many inhabitants (over 28,071) than the minor units (populations of less than 11,586).

The surprising results of the survey were the lack of a statistical relationship between the willingness to use statistical analysis as a standard method of examining bids and the experience of the organisation gained during legal or administrative proceedings against bidding cartels. Furthermore, awareness of the risk of collusive bidding also seems to have no bearing on the use of methods in question. A very intriguing result of the study is the lack of a clear link between the effects of collusive tendering and the ability of a local authority to perform its procurement tasks.

Thus, there are grounds for considering the research hypothesis as correctly formulated in terms of the resources of the local government unit. The study results allow concluding that the unit's resources in the form of the number of employees and knowledge are significantly related to the preference for using statistical methods in tender evaluation. At the same time, the results did not confirm the influence of experience and knowledge on the use of discussed methods. Respondents are unwilling to use statistical methods despite recognising the problem of bid-rigging and the declared responsibility for its prevention. Their reluctance may result from limited resources in most local authorities (number of posts dedicated to public procurement tasks).

Research in this area will be continued. It seems particularly important to identify the reasons for the relatively low assessment of the impact of collusive tendering on a unit's ability to achieve its procurement policy objectives.

References

Abrantes-Metz, R.M. (2013). Ex officio cartel investigation and the use of screens to detect cartels In *OECD policy roudtables: ex officio cartel investigations and the use of screens to detect cartels* (pp. 223–246). Retrieved 06.09.2022 from https://www.oecd.org/daf/competition/exofficio-cartel-investigation-2013.pdf.

Abrantes-Metz, R.M., Froeb, L.M., Geweke, J.F., & Taylor, C.T. (2006). A variance screen for collusion. *International Journal of Industrial Organization*, 24(3), 467–486. https://doi.org/10.1016/j.ijindorg.2005.10.003.

Abrantes-Metz, R.M., Villas-Boas, S.B., & Judge, G. (2011). Tracking the Libor rate. *Applied Economics Letters*, 18(10), 893–899. https://doi.org/10.1080/13504851.2010.515197.

Anysz, H., & Foremny, A. (2019). *Analityczne metody detekcji zmów przetargowych w budownictwie*. Retrieved 06.09.2022 from https://www.researchgate.net/profile/Hubert-Anysz-2/publication/331977318_Analityczne_metody_detekcji_zmow_przetargowych_w_budownictwie/links/5c996fbc92851cf0ae98125d/Analityczne-metody-detekcji-zmow-przetargowych-w-budownictwie.pdf.

Anysz, H., Kulejewski, J., & Foremny, A. (2014). Estimating potential losses of the client in public procurement in case of collusion utilizing a MLP neural networks. *Czasopismo Techniczne: Budownictwo*, 111(1-B), 105–118. https://doi.org/10.4467/2353737XCT.14.088.2538.

Bejger, S. (2010). Detekcja równowagi zmowy w branży z wykorzystaniem analizy falkowej: model teoretyczny. *Acta Universitatis Nicolai Copernici: Ekonomia*, 41, 7–26. https://doi.org/10.12775/AUNC_ECON.2010.001.

Bejger, S. (2016). *Wykrywanie, pomiar i ocena strategicznych, horyzontalnych zachowań niekonkurencyjnych przedsiębiorstw: analiza ilościowa*. Uniwersytet Mikołaja Kopernika.

Bolotova, Y., Connor, J.M., & Miller, D.J. (2011). Cartel stability: an empirical analysis. *SSRN Electronic Journal*, 1–56. https://doi.org/10.2139/ssrn.939078.

Dorabialski, W., & Jóźwiak-Górny, S. (2017). Zmowy przetargowe. UOKiK.

Estrada, E., & Vazquez, S. (2013). Bid rigging in public procurement of generic drugs in Mexico. *Competition Policy International*, 9(1), 100–122.

Fazekas, M., & Tóth, B. (2016). *Assessing the potential for detecting collusion in Swedish public procurement*. Retrieved 06.09.2022 from http://www.govtransparency.eu/wp-content/uploads/2021/08/Fazekas-Toth_SE_PPcartel_detection_20161115.pdf.

Froeb, L.A., Koyak, R.A., & Werden, G.J. (1993). What is the effect of bid-rigging on prices. *Economics Letters*, 42(4), 419–423. https://doi.org/10.1016/0165-1765(93)90095-T.

Grzelak, M.M. (2017). Parametry opisujące strukturę zbiorowości. In M. Grzelak, B. Dobrowolska, & J. Jarczyński (Eds.), *Praktyczne aspekty analizy danych w biznesie* (pp. 22–52). Wydawnictwo Biblioteka.

Harrington, J.E. (2008). Detecting cartels. In P. Buccirossi (Ed.), *Handbook of antitrust economics* (pp. 213–258). MIT Press.

Hosmer, D.W., & Lemeshow, S. (2000). *Applied logistic regression*. John Wiley & Sons.

Huber, M., & Imhof, D. (2018). Machine learning with screens for detecting bid-rigging cartels. *Working Papers SES*, 4(494), 1–29.

Hüschelrath, K. (2010). How are cartels detected: the increasing use of proactive methods to establish antitrust infringements. *Journal of European Competition Law & Practice*, 1(4), 522–528. https://doi.org/10.1093/jeclap/lpq047.

Imhof, D. (2017). Simple statistical screens to detect bid rigging. *Working Papers SES*, 7(484), 1–48.

Imhof, D., & Karagök, Y., & Rutz, S. (2016). Screening for bid rigging-does it work. *Working Papers SES*, 4(468), 1–27.

International Competition Network. (2012). *Anti-cartel enforcement manual: cartel working group: subgroup 2: enforcement techniques*. Retrieved from https://www.internationalcompetitionnetwork.org/wp-content/uploads/2018/05/CWG_ACEMAwarenessOutreachCompliance.pdf.

Jurczyk, Z. (2012). *Kartele w polityce konkurencji Unii Europejskiej*. C.H. Beck.

Korczyński, A. (2018). *Screening wariancji jako narzędzie wykrywania zmowy cenowej: istota i znaczenie imputacji danych*. Szkoła Główna Handlowa.

Kovacic, W.E. (2013).The value of policy diversifications in cartel detection and deterrence In *OECD policy roudtables: ex officio cartel investigations and the use of screens to detect cartels* (pp. 247–256). Retrieved 06.09.2022 from https://www.oecd.org/daf/competition/exofficio-cartel-investigation-2013.pdf.

McMillan, J. (1991). Dango: Japan's price-fixing conspiracies. *Economics and Politics*, 3(3), 201–218, https://doi.org/10.1111/j.1468-0343.1991.tb00047.x.

Mena-Labarthe, C. (2012). Mexican experience in screens for bid-rigging. *CPI Antitrust Chronicle*, 1, 1–8.

Morozov, I., & Podkolzina, E. (2011). *Detecting bid-rigging in procurement auctions: three-step approach to reveal conspiracy*. Retrieved 06.09.2022 from https://www.hse.ru/data/2011/12/12/1258855184/Revealing_conspiracy_in_procurement_first-price_open_auctions.pdf.

Morozov, I., & Podkolzina, E. (2013). Collusion detection in procurement auctions. *Higher School of Economics Research Paper*, 25/EC/2013, 1–36. http://dx.doi.org/10.2139/ssrn.2221809.

MSWiA. (2021). *Baza JST*. Retrieved 23.03.2021 from https://www.gov.pl/web/mswia/baza-jst.

OECD. (2012). *Detecting bid rigging in public procurement: helping governments to obtain best value for money*. Retrieved 06.09.2022 from http://www.oecd.org/competition/cartels/42594486.pdf.

OECD. (2013). *OECD policy roudtables: ex officio cartel investigations and the use of screens to detect cartels*. Retrieved 06.09.2022 from https://www.oecd.org/daf/competition/exofficio-cartel-investigation-2013.pdf.

OECD. (2016). *Fighting bid rigging in public procurement: report on implementing the OECD recommendation*. Retrieved 06.09.2022 from https://www.oecd.org/competition/Fighting-bid-rigging-in-public-procurement-2016-implementation-report.pdf.

Ragazzo, C. E. J. (2012). Screens in the Gas Retail Market: The Brazilian Experience. *CPI Antitrust Chronicle*, 1, 1–8.

Schinkel, M.P. (2013). Balancing proactive and reactive cartel detection tools: some observations. In *OECD policy roudtables: ex officio cartel investigations and the use of screens to detect cartels* (pp. 257–262). Retrieved 06.09.2022 from https://www.oecd.org/daf/competition/exofficio-cartel-investigation-2013.pdf.

Sztabiński, F., & Żmijewska-Jędrzejczyk, T. (2012). Mixed mode survey designs: problem wyboru techniki. *Przegląd Socjologiczny*, 61(1), 31–63.

Szymczak, W. (2020) *Podstawy statystyki dla psychologów*. Diffin.

Ustawa z dnia 11 września 2019 r. Prawo zamówień publicznych [Public Procurement Law Act of September 11, 2019] (Dz.U. 2019 poz. 2019) (Poland).

UZP. (2019) *Sprawozdanie prezesa Urzędu Zamówień Publicznych o funkcjonowaniu systemu zamówień publicznych w 2018 r.* Retrieved 06.09.2022 from https://www.uzp.gov.pl/__data/assets/pdf_file/0020/41555/Sprawozdanie-UZP-za-2018.pdf.

UZP. (2020) *Sprawozdanie prezesa Urzędu Zamówień Publicznych o funkcjonowaniu systemu zamówień publicznych w 2019 r.* Retrieved 06.09.2022 from https://www.uzp.gov.pl/__data/assets/pdf_file/0020/43418/Sprawozdanie-2019-r.pdf.

Wensink, W,. & de Vet, J.M. (2013). *Identifying and reducing corruption in public procurement in the EU*. Retrieved 06.09.2022 from https://vpt.lrv.lt/uploads/vpt/documents/files/mp/kiti_leidiniai/identifying_reducing_corruption_in_public_procurement_en.pdf.

Acknowledgements

Author contributions: author has given an approval to the final version of the article.

Funding: this research was undertaken as part of the *Bid-rigging in the perspective of contracting authorities in the Polish public procurement system* project and was fully funded by a grant (B2111200002252.02) by the University of Lodz, Faculty of Economics and Sociology.

Note: the results of this study were presented at the *39th International Scientific Conference Multivariate Statistical Analysis* (November 8–10, 2021, Lodz, Poland).

Appendix

Table 1.
Population and sample structure of the questionnaire interview

Type of local authority	Number of observations			Response rate (%)	
	Population	Sample (total)	Sample (valid)	Total	Valid
municipalities, including:	2,411	1,996	1,934	83	80
– rural	1,533	1,237	1,212	81	79
– urban-rural	642	494	476	77	74
– urban	302	265	246	88	81
districts of Warsaw	18	17	17	94	94
poviats	314	269	262	86	83
voivodenships	16	14	12	88	75
total	2,825	2,296	2,225	81	79

Source: Own preparation based on MSWiA (2021) and information gathered in a survey performed under the project *Bid-rigging in the perspective of contracting authorities in the Polish public procurement system*.

Table 2.
Local authorities characteristics and the use of statistical analysis as standard practice

Variable	Variant	n (in total)	%	p	Cramér's V
X1	0	61	14.8	<0.001	0.131
	1	1,281	16.5		
	2	431	25.6		
	3	143	25.9		
	4–5	138	24.6		
	6 and above	123	33.3		
X2	yes	1,048	23.3	<0.001	0.080
	no	1,134	17.1		
X3	yes	31	22.6	0.744	0.007
	no	2,153	20.2		
X4	yes	45	28.9	0.148	0.031
	no	2,117	20.1		
X5	insignificant	1,221	20.2	0.160	0.056
	minor	499	21.0		
	moderate	341	15.5		
	major	51	27.5		
	significant	12	25.0		
X6	0%	641	19.8	0.228	0.046
	1–3%	431	22.7		
	3–10%	750	19.2		
	above 10%	250	16.4		
X7	up to PLN 4,000	592	18.9	0.626	0.028
	PLN 4,000–4,250	472	20.6		
	PLN 4,250–4,600	547	19.4		
	above PLN 4,600	555	21.8		

Variable	Variant	n (in total)	%	p	Cramér's V
X8	rural	1,201	17.1	<0.001	0.111
	urban-rural	466	23.0		
	urban	236	23.3		
	poviat	255	24.7		
	district of Warsaw	14	35.7		
	voivodenship	12	58.3		
X9	up to 4,852	444	13.6	<0.001	0.132
	4,853–7,166	443	19.5		
	7,167–11,585	438	16.6		
	11,586–28,070	439	23.0		
	28,071 and above	413	27.3		

Notes: n — number of observation; % — per cent of observation using statistical analysis as standard practice; p — p-value.

Source: Own preparation based on own research.

Table 3.
Logistic regression model: statistical analysis as standard practice (model 2)

Specification		B	S.E	Wald	df	p	OR
X1 (ref.=6 and above)				16.314	5	0.006	
0		−0.867	0.414	4.389	1	0.036	0.420
1		−0.693	0.215	10.436	1	0.001	0.500
2		−0.299	0.226	1.758	1	0.185	0.742
3		−0.385	0.276	1.942	1	0.163	0.681
4–5		−0.345	0.278	1.543	1	0.214	0.708
X2 (reference=negative)		−0.342	0.109	9.806	1	0.002	0.710
X9 (ref.=28 071 and above)				18.484	4	<0.001	
up to 4,852		−0.723	0.186	15.089	1	<0.001	0.485
4,853–7,166		−0.326	0.171	3.637	1	0.057	0.722
7,167–11,585		−0.499	0.176	8.039	1	0.005	0.607
11,586–28,070		−0.161	0.162	0.987	1	0.320	0.851
constant		−0.211	0.318	0.440	1	0.507	0.810
n				2,168			
Nagelkerke's R^2				0.046			
Omnibus test of model coefficient	χ^2			64.696			
	df			12			
	p			<0.001			
Hosmer–Lemeshow test	χ^2			13.034			
	df			8			
	p			0.111			
classification	y=1 (%)			100.0			
	y=0 (%)			0.0			

Notes: ref. — reference group; B — regression coefficient; S.E. — standard error; Wald — Wald's statistics; df — degrees of freedom; p — p-value; OR — odds ratio; χ^2 — chi-square statistic; df — degrees of freedom.

Source: Own preparation based on own research.