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Can E-procurement Reduce Bid Rigging in Public Auctions?

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Abstract

The adoption of e-procurement may reduce bid rigging in public auctions by limiting in-person meetings of bidders. Using the data from construction auctions tendered by a Japanese local government where paper-based manual procurement is replaced by e-procurement, we find that the adoption of e-procurement reduced bids in a section of the market where the bids were initially higher than the other section of the market. The degree of reduction was smaller in an auction when the bidders were likely to be in the same industrial community, suggesting that the effect of e-procurement by limiting in-person meetings is smaller when the bidders have chances to communicate via other than the procurement processes.

Keywords: auction, public procurement, e-procurement, bid rigging
JEL Classification H4 H57 D44

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1 Introduction

This paper analyses the effect of e-procurement in reducing bid rigging in public procurement auctions. E-procurement is the implementation of procurement processes using a special online platform. In e-procurement, the buyer can provide information to the potential bidders, exchange documents with them, and communicate with them all online. It also enables the potential bidders to submit their bids online. Many regional governments in Japan have adopted e-procurement since 2001.

The adoption of e-procurement is considered to be effective in promoting competition in public procurement auctions through three channels. First, e-procurement may lower the cost of participation in auctions for bidders who are distant from the auction site, and hence may increase the number of actual bidders. Second, e-procurement may prevent the buyer from favouring a specific bidder, and hence eliminate the motivation of the potential bidders to bribe. Lastly, e-procurement may prevent bid rigging by eliminating the chance of the bidders meeting in person.

Recently, Lewis-Faupel et al. (2016) revealed the effectiveness of e-procurement in promoting competition focusing on the first two channels, using data from India and Indonesia where corruption of government officials is a severe problem and many potential bidders were likely to be excluded from bidding by bribed government officials.

The third channel has attracted less attention, nevertheless, several bid-rigging cases show that in-person meetings in the manual procurement process helped bid-rigging cartels by providing information on the identities of the participants of auctions, or by providing them with an opportunity to communicate with each other. For example, a construction cartel identified in 2000 operated in auctions run by Tokyo Urban Planning and Development Public Corporation, where the bidders negotiated on who would win the contract after briefing sessions run by the buyer. In another cartel identified in 2001 that operated within auctions for the procurement of road painting services run by Metropolitan Police Department, the leading companies of the market gathered the business cards of the invited bidders when they received project documents, to organize the bidding cartel. Lastly, in a bridge construction cartel identified in 2005, the cartel members co-ordinated their bids until the final minutes based on the identity of the bidders appeared in the auction, to maximize cartel revenue: the cartel members bid very low when they recognized the participation of a particular non-ring bidder who was known to have a low cost, while they bid very close to the reserve price in the absence of that non-ring bidder. Some practitioners recognize that in-person meetings in the procurement process facilitate bid rigging. For example, the OECD recommends e-procurement as a way to limit in-person meetings and deter bid rigging (OECD(2012)).

This paper analyses the effect of e-procurement in promoting competition. Specifically, we focus on the effect of e-procurement in reducing bid rigging, by comparing the effects of e-procurement in two segments of a market. We use data from invited auctions for civil engineering projects organized by Okinawa Prefectural Government (henceforth, OPG), Japan, where paper-based manual procurement was replaced by e-procurement. The dataset is unique in the following respects. The OPG has partitioned the market by size of the project, and in one segment of the market for large projects the bidders were already competitive under the manual procurement because the Japanese Fair Trade Commission filed a bid-rigging case one year before the data period against many of the bidders who operated in that segment of the market.

The bidders in another segment of the market for small projects remained uncompetitive after the event. In fact, the bid was 97% of the reserve price on average in manual auctions for small projects, compared with 88% in auctions for large projects.

We estimate the effect of replacing paper-based manual procurement by e-procurement on the bid levels using a difference-in-differences approach. We use the data from construction auctions conducted by Naha City Government as the control group. Naha City is the largest city unit in Okinawa area and used paper-based manual procurement throughout the data period.

Our results show that the adoption of e-procurement reduced the bids by about 2% and the win bids by about 4% in auctions for small projects where the bids were initially high. On the other hand, the adoption of e-procurement did not change the bids in auctions for large projects where the bidders were initially competitive. We also show that the participation rate, which is the ratio of the number of actual bidders to the number of potential bidders was not changed by the adoption of e-procurement. Furthermore, we show that the effect of adopting e-procurement is smaller in auctions where the bidders are likely to be in the same industrial community. This result is consistent with our conjecture that the effect of e-procurement on eliminating bidder's in-person meetings may be smaller if they can meet outside of the procurement process. Our results suggest that the replacement of paper-based manual procurement by e-procurement reduced the bids by deterring bid rigging, rather than by promoting entrance to auctions.

This study contributes to three strings of literature as follows. First, this study contributes to the literature trying to quantify the effect of e-procurement in public procurement. As mentioned earlier, Lewis-Faupel et al. (2016) is the seminal paper in this literature. They use road construction contract data in India and Indonesia, and find that the adoption of e-procurement does not decrease bids, but does improve the quality of the works by encouraging the entrance of more efficient firms. Their primary focus is on the effect of e-procurement in eliminating contact between potentially corrupt officials and potentially bribing bidders, because their data evidently show that the government officials involved in traditional paper-based manual procurement are very likely to be corrupt. In contrast to their paper, we confirm that the adoption of e-procurement decreased the bids in a potentially collusive market by contrasting the effects in two segments in the same market with different levels of initial competitiveness.

Second, this study contributes to the vast literature on how policy change affects bidding behaviour in public procurement auctions. For example, Iimi (2006) and Li and Zheng (2009) analyse the effect of the number of bidders. Ohashi (2009) analyses the effect of the transparency of the bidder qualification process. De Silva et al. (2008) analyse the effect of the release of the government's internal cost estimates.

Third, this study contributes to the literature on bid rigging by showing the possibility that information about other bidders' identities facilitates collusion. Bid rigging, for example, is empirically analysed by Porter and Zona (1993), Bajari and Ye (2003) and Asker (2010).

The structure of the paper is as follows. In Section 2, we describe the market and the data. In Section 3, we explain our estimation procedure. In Section 4, we show the results and Section 5 concludes.

2 The market and data

2.1 Institutional background

Invited auctions are a form of auction where the buyer invites eligible bidders to the auction. We restrict our attention to invited auctions because the number of invited bidders is determined by the value of the project, although there are some exceptions in the actual data. By knowing the number of potential bidders, each bidder faces less uncertainty in an invited auction compared with an open auction where the number of potential bidders is unknown. As shown in Li and Zheng (2009), a change in the number of potential bidders may make the bidding behaviour more aggressive or more passive. In an invited auction, the bidders are free from such behavioural change.

The invited auction system used by the OPG for its civil engineering work is as follows. When the OPG wants to procure a construction project in an invited auction, it first determines the reserve price of the auction based on the internal cost estimate. The OPG then assigns the project to either of five project ranks from A+ and A to D, where A+ is the highest, based on the reserve price.

As well as the project ranking, firms that are willing to participate in the OPG's procurement auctions are classified into five bidder ranks, A+ and A to D based on qualification. A firm must be qualified on their amount of completed work, the level of financial health, and the technical level every two years.

The OPG invites a set of bidders from the same rank as the rank of the project. For example, a bidder in rank A is invited to auctions for projects of rank A. However, there are many exceptions. The OPG often extends the range of the bidders to those in adjacent ranks. In our data, the OPG invited bidders from more than one bidder rank in 47% of its auctions.

The number of invitations to the auction is determined by the project rank. For example, 21 bidders are invited to an auction for a rank A+ project. Table 1 shows the criteria of the project classifications and the specified number of invitations for each project rank. The OPG, therefore, screens the set of bidders to be invited from the firms in the corresponding bidder rank. Although the screening process is discretionary and opaque, the OPG's invitation policy states that it invites firms that are located close to the project site, have conducted similar work in the past three years, and do not have a large amount of uncompleted works. Once a firm is invited to an auction, it can choose whether to submit a bid or to decline the invitation. An invited bidder can decline the invitation to the auction by simply ignoring it.

The auctions analysed here are first-price sealed-bid auctions with an unknown reserve price and an unknown minimum price. That is, a bidder will win the contract if his bid is the lowest in the range between the minimum price and the reserve price. Although the reserve price was unknown, it is easily inferred by the bidders because the OPG revealed its own cost estimate, and the reserve price was usually very close to the cost estimate. Tiebreaking is resolved by public randomization.

In the paper-based manual auctions that were conducted until March 2008, the invited bidders were directed to receive the project documents at the OPG's office during a specified period. On the day of the auction, the invited bidders and the auctioneer gathered at the auction site in the OPG's office, and each bidder submitted a sealed paper bid. The auctioneer opened the bids immediately after submission, and all the bids and the winner were revealed.

Manual procurement was replaced by e-procurement in April 2008 in public procurement auctions for construction works tendered by the OPG. It was planned in 2001 in accordance with the policy of the national government of Japan. In e-procurement, the invited bidders download the project document from the e-procurement system, and then each bidder submits its bid through the system before the submission deadline. The bids are usually revealed the day following the deadline, and all bids and the winner are revealed online.

The major difference between manual procurement and e-procurement is that the bidders have no opportunity to meet the other bidders or the government officials in e-procurement. In a manual procurement, the bidders have opportunities to see each other during the procurement process, typically when the bidders visit the OPG's office to receive the project documents and when they bid. The bidders may have utilized those opportunities to identify who to co-ordinate with, and then elaborately organized a bidding cartel.

2.2 Data

We use data of invited auctions for civil engineering work tendered by the OPG, which were publicly available on the OPG website. The data period is from April 2007 to December 2008. Given that e-procurement was adopted by the OPG in April 2008, we divide our data period into two subperiods, the "manual procurement period" from April 2007 to March 2008 and the "e-procurement period" from April 2008 to December 2008. The data period is limited, because the data of both the control group and the treatment group in our difference-in-differences approach are both available only in this period.

The OPG tendered 945 civil engineering projects during the data period, however, the reserve price for 177 of 415 e-procurement auctions was not revealed for unknown reason.[1] In total, 12484 bidders were invited and 10677 of them submitted a bid in 768 auctions, 530 of which were manual procurement and 238 were e-procurement.

During the data period, 1518 bidders submitted at least once in the OPG auctions. Table 2 shows the number of auctions in each project rank, and the number of firms in the corresponding bidder rank in our data. For each auction, we have data on the auction date, reserve price, minimum price, identity of the invited bidders and the winner, their bid and the bidder rank, as well as the location of each invited bidder. Table 3 shows the definitions of the variables used in this paper.

We also use the bid data of invited auctions for construction work tendered by the Naha City Government as a control group, which is the largest city unit in Okinawa. Naha City projects have the same macroeconomic background as the OPG projects, and Naha City used paper-based manual procurement throughout the data period independently. There were no major institutional changes in its procurement system. We use 2119 bids submitted in 207 Naha City construction auctions. Summary statistics are presented in Table 4 for OPG auctions and Table 5 for Naha auctions.

Our difference-in-differences approach demands that the trends in the OPG auc-

[1]The absence of a reserve price tends to occur with auctions for projects on remote islands or in rural areas of Okinawa Main Island. For example, 34 out of 35 projects in the Yaeyama Islands are missing data because of the lack of reserve prices. If the competitiveness in auctions in such areas remains lower under e-procurement, the effectiveness of e-procurement can be exaggerated by the unavailability of data for those projects.

tions and the Naha City auctions are parallel. Figure 1 shows the quarterly transitions of the average of the bids in the OPG auctions and the Naha City auctions. Graphically, the trends are almost parallel in the manual procurement period, while the lines cross each other after the change of the procurement system. To examine further the validity of the assumption of parallel trends, we apply an event study analysis in Section 4.

2.3 Descriptive analysis

In this subsection, we provide a brief descriptive analysis of the distribution of the bids and how it changed from the manual procurement period to the e-procurement period. Hereafter, we observe the relative value of the bids and the win bids to the reserve price, rather than the actual values. Henceforth, a bid and a win bid refer to the relative value of the bid and the win bid to the reserve price, respectively.

First, it should be noted that a bid-rigging case was revealed in this market one year before the data period, following which 152 firms received a legal penalty in March 2006. The punished firms were bidders in rank A+.

After the breakdown of the cartel among rank A+ bidders, the auctions for ranks A+ and A were competitive in the manual procurement period, while the auctions for ranks B, C and D remained less competitive. Figure 2 shows how the distributions of the win bids differ between rank A and A+ projects and rank B-D projects in the manual procurement period. As shown, the win bids in ranks A and A+ are concentrated in a low range between 0.8 and 0.85, while those in ranks B–D are concentrated in a high range between 0.95 and 1.

Figure 3 shows how the average of the bids is different across the project ranks and across periods. For rank A and A+ projects, the bids were lower and relatively stable across periods. In contrast, for rank B–D projects, the bids were initially higher than 0.95 and then, decreased after the adoption of e-procurement.

Figures 4 and 5 show the differences in average bids and average win bids between the manual procurement period and e-procurement period, respectively. Each figure includes five dots, each of which shows the difference in the averages between the manual procurement period and e-procurement period and the confidence interval for each project rank from A+, A, B, C and D. As shown in the figures, the bids and the win bids in rank A and A+ projects were either higher or not significantly changed after the replacement of the procurement system. In contrast, both the bids and the win bids in rank B, C, and D projects were significantly lower after the change of the procurement system.

Hereafter, we call rank A+ and A projects “high-rank projects” and rank B, C, and D projects “low-rank projects”, and illustrate the difference between these two groups. Figures 6 and 7 show the distribution of the bids in each period for high-rank projects and low-rank projects, respectively. As shown in Figure 6, many bids are concentrated in the interval between 0.8 and 0.85 in auctions for the high-rank projects in both periods. Because the minimum price is secret and usually set in the range between 0.8 and 0.85 of the reserve price, these bids are likely to be submitted aiming to win at the minimum price.

In contrast, as shown in the left panels of Figure 7, in auctions for the low-rank projects in the manual procurement period, the majority of the bids are concentrated between 0.95 and 1, which is very close to the reserve price. It is likely that those bids were aimed at winning at the reserve price, or were non-serious bids in less competitive auctions. In the e-procurement period, however, more bids in the low-rank auctions were submitted in the interval of [0.8, 0.85] as shown in the right panel of Figure 7. A simple overview of the data shows that the bids are lower in the e-procurement period than in the manual procurement period in auctions for the low-rank projects, while bid distributions are relatively stable in auctions for the high-rank projects.

We next observe the entrance to the auctions. The number of invitations to the auctions is interpreted as the number of potential bidders, and is systematically determined by the reserve price. We observe the participation rate, which is the ratio of the number of bidders who submitted a bid, to the number of invitations to the auction.

Table 6 shows the average of participation rates for the high-rank projects, the low-rank projects, and Naha City projects. The participation rate decreased in both the high-rank and the low-rank projects. As discussed by Lewis-Faupel et al.(2016), the adoption of e-procurement may discourage the entrance of some potential bidders to auctions, because e-procurement requires an internet connection and IT skills. However, the cause of the decrease could be a macroeconomic shock such as high demand in the private sector, given the fact that the participation rate also decreased from 0.91 to 0.80 in the Naha City auctions.

We formally test the changes in the distributions described above. Table 7 shows the results of the Mann–Whitney test and Kolmogorov–Smirnov test for the bids, the win bids, and the participation rate for comparison across periods. As shown in the table, the null hypotheses of equality in the bids and the win bids are rejected by both tests for the low-rank projects, while the null hypotheses are not rejected by the Mann-Whitney test for the high-rank projects. In both groups, the null hypothesis of equality in the participation rate is rejected by both tests.

3 Empirical procedure

3.1 Conceptual framework

We assume that the degree of competition can be represented by the level of the bids throughout the analysis. We then hypothesize that the adoption of e-procurement reduces the bids by reducing bid rigging. In a paper-based manual procurement, the bidders have opportunities to meet in person during the procurement process before and on the day of the auction. Such opportunities help the bidders to identify other bidders to communicate with, or enable them to co-ordinate their bids until the last minute. E-procurement is expected to reduce bid rigging by limiting such in-person meetings.

E-procurement may reduce bids through a channel other than reducing bid rigging; it may change the entrance behaviour of the bidders to the auction. Compared with manual procurement, the entrance cost of a distant bidder is lower in e-procurement, while the entrance cost is higher for a bidder who has poor IT skills. The adoption of e-procurement, therefore, may increase or decrease the bid level by changing the number of actual bidders in an invited auction. Hence, we analyse the impact of e-procurement on entrance behaviour, as well as bidding behaviour.

To confirm the effect of e-procurement on reducing bid rigging, we further analyse the heterogeneity in the effect of e-procurement. The effect of e-procurement vanishes when the bidders communicate outside of the procurement process, while the effect is sustained when the bidders have no communication outside of the procurement process. We therefore expect that the impact of e-procurement may be lower in a set of bidders who regularly communicate with each other in their community, and higher in a set of bidders who have no community in common.

Industry associations are such communities that facilitate communication among bidders. In the Okinawa area, there are industry associations for construction companies, and one of them is exclusively for large-scale companies that hold a high-level construction license; the others are for smaller companies in specific construction fields. This means that if a group of bidders is similar in their business scale and business specialty, then they are likely to be a member of the same industry association. When all the bidders in an auction are members of the same industry association, it will be easy for them to collude even under e-procurement.

We name an auction a "narrow auction" if all the bidders are in the same bidder rank, and an auction a "wide auction" otherwise. We use the bidder rank to represent the bidder's business scale because the bidder rank is determined based on the amount of completed work of the bidder. We then hypothesize that the impact of adopting e-procurement in reducing bids is greater in wide auctions than in narrow auctions if limiting in-person meetings is indeed effective in reducing bid rigging.

3.2 Estimation methods

Impact of e-procurement on auction outcomes We estimate how the replacement of the manual procurement by e-procurement affects the outcome of the auctions for civil engineering work tendered by the OPG. To control for macroeconomic shocks, we apply a difference-in-differences approach using bid data from the invited auctions for construction work tendered by the Naha City Government as the control group. We compare the changes in the outcomes in the OPG auctions and Naha City auctions from the manual procurement period to the e-procurement period. We estimate a model whose basic specification is as follows.

$$y_{iat} = \phi_i + \beta_1 \text{OPG}_a + \beta_2 \text{ e-proc}_t + \beta_3 \text{OPG}_a \times \text{e-proc}_t + X'_{iat}\delta + u_{iat} \tag{1}$$

The dependent variable y_{iat} can be either log of the bids, log of the average of the bids, log of the win bids or the participation rate. We use the logarithm of the bids because the explanatory factors may impact the bids non-linearly. The unit of observation is each submitted bid by bidder i in auction a at time t when y_{iat} is the log of the bid, and the unit is each auction a at time t when we use the auction level variable such as the log of the average of the bids, the log of the win bid or the participation rate as the dependent variable.

OPG_a is a dummy variable that equals 1 if the auction is conducted by the OPG and 0 if it is conducted by the Naha City Government. e-proc_t is a dummy variable that equals 1 if the auction is conducted in the e-procurement period, and 0 otherwise. X_{iat} is a vector of independent variables to control for additional factors that may affect a bidder's behaviour, which mainly consists of two groups of variables: auction characteristics and bidder characteristics. Variables to control for the auction characteristics are the reserve price, the minimum price, the number of actual bidders, and the dummy variables for each quarter-by-year. Variables to control for bidder characteristics are the frequency of winning and the frequency of bidding in auctions during the data period. When the dependent variable is the log of the average of the bids, we use the mean of the frequencies of bidding or winning among the bidders in each auction. Dummy variables for the 30 major contractors are also included in the regression at the bid level.

Our main interest is the impact of e-procurement on the auction outcome estimated as β_3 in Eq. (1), which is the average difference in y_{iat} that occurs in the OPG auctions compared with that of the Naha City auctions in the e-procurement period. We expect that the adoption of e-procurement will reduce the bids and the win bids and promote the entrance of bidders, which corresponds to β_3 being negative when y_{iat} is either the log of the bids, the average of the bids, or the win bids, and β_3 being positive when y_{iat} is the participation rate.

Two problems in estimating Eq. (1) arise given that each bidder endogenously chooses whether to participate in the auctions. First, sample selectivity arises because the entry decision depends on each bidder's cost. An invited bidder will not participate in the auction when the expected return from participating in the auction is lower than the cost of participation. Second, the number of actual bidders may be an endogenous variable. The number of actual bidders tends to be low if the project is costly for everyone, and thus it is correlated with the cost of the project which is part of the error term.

Given these problems, we estimate the impact of e-procurement on the bids at the auction level as well as the bid level. That is, we estimate Eq. (1) using both the bids and the average of the bids as the dependent variable and compare the results to discuss the severity of the selection bias. In addition, we estimate Eq. (1) by two-stage least squares estimation using an instrumental variable for the number of actual bidders. We employ the number of invitations as the instrument for the number of actual bidders, following Iimi (2013).

Heterogeneity in the impact of e-procurement A negative coefficient of β_3 in Eq. (1) is not sufficient to conclude that adoption of e-procurement reduces bid rigging, given that e-procurement may promote competition by encouraging bidder entry. We then estimate the following triple difference model to examine the heterogeneity in the effect of e-procurement across wide/narrow auctions.

$$\begin{aligned} y_{iat} &= \phi_i + \beta_1 \text{OPG}_a + \beta_2 \text{ e-proc}_t + \beta_3 \text{OPG}_a \times \text{e-proc}_t \\ &\quad + \beta_4 \text{OPG}_a \times \text{wide}_a + \beta_5 \text{OPG}_a \times \text{wide}_a \times \text{e-proc}_t + X'_{iat}\delta + u_{iat} \qquad (2) \end{aligned}$$

Again, we use the log of the bids or the log of the average of the bids as y_{iat}. The unit of observation is each submitted bid by bidder i in auction a at time t when we use the log of the bids as the dependent variable, and it is each auction a at time t when we use the log of the average of the bids as the dependent variable.

wide_a equals 1 if auction a is a wide auction, that is, at least one bidder belongs to a different bidder rank from the other bidders, and 0 otherwise. X_{iat} again includes the variables of bidder and auction characteristics we use in Eq. (1). Note that we include five interaction terms, because $\text{wide}_a = 0$ for every Naha City auction. We estimate Eq. (2) by 2SLS using the number of invitations as an instrumental variable for the number of actual bidders.

The testable hypothesis is that the impact of e-procurement is larger in wide auctions than in narrow auctions, as discussed earlier. We thus expect β_5 in Eq. (2) to be negative. We interpret the heterogeneity in effects as support of our hypothesis that e-procurement may reduce bid rigging by eliminating in-person meetings of the bidders.

In the estimation, two problems are relevant. First, there may be omitted variables that are correlated with both the wide auction dummy and e-procurement period dummy. One candidate for such a factor is the entrance of strong bidders from other bidder ranks to e-procurement auctions. To examine the robustness for omitted variables, we construct a variable rank-above_{iat} as a proxy for a strong entrant in a wide auction. rank-above$_{iat}$ indicates whether the bidder is an entrant from a higher bidder rank than the project rank. It indicates whether the bidder is larger and therefore potentially stronger than other bidders in the auction. It equals 1 if bidder i's bidder rank is higher than the project rank of auction a in period t, and 0 otherwise. rank-above$_{iat} = 0$ for all bids in Naha City auctions because we have no data about bidder ranking for Naha City auctions. We include rank-above$_{iat}$ and its interaction term with e-proc$_t$ in the model. When the use of rank-above$_{iat}$ is insufficient, the effect of e-procurement in the triple difference model is biased.

Second, two variables are potentially bad controls. Table 8 shows the test results for the mean difference across periods for four variables that are determined by the OPG. As shown, the minimum price slightly decreased in the e-procurement period. To examine the robustness to potential selection bias because of the minimum price, we estimate specifications with and without the minimum price in the models.

The average of the dummy variable for a wide auction is significantly higher in the e-procurement period than in the manual procurement period in the auctions for the low-rank projects. The mean is 0.42 in the manual procurement period and 0.61 in the e-procurement period. It should be noted that the effect of e-procurement estimated by triple difference estimation can be biased.

4 Results

This section shows the results of the estimations described in the previous section. First, we show the result of an event study to examine the validity of the parallel trend assumption that we need in our difference-in-differences approach. Second, we show our main result for the difference-in-differences model to examine the effect of e-procurement. Finally, we show the results of the triple difference model to estimate the heterogeneity of the effect of e-procurement across wide/narrow auctions.

Validity of the parallel trend assumption We first show the results of an event study using the data from the manual procurement period, to examine the validity of the parallel trend assumption of the difference-in-differences estimation. In addition to the auction characteristics and the bidder characteristics, we include the quarter-by-year dummies and the OPG dummy and their interactions, using the first quarter of FY2007 as the base period. In Table 9, the first two columns show the results using the high-rank auction data, and the latter two columns correspond to the low-rank auction data. If the trends in the OPG auctions and Naha City auctions are parallel, the interaction terms of $\text{OPG}_a \times \text{FY2007q2}, \text{OPG}_a \times \text{FY2007q3}$, and $\text{OPG}_a \times \text{FY2007q4}$ should all be zero. As shown in the table, these three interaction terms are significantly different from zero in every column, which suggests that the trends are not perfectly parallel.

However, the joint hypothesis of parameter equality $\text{OPG}_a \times \text{FY2007q2} = \text{OPG}_a \times \text{FY2007q3} = \text{OPG}_a \times \text{FY2007q4}$ is not rejected in columns (3) and (4). The chi squared test statistics are 2.95(0.22) and 1.85(0.39) with corresponding p-values in parentheses, respectively. In columns (1) and (2), the same joint hypothesis is rejected, but the hypothesis of parameter equality $\text{OPG}_a \times \text{FY2007q2} = \text{OPG}_a \times \text{FY2007q3}$ is not rejected with the test statistics of 0.50(0.47) and 0.05(0.81), respectively.

These indicate that the trends in the manual procurement period are parallel from the second quarter to the final quarter of FY2007, after non-parallel trends from the first quarter to the second quarter of 2007 for the low-rank auction data, which is consistent with the graphical observation in Figure 1. The trends are parallel from the second quarter to the third quarter of FY2007 for the high-rank auction data. The results suggest that the parallel trend assumption is partially valid in our data.

Impact of e-procurement on auction outcome We next proceed to our main results and examine the effect of e-procurement on bidding behaviour. Table 10 presents the 2SLS estimation results of Eq. (1) using the bids as the dependent variable. Columns (1) and (2) show the results using the auction data for the high-rank projects, while columns (3) and (4) show the results using the auction data for the low-rank projects. As shown in columns (1) and (2), the interaction term $\text{OPG}_a \times \text{e-proc}_t$ is not significant when the data from the high-rank projects are used. However, it is significantly negative in the results using the data from the low-rank projects as shown in columns (3) and (4). The results suggest that the adoption of e-procurement did not change the bids in the high-rank projects, while it reduced the bids by 1.8–2.3% in the low-rank projects. These results are consistent with our observation obtained in Figure 3.

OPG_a is positive and significant in every specification, showing that the bids were higher in the OPG auctions than in the Naha City auctions by about 1% in the high-rank projects and about 6% in the low-rank projects on average. The number of actual bidders has a negative impact on the bids after controlling for the endogeneity of the variable, suggesting that one additional bidder decreased the bids by 0.5–1%. The bidder with a high frequency of winning tends to bid lower. Additional experience of winning decreased the bids by 1–1.5%. We see that including the minimum price in the model leads to an overestimation of the impact of e-procurement. The estimated impact is smaller by 0.5% when we omit the minimum price.

Table 11 shows the 2SLS estimation results using the average of the bids in each auction as the dependent variable. The interaction term $\text{OPG}_a \times \text{e-proc}_t$ is insignificant in the results of the high-rank projects as shown in columns (1) and (2) as expected. In the results of the low-rank projects, it is still significantly negative in column (3) and the estimated impact is similar in the same column in Table 11. In column (4), the interaction term is negative but only significant at the 10% level. As a whole, the negative impact of e-procurement is confirmed in the results using the average of the bids as the dependent variable, although it is less clear compared with the results at the bid level.

Table 12 shows the 2SLS estimation results using the win bids as the dependent variable. The explanatory variables are the auction characteristics. As we expected, the interaction term $\text{OPG}_a \times \text{e-proc}_t$ is not significant in the high-rank project auctions as shown in columns (1) and (2), but is significantly negative in the low-rank projects shown in columns (3) and (4). The estimated impact of e-procurement on the win bids in the low-rank projects is a reduction of about 4%.

Lastly, Table 13 shows the results of the OLS estimation of Eq. (1) using the participation rate as the dependent variable. As well as the specification for the win bids, the explanatory variables are the auction characteristics. We use the number of invitations as an explanatory variable for this specification instead of the number of actual bidders. In every column, $\text{OPG}_a \times \text{e-proc}_t$ is not significant, suggesting that the participation rate is not increased by the adoption of e-procurement. The participation rate is lower in the low-rank OPG auctions than in the Naha City auctions by about 0.08, and it is lower in the e-procurement period in both the low-rank OPG auctions and Naha City auctions by about 0.13 as shown in columns (3) and (4).

Heterogeneity across wide/narrow auctions We further show the results of the triple difference estimation to see whether the impact of e-procurement on bids is greater in a wide auction than in a narrow auction. Table 14 shows the 2SLS estimation results of Eq. (2) using the bids as the dependent variable. The triple difference term $\text{OPG}_a \times \text{wide}_a \times \text{e-proc}_t$ is significantly negative in every column, indicating that e-procurement decreased the bids by a larger degree in wide auctions than in narrow auctions by 1.8–3.4 %. The results of a robustness check by including rank-above_{iat} and its interaction with e-proc_t are shown in columns (3) and (6) of the table. The estimates of $\text{OPG}_a \times \text{wide}_a \times \text{e-proc}_t$ are still significantly negative in both columns. The estimates of rank-above_{iat} are significantly negative, suggesting that a strong entrant tends to bid lower by 4.2% in high-rank auctions and 1.9% in low-rank auctions. The estimates of the interaction term $\text{rank-above}_{iat} \times \text{e-proc}_t$ is significantly positive only in column (6), suggesting that the strong entrants bid less aggressively by about 1.6% after the adoption of e-procurement in the low-rank auctions.

Table 15 shows the estimation results of Eq. (2) using the average of the bids as the dependent variable. The results are less clear compared with the estimation results at the bid level shown in Table 14. The triple difference term $\text{OPG}_a \times \text{wide}_a \times \text{e-proc}_t$ is negative in every column, but not significant at the 5% significance level in columns (3), (4) and (5). In column (6), the triple difference term is significantly negative, suggesting that e-procurement decreased the bids by a larger degree of 4.5% in wide auctions than in narrow auctions. In columns (1)–(5), the estimated values of the triple difference term are slightly lower in absolute value by at most 0.8%, but the standard errors are much greater compared with the values in the corresponding column in Table 14.

In summary, the results of the difference-in-differences estimation show that the adoption of e-procurement reduced the bids by about 2%, and the win bids by about 4% in auctions for low-rank projects that were initially less competitive under the manual procurement. By contrast, e-procurement did not change the bids or the win bids in high-rank projects that were initially competitive before the adoption of e-procurement. The results also show that the adoption of e-procurement did not change the participation rate of the bidders in the auctions. The results of the triple difference estimation show that the degree of decrease in bids is greater in wide auctions than in narrow auctions, suggesting that the effect of e-procurement is smaller when the bidders are likely to be in the same industrial community. However, the results are less clear when we use the average of the bids in each auction instead of the bids as the dependent variable.

5 Conclusion

Several legal cases of bid rigging show that in-person meetings in the manual procurement process facilitate bid rigging by providing information on the identities of other bidders to organize a bidding cartel, or by enabling the ring bidders to co-ordinate their bids until the last minute based on information about who is in the auction. E-procurement is expected to deter collusion by limiting in-person meetings during the procurement process and reduce bid rigging.

This paper analysed the effect of replacing the paper-based manual procurement by e-procurement, using a unique dataset from the invited auctions conducted by the OPG where one segment of the market was initially competitive and the other was not.

Our results show that the adoption of e-procurement reduced the bids by about 2% in the segment of the market where the bidders were initially less competitive. In contrast, the adoption of e-procurement did not change the bids in another segment of the market where the bidders were already competitive. Furthermore, the impact of e-procurement is smaller when the bidders are likely to be in the same industrial community, and hence, have opportunities to communicate outside of the procurement process. We also show that the adoption of e-procurement did not change the ratio of the number of participants to the number of invitations to the auctions.

These results are consistent with our conjecture that the decrease in the bids by e-procurement is because of a reduction of bid rigging, rather than promoted entrance. Our results justify the policies of national and local governments to promote e-procurement. The adoption of e-procurement can be effective, even though corruption within the government is not relevant, wherever collusion among the bidders is likely.

However, there are several caveats to our analysis as discussed in Section 3. First, the estimated impact could be biased because of sample selectivity, because each bidder decides whether to enter the auction depending on its cost. In fact, the estimated impact on the bids is lower and less clear when we use the average of the bids in each auction as the auction outcome, as discussed in Section 4.

Second, we do not sufficiently observe relevant factors that potentially correlate with both e-procurement and a wide auction. Because of potential omitted variables, the effect of e-procurement in the triple difference estimation can be biased.

Third, the problem of bad control is relevant to the wide auction dummy variable. The frequency of the wide auction is greater in the e-procurement period than in the manual procurement period for the low-rank projects. This suggests that the choice of the OPG regarding whether it invites bidders from multiple ranks or a single rank might be affected by the adoption of e-procurement. We must again admit that the estimate of the impact of e-procurement can be biased in the triple difference approach.

Lastly, missing data because of the lack of reserve prices may cause estimation bias. As described in Section 2.2, the unavailability of reserve prices tends to occur in rural areas or remote islands. If the competitiveness in auctions in those areas remained lower under e-procurement, the effectiveness of e-procurement could be exaggerated.

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Table 1: Project ranks and the number of bidders to be invited

Rank	Reserve price(yen)	Number of invited bidders
A+	150 million and higher	21
A	50 -150 million	18
B	25 - 50 million	15
C	10 - 25 million	15
D	below 10 million	15

Table 2: Project ranks and the number of bidders to be invited

Project/Bidder rank	Num. of auctions	Num. of bidders
A+	83	87
A	173	397
B	181	219
C	252	263
D	79	537
Other	–	15
Total	768	1518

Note: 15 bidders in "Other" category are from outside of Okinawa Prefecture and are not assigned to any bidder rank.

Table 3: Variable definitions

Variable name	Definition
Bid	Bid divided by the reserve price.
Win bid	Win bid divided by the reserve price.
Participation rate	Number of actual bidders divided by the number of invitations to the auction.
OPG	Dummy for the OPG auctions. 1 if the buyer is the OPG and 0 if the buyer is Naha City Government.
e-proc	Dummy for the e-procurement period. 1 if the auction is conducted after April 2008, and 0 otherwise.
Reserve	Reserve price of the auction.
Minimum price	Minimum price divided by the reserve price.
Num. of invited bidders	Number of invited bidders to each auction.
Num. of actual bidders	Number of actual bidders in each auction.
Freq. of bidding	Frequency of bidding of each bidder during the data period.
Freq. of winning	Frequency of winning of each bidder during the data period.
Wide auction	Dummy variable for a wide auction. 1 if the OPG invited bidders from more than one bidder rank to the auction, and 0 otherwise.
Rank-above	Dummy variable that is 1 if the bidder's rank is higher than the rank of the project, and 0 otherwise.

Table 4: Summary statistics for OPG auction data

Variable	**Mean**	**Std. Dev.**	**Min.**	**Max.**	**N**
Bid level variables					
Bid	0.937	0.07	0.758	1.089	10677
Freq. of bidding	15.921	8.814	1	54	12484
Freq. of winning	0.519	0.809	0	6	12484
Rank-above	0.128	0.334	0	1	12484
Auction level variables					
Win bid	0.905	0.068	0.785	1	768
Participation rate	0.857	0.193	0.067	1	768
OPG	1	0	1	1	768
e-proc	0.31	0.463	0	1	768
Reserve price	0.058	0.061	0.003	0.3	768
Minimum price	0.818	0.046	0	0.983	768
Num. of invited bidders	16.267	2.359	5	25	768
Num. of actual bidders	13.914	3.667	1	24	768
Wide auction	0.387	0.487	0	1	768
FY2007 Q2	0.27	0.444	0	1	768
FY2007 Q3	0.156	0.363	0	1	768
FY2007 Q4	0.178	0.383	0	1	768
FY2008 Q2	0.234	0.424	0	1	768
FY2008 Q3	0.044	0.206	0	1	768

Table 5: Summary statistics for Naha auction data

Variable	**Mean**	**Std. Dev.**	**Min.**	**Max.**	**N**
Bid level variables					
Bid	0.933	0.079	0.700	1.037	2119
Freq. of bidding	7.419	6.02	1	35	2435
Freq. of winning	0.495	0.754	0	5	2435
Rank above	0	0	0	0	2435
Auction level variables					
Win bid	0.888	0.081	0.705	1	207
Participation rate	0.865	0.165	0.143	1	207
OPG	0	0	0	0	207
e-proc	0.382	0.487	0	1	207
Reserve price	0.048	0.121	0.001	0.868	207
Minimum price	0.512	0.389	0	0.85	207
Num. of invited bidders	11.155	2.128	3	24	207
Num. of actual bidders	9.681	2.663	1	15	207
Wide auction	0	0	0	0	207
FY2007 Q2	0.106	0.309	0	1	207
FY2007 Q3	0.246	0.432	0	1	207
FY2007 Q4	0.198	0.4	0	1	207
FY2008 Q2	0.155	0.362	0	1	207
FY2008 Q3	0.203	0.403	0	1	207

Table 6: Participation rate in OPG auctions and Naha City auctions

Auction category	Manual procurement period	e-procurement period	t-value
OPG, rank A, A+	0.895	0.751	-24.8
OPG, rank B–D	0.882	0.822	-12.1
Naha	0.913	0.802	-17.3

Table 7: Tests for equality in distributions of the dependent variables

		MW test		KS test	
Variables	Project rank	z-statistics	p-value	KS statistics	p-value
Bid	A and A+	0.98	0.33	0.12	0.00
	B–D	11.67	0.00	0.21	0.00
Win bid	A and A+	1.16	0.25	0.18	0.03
	B–D	5.00	0.00	0.27	0.00
Participation rate	A and A+	6.74	0.00	0.28	0.00
	B–D	3.16	0.00	0.17	0.01

Table 8: The variables determined by the OPG

Variables	Projects	Manual auction N	Mean	SD	Online auction N	Mean	SD	t value	pvalue
Reserve	A, A+	125	0.13	0.06	131	0.13	0.06	0.01	0.99
	B–D	405	0.02	0.01	107	0.02	0.01	-0.86	0.39
Min. price	A, A+	125	0.83	0.02	131	0.83	0.01	2.11	0.04
	B–D	405	0.82	0.02	107	0.79	0.11	3.71	0.00
Num. of invited bidders	A, A+	125	18.82	3.15	131	18.90	1.48	-0.28	0.78
	B–D	405	14.96	0.69	107	15.02	0.14	-0.83	0.40
Wide auction	A, A+	125	0.18	0.39	131	0.28	0.45	-1.86	0.06
	B–D	405	0.42	0.49	107	0.61	0.49	-3.40	0.00

Table 9: Event study on the bids

VARIABLES	(1) High ranks 1	(2) High ranks 2	(3) Low ranks 1	(4) Low ranks 2
Num. of actual bidders	-0.00814**	-0.00904**	-0.00342**	-0.00663**
	(0.000837)	(0.000813)	(0.000836)	(0.000765)
Minimum price	-0.0353**		-0.0450**	
	(0.00600)		(0.00505)	
Freq. of bidding	0.00169**	0.00166**	0.000647**	0.000710**
	(0.000248)	(0.000249)	(0.000120)	(0.000122)
Reserve price	-0.0238	-0.0441**	0.0221	-0.0191
	(0.0162)	(0.0161)	(0.0137)	(0.0132)
Freq. of winning	-0.00931**	-0.00920**	-0.00696**	-0.00718**
	(0.00188)	(0.00190)	(0.000973)	(0.000993)
OPG	0.0396**	0.0313**	0.0840**	0.0711**
	(0.00945)	(0.00948)	(0.00569)	(0.00562)
FY2007 Q2	0.0315**	0.0248**	0.0331**	0.0236**
	(0.00780)	(0.00777)	(0.00612)	(0.00615)
FY2007 Q3	0.0279**	0.0241**	0.0345**	0.0279**
	(0.00687)	(0.00688)	(0.00539)	(0.00545)
FY2007 Q4	0.00596	0.000424	0.0141*	0.00492
	(0.00714)	(0.00712)	(0.00562)	(0.00564)
OPG×FY2007 Q2	-0.0320**	-0.0248*	-0.0316**	-0.0211**
	(0.00976)	(0.00974)	(0.00667)	(0.00670)
OPG×FY2007 Q3	-0.0264**	-0.0228*	-0.0270**	-0.0224**
	(0.00959)	(0.00964)	(0.00604)	(0.00614)
OPG×FY2007 Q4	-0.0469**	-0.0425**	-0.0227**	-0.0163**
	(0.00940)	(0.00944)	(0.00622)	(0.00630)
Constant	0.00785	0.00576	-0.0389**	-0.0179
	(0.0104)	(0.0105)	(0.00985)	(0.00973)
Observations	3,471	3,471	6,712	6,712
R-squared	0.186	0.174	0.104	0.066

Standard errors in parentheses

** p<0.01, * p<0.05

Table 10: Difference-in-differences estimation for the bids

VARIABLES	(1) High rank	(2) High rank	(3) Low rank	(4) Low ranks
Num. of actual bidders	-0.00929**	-0.0103**	-0.00497**	-0.00781**
	(0.000796)	(0.000752)	(0.000891)	(0.000766)
Pref. × e-proc	-0.000736	0.00149	-0.0232**	-0.0183**
	(0.00460)	(0.00463)	(0.00385)	(0.00384)
OPG	0.0143**	0.0126*	0.0588**	0.0551**
	(0.00527)	(0.00534)	(0.00290)	(0.00292)
e-proc	-0.0140*	-0.0167*	-0.0214**	-0.0269**
	(0.00672)	(0.00675)	(0.00560)	(0.00561)
Minimum price	-0.0284**		-0.0318**	
	(0.00492)		(0.00452)	
Freq. of bidding	0.00160**	0.00165**	0.000982**	0.00107**
	(0.000190)	(0.000190)	(0.000114)	(0.000114)
Reserve price	-0.0365*	-0.0489**	0.00710	-0.0226
	(0.0142)	(0.0142)	(0.0137)	(0.0132)
Freq. of winning	-0.0154**	-0.0156**	-0.0104**	-0.0107**
	(0.00143)	(0.00144)	(0.000890)	(0.000900)
FY2007 Q2	0.0128**	0.0112*	0.00665**	0.00630*
	(0.00456)	(0.00458)	(0.00255)	(0.00258)
FY2007 Q3	0.0114*	0.00997*	0.0122**	0.00997**
	(0.00472)	(0.00474)	(0.00273)	(0.00274)
FY2007 Q4	-0.0225**	-0.0254**	-0.00627*	-0.00959**
	(0.00473)	(0.00471)	(0.00282)	(0.00281)
FY2008 Q2	0.00849	0.00507	0.0146**	0.0128**
	(0.00513)	(0.00511)	(0.00470)	(0.00475)
FY2008 Q3	0.000470	-0.00296	0.0262**	0.0234**
	(0.00589)	(0.00587)	(0.00530)	(0.00535)
Constant	0.0393**	0.0388**	-0.00879	0.00890
	(0.00887)	(0.00894)	(0.00922)	(0.00875)
Observations	6,132	6,132	8,783	8,783
R-squared	0.179	0.169	0.120	0.096

Standard errors in parentheses
** p<0.01, * p<0.05

Table 11: Difference-in-differences estimation for the average of bids

VARIABLES	(1) High ranks	(2) High ranks	(3) Low ranks	(4) Low ranks
Num. of actual bidders	-0.00707**	-0.00891**	-0.00294	-0.00744**
	(0.00167)	(0.00162)	(0.00209)	(0.00188)
Pref. × e-proc	0.00378	0.00642	-0.0273*	-0.0186
	(0.0118)	(0.0121)	(0.0108)	(0.0109)
OPG	-0.00608	-0.00994	0.0491**	0.0388**
	(0.0129)	(0.0134)	(0.00906)	(0.00865)
e-proc	-0.00258	-0.00729	-0.0127	-0.0249
	(0.0227)	(0.0229)	(0.0200)	(0.0203)
Minimum price	-0.0525**		-0.0579**	
	(0.00950)		(0.0114)	
Reserve price	-0.0131	-0.0482	0.0280	-0.0295
	(0.0315)	(0.0313)	(0.0271)	(0.0285)
Mean freq. of bidding	0.00167**	0.00182**	0.00141**	0.00171**
	(0.000645)	(0.000648)	(0.000379)	(0.000392)
Mean freq. of winning	-0.0267*	-0.0267*	-0.0192*	-0.0199*
	(0.0124)	(0.0136)	(0.00841)	(0.00932)
FY2007 Q2	0.0141	0.0120	0.00541	0.00632
	(0.0135)	(0.0140)	(0.00642)	(0.00686)
FY2007 Q3	0.00667	0.00737	0.00905	0.00630
	(0.0140)	(0.0147)	(0.00615)	(0.00682)
FY2007 Q4	-0.0206	-0.0229	-0.00717	-0.0112
	(0.0140)	(0.0147)	(0.00733)	(0.00793)
FY2008 Q2	-0.000738	-0.00493	0.0120	0.0114
	(0.0179)	(0.0174)	(0.0167)	(0.0171)
FY2008 Q3	-0.00829	-0.00960	0.0174	0.0186
	(0.0198)	(0.0195)	(0.0183)	(0.0188)
Constant	0.0387	0.0333	-0.00815	0.0126
	(0.0205)	(0.0221)	(0.0193)	(0.0195)
Observations	463	463	719	719
R-squared	0.358	0.321	0.183	0.089

Robust standard errors in parentheses

** p<0.01, * p<0.05

Table 12: Difference-in-differences estimation for the win bids

	High rank		Low rank	
VARIABLES	(1)	(2)	(3)	(4)
Num. of actual bidders	-0.00317	-0.00474**	-0.00510	-0.00770**
	(0.00168)	(0.00175)	(0.00276)	(0.00244)
OPG×e-proc	-0.00940	-0.00653	-0.0435**	-0.0383*
	(0.0158)	(0.0159)	(0.0166)	(0.0163)
OPG	0.00414	0.000146	0.0821**	0.0772**
	(0.0165)	(0.0171)	(0.0131)	(0.0127)
e-proc	-0.00880	-0.0134	-0.0243	-0.0317
	(0.0327)	(0.0324)	(0.0298)	(0.0298)
Minimum price	-0.0513**		-0.0346	
	(0.0168)		(0.0183)	
Reserve price	0.0443	0.0119	0.0446	0.0107
	(0.0281)	(0.0272)	(0.0323)	(0.0307)
FY2007 Q2	0.0184	0.0161	0.0188	0.0191
	(0.0202)	(0.0201)	(0.0112)	(0.0113)
FY2007 Q3	0.00839	0.00910	0.0117	0.00986
	(0.0220)	(0.0220)	(0.0112)	(0.0116)
FY2007 Q4	-0.00489	-0.00681	-0.00579	-0.00840
	(0.0208)	(0.0208)	(0.0120)	(0.0123)
FY2008 Q2	0.0203	0.0164	0.0322	0.0318
	(0.0223)	(0.0217)	(0.0246)	(0.0248)
FY2008 Q3	0.0179	0.0171	0.0346	0.0354
	(0.0248)	(0.0244)	(0.0274)	(0.0275)
Constant	-0.0749**	-0.0814**	-0.0648*	-0.0520
	(0.0255)	(0.0256)	(0.0269)	(0.0269)
Observations	463	463	719	719
R-squared	0.130	0.114	0.100	0.062

Robust standard errors in parentheses
** p<0.01, * p<0.05

Table 13: Difference-in-differences estimation for the participation rate

	High rank		Low rank	
VARIABLES	(1)	(2)	(3)	(4)
OPG×e-proc	-0.0259	-0.0346	0.0582	0.0498
	(0.0378)	(0.0379)	(0.0334)	(0.0332)
OPG	-0.0530	-0.0455	-0.0813**	-0.0746**
	(0.0379)	(0.0380)	(0.0270)	(0.0269)
e-proc	-0.0306	-0.0223	-0.134*	-0.128*
	(0.0618)	(0.0621)	(0.0521)	(0.0522)
Minimum price	0.0885*		0.0711*	
	(0.0354)		(0.0344)	
Num. of invited bidders	0.00242	0.00472	0.00412	0.00901
	(0.00388)	(0.00380)	(0.00562)	(0.00512)
Reserve price	-0.0788	-0.0232	-0.0129	0.0607
	(0.0965)	(0.0944)	(0.103)	(0.0970)
FY2007 Q2	-0.0270	-0.0236	-0.00938	-0.0103
	(0.0422)	(0.0424)	(0.0243)	(0.0243)
FY2007 Q3	-0.00824	-0.00994	-0.0752**	-0.0774**
	(0.0421)	(0.0424)	(0.0249)	(0.0249)
FY2007 Q4	-0.0685	-0.0684	-0.0876**	-0.0891**
	(0.0413)	(0.0416)	(0.0251)	(0.0252)
FY2008 Q2	-0.0983*	-0.0960*	-0.0240	-0.0247
	(0.0473)	(0.0475)	(0.0440)	(0.0441)
FY2008 Q3	-0.146**	-0.151**	-0.0596	-0.0646
	(0.0514)	(0.0517)	(0.0486)	(0.0487)
Constant	0.871**	0.886**	0.887**	0.865**
	(0.0560)	(0.0561)	(0.0616)	(0.0608)
Observations	463	463	719	719
R-squared	0.135	0.123	0.087	0.081

Standard errors in parentheses

** p<0.01, * p<0.05

Table 14: Triple difference estimation for the bids

VARIABLES	(1) High ranks 1	(2) High ranks 2	(3) High ranks 3	(4) Low ranks 1	(5) Low ranks 2	(6) Low ranks 3
Num. of actual bidders	-0.00975**	-0.0108**	-0.0117**	-0.00505**	-0.00787**	-0.00784**
	(0.000784)	(0.000740)	(0.000817)	(0.000887)	(0.000763)	(0.000760)
e-proc	-0.00980	-0.0124	-0.0127	-0.0228**	-0.0283**	-0.0284**
	(0.00664)	(0.00667)	(0.00667)	(0.00558)	(0.00560)	(0.00559)
OPG	0.00717	0.00565	0.0129*	0.0630**	0.0592**	0.0594**
	(0.00526)	(0.00532)	(0.00581)	(0.00302)	(0.00305)	(0.00304)
OPG×e-proc	0.00284	0.00507	0.00248	-0.0110*	-0.00652	-0.00664
	(0.00468)	(0.00471)	(0.00476)	(0.00451)	(0.00453)	(0.00452)
OPG×wide	0.0580**	0.0580**	0.0626**	-0.00785**	-0.00767**	-0.00110
	(0.00439)	(0.00442)	(0.00455)	(0.00184)	(0.00187)	(0.00210)
OPG×wide×e-proc	-0.0339**	-0.0344**	-0.0322**	-0.0182**	-0.0176**	-0.0233**
	(0.00592)	(0.00596)	(0.00622)	(0.00415)	(0.00420)	(0.00464)
Freq. of bidding	0.00144**	0.00148**	0.00156**	0.000911**	0.00100**	0.00101**
	(0.000188)	(0.000188)	(0.000192)	(0.000114)	(0.000114)	(0.000114)
Reserve price	-0.0270	-0.0388**	-0.0397**	0.00852	-0.0211	-0.0181
	(0.0140)	(0.0140)	(0.0141)	(0.0137)	(0.0132)	(0.0132)
Freq. of winning	-0.0157**	-0.0159**	-0.0159**	-0.0104**	-0.0108**	-0.0108**
	(0.00141)	(0.00142)	(0.00142)	(0.000887)	(0.000897)	(0.000895)
Rank-above			-0.0423**			-0.0190**
			(0.00945)			(0.00282)
Rank-above×eproc			-0.0171			0.0166**
			(0.0136)			(0.00533)
FY2007 Q2	0.0112*	0.00968*	0.00829	0.00693**	0.00658*	0.00613*
	(0.00449)	(0.00451)	(0.00453)	(0.00254)	(0.00258)	(0.00257)
FY2007 Q3	0.0105*	0.00913	0.00853	0.0125**	0.0103**	0.00967**
	(0.00465)	(0.00467)	(0.00468)	(0.00272)	(0.00273)	(0.00273)
FY2007 Q4	-0.0179**	-0.0207**	-0.0213**	-0.00582*	-0.00913**	-0.00948**
	(0.00467)	(0.00466)	(0.00468)	(0.00281)	(0.00280)	(0.00280)
FY2008 Q2	0.00383	0.000681	0.000319	0.0176**	0.0157**	0.0155**
	(0.00508)	(0.00507)	(0.00509)	(0.00470)	(0.00476)	(0.00475)
FY2008 Q3	-0.00335	-0.00654	-0.00809	0.0273**	0.0245**	0.0242**
	(0.00580)	(0.00579)	(0.00583)	(0.00528)	(0.00534)	(0.00533)
Minimum price	-0.0268**			-0.0316**		
	(0.00485)			(0.00450)		
Constant	0.0436**	0.0431**	0.0534**	-0.00791	0.00964	0.00963
	(0.00874)	(0.00881)	(0.00953)	(0.00918)	(0.00872)	(0.00869)
Observations	6,132	6,132	6,132	8,783	8,783	8,783
R-squared	0.204	0.193	0.192	0.126	0.102	0.107

Standard errors in parentheses
** $p<0.01$, * $p<0.05$

Table 15: Triple difference estimation for the average of bids

VARIABLES	(1) High ranks 1	(2) High ranks 2	(3) High ranks 3	(4) Low ranks 1	(5) Low ranks 2	(6) Low ranks 3
Num. of actual bidders	-0.00707**	-0.00897**	-0.0116**	-0.00274	-0.00728**	-0.00748**
	(0.00174)	(0.00169)	(0.00252)	(0.00192)	(0.00177)	(0.00176)
e-proc	-0.000690	-0.00581	-0.00534	-0.0130	-0.0249	-0.0290
	(0.0176)	(0.0182)	(0.0185)	(0.0146)	(0.0152)	(0.0152)
OPG	-0.0158	-0.0194	-0.00332	0.0537**	0.0433**	0.0437**
	(0.0112)	(0.0116)	(0.0162)	(0.00699)	(0.00721)	(0.00716)
OPG×e-proc	0.00798	0.0107	0.00262	-0.0152	-0.00868	-0.0103
	(0.0116)	(0.0120)	(0.0132)	(0.0109)	(0.0115)	(0.0114)
OPG×e-proc	0.0552**	0.0532**	0.0576**	-0.00732	-0.00768	0.00935
	(0.0124)	(0.0128)	(0.0131)	(0.00481)	(0.00507)	(0.00666)
OPG×wide×e-proc	-0.0325*	-0.0331*	-0.0239	-0.0178	-0.0139	-0.0448**
	(0.0159)	(0.0164)	(0.0194)	(0.0106)	(0.0111)	(0.0158)
Reserve price	0.00217	-0.0312	-0.0282	0.0325	-0.0232	-0.0171
	(0.0293)	(0.0296)	(0.0302)	(0.0289)	(0.0287)	(0.0285)
Mean freq. of bidding	0.00151*	0.00174*	0.00240**	0.00121**	0.00158**	0.00173**
	(0.000688)	(0.000703)	(0.000830)	(0.000434)	(0.000449)	(0.000450)
Mean freq. of winning	-0.0281*	-0.0310*	-0.0382*	-0.0168*	-0.0198*	-0.0225**
	(0.0141)	(0.0145)	(0.0157)	(0.00827)	(0.00869)	(0.00868)
Mean of Rank-above			-0.0588			-0.0498**
			(0.0320)			(0.0127)
Mean of Rank-above×eproc			-0.0710			0.0877**
			(0.0746)			(0.0316)
FY2007 Q2	0.0144	0.0121	0.0108	0.00619	0.00701	0.00549
	(0.0121)	(0.0124)	(0.0126)	(0.00675)	(0.00712)	(0.00705)
FY2007 Q3	0.00719	0.00752	0.00624	0.0103	0.00738	0.00533
	(0.0121)	(0.0125)	(0.0127)	(0.00704)	(0.00740)	(0.00737)
FY2007 Q4	-0.0164	-0.0192	-0.0226	-0.00584	-0.00999	-0.0113
	(0.0122)	(0.0125)	(0.0130)	(0.00719)	(0.00754)	(0.00748)
FY2008 Q2	-0.00279	-0.00672	-0.0103	0.0136	0.0125	0.0151
	(0.0139)	(0.0143)	(0.0148)	(0.0122)	(0.0129)	(0.0129)
FY2008 Q3	-0.00707	-0.00829	-0.0141	0.0189	0.0198	0.0226
	(0.0152)	(0.0157)	(0.0166)	(0.0135)	(0.0143)	(0.0143)
Minimum price	-0.0517**			-0.0576**		
	(0.0106)			(0.0100)		
Constant	0.0379	0.0347	0.0619*	-0.0112	0.0108	0.0142
	(0.0215)	(0.0222)	(0.0298)	(0.0197)	(0.0201)	(0.0201)
Observations	463	463	463	719	719	719
R-squared	0.391	0.351	0.332	0.194	0.103	0.121

Standard errors in parentheses
** p<0.01, * p<0.05

Figure 1: Transition of the average of Bids

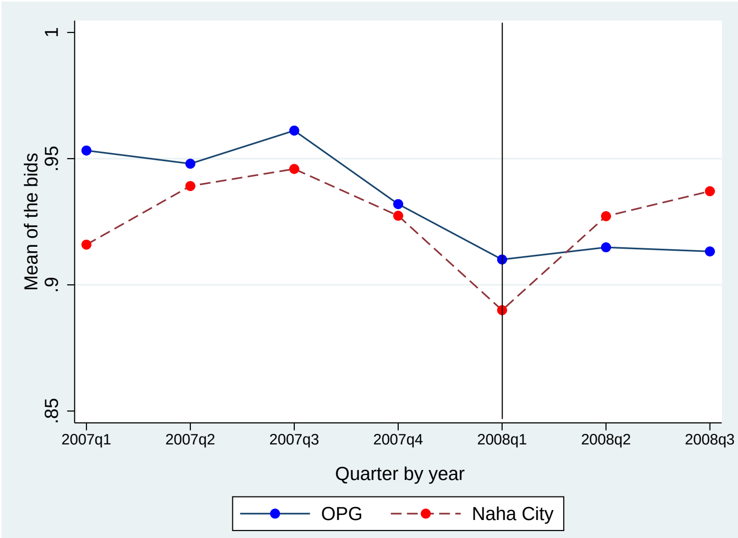

Figure 2: Distribution of the win bids in OPG auctions in the manual procurement period

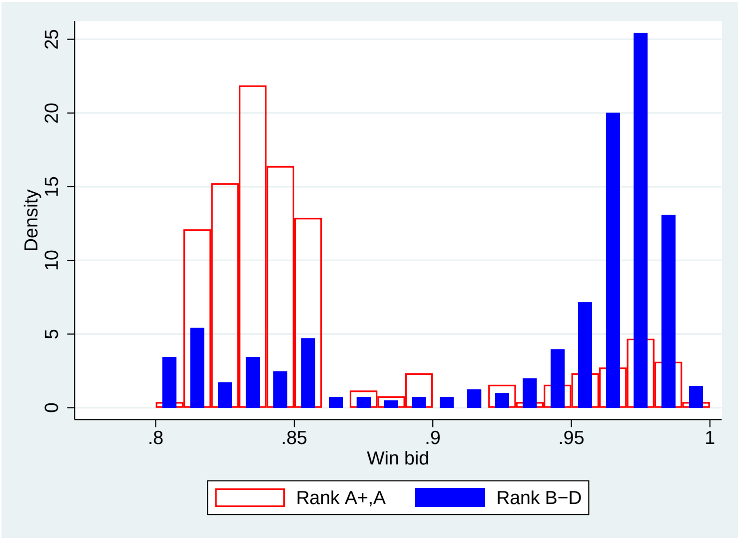

Figure 3: Average of bids

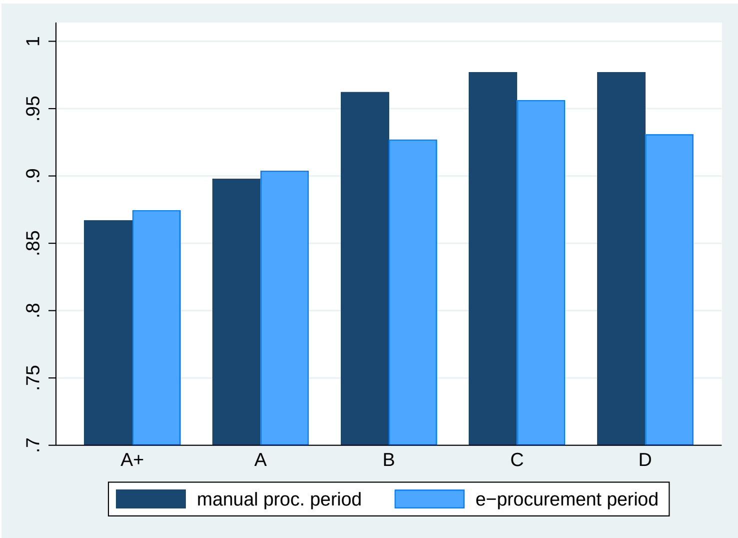

Figure 4: Difference between manual and e-procurement in average of bids

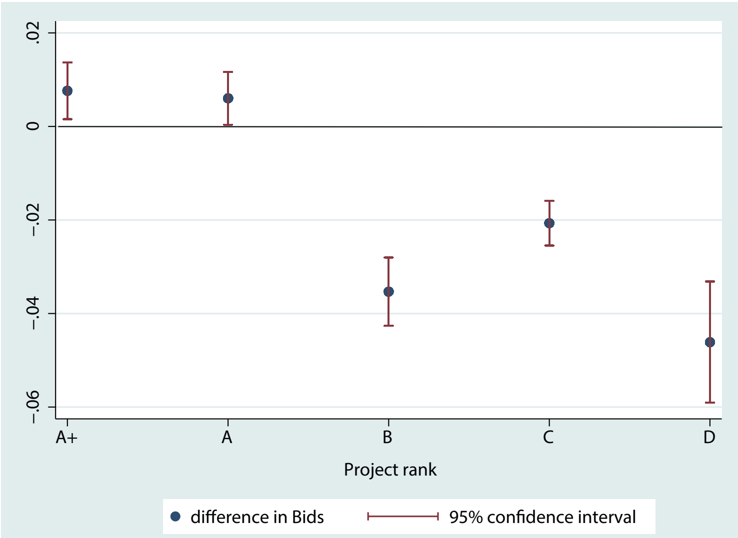

Figure 5: Difference between manual and e-procurement in average of win bids

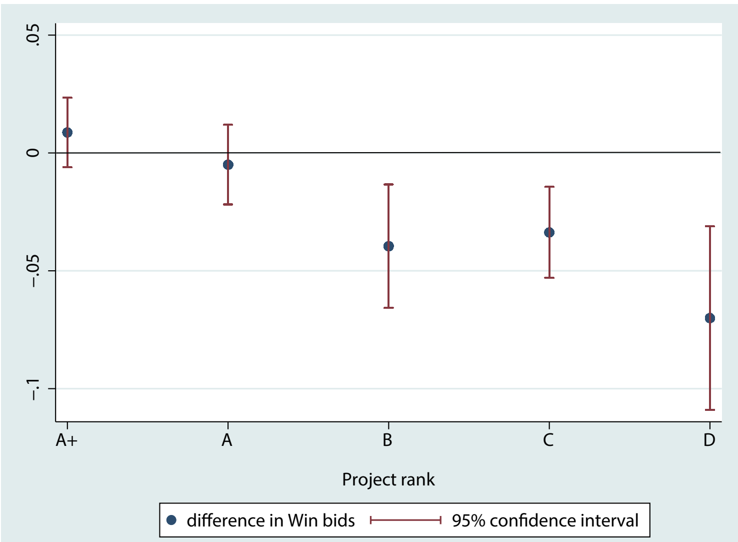

Figure 6: Distribution of bids: Ranks A and A+

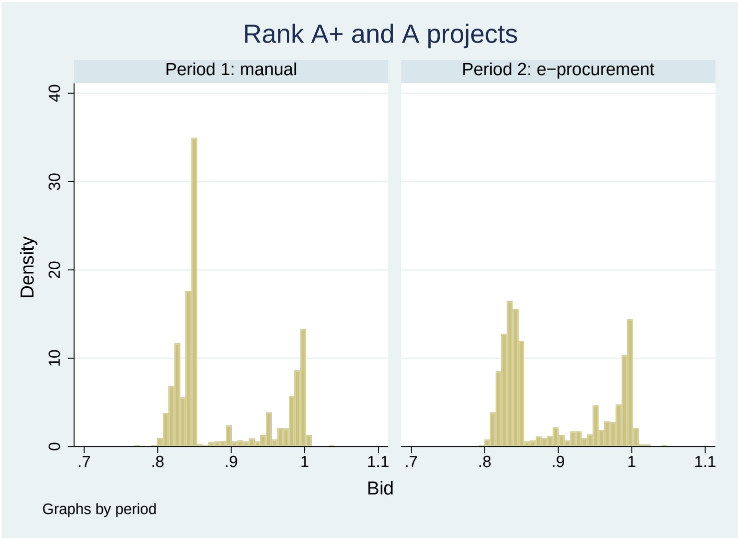

Figure 7: Distribution of bids: Ranks B–D