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COLLUSION IN REPEATED PROCUREMENT AUCTION: A STUDY OF A PAVING MARKET IN JAPAN

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Abstract

We examine auction data to determine if bid rigging presents in procurement auctions for paving works in Ibaraki City, Osaka, Japan. We first show that sporadic bidding wars are caused by the participation of potential "outsiders." Assuming that the ring is all-inclusive if the auction is not the bidding war, we estimate the scheme by which the ring allocates a win to its members. It is found that the ring tends to select a bidder whose winless period is long and whose winning amount in the past is small relative to other bidders.

JEL Classification D44, H57, L44
Keywords: Bid rigging, repeated auction.

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1 Introduction

Bid rigging is pervasive in public procurement auctions. As it becomes a major social problem and attracts more public attention, the inner working of bidding rings is gradually revealed by journalists, lawyers and industry experts some of whom were formally involved in ring activities themselves.[1] In a typical process of bid rigging, the ring bidders gather in prior to each auction and discuss who win the auction. According to Suzuki (2004) who documents all bid rigging cases between 1947 and 2000, typically the ring has its own "collusion scheme", the rule under which the ring chooses a winner.

Suzuki's survey of a wide variety of collusion schemes reveals that a number of rings use the history of auctions (such as the date, the identity of the winner and other participants, and the winning price) as a basis for allocating contracts to their members. For example, in a bid rigging case of water meter producers in 1992 in Osaka Prefecture, they calculate each ring bidder's win amount in the past according to a particular calculation formula, and then, the bidder who has the least win amount among the ring bidders is chosen as the winner. In another case of pesticide suppliers in 1998 in Osaka Prefecture, the ring used the bid rotation scheme, in which the ring members take turns being the winner in order.

We examine the public auction data of a paving market in Japan, in order to determine whether the bid rigging occurred. Specifically, we illustrate the correlation between the current auction result and the past results, which is more explained by collusion than competition. If the ring exists and uses some collusion scheme which is based on the history, there must be a link between each auction result and the history.

It has been pointed out that a correlation between the current result and the past results is not necessarily due to collusion. Particularly, when bidders' cost functions exhibit decreasing returns to scale, bid rotation can also result from a competitive bidding behavior. That is, firms with idle capacity have lower marginal cost and hence, are more likely to win a contract than those with ongoing contracts (Zona (1986), Porter and Zona (1993), Porter (2005)). Our approach discriminates between collusive and non-collusive bid rotation by separating the effect of capacity

[1] Hironaka (1994), Kato (2005). McMillan (1991) also documents the formation and the operation of Japanese bid rigging.

utilization from that of the collusion scheme. We construct variables for the used capacity and for the priority index that determines the turn in the collusion scheme, separately, and analyze their effect on the events of winning or losing. We can discriminate competition and collusion by testing the independence of the events from the priority measure of the rotation scheme.

We look at auctions for road-paving works in Ibaraki City, Osaka, Japan in the four-year period between 2002 and 2005. A remarkable characteristic of this market is consistently high winning prices with the exception of sporadic bidding wars.[2] Though there is no legal case of bid rigging filed against the bidders participating in these auctions, it suggests the coexistence of collusion and cartel breakdown.

We first observe each incident of the bidding war and its participants, and find that the bidding war during the data period mainly occurred when either of two specific firms was present.[3] It is supposed that the bidding wars were between the ring and a small number of outsiders in the market, and that all the ring bidders submitted low bids in order to prevent the outsiders from winning. We then examine the data to see how the ring selects the winner among its members assuming that the high prices were maintained by an all-inclusive ring which allocates contracts to its members by some prespecified rule. We find that the ring tends to assign a win to its member whose duration of no win is long and whose amount of win is small.

Theories of collusion in auctions highlight the role of pre-auction meeting of bidders. The seminal paper by McAfee and McMillan (1992) show that the most efficient bidder collusion in a first price auction is that the ring member with the minimum cost bids at the reserve price while the other members bid high. Incentives are provided through monetary transfers from the winner to the losers. McAfee and McMillan also characterize efficient collusion when no side transfer is possible. It is a static scheme in which the choice of the designed winner is independent of the history. The analysis is extended to a repeated framework by Aoyagi (2003) and Skrzypacz and Hopenhayn (2004), who analyze collusion without side transfer in repeated auctions. In contrast to McAfee and McMillan's static bid rotation, they construct dynamic bid rotation schemes in which bid coordination is based on past

[2] In this paper, we use the term, a "bidding war" to indicate an auction whose winning price is significantly lower than the other prices.

[3] Yanagawa et.al. (2005) reports that bidding wars tend to occur in March, the end of the fiscal year. We observe no such seasonal pattern of bidding wars in our data.

history.

In contrast to the theoretical literature, the inner working of the ring has attracted little attention in the empirical literature although there is much empirical work on bid rigging aiming at detecting collusion in procurement auctions.[4] Most of them illustrate how the bidding behavior of a set of collusive bidders is different from competitive behavior.

Porter and Zona (1993) study auctions for paving works on Long Island, New York. They divide the bid data into collusive bids and competitive bids, knowing which bidder is collusive. In each dataset, they examine if the impact of the cost factors such as the capacity utilization on the realization probability of the bid ranks is consistent with competitive equilibrium. They find that in the collusive data the estimated impacts of the cost factors on the realization of the first rank and on the higher ranks are different, while there is not such difference in the competitive data. Porter and Zona (1999) analyze the ring members' bidding behavior in school milk procurement auctions in Ohio State. They focus on the relationship between the bids and the distance between schools and bidders, and find that the collusive bids and the competitive bids reflect the distance differently, suggesting that the ring allocates contracts by territory. Bajari and Ye (2003) observe the violation of two conditions, conditional independence and exchangeability, that a competitive bidding strategy must satisfy, using the auction data for highway construction works in the Midwest. These approaches make full use of observable cost asymmetry among bidders by measuring firms' used capacity or the distance between the office and the work site.

The distinguishing feature of this paper is that we illustrate how the outcome of auctions is consistent with a particular collusion scheme. In contrast to the previous works, we exclusively examine the identities of the winner and the participants, ignoring the bid levels. Because the ring is very likely to be all-inclusive in most auctions as described in Section 3.1, and if so, all the bids are phony and the bid levels bring little information about the cost of the bidders or about how they collude. In that case, instead, the identity of the winner perfectly reflects the collusive agreement.

The collusion schemes considered in this paper are most closely related to those analyzed by Skrzypacz and Hopenhayn (2004) and Pesendorfer (2000). Skrzypacz

[4] Harrington (2005) provides a thorough survey of this field.

and Hopenhayn (2004) propose a collusion scheme named a “chips mechanism”, in which the winner gives one chip to each loser, and when a bidder runs out of chips he is supposed to allow other bidders to win for a specific number of periods. An important factor in the scheme is the number of winning and losing in the past. It is known that such a mechanism was indeed used by some bidding rings in Japan, and the aim of the paper includes detecting this type of scheme. We name it the “contribution point scheme”. Pesendorfer (2000) studies the difference between two forms of cartel, in which one cartel in Florida uses side payments and the other in Texas does not. He finds that the cartel without side payments maintains relatively constant market shares, despite some efficiency losses from not allocating a contract to the low cost firm, in order to maintain internal discipline. One of our targets of detection is the scheme which keeps the balance of the members’ total revenues in the past, which is the very scheme used by the cartel in Texas.

The paper is organized as follows. In Section 2, we describe the market, the auction procedure, and the data we analyze. In Section 3, we document the bidding war and analyze its cause. We also describe the collusion schemes that we expect to be used by the ring. In Section 4, we show the empirical model to estimate the collusion scheme, and the estimation results. We conclude in Section 5.

2 The market description

This study looks at auctions for paving contracts awarded by Ibaraki City, Osaka, Japan, during four years between April 2002 and March 2006. In the data period, Ibaraki City awards 139 contracts through auction. Typically, the contracted work involves the resurfacing of local roads for hundreds of meters. The winning price varies from 1 to 40 million yen, with an average of about 7 million yen. Figure 1 shows the winning price of each auction. An annual total of 2-3 hundred million yen is contracted out.

Thirteen firms participated in the auctions in the data period with one firm exiting early. Most firms do paving work as their primary business, and other civil engineering works as secondary. Nine firms are local in the sense that their headquarters are located within Ibaraki City, and the rest that we call “out-of-town” firms have only a branch in the city. Table 3 describes the firms.

2.1 Auction procedure

The auction is in the first price sealed bid format with a maximum acceptable (reserve) price and a minimum acceptable price (henceforth a minimum price). The minimum price is set for the purpose of prevent firms from doing low quality works. A bidder with the lowest bid wins the contract if and only if his bid is between the minimum price and the reserve price. Auction proceeds as follows: Prior to each auction, the city officials estimate how much it will cost an average firm to complete the work, taking into account material prices and the budget of the city. The estimated price plus some profit margin is then used as the reserve price in the auction. The minimum price is set at about 80% of the reserve price. The city announces the reserve price and the minimum price one week before the auction.

Actual participants of the auction are chosen by the city. A limited number of firms are nominated from a list of candidates one week before each auction. Technical documents, which are needed to estimate the cost, are distributed to eligible bidders at the city office at the announced date and time prior to the auction. It gives the bidders a chance to see each other in advance and to know whether there is an outsider. On the date of the auction, bidders gather and submit sealed bids. If there are more than two bidders who submit the lowest bid, then the winner is determined by a public lottery. Bidders can refrain from bidding. In our data, 10 bidders refrained from bidding in four auctions (see Table 2).

When a bidder wins an auction, he would earn profit equal to the winning price minus the cost of doing the work. The cost of each contract is private information of each bidder, and hence, each auction is a private value auction. However, a large part of a bidder's cost can be inferred by other bidders, since they operate in the market for decades and the work is done according to a detailed specification given by the city officials.

The number of nominated bidders depends on the reserve price of the auction. When the reserve price is high, the number of bidders tends to be large. Table 1 summarizes the number of bids per auction.

2.2 The data source

We have two data sources, bid data and corporate data. The bid data were provided by Ibaraki City Office. The bid data contain the following information on every project awarded: date of auctions, submitted bids, names of bidders, the reserve price and the minimum price, the starting and ending dates of projects, and location of projects.

The corporate data of each firm were provided by Construction Industry Information Center's database. The corporate data contain the number of years of running, number of technical workers, annual sales, and profit per sales.

In the analyses, we used a variable which represents bidder's used capacity. It is not sufficient in capturing the firm's used capacity as long as we see only the contracts bought by Ibaraki City, since the firms do the works bought by private firms and other local governments neighboring Ibaraki City. In calculating each bidder's used capacity, we used the data of contracts which were awarded by Osaka Prefectural Government, as well as by Ibaraki City. Osaka Prefectural Government is one of the major clients of firms, and provides contract data through its website. The definition of variables is shown in Table 4.

3 Possible collusion scheme

3.1 Agreement to fight against outsiders

We describe a series of bidding wars observed in the data and infer the cause. The observation in this section shows that most bidders bid at the minimum price in those auctions that result in the bidding war, and that such a bidding war is triggered by the presence of specific firms among the participants. It is natural to think that an implicit agreement is behind such coordinated reversion to the minimum price. It is likely that the ring bidders have an agreement to bid the minimum price when they face an outsider in an auction. As mentioned previously, the bidders meet each other prior to the auction. Once the existence of an outsider is confirmed, all of the ring bidders must be instructed to bid at the minimum price in the auction.[5]

[5]Bajari and Ye (2003) models a cartel behavior when it faces outsiders in auctions. In their model, the member with the minimum cost in the cartel submits a serious bid, and the other member submit phony high bids. In contrast to the model, all the ring members seem to be supposed to submit the lowest possible bid when they face an outsider in the market we analyze.

Figure 2 shows the variance of "normalized bids" of each auction, and Figure 3 shows the "normalized winning bids" of each auction. "Normalized" means that the bids are divided by the reserve price. As Figure 3 shows, in 123 out of 139 auctions, winning prices are in the neighborhood of 93% of the reserve price.

On the other hand, remaining 16 contracts were won at the minimum price which was set at 77-85% of the reserve price. We identify these 16 auctions as the bidding wars. In no auction was the winning bid between 85% and 90% of the reserve price, and therefore, the distribution of winning bids has a gap as shown in Figure 3. Furthermore, in 13 incidents of the bidding war, the variance of the normalized bids is zero as shown in Figure 2, indicating that all the bids were at the minimum price and that the winner was determined by a public lottery.

We further show that bidding wars are mainly caused by the participation of either of two specific firms. Figure 4 shows the participation of every firm in every auction. The X axis shows auction ID, $t = 1, 2, ..., 139$, and the Y axis shows firm ID, $i = 1, 2, ..., 13$. A white dot in the figure indicates that the auction was a bidding war, and a black dot indicates that it was not. The square around a dot indicates the winner: bidder y wins in auction x if there is a square at (x, y). For example, the black dot with a frame at coordinate $(15, 2)$ implies that firm 2 submitted a bid and won in auction 15, and that the auction was not a bidding war.

In Figure 4, there exists a sequence of 4 white dots from coordinate $(2, 13)$ to coordinate $(10, 13)$, which are indicated as A. The dots indicate the bidding wars which may have been caused by the participation of firm 13. These auctions took place during 3 months from May 2002 to July 2002. No bidding war was observed in the absence of firm 13 in this period. It can be inferred that firm 13 is an outsider. Firm 13 disappeared after auction 11 suggesting that it went out of the market, perhaps because of the bidding war.

There exists another sequence of 8 white dots from coordinate $(68, 8)$ to coordinate $(81, 8)$ indicated as B. These incidents of the bidding war during 5 months from May 2004 to October 2004, were probably caused by the participation of firm 8. The other 53 auctions in which firm 8 bid did not result in the bidding war. This may suggest that firm 8 stayed out of the ring only during the 5 months, and reconciled with the ring after that.

We find that the bidding war took place whenever firm 13 was present and in a series of auctions during 5 months where firm 8 was present. This suggests the existence of a ring agreement to bid the minimum price when one of the two firms participated. We further infer that the ring must have been all-inclusive after firm 13's exit, except the five months in which firm 8 stayed out of the ring. 12 incidents of the bidding wars out of 16 are explained: 4 of them were caused by firm 13, and 8 were caused by firm 8. However, 4 incidents: auction 28, 78, 131 and 139 are left unexplained. A possible interpretation is that the ring bidders failed in reaching an agreement and switched to a competitive bidding temporarily.

The exit of firm 13 suggests that the bidding war worked as predation. It is likely that winning a contract at the minimum price is unprofitable for most of the firms, since the profit-to-sales ratio is 0.27% on average (Table 3). If so, we have a case of "deep pocket predation" which is aimed at driving the outsiders out while making a loss. When the number of the ring members is large relative to that of the outsiders, the loss is not so severe for the ring members since they can take turns bearing the loss and recover by earning profit of collusion in the absence of the outsiders. In contrast, the bidding war brings about a financial difficulty to the outsider since he either win a contract with a very low price in auctions or loses. Sooner or later, the outsiders have to give up and leave the market or join the ring, allowing the ring to be all inclusive and recoup losses.

Predatory bidding war in auctions is not so rare in Japan. In a case of a bridge construction cartel which allocated public contracts to 47 firms for years, the cartel was nearly all-inclusive in the bridge construction market. It is reported that cartel members submitted extremely low bids, which were sometimes as low as 60% of the reserve price when they faced an outsider in auctions, whereas they bid the reserve price in the absence of the outsider. The low bids were aimed at preventing the outsider from winning, even though they imply a negative profit from winning. The member who won in the bidding war was compensated with a profitable contract afterwards.(Asahi Shin bun May 19, 2005, Kahoku Shin pou, May 25, 2005.)

Meanwhile, the serial incidents of the bidding war in which firm 8 was targeted can be interpreted as a punishment. The win of firm 8 in Auction No. 65, which is just before the start of the incidents, may be the betrayal that triggered the punishment.[6]

[6]If so, the punishment seems to be so called "stick-and-carrot" type, which gives a severe damage

It is noteworthy that the normalized winning bids are not so high in auctions that are not the bidding war: They are below 95% with one exception. We think this is due to the warning made by the city officials. We find a notice near the auction room at the city office, which says "in case that the normalized winning bid is higher than a certain level, signing the contract is postponed and bidders are required to show their cost estimates". Knowing that collusion will be under investigation in case of a high price, the ring must lower the price elaborately.

Note that the bidding wars cannot be an evidence of collusion by itself. There still remains a possibility that there is no agreement among bidders.[7] However, the observation described above gives a strong support for the assumption we use in the main analysis that all the bidders belong to the ring if the auction is not the bidding war.

3.2 Operation of a collusion scheme as a comparison of bidders' priority

We next hypothesize the rules under which the winner is selected when the ring is all-inclusive in the auction. These schemes are based on comparing its members' *priority* to win the contract. We focus on the following four classes of history dependent schemes that are common in the past bid rigging cases.

1) Simple rotation

   In a simple rotation scheme, the ring members rotate the winning right. In the presence of the nomination process by the local government, simple rotation chooses the winner based on the duration of winless period sustained by each bidder. That is , a bidder is chosen as the winner if his winless period up to the date is longer than that of any other bidder in the ring.

2) Revenue equalization

   A revenue equalization scheme maintains equity of the revenue of its members

for finite periods.

[7] Consider a situation where the minimum price is higher than the cost of every bidder, that is, bidders earn a positive profit even when they win at the minimum price. If firm 8 and firm 13 are known to be so low cost firms that every other bidder always expects them to bid at the minimum price, then a series of bidding wars we observe can be an equilibrium outcome without any agreement.

by assigning a contract to the bidder whose total revenue as measured by the winning amount in the past is the smallest among the members.

3) Contribution point

A contribution-point scheme chooses as the winner the bidder who has the highest contribution point. A ring bidder earns a contribution point when he submits a phony bid which allows another ring bidder to win. A bidder's contribution point is decreased once he wins.

In some cases in Japan, the ring uses a sophisticated way in calculating the contribution point. For example, in a case in Tokushima City, a bidder's contribution point equals the sum of p_t/n_t for all past auctions t in which he lost, minus the sum of p_s for all past auctions s in which he won, where p_t is the price and n_t is the number of bidders in auction t.[8]

In this paper, we consider the most simple way to calculate the contribution point in which it equals (the total number of losing) $-$ c $\times$(the total number of winning), where c is some constant.

4) Combination

The combination scheme combines some or all elements of the above schemes. For example, a bidding ring in Okayama prefecture used a combination of the simple rotation scheme and the revenue equalization scheme, that is, the ring basically uses revenue equalization scheme, and in case of a tie, they compared the number of days elapsed from one's last win.

Each of the above schemes is "public" in the sense that its operation depends only on the public history such as the date of auctions, the participants, the winner's identity, and their bids, and not on the private information such as cost of doing the work. A merit of these schemes is their simplicity: They do not require any communication among bidders even when there is private information. They sustain collusion without side transfer by giving each member the expectation that they will win in the near future.

When any of above schemes is in operation, it is possible for us to detect it, since the scheme creates a link between the outcome of each auction and history.

[8] A speech at Tokushima City Council by Councilor Satoru Kako, June, 2004.

Competitive bidding, on the other hand, creates no such link. Therefore, we test if the history impacts the auction result in a supposed way in Section 4.

4 Estimation of the model of the ring's decision

In what follows, we analyze if the data can be explained by any of the collusion schemes described above. Specifically, we examine if there is a factor that has nothing to do with the cost, but has an impact on the auction result. The existence of bid rigging is supported by the existence of such a factor. In the analysis, we use the data from 123 auctions that did not result in the bidding war in the sense described in Section 3.1.

An important assumption here is that the ring was all-inclusive in these auctions. When the ring is all-inclusive in an auction, the designated winner wins the contract for sure. Therefore, the winner's characteristic in all-inclusive ring must reflect characteristics of the collusion scheme.

4.1 Empirical model

Porter and Zona (1993) model the probability of a bidder's win under competitive bidding. They specify a bidder's bidding function to be linear in observable cost factors imposing an assumption that their coefficients are the same among firms, and then analyze the probability of each bidder's win given the cost factors as a conditional logit model.

We extend their model by allowing the ring to designate the winner according to the collusion schemes described in Section 3.2. Their model is adapted to the ring's choice as follows. We suppose that the ring chooses bidder i as the winner if his measure of priority w^*_{it} is the highest among the set of bidders M_t in auction t, where

$$w^*_{it} = \beta'\mathbf{x}_{it} + \gamma'\mathbf{z}_{it} + u_{it},\ i \in M_t. \tag{1}$$

$\mathbf{x}_{it}$ denotes the vector of factors that determine bidder i's priority in the collusion schemes. $\mathbf{z}_{it}$ is a vector of observable variables affecting bidder i's cost on project t. u_{it} is the disturbance that arises in bidder's priority.

The probability that bidder i is chosen as the winner in auction t conditional on M_t and $\mathbf{x}_t$ is written as:

$$\Pr(w_t = i \mid M_t, \mathbf{x}_t, \mathbf{z}_t) = \Pr(w_{it}^* \geq w_{jt}^* \ \forall j \in M_t, j \neq i \mid M_t, \mathbf{x}_t, \mathbf{z}_t),$$

where w_t indicates the identity of the winner in auction t, and $\mathbf{x}_t$ and $\mathbf{z}_t$ are vectors that consist of $\mathbf{x}_{it}$ and $\mathbf{z}_{it}$ for all $i \in M_t$, respectively. McFadden (1973) showed that when the u_{it}'s are independent and identically distributed with the Type I extreme distribution, the above probability can be written as:

$$\Pr(w_t = i | \ M_t, \mathbf{x}_t, \mathbf{z}_t) = \frac{\exp(\beta' \mathbf{x}_{it} + \gamma' \mathbf{z}_{it})}{\sum_{j \in M_t} \exp(\beta' \mathbf{x}_{jt} + \gamma' \mathbf{z}_{jt})}. \tag{2}$$

We obtain the estimator of parameters by maximizing the following log likelihood function:

$$\ln L(\beta, \gamma | w_t, M_t, \mathbf{x}_t, \mathbf{z}_t) = \sum_{t \in S} \sum_{i \in M_t} e_{it} \ln \Pr(w_t = i | \ M_t, \mathbf{x}_t, \mathbf{z}_t),$$

where e_{it} is an index variable which is 1 if i won in auction t and 0 otherwise and S is the set of auctions that were not the bidding wars.

Recall that the determinant of bidder i's priority in auction t is 1) the number of days elapsed from i's last win (simple rotation), 2) i's total revenue up to t (revenue equalization), 3) the number of wins and the number of losses up to t (contribution point). Therefore, $\mathbf{x}_{it}$ = (NUMDAYS$_{it}$, WINVALUE$_{it}$, WINNUM$_{it}$, LOSENUM$_{it}$). We construct two variables which capture the revenue in the past, WINVALUE1$_{it}$ and WINVALUE2$_{it}$, since the ring may refer to the total revenue in a long time or in a relatively short time in case that the revenue equalization scheme is used. WINVALUE1$_{it}$ is the total value of contracts that Firm i has won since the start of the data period until the date of auction t, and WINVALUE2$_{it}$ is that within half a year of auction t. Since the total revenue and the number of wins in the past are highly correlated, we estimate some specifications dropping either of them.

The variables which represent observable cost factors in our model are $\mathbf{z}_{it}$ = (CAP$_{it}$, CAPSQ$_{it}$, YEARS$_i$, WORKER$_i$, PROFRATE$_i$, DIST$_{it}$, OUTOFTOWN$_i$).[9] We also estimate a model with bidder specific intercept α_i in w_{it}^*.

[9] In Porter and Zona (1993), the cost factors $\mathbf{z}_{it}$ include the capacity utilization rate (CAP$_{it}$), squared utilization rate (CAPSQ$_{it}$), a firm's maximum capacity, squared maximum capacity, and only CAP$_{it}$ and CAPSQ$_{it}$ are statistically significant.

Since we are interested in whether $\mathbf{x}_{it}$ has an impact on the winning probability, we test the null hypothesis $H_0 : \beta = \mathbf{0}$ against $H_1 : \beta \neq \mathbf{0}$.

We also try the following extension in which the impact of $\mathbf{x}_{it}$ on the priority is allowed to be different across bidders:

$$w^*_{it} = e^{\delta_i} \beta' \mathbf{x}_{it} + \gamma' \mathbf{z}_{it} + u_{it}. \tag{3}$$

This extension allows us to estimate the schemes which treat the ring members differently. Bidders may be treated differently because, for example, some are more established members of the ring than the others. We set $\delta_1 = 0$ for bidder 1. The greater the value of δ_i the better treatment does bidder i receive.

4.2 Result

Table 5 shows the estimation results of the conditional logit model. We have estimated both models with and without bidder fixed effects. Columns (1)-(6) shows the results of equation (1). Columns (1) and (2) contain the results using WIN-VALUE1 as the proxy for the total revenue in the past, and columns (3) and (4) use WINVALUE2. Columns (5) and (6) show the results using the number of wins in the past, instead of the total revenue. Column (7) corresponds to the extended model which allows the heterogeneity of bargaining power given in equation (3). Columns (8) and (9) show the estimation results of equation (1) under the assumption $\beta = \mathbf{0}$.

In all specifications except for (8) and (9), the coefficient of NUMDAYS, the length of time since the last win, is positive and statistically significant at 1% level. It can be said that the impact of the duration of no win period has a robust positive impact on the winning probability. The total revenue in the past is negative in all columns and statistically significant at 1% or 5 % in columns (2), (3) and (4). These results suggest that either simple rotation scheme or the combination of simple rotation and revenue equalization is most likely used. That is, the ring selects the winner based on the duration of the winless period and the winning value up to the auction.

The coefficient of the OUTOFTOWN dummy is negative and statistically significant at least 5% level in all columns, suggesting that having a headquarter in the city increases the firm's bargaining power in collusive negotiations. Table 3 also shows that the number of win tends to be small if a firm is out-of-town. Firms 1,2,6 and 11 are out-of-town firms, and they won half as many times as the local firms.

These findings can be the evidence of collusion if competitive bidding is never affected by the duration of the winless period. However, there remains a possibility that the duration of no win creates financial difficulty which leads to more aggressive bidding in competitive paradigm. When bidders are in financial difficulty, their objective is not to maximize the profit but to earn for the operational expenses immediately. If this is the case, it is natural that the winner tends to have a longer winless period or a less amount of win in the past.

In order to see if these properties lead to aggressive bidding, we examine their impact on the bid levels of losing bids. Table 6 and Table 7 show the results of OLS estimations and Tobit estimations, respectively.

In Table 6, estimations in the first four columns use all bids in non-bidding war auctions, whereas only losing bids are used in the remaining columns. The dependent variable of columns (1), (2), (5) and (6) is the normalized bid, and that of the remaining columns is log of the normalized bid. It can be seen that the impact of NUMDAYS is significant and has expected sign in the results using all bids (columns (1)-(4)), whereas it turns out to be insignificant when winning bids are removed from the dataset (columns (5)-(8)). The impact of WINVALUE2 is insignificant throughout datasets and specifications.

In Table 7, the dependent variable of the Tobit models is the difference between the bid level and the minimum price, divided by the difference between the reserve price and the minimum price. In contrast to the OLS estimations, we include bid data of bidding wars where the dependent variable is left truncated at the minimum price. All bids are used in the first two columns, and only losing bids are used in the latter two columns. In all columns, WINVALUE2 is significant but NUMDAYS is not.

In summary, there is little support for the alternative explanation for the results of the conditional logit model that the positive impact of the duration of the winless period and the negative impact of the winning value up to the auction, on the winning probability is due to financial difficulty. We therefore conclude that those impacts are due to collusion.

The reuslts in columns (8) and (9) in Table 5 show that when we omit variables such as NUMDAYS in the conditional logit model, CAP turns out to be significant. It means that when our data are analyzed using a model with only cost relevant terms, the estimation result looks competitive because of the negative correlation between CAP and NUMDAYS. We confirm that it is difficult for the standard model to discriminate whether the data are competitive or collusive when the ring uses bid rotation.

We should note that there may exist other factors omitted in our model. Figure 5 shows the relationship between the size of the contract and the identity of the winner. A small, medium, big dot indicates a small (less than 5 million yen), medium (5-10 million yen) and big (greater than 10 million yen) contract, respectively. It can be seen from the figure that firm 3 tends to win big contracts with long intervals, while firms 9 and 10 tend to win small or medium contracts with short intervals. This suggests the presence of firm specific patterns not captured in our analysis.

5 Conclusion

We analyze procurement auction data to determine if bid rigging is present. We first observe the incidents of the bidding war and find that most bidding wars occurred when either of specific two firms submitted bids. It is inferred that the two firms are possible outsiders and that all the ring bidders submit bids at the minimum price only when the outsiders were in the auction.

We next analyze if the auction results is explained by some collusion scheme in which the ring chooses the winner based on the history of auctions, assuming that the auction is all-inclusive if it is not a bidding war. Specifically, we model four collusion schemes typically used in Japan, as the ring's multinomial choice of the winner. In the schemes, the ring compares each member's priority to win, and selects the member whose priority is the greatest among the bidders. The members' priority is measured based on the history. It is found that a bidder tends to win when his duration of no win is long, and his amount of win in the past is low relative to other bidders.

The duration of no win or the win value in the past may be related to the financial pressure which makes a competitive bidder aggressive, and therefore, their impacts can be due to competition. We further confirm that there is little support for such an explanation by analyzing the bid level of losing bids. We then conclude that the impacts of those variables on the winning probability are due to collusion.

Our finding figures out the behavior of the ring. The ring allocates contracts to the ring bidders, balancing the frequency of winning and the revenue among its members, and when an outsider is in an auction, all the ring bidders bid at the minimum price.

We should note the limitation of our approach. First, the measure of bidders' backlog is inaccurate since it is based only on the public contracts and their private contracts are not taken into account. Second, the correlation between the current result and the past results in competitive auctions may come from some unknown causality other than capacity constraint or financial pressure, but we do not handle it. Finally, our analysis is effective only when the ring is nearly all inclusive in the market and multimarket contact of bidders is infrequent. Otherwise it is difficult for us to analyze if the auction results are consistent with some collusion scheme.

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Table 1: Bid concentration

Number of bidders	5	6	7	8	9	Total
Number of auctions	52	52	28	5	2	139

Table 2: Abstention from bidding

Auction ID	Bidding war	Bidder
39	No	8
137	No	4,5,9,11
138	No	6,7,9
139	Yes	5,7

Table 3: Information of firms

Firm ID	Local/Out-of-town	Num. workers	Num. offices	Years of operating	Sales	Profit-sales ratio	Num. bids	Num. winning	Total win amount
1	O	158	12	55	13,059,582	5.79%	29	4	54,128
2	O	22	2	15	344,832	-0.33%	40	5	52,605
3	L	16	1	15	575,285	1.21%	93	14	178,941
4	L	12	1	31	242,361	1.27%	95	17	129,749
5	L	19	1	36	628,776	1.14%	97	13	100,044
6	O	9	2	34	286,748	-0.86%	37	3	17,714
7	L	3	1	30	115,744	2.58%	95	14	80,126
8	L	9	1	24	318,985	0.41%	61	13	68,103
9	L	6	1	22	144,423	0.60%	72	20	110,670
10	L	4	1	6	249,260	1.04%	83	13	59,346
11	O	16	2	26	380,573	-9.50%	39	6	33,096
12	L	7	1	21	67,056	-0.17%	81	17	104,470
13	L	-	-	-	-	-	4	0	0

Note: Sales and Total win amount are in 1000 yen.

Table 4: Definition of variables

Variable name	Description	Num.Obs.	Mean	Std. Dev.	Min	Max
CAP_{it}	The measure of capacity utilization. Defined as the value of backlog contracts divided by the firm's annual sales in 2004. (If the firm has more than two offices, sales are divided by the number of the offices.) Firm i's backlog contract at auction t is the contract won by Firm i in public auctions in Ibaraki City or Osaka Prefecture, overlapping the contract of auction t.	725	0.04	0.07	0	0.59
$CAPSQ_{it}$	Square of CAP.	725	0.01	0.02	0	0.35
$YEARS_i$	Years since Firm i's establishment, as of 2004.	725	24.74	10.58	6	55
$WORKER_i$	Number of technical employees of Firm i, as of 2004, divided by the number of offices.	725	9.57	5.24	3	19
$PROFRATE_i$	Profit-sales ratio as of 2004.	725	0.53	2.64	-9.50	5.79
$DIST_{it}$	Direct distance in kilometer between the work site and Firm i's office.	725	3.64	2.29	0.21	14.92
$OUTOFTOWN_i$	A dummy variable that takes 0 if Firm i has a headquarter in Ibaraki City, and 1 otherwise.	725	0.18	0.39	0	1
$NUMDAYS_{it}$	The number of days between Firm i's last winning and the date of auction t.	725	106.31	112.50	0	695
$WINVALUE1_{it}$	The total value of contracts that Firm i has won since the start of the data period until the date of auction t (in million yen).	725	47.04	39.13	0	176.27
$WINVALUE2_{it}$	The total value of contracts that Firm i has won within half a year of auction t (in million yen).	725	10.56	9.53	0	47.04
$WINNUM_{it}$	The number of times that Firm i won in auctions from the start of the data period until the date of auction t.	725	6.67	4.77	0	20
$LOSENUM_{it}$	The number of times that Firm i lost in auctions from the start of the data period until the date of auction t.	725	31.90	21.40	0	82

Table 5: Estimation results for conditional logit model

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
WINVALUE1	-0.010	-0.027**					-0.007		
	(0.006)	(0.009)					(0.010)		
WINVALUE2			-0.033*	-0.038*					
			(0.016)	(0.018)					
WINNUM					-0.065	-0.139			
					(0.060)	(0.077)			
LOSENUM	0.006	0.031	-0.005	-0.006	-0.004	0.008	0.021		
	(0.015)	(0.023)	(0.014)	(0.021)	(0.014)	(0.021)	(0.020)		
NUMDAYS	0.006**	0.006**	0.006**	0.006**	0.006**	0.006**	0.012**		
	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.004)		
CAP	-3.810	-5.978	-2.126	-3.401	-3.793	-5.100	-3.587	-8.586*	-9.804*
	(3.985)	(4.116)	(4.186)	(4.291)	(4.022)	(4.106)	(4.809)	(3.834)	(3.941)
CAPSQ	5.024	7.278	2.500	3.310	4.587	5.119	3.603	12.012	12.391
	(10.120)	(10.690)	(11.235)	(11.785)	(10.032)	(10.560)	(12.354)	(9.478)	(9.863)
YEARS	-0.004	-0.042	-0.002	-0.047	0.002	-0.042	-0.018	-0.005	-0.018
	(0.012)	(0.027)	(0.012)	(0.027)	(0.012)	(0.027)	(0.027)	(0.011)	(0.024)
WORKER	-0.013	0.011	-0.021	-0.069	-0.034	-0.079	0.089	-0.032	-0.044
	(0.026)	(0.057)	(0.024)	(0.046)	(0.022)	(0.045)	(0.053)	(0.020)	(0.039)
PROFRATE	-0.052	0.032	-0.053	0.033	-0.065	0.029	-0.367*	-0.037	0.018
	(0.056)	(0.071)	(0.055)	(0.070)	(0.056)	(0.071)	(0.149)	(0.052)	(0.061)
DIST	-0.146**	-0.114	-0.152*	-0.125	-0.139*	-0.116	-0.107	-0.129*	-0.121
	(0.062)	(0.064)	(0.062)	(0.064)	(0.062)	(0.064)	(0.065)	(0.061)	(0.062)
OUTOFTOWN	-2.287**	-1.722*	-2.300**	-1.728*	-2.561**	-1.750*	-3.349*	-0.822*	-0.212
	(0.560)	(0.732)	(0.552)	(0.734)	(0.659)	(0.790)	(1.477)	(0.391)	(0.521)
δ_2							0.108		
							(0.263)		
δ_3							-1.179		
							(0.797)		
δ_4							-0.005		
							(0.384)		
δ_5							-1.191		
							(1.017)		
δ_6							-0.092		
							(0.244)		
δ_7							0.620		
							(0.384)		
δ_8							-0.240		
							(0.502)		
δ_9							0.201		
							(0.456)		
δ_{10}							-0.034		
							(0.552)		
δ_{11}							-1.791		
							(1.256)		
δ_{12}							0.273		
							(0.461)		
Bidder fixed effect	No	Yes	No	Yes	No	Yes	No	No	Yes
Log likelihood	-194.23	-187.70	-193.39	-189.65	-195.15	-190.52	-181.30	-208.71	-206.13
Pseudo R^2	0.105	0.135	0.108	0.126	0.100	0.122	0.164	0.037	0.049
IIA violation	Yes	No	No	No	Yes	No	No	No	Yes

Notes:

(i) **: 1% significance level, *: 5% significance level.

(ii) The number of observations of each model is 725.

(iii) 'Yes' in 'IIA violation' implies that the Hausman test suggests that the model violates Independence of Irrelevant Alternatives (IIA) assumption.

Table 6: OLS estimations for bid levels

Data set	All bids				Losing bids			
Dependent Variable	Normalized bid		log(Norm. bid)		Normalized bid		log(Norm. bid)	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Reserve price	-0.004	0.004	-0.003	0.005	-0.081	-0.072	-0.083	-0.074
	(0.086)	(0.087)	(0.090)	(0.091)	(0.081)	(0.082)	(0.084)	(0.085)
WINVALUE2	0.005	0.006	0.005	0.006	0.003	0.006	0.003	0.006
	(0.007)	(0.007)	(0.007)	(0.008)	(0.007)	(0.007)	(0.007)	(0.008)
NUMDAYS	-0.026**	-0.026**	-0.028**	-0.028**	-0.007	-0.007	-0.008	-0.007
	(0.006)	(0.006)	(0.007)	(0.007)	(0.006)	(0.006)	(0.006)	(0.007)
CAP	-0.012	-0.009	-0.012	-0.009	-0.014	-0.018	-0.015	-0.018
	(0.018)	(0.019)	(0.019)	(0.020)	(0.017)	(0.018)	(0.018)	(0.019)
CAPSQ	0.032	0.021	0.033	0.022	0.032	0.022	0.033	0.023
	(0.045)	(0.046)	(0.047)	(0.048)	(0.041)	(0.042)	(0.043)	(0.044)
YEARS	0.000*	0.000*	0.000*	0.000	0.000**	0.000**	0.000**	0.000*
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
WORKER	0.000	0.052**	0.000	-0.002**	0.000	0.052**	0.000	-0.002**
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
PROFRATE	0.001**	-0.016**	0.001**	0.002**	0.001**	-0.016**	0.001**	0.002**
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
DIST	0.001*	0.001*	0.001*	0.001*	0.000	0.000	0.000	0.000
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
OUTOFTOWN	0.011**	0.394**	0.012**	-0.008**	0.007**	0.395**	0.007**	-0.008**
	(0.002)	(0.003)	(0.002)	(0.003)	(0.002)	(0.003)	(0.002)	(0.003)
Intercept	0.956**	-	-0.046**	-	0.963**	-	-0.038**	-
	(0.002)		(0.002)		(0.002)		(0.002)	
Num. of Obs.	717	717	717	717	594	594	594	594
R^2	0.054	0.99	0.054	0.905	0.042	0.999	0.042	0.914
Bidder Fixed Effect	No	Yes	No	Yes	No	Yes	No	Yes

Notes:

(i) **: 1% significance level, *: 5% significance level.

(ii) The data sets do not include bids submitted in bidding wars.

(iv) The units of Reserve price and NUMDAYS are in 10^9 yen and 1000 days, respectively.

Table 7: Estimation results of Tobit models

	(1)	(2)	(3)	(4)
Reserve price	-6.165**	-6.425**	-6.393**	-7.020**
	(1.485)	(1.494)	(1.601)	(1.606)
CAP	0.595	0.779*	0.496	0.799*
	(0.320)	(0.335)	(0.353)	(0.371)
CAPSQ	-1.244	-1.547	-0.721	-1.173
	(0.805)	(0.820)	(0.869)	(0.885)
YEARS	-0.001	0.001	-0.001	0.003
	(0.001)	(0.002)	(0.001)	(0.002)
WORKER	-0.002	0.034**	-0.004	0.030**
	(0.002)	(0.004)	(0.002)	(0.004)
PROFRATE	0.002	-0.014**	0.001	-0.015**
	(0.004)	(0.005)	(0.005)	(0.005)
DIST	-0.006	-0.008	-0.005	-0.007
	(0.004)	(0.004)	(0.005)	(0.005)
OUTOFTOWN	0.111**	0.343**	0.108**	0.336**
	(0.036)	(0.048)	(0.039)	(0.052)
WINVALUE2	0.324**	0.335**	0.389**	0.392**
	(0.123)	(0.130)	(0.135)	(0.143)
NUMDAYS	-0.043	-0.042	0.035	0.020
	(0.111)	(0.114)	(0.127)	(0.130)
Intercept	0.714**	-	0.728**	-
	(0.040)		(0.044)	
Num. of Obs.	812	812	673	673
Log-likelihood	-220.398	-216.398	-186.183	-179.038
Bidder Fixed Effect	No	Yes	No	Yes

Notes:

(i) **: 1% significance level, *: 5% significance level.

(ii) The definition of the dependent variables:

(bid level−minimum price)/(reserve price−minimum price)

(iv) The units of Reserve price and NUMDAYS are in 10^9 yen and 1000 days, respectively.

Figure 1: Winning price

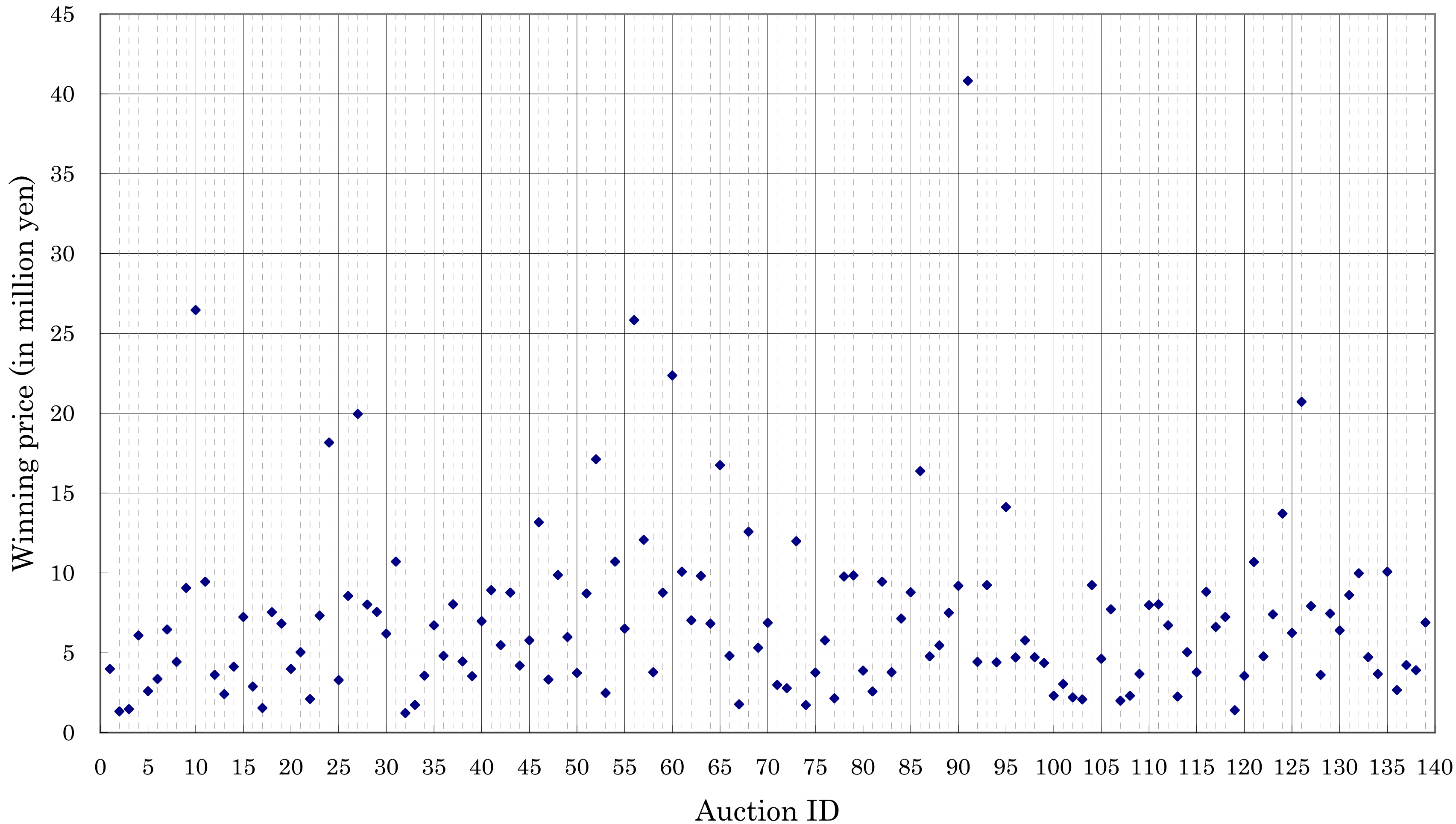
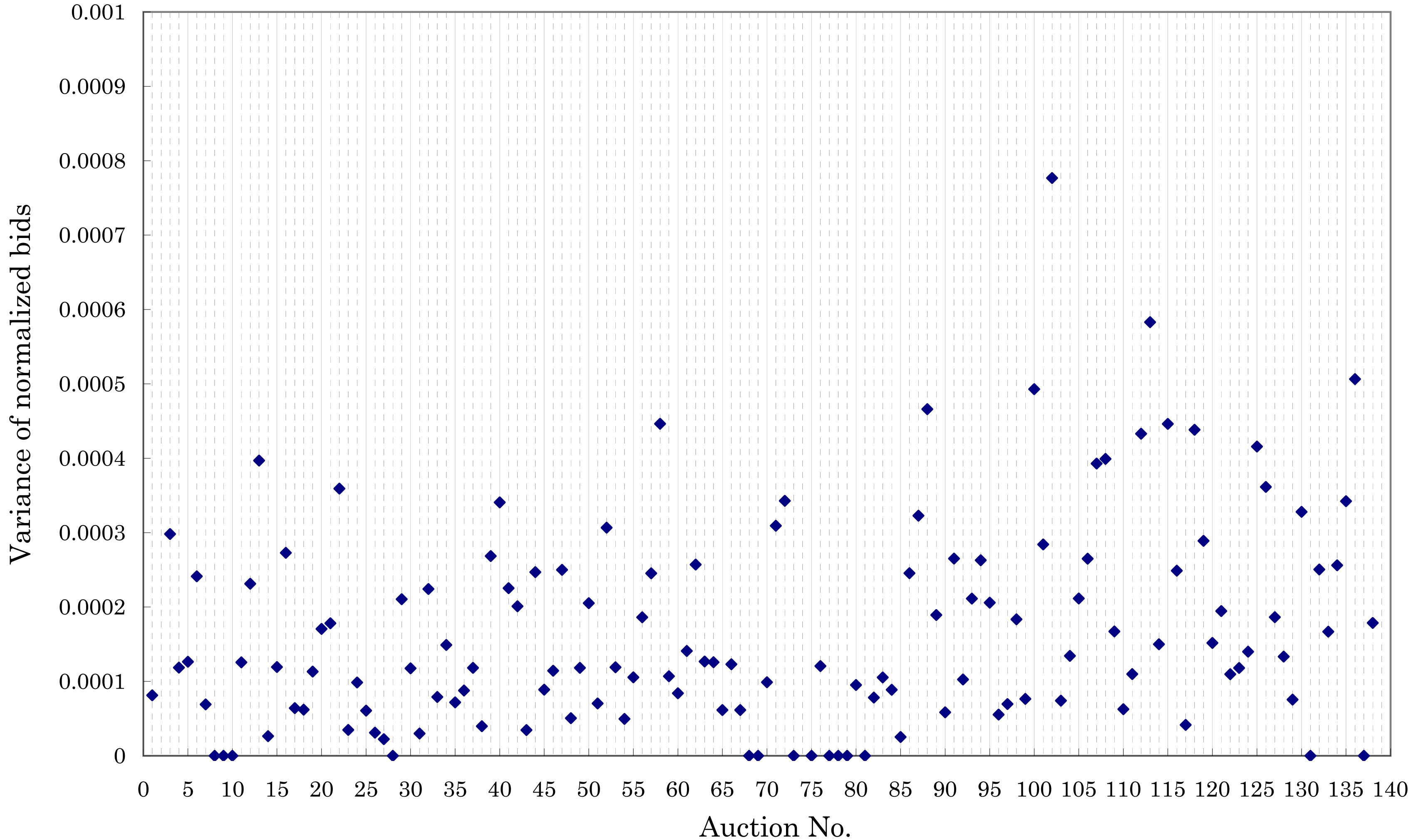
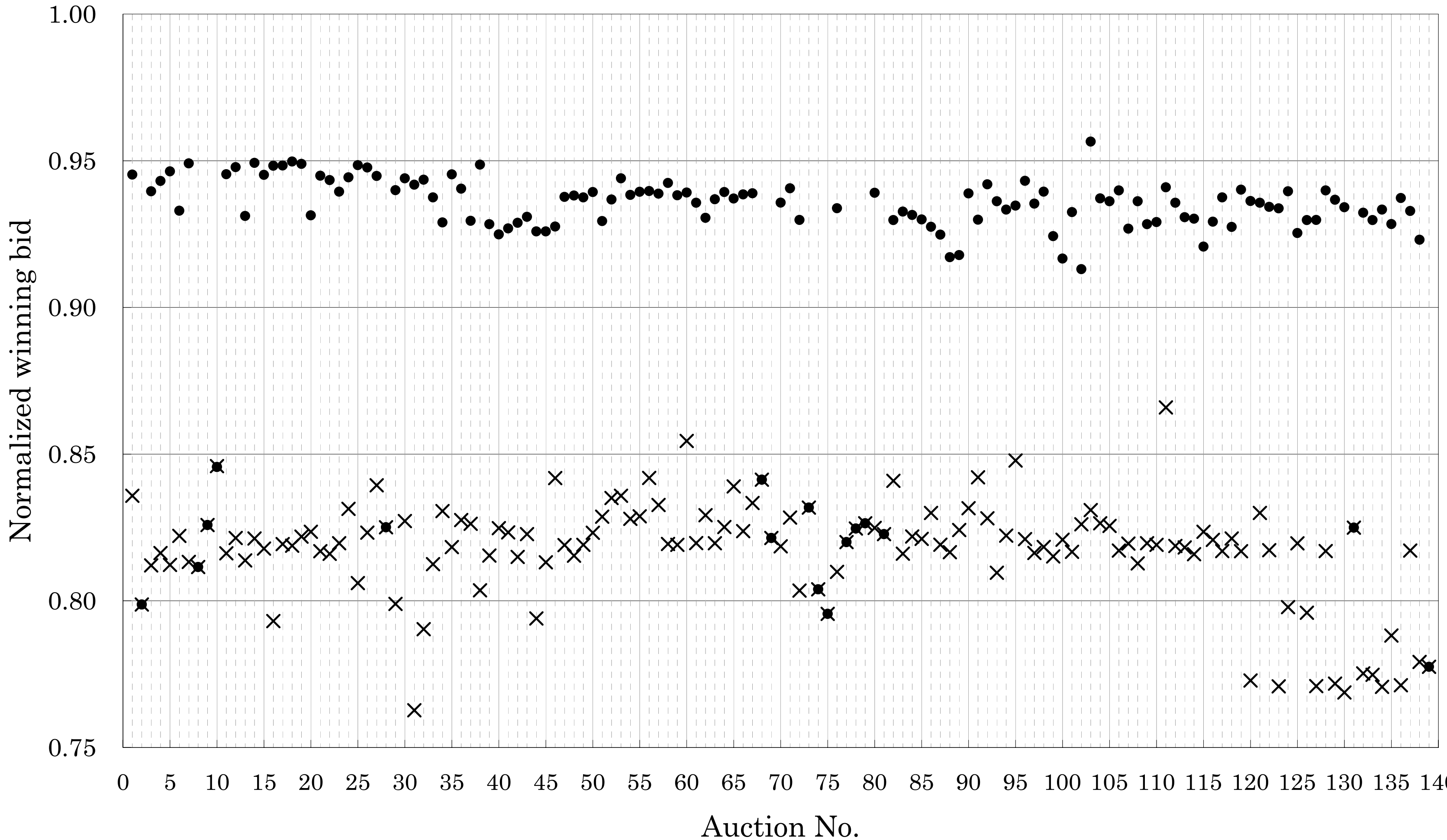


Figure 2: Variance of normalized bids



Note: The figure does not include three exceptionally large values 0.0023, 0.0011, and 0.0076 for Auction No. 2, 74, and 139, respectively.

Figure 3: Normalized winning bids



Notes: For each auction, the normalized winning bid and the minimum price are indexed by • and ×, respectively.

Figure 4: Participation and bidding wars

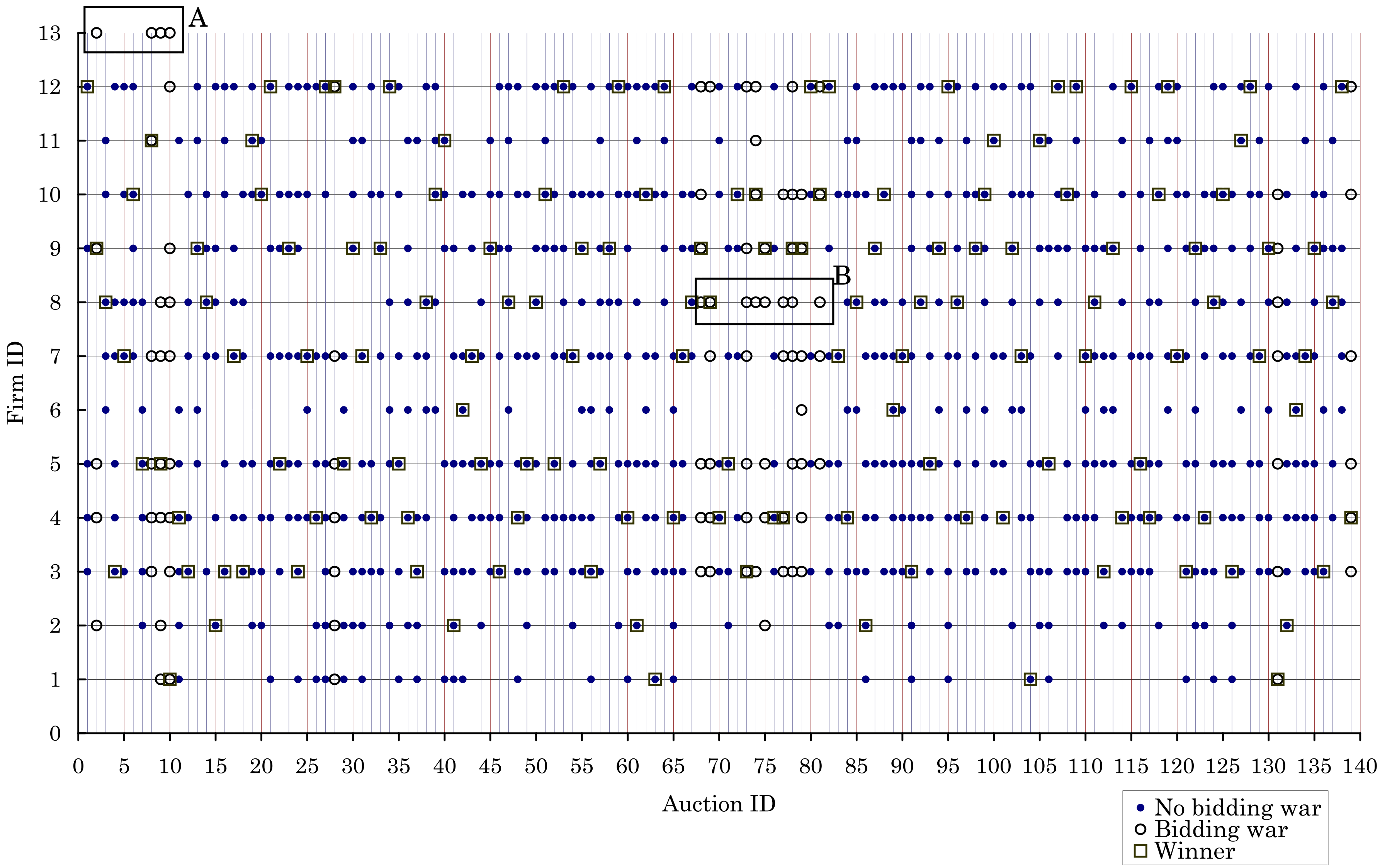


Figure 5: Winner of auctions