An Empirical Analysis of Entrant and Incumbent Bidding in Electric Power Procurement Auctions

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Abstract

This paper explores differences in the bidding patterns of entrants and incumbents in electric power procurement auctions. The entrants have significant disadvantage in the cost structure, and their participation rate remains very low in the auctions. We model their bidding patterns where there participation decision depends on reserve price and estimate their cost distribution and the equilibrium strategies. We also consider a policy experiment in the spirit of a price-preference policy to enhance competition on incumbent and participation of entrants.

1 Introduction

When asymmetry among bidders exits, all bidders cannot be treated alike in a first-price sealed-bid auction. For example, within the private value paradigm, the theoretical literature has shown that the revenue equivalence theorem no longer holds with asymmetric bidders and that it might induce some inefficiency: weak bidders bid more aggressively, and as a result, the winning bidder may not be the one with the highest value (see Krishna (2002)). In such a case, the auctioneer may be better off giving a price preference to bidders who are in a weak position to win the auction.[1] It has been also shown that in procurement auctions with asymmetric bidders, the least efficient firms may be prevented from participating to the auction as their bids will not be competitive. Thus, asymmetry may act as a barrier to entry and potentially reduce the level of competition (McAfee and McMillan

[1] Such price-preference policies are frequently observed, including the recent example of the spectrum auctions held by the Federal Communications Commission (FCC) that use of various discriminatory policies in the spirit of affirmative action.

(1989), Harstad et al. (2003)). Therefore, it is important to identify whether there exist asymmetry among bidders when considering efficient auction mechanisms.

This paper investigates the bidding patterns of entrant and incumbent firms in electric power procurement auctions in Japan. In the Japanese retail electricity market, there had been ten firms that supply electricity locally as monopolists. The partial liberalization started in 2000, allowing new firms, called the Power Producers and Suppliers (PPS), to enter the market and to supply electricity to large demand with power and voltage higher than $2000kW$ and $20000V$, respectively. With such a wave of liberalization, the public agencies have started to utilize open bidding systems for electric power supply contracts. The target of liberalization has been step by step expanded and the PPS are now allowed to participate any auctions with the power higher than $50kW$.

Nevertheless, the participation rate of entrants remains very low, implying the significant disadvantage of the entrants compared with the incumbents. In fact, the cost structure between entrants and incumbents in this market differs significantly. All incumbent firms are vertically integrated and have production sections, while most of entrants purchase electricity from outside sources, including the Japanese electric power exchange market. Even for entrants that have production sections, cost disadvantage still exists because such entrants have only thermal power stations that incur higher cost to generate electricity than atomic power plants do, while most of incumbents possess the latter. Furthermore, the transmission network is operated only by incumbents and hence, entrants must pay transmission fee to incumbents to use the transmission networks to supply electricity to consumers.[2] Therefore, entrants in general face higher cost to supply electricity. Such asymmetry imply the large potential to improve competition by the preferential policy.

The purpose of this study is, first, to empirically assess the extent of asymmetry and inefficiency due to asymmetry by recovering cost estimates using the structural estimation proposed by Guerre et al. (2000), and second, to conduct a policy experiment in the spirit of a price-preference policy to enhance competition on incumbent and participation of entrants. We model the bidding behavior of incumbents and entrants whose participation decision depend on reserve price only. Because we only have winning bids, we nonparametrically estimate winning bid distribution and use the rela-

[2] Such transmission fee varies from 0.57 to 3.42 yen/kWh, with fixed fee from 346.50 to 656.25 yen/kW, depending on area, time, and voltage.

tionship between that distribution and bid distribution to apply Guerre et al. (2000) approach to obtain cost estimate of the winning firm for each observed auction. We then simulate bids from the estimated bid distributions and estimate pseudo costs to obtain the equilibrium strategies of two types.

We find that entrants have much higher cost for given auction; the average cost of entrants is 5.77 yen/kwh higher than that of incumbent, while the average margin of entrants is 3.97 yen/kwh lower than that of incumbent. The entrants bid much more aggressively than does the incumbent, and win most of the auctions where they participate.

While asymmetries among bidders caused by many different sources have been empirically examined in the previous studies, asymmetries between incumbent and entrant firms have not been emphasized in the literature. The previous studies have shown that asymmetries arise from firms' size as noted by Laffont et al. (1995), their capacity constraints as in Jofre-Bonet and Pesendorfer (2003), the possession of better information as in Hendricks and Poter (1992), their distance from the places where the service is required as in Bajari (1997) and Flambard and Perrigne (2006) or collusion among a group of bidders as in Porter and Zona (1993) and Bajari and Ye (2003). The notable exception that examines asymmetry between incumbent and entrant firms is De Silva et al. (2003). They investigate differences in the bidding patterns of entrants and incumbents in road construction auctions in Oklahoma. Their findings are consistent with their assumption that entrants are less efficient and their cost's distribution has a greater dispersion.

2 The electricity procurement auction data

As described in Introduction, in the Japanese retail electricity market, the partial liberalization was started in 2000, allowing new firms, called the Power Producers and Suppliers (PPS), to enter the market and to supply electric power to large demand with power and voltage higher than $2000kW$ and $20000V$, respectively. The target of liberalization was expanded to demand with power and voltage higher than $500kW$ and $6000V$ in 2004, and to demand with power higher than $50kW$ in 2005. With such a wave of liberalization, the public agencies have started to utilize open bidding systems for electric power supply contracts for public places such as waterworks, roadway facilities, schools, hospitals, or markets.

Each public agency advertises auctions in its web page, official gazette, and other newspapers, with detailed information including the required maximum (peak) power (kW), the amount of electricity to be supplied (kWh), the delivery period, the delivery place, the qualification for participating in tendering procedures, and the time-limit for tender. The firm submitting the lowest bid wins the auction and is paid a total of its bid times tax rate. Although the reserve price exists, it is usually not announced (even after the bids are opened). If the lowest bid is higher than the reserve price, then the contract is not offered. In such a case, the agency either offers the second auction or bargains with one of the bidders. In the latter case, a supplier will eventually supply the electricity with the negotiated rate. Supplying electric power to public agencies is often a secondary activity while their main activity focuses on large private demand where prices are often determined by bargaining processes.

2.1 The winning bid data

This section describes the our data set that consists of the winning bids of all the electricity procurement auctions throughout Japan between April 2004 to March 2008. The winning bid data is offered by *Electric Daily News*, a newspaper specialized to electricity. The data contains information of date the bids are opened, the government agency (the auctioneer), the required maximum power (kW), the amount of electricity to be required (kWh), the contract period, the delivery place, a winner of each auction, the winning bid, either the identification or the number of other bidders, and other descriptive auction information including whether there is a restriction for CO_2 emission.[3] While the data contains the rich number of observations, the disadvantage of this dataset is, firstly, it does not include losing bids, and secondly, the identifications of non-winners are not observed for many observations.

A total of 1368 auctions without missing information are observed from April 2004 to March 2008.[4] Nineteen different firms participate in these auctions, with nine incumbents and ten entrants. We define the suppliers that operated even before the liberalization and have continued to operate

[3] The Environmental-Conscious Contract Law has been enforced since November 2007. The law clarifies the public sector's responsibility to take into account not only economic concerns but also the reduction of greenhouse gas emissions when they sign a contract. Specifically, contracts concerning the purchase of electricity and official vehicles, as well as service contracts such as those with energy service companies (ESCO) and architects are subject to the law. Following the law, public agencies started to set the numerical targets such as maximum $CO2$ emission coefficient as the qualification for participating.

[4] Japanese fiscal year starts in April. Hereafter, we use the term "year" for fiscal year unless otherwise noted.

as incumbents, and the suppliers that have entered the market after the liberalization as entrants. The incumbents firms were local monopolists before the liberalization, and mainly operate only in the local area even after the liberalization. Therefore, we do not observe any auctions where multiple incumbents bid.

Table 1 shows summary statistics. The auctions are not so competitive with an average number of active participants varying from 1.50 to 2.04. The PPS did not enter all the auctions and an incumbent is the only bidder in many auctions. The number of bidders increased in 2005, but decreased after that. This may reflect the fact that the number of auctions with CO_2 emission restriction have gradually increased since 2006. *Green* refers to the dummy variables that takes the value 1 if the auction has any restrictions regarding CO_2 emission. It can be seen that 42% and 34% of auctions in 2006 and 2007, respectively, are such auctions. Because entrants usually have only thermal power stations that generate more CO_2, they tend to have disadvantage in such auctions with CO_2 emission restriction.

The average winning bids have been increasing during this period. Both the maximum (peak) power (kW) and the size (kWh) decreased until 2006 but increased in 2007. The downward trend till 2006 reflect the fact that the number of auctions with relatively small size increased as the liberalization proceeded. In 2007, we observe many public agencies that bundle several contracts to offer in one auction. This may be the reason for the increased size in 2007. *Load* refers to the load factor: the ratio between the average and the maximum (peak) usage of electricity during the contract period. It is calculated as the required amount per year divided by the required capacity: (kWh) / (the maximum power (kW) $\times$ 24 $\times$ 365). The low load factor induces inefficiency because suppliers need to hold capacity for peak usage that are not used for most of the time.

The load factor seems to play an important role for firms' participation and bidding decision. Table 2 presents the summary statistics of winning bids by load factor. It can be seen, in the first two columns, that winning bids decrease as load factor increases implying that firms can enjoy efficiency with high load factor. In the third column, we can see that entrant's winning rate decreases with load factor significantly. Actually, this is partly because entrant's participation rate also decreases with load factor (see the fifth column. Inside parentheses are participation rates). The sixth column shows the number of auctions where entrants win and the entrant's winning rate conditional on entrant's participation. Such conditional winning rate of entrants again decreases with the load factor. It seems that entrants have significant disadvantage in auctions with high load factor. Takagi and Hosoe

(2007) notes that as entrants depend on peak power supply such as petroleum thermal, supplying electricity continuously throughout a day is costly for them. Therefore, in auctions that require high load factor, entrants are likely to have disadvantage.

2.2 Some evidence of asymmetry

Figure 1 presents the cumulative distributions of winning bids of incumbent and entrant. *cumin* refers to the cumulative distribution of winning bid of incumbent and *cumen* refers to that of entrant. We can see that the winning bid distribution of entrant stochastically dominates the one of incumbent. This may suggest that the incumbents are strong bidders with a cost distribution that is stochastically dominated by that of entrants (Maskin and Riley 2000a).

In total, 1363 bids were submitted by incumbents and 879 of them won the contracts while 1088 bids were submitted by entrants and 489 of them won the contracts. Therefore, the winning rates of incumbents and entrants are, respectively, 64.5% and 44.9%, which show the significant difference. The incumbents are more likely to win in the auctions.

We also run the simple regressions as follows:

$$y_i = X_i B + D + T + \varepsilon_i$$

where the subscript i refers to an auction. Because we have winning bid data, the data is at auction level. We use the dependent variable, the average bid (yen/kWh), through our analysis. The independent variables include three sets of controls: the $X's$ control for auction level variables, the D is a vector of the district fixed effects, and the T is a vector of year dummies. Because there is only one incumbent in each district, the D can also be considered as incumbent fixed effects. With respect to auction characteristics X, we include the following variables. In order to distinguish entrants and incumbents, we simply include an incumbent dummy variable that takes 1 if the winner is an incumbent. We include the number of bidders. We expect that the auctions will be more competitive and bids should be more aggressive as the number of bidders rise. The number of bidders, however, may have a negative effect if auctions are common valued because of the existence of winners curse. Because winners curse is more significant when the number of bidders is large, bidders may become less aggressive as the number of bidders rise in common value auctions. We also include the high voltage dummy that take 1 if the contract of the auction is for voltage higher than 20000V. We also include the load factor as independent variable. Because bids seem to be increasing with the load factor, but not linearly, we also include its square. The peak power (kW) and the size (kWh) are also included. However, because the two variables kW and kWh perfectly determine the load factor, we include only one of them in an empirical model. We expect that the size kWh negatively affect winning bids as firms can enjoy scale economy for larger size. For the similar reason, we expect that the contract length ($year$) has a negative effect on winning bids. The variable $green$ is included to identify auctions with CO_2 emission restrictions.

In the previous studies, the bidder characteristics such as winning rate and backlogs are commonly included in empirical specifications. The winning rate is commonly used to represent firm's efficiency while the backlog is used to represent firm's capacity constraint. Because we cannot identify losing firms in most of auctions in our dataset, we cannot construct such variables of bidder characteristics. We cannot construct similar rival characteristic variables for the same reason. This is a significant disadvantage of our data. In the later study, we will use the dataset that consists of less observations but include bidder level information and include these variables. As for the capacity constraint, however, we believe that it is not binding because supplying electric power to public sector is often a secondary activity for both incumbents and entrants.

We do not include variables for project types (delivery place) because it seems that once we control for the load factor, the project type itself does not seem to matter much for electricity suppliers (see Takagi and Hosoe (2007)).

Table 3 shows the estimation results with the basic specifications with and without kW and kWh. The dependent variable is average bid (yen/kWh). The results are robust to the four specifications in Table. The incumbent dummy does not have statistically significant effect although it is positive. We can see that the number of bidders has negative and significant effect on the average bid. This may suggest that the electric power procurement auctions are likely to fit to the private value paradigm.[5] The contract for

[5] Gilley and Karels (1981) show that one of the basic qualitative predictions in the common value paradigm is that "a greater number of competitors on a tract will lower the optimal bid of the firm" (in higher value auctions for oil tracts). This is because if a bid wins against a relatively large number of competitors, it is more likely that the object has been overvalued and as a result, firms must take a more pessimistic view of winning bids when more competitors enter. However, Pinkse and Tan (2002) shows that strategic behavior can cause bids to increase or decrease in the number of opponents under either private or common value paradigm. Gilley and Karels (1981) themselves also show that the above prediction does not always hold when the number of bidders is very small. Therefore, we cannot conclude that auctions here can be modeled in the private value

the voltage higher than 20000V is won with lower bid. As expected, the load factor has negative and significant effect on the winning bid, and such negative effect seems to be weakened in the higher range of the load factor. The coefficients on the size (kWh) and the contract length are negative (except the specification (1)), implying that there exists scale economy. These effects are, however, not statistically significant. The variable *green* has positive effect implying that the auctions with CO_2 emission restriction are more costly for suppliers. This effect is again not significant.

Next we include the dummy variable *single* that takes value 1 if no entrant participate the auction in our empirical model. Because we do not observe multiple incumbents in an auction, there is only one bidder (who is incumbent) in the auction if single=1. We include this variable in order to control the participation decision of entrants. As shown in Table 2, we observe that entrants do not participate all auctions. For example only 3.1 percent of auctions with load factor higher than 80% are observed with entrants. If we cannot control for all the variables that affect entrant's participation decision and the bidding behavior simultaneously, our result is likely to be biased. Gilley and Karels (1981) point out the importance of the link between the dichotomous bidding decision (bid, do not bid) and the bid level decision, and suggest Heckman two stage estimation (Heckman 1976, 1979). However, again as we do not have losing bids and identification of losing firms, we cannot utilize such estimation method. Therefore, we control for the auctions where an incumbent is the only bidder using this dummy variable. Table 4 presets the estimation results including the dummy variable *single*. The dummy variable *single* has a negative and significant effect on the winning bid. This may imply that entrants do not enter auction for which they have significant disadvantage. Once we control for the auctions with incumbent only, the incumbent dummy has a positive and significant effect on the winning bid. That is, entrants win with much more aggressive bids as compared to incumbents' bids.

3 Estimation strategy

3.1 Model

We consider an asymmetric auction model with independent costs. Cost independence is a reasonable approximation because firms have different

paradigm only by this result. Recent studies introduce the selection tests for common and private value auctions (see for example, Haile, Hong, and Shum (2003)).

opportunity costs resulting from their different main activities. In procurement auctions, Bajari (1997), Jofre-Bonet and Pesendorfer (2003), Krasnokutskaya (2002) and Flambard and Perrigne (2006) have also assumed independence. Though a common component may exist, we consider it as negligible in this activity. The observed auctions have secret reserve prices. That is, the reserve prices are never announced most of time even after the bids are opened. Nevertheless, we assume that both the incumbent and entrants make the identical estimate for the reserve price. We believe that this is fairly reasonable assumption, because the reserve price reflects the expected performance for a firm with an average efficiency, and firms should be able to calculate such a price. The reserve price introduces a truncation on the bids distribution and differ the number of actual firms participated to auctions from the number of potential firms. For the most of the auctions held by local public agencies, firms need to first register to be on the list of the agency to participate in auctions. Therefore, active participants each year should be on the lists of these agencies which are open to public. Therefore, we assume that the number of potential bidders equal to the number of maximum active participants each year.

We conduct the nonparametric approach by Guerre et al. (2000) to estimate firms' cost and strategy. Flambard and Perrigne (2006) consider the same approach for binding reserve price, and show that the IPV model with the binding reserve price is identified. Their approach first involve identifying the relationship between bid and cost using the observed bid distribution. Then they estimate the bid distribution nonparametrically, and recover the cost using the estimated distribution function. Because we only observe winning bids, we use the relationship between winning bid distribution and bid distribution to fully apply the approach. That is, we first estimate winning bid distribution nonparametrically, and recover the bid distribution using the relationship between winning bid and bid distributions. Then we recover firms' cost using the relationship. For the firms' strategy, we simulate bids from the estimated bid distributions in order to estimate pseudo costs.

In practice, the auctions can be heterogeneous and we need to control such heterogeneity. Specifically, we control for the load factor and the size (kW) of auctions as these factors affect the winning bid most significantly as shown above. We also control for the number of potential bidders and the number of actual bidders when estimating winning bid distributions as the both affect winning bid. But we assume that former vary over years, but not over auctions. Furthermore, we conduct nonparametric estimation by each district as auction and participant characteristics differ significantly over districts. We consider the model in Tokyo district in followings. In Tokyo district, the number of potential bidder is 7 throughout the observed periods (fiscal year 2004 to 2007): $I = 7$.

We consider a procurement auction in which I risk neutral firms compete for a contract to provide electricity throughout the contract period. Before bidding starts, each firm i forms an estimate of its cost to complete the task. The cost estimate is firm i's private information. Thus, firm i knows its own cost estimate but does not know the cost estimates for other firms. The cost estimate for firm i is a random variable C_i with a realization denoted as c_i and is drawn independently across all firms. We consider two types of firms. Type 1 (0) refers to incumbent (entrant). Types 1 and 0 consists of $I_1 = 1$ and $I_0 = I - 1$ firms, respectively, with $I \geq 2$. Let c_{1i} and $c_{0i}, i = 1...I-1$ are drawn from the distribution $F_1(\cdot)$ and $F_0(\cdot)$, respectively, defined on the common support $[\underline{c}, \overline{c}]$. The costs are all independent. Both distributions are continuous with densities $f_1(\cdot)$ and $f_0(\cdot)$. We consider a first-price sealed-bid auction in which there is the binding reserve price.

In order to win the contract, firm i must submit the bid that is lowest among the participants and lower than the reserve price. If firm i submits a bid of b, given that it is lower than the reserve price, it will win the contract when $c_j \geq \phi_j(b)$ for all $j \neq i$, where ϕ_j is the inverse strategy function. At the Bayesian Nash equilibrium, each firm i chooses his bid b to maximize its expected profit:

$$\max_b \pi_i(b, c_i) = (b - c_i) \prod_{j \neq i} \left[1 - F_j(\phi_j(b))\right]. \quad (1)$$

if $c_i \leq p^e$ where p^e is the estimate for the reserve price formed by the firm. As we can see, firm i's expected profit is a markup times the probability that firm i is the lowest bidder. Differentiating (1) with respect to b gives the following two first order conditions for type 1 and 0.

$$\begin{aligned} c_1 &= b_1 - \frac{1}{(I-1)\frac{f_0(\phi_0(b_1)\phi_0'(b_1)}{1-F_0(\phi_0(b_1))}} \\ c_0 &= b_0 - \frac{1}{\frac{f_1(\phi_1(b_0)\phi_1'(b_0)}{1-F_1(\phi_1(b_0))} + (I-2)\frac{f_0(\phi_0(b_0)\phi_0'(b_0)}{1-F_0(\phi_0(b_0))}} \end{aligned} \quad (2)$$

with the boundary conditions

$$\begin{aligned} \phi_k(p^e) &= p^e \text{ for } k = 0, 1 \\ \exists \beta \text{ s.t. } \phi_k(\beta) &= \underline{c} \text{ for } k = 0, 1 \end{aligned} \quad (3)$$

Because the distribution of costs are usually not observed, Guerre et al. (2000) re-write the above first-order conditions by the distribution of observed bids only, and estimate the latter nonparametrically. Flambard and Perrigne (2006) extend the approach to the case with binding reserve price. Let $G_1(\cdot)$ be the distribution for the incumbent bidder with density $g_1(\cdot)$. Let $G_0(\cdot)$ be the marginal distribution of bids for the other bidders with density $g_0(\cdot)$. Because observed bids are the equilibrium bids, we have, for every $b \in [\underline{b}, p^e]$, $G_1(b) = F_1(\phi_1(b)) = F_1(c)$, and $G_0(b) = F_0(\phi_0(b)) = F_0(c)$. With a binding reserve price, we need to consider the truncated distributions $G_1^*(\cdot|\cdot \leq p^e)$ and $G_0^*(\cdot|\cdot \leq p^e)$. Note that $G_1^*(b_1) = F_1[\phi_1(b_1)]/F_1(p^e)$ and $G_0^*(b_0) = F_0[\phi_0(b_0)]/F_0(p^e)$. The system of 2 can be rewritten as

$$\begin{aligned} c_1 &= b_1 - \frac{1}{(I-1)\frac{g_0^*(b_1)F_0(p^e)}{1-G_0^*(b_1)F_0(p^e)}} \\ c_0 &= b_0 - \frac{1}{\frac{g_1^*(b_0)F_1(p^e)}{1-G_1^*(b_0)F_1(p^e)} + (I-2)\frac{g_0^*(b_0)F_0(p^e)}{1-G_0^*(b_0)F_0(p^e)}} \end{aligned} \quad (4)$$

Their two step estimation method is first to estimate the bid distribution and bid density G_i, g_i nonparametrically, and obtain pseudo cost c_i, and then to estimate the cost distribution using the obtained pseudo costs.

Since we have only winning bids, we need to transfer the equations 4 for the ones which relates costs and winning bid distributions. Let $W_i(y)$ be the distribution of bidder $i's$ winning bids. This is the union of two disjoint event, b_i being $\min(b_1, ..., b_n)$ and $b_i \leq y$. Then

$$\begin{aligned} W_i(y) &= \Pr(Y \leq y, \text{winner is } i) \\ &= \int_{-\infty}^{y} \prod_{j \neq i} [1 - G_j(t)]\, g_i(t) dt \\ &= \int_{-\infty}^{y} \frac{\prod_{j=1}^{n} [1 - G_j(t)]}{1 - G_i(t)} g_i(t) dt \\ &= \int_{-\infty}^{y} \frac{1 - \Pr(y \leq t)}{1 - G_i(t)} g_i(t) dt \\ &= \int_{-\infty}^{y} \frac{1 - \sum_{j=1}^{n} W_j(t)}{1 - G_i(t)} g_i(t) dt \\ &= \int_{-\infty}^{y} -\left[1 - \sum_{j=1}^{n} W_j(t)\right] d\log(1 - G_i(t)) \end{aligned}$$

where n is the number of bidders who actually participated to the auction.

$$
\begin{aligned}
dW_i(y) &= -\left[1-\sum_{j=1}^{n} W_j(t)\right] d\log(1-G_i(t)) \\
d\log(1-G_i(y)) &= -\frac{dW_i(y)}{1-\sum_{j=1}^{n} W_j(t)} \\
\log(1-G_i(y)) &= -\int_{-\infty}^{y} \frac{dW_i(y)}{1-\sum_{j=1}^{n} W_j(t)} \\
1-G_i(y) &= \exp\left[-\int_{-\infty}^{y} \frac{dW_i(y)}{1-\sum_{j=1}^{n} W_j(t)}\right] \\
G_i(y) &= 1-\exp\left[-\int_{-\infty}^{y} \frac{dW_i(y)}{1-\sum_{j=1}^{n} W_j(t)}\right] \\
g_i(y) &= \exp\left[-\int_{-\infty}^{y} \frac{dW_i(y)}{1-\sum_{j=1}^{n} W_j(t)}\right] \times \frac{dW_i(y)}{1-\sum_{j=1}^{n} W_j(t)} \qquad (5) \\
&= [1-G_i(y)] \times \frac{dW_i(y)}{1-\sum_{j=1}^{n} W_j(t)}
\end{aligned}
$$

Then, we estimate the winning bid distribution and density for $i = 1, 0$ and obtain G_i and g_i for $i = 1, 0$ from the above relationship. The cost of the winner corresponding to each observe auction is recovered as

$$
\begin{aligned}
c_1^w &= b_1^w - \frac{1}{(I-1)\frac{g_0^*(b_1^w)F_0(p^e)}{1-G_0^*(b_1^w)F_0(p^e)}} \qquad (6) \\
c_0^w &= b_0^w - \frac{1}{\frac{g_1^*(b_0^w)F_1(p^e)}{1-G_1^*(b_0^w)F_1(p^e)} + (I-2)\frac{g_0^*(b_0^w)F_0(p^e)}{1-G_0^*(b_0^w)F_0(p^e)}}
\end{aligned}
$$

3.2 Estimation

In practice, the auctioned objects can be heterogenous. Now we consider L auctions indexed by l, $l = 1, ..., L$. Let X_l be a vector of variables characterizing the auction and p_l^e be the estimates for reserve price for auction l estimated by firms. We assume that all the information characterizing the auctioned object is available to the analyst and unobserved heterogeneity comes only from differences in bidders' private costs, which are the unobserved random terms in the model. We observe b_{1l}^w or b_{0l}^w for $l = 1, ..., L$.The number of potential bidders $I = 7$ in Tokyo district. The number of actual participant n^* is also observed. We assume that p^e is an unknown deterministic function of X_l and is bounded away from $\underline{c}(X_l)$ and $\overline{c}(X_i)$. Then the model can be written conditionally upon X_l only while the winning bid can be written conditionally upon X_l and the number of actual participant, n^*.

Using observed winning bids, we can estimate $W_1(\cdot, X_l|\cdot \leq p^e), W_0(\cdot, X_l|\cdot \leq p^e), W'(\cdot, X_l|\cdot \leq p^e), W_0'(\cdot, X_l|\cdot \leq p^e)$. We propose the following nonparametric estimators following Guerre et al. (2000) and Brendstrup and Paarsch (2003).

$$\begin{aligned}
\hat{W}_i(y, X, n|\cdot \quad &\leq \quad p^e) = \frac{1}{Lh_x h_n} \sum_{l=1}^{L_i} \mathit{1}(y_{il} \leq y) K_G \left(\frac{x - X_l}{h_x}, \frac{n - n_l^*}{h_n} \right), \\
\hat{W}_i'(y, X, n|\cdot \quad &\leq \quad p^e) = \frac{1}{Lh_y h_n h_{in}} \sum_{l=1}^{L_i} K_g \left(\frac{y - y_{il}}{h_y}, \frac{x - X_l}{h_x}, \frac{n - n_l^*}{h_n} \right), \\
\hat{f}_x(X) \quad &= \quad \frac{1}{Lh_x} \sum_{l=1}^{L} K_x\left(\frac{x - X_l}{h_x}\right).
\end{aligned}$$

for any value (b, X, n), where $\mathit{1}(\cdot)$ is the indicator function, K_G, K_g, K_x are some kernels defined on compact supports, and hs are some smoothing parameters. We use a principal component analysis to reduce the dimension of X_l to 1. Following Flambard and Perrigne (2006), we choose the biweight kernel. $K_G(\cdot, \cdot)$ and $K_g(\cdot, \cdot, \cdot)$ are the products of two and three univariate biweight kernels, respectively. For the choice of bandwidth, we follow Simonoff(1996). We also need to estimate the boundary of the support of $[\underline{b}(X), \overline{b}(X)]$, which is unknown. We use the nonparametric boundary estimators proposed by Guerre et al. (2000) that generalize Greffroy(s (1984) estimators to the multidimensional case. Then using the relationship 5, we have

$$\hat{G}_i^*(b, X, n) = 1 - \exp\left[- \int_{-\infty}^{b} \frac{d\hat{W}_i(t, X, n|\cdot \leq p^e)}{1 - \sum_{j=1}^{n} \hat{W}_j(t, X, n|\cdot \leq p^e)} \right]$$

and

$$\begin{aligned}
\hat{G}_i^*(b, X) \quad &= \quad \sum_{n=1}^{7} \hat{G}_i^*(b, X, n) \\
\hat{G}_i^*(b|X) \quad &= \quad \frac{\hat{G}_i^*(b, X)}{\hat{f}(X)}.
\end{aligned}$$

Conditional density can be obtained similarly. Using $E(n^*_{0l}|X_l) = I_0F_0(p^e|X_l)$ and $E(n^*_{1l}|X_l) = F_1(p^e|X_l)$, and solving for $F_0(p^e|X_l)$ and $F_0(p^e|X_l)$, we obtain

$$\hat{F}_i(X) = \frac{1}{I_iLh_x\hat{f}(X)}\sum_{l=1}^{L} n^*_{il}K_x(\frac{x-X_l}{h_x})$$

for $i = 1, 0$. Then, from the first order conditions, we can estimate the cost of winning firm for each observed auction as:

$$\begin{aligned} \hat{c}^w_{1l} &= b^w_{1l} - \frac{1}{(I-1)\frac{\hat{g}^*_0(b^w_1|X_l)\hat{F}_0(p^e|X_l)}{1-\hat{G}^*_0(b^w_1|X_l)\hat{F}_0(p^e|X_l)}} \qquad (7) \\ \hat{c}^w_{0l} &= b^w_{0l} - \frac{1}{\frac{\hat{g}^*_1(b^w_0|X_l)\hat{F}_1(p^e|X_l)}{1-\hat{G}^*_1(b^w_0|X_l)\hat{F}_1(p^e|X_l)} + (I-2)\frac{\hat{g}^*_0(b^w_0|X_l)\hat{F}_0(p^e|X_l)}{1-\hat{G}^*_0(b^w_0|X_l)\hat{F}_0(p^e|X_l)}}. \end{aligned}$$

The equations 7 recover the winning firm's cost. We need to obtain the costs of all the firms to see the asymmetry in strategy of two types. We obtain T random draws from the estimated bid distribution $\hat{G}^*_i(b|X)$ for the median value of X, and for each draw b_t, calculate the pseudo cost $\hat{c}_{it}$ using 4 to obtain the strategy of each firm and distribution of the pseudo cost for each firm.

4 Result

Figure 2 provides some summary statistics on estimated costs of winning firms. The estimated average cost of winning firms for type 1 and 0 are, respectively, 7.86 yen/kWh and 13.63 yen/kWh. We observed such a large difference between the two firms' types. The average margin is about 3.97 yen/kWh higher for incumbent than entrants, implying that the entrants bid more aggressively than the incumbent does. The next table (Figure 3) shows the results from the regressions of estimated costs and margins on auction characteristics. We can see that after controlling on auction characteristics, the incumbent's cost is still lower than that of entrants while the incumbent's margin is much higher than that of the entrants. It can be also observed that the auctions with higher load factor are less costly and more profitable for firms. Figure 4 plots the estimated costs of winning firms with the load factor. We can see that the incumbent tends to win auctions with high load factors while entrants win auctions with low load factor. This is presumably because entrants do not participate much in auctions with high load factor.

When entrants enter, then for the most of the time, entrants win. Figure 5 plots the estimated margin with load factor. We can see that the incumbents' margin is much higher when load factor is high. Because entrant is unlikely to enter auctions with high load factor, incumbents become less aggressive in such auctions and still be able to win the contract. Figure 6 displays the estimated equilibrium strategies for the incumbent and entrants, considering the median value of the characteristic X_l. It can be seen that the entrant's strategy is much more aggressive compared with the incumbent.

The next step is to conduct a policy experiment to see the extent of efficiency improvement when introducing a preferential price policy. The above asymmetry imply that there is a large potential for the improvement.

5 Conclusion

This paper investigates the bidding patterns of entrant and incumbent firms in electric power procurement auctions in Japan. In the Japanese retail electricity market, there had been ten firms that supply electricity locally as monopolists. The partial liberalization started in 2000, allowing new firms, called the Power Producers and Suppliers (PPS), to enter the market and to supply electricity to large demand with power and voltage higher than $2000kW$ and $20000V$, respectively. With such a wave of liberalization, the public agencies have started to utilize open bidding systems for electric power supply contracts. Although PPSs are now allowed to participate any auctions with the power higher than $50kW$, their participation rate remains very low, implying the significant disadvantage of the entrants compared with the incumbents.

The purpose of this study is, first, to empirically assess the extent of asymmetry and inefficiency due to asymmetry by recovering cost estimates using the structural estimation proposed by Guerre et al. (2000), and second, to conduct a policy experiment in the spirit of a price-preference policy to enhance competition on incumbent and participation of entrants. We model the bidding behavior of incumbents and entrants whose participation decision depend on reserve price only. Because we only have winning bids, we nonparametrically estimate winning bid distribution and use the relationship between that distribution and bid distribution to apply Guerre et al. (2000) approach to obtain cost estimate of the winning firm for each observed auction. We then simulate bids from the estimated bid distributions and estimate pseudo costs to obtain the equilibrium strategies of two types.

We find that entrants have much higher cost for given auction; the average cost of entrants is 5.77 yen/kwh higher than that of incumbent, while the average margin of entrants is 3.97 yen/kwh lower than that of incumbent. The entrants bid much more aggressively than does the incumbent, and win most of the auctions where they participate. On the other hand, incumbents conduct less agressive strategy especially in auctions with higher load factor because they expect there will be few entrants who participate to such auctions.

The next step is to conduct a policy experiment to see the extent of efficiency and competition improvement by preferential policy.

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FY	**# of Auction**	**# of Bidder**	**Average winning Bid (yen/kWh)**	**kW**	**kWh** (thousand)	**Load**	**Green**
2004	335	1.50	14.25	2110.04	9565.24	0.44	0.00
2005	279	2.04	14.75	2047.39	8774.40	0.41	0.00
2006	325	1.97	15.10	1680.67	6755.52	0.38	0.42
2007	429	1.72	15.75	2202.09	9830.32	0.38	0.34
Total	1368	1.80	15.02	2024.12	8819.57	0.40	0.21

Table 1: Auctions from FY2004 to FY2007

Load factor	Win bid of incumbent	Win bid of entrant	Entrant win rate	# observation	# with entrant	# entrant win
−10%	37.08	27.28	0.83	60	50(83.3%)	50(100%)
10 − 20%	20.24	20.23	0.52	125	70(56.0%)	60(85.7%)
20 − 40%	16.10	15.51	0.46	528	266(50.4%)	243(91.4%)
40 − 60%	12.89	12.32	0.28	420	175(41.7%)	116(66.3%)
60 − 80%	11.09	10.62	0.06	203	37(18.2%)	13(35.1%)
80%−	10.56	11.50	0.03	32	1(3.1%)	1(100%)

Table 2: Load factor and bid difference between incumbent and entrant

	(1)	(2)	(3)	(4)
Incumbent wins	0.120	0.116	0.120	0.113
	(0.273)	(0.273)	(0.273)	(0.273)
Number of bidders	-0.246**	-0.250**	-0.250**	-0.249**
	(0.121)	(0.121)	(0.121)	(0.121)
high voltage	-1.122***	-1.076***	-1.060***	-1.099***
	(0.215)	(0.211)	(0.203)	(0.196)
Load	-0.551***	-0.551***	-0.551***	-0.551***
	(0.017)	(0.017)	(0.017)	(0.017)
load^2	0.004***	0.004***	0.004***	0.004***
	(0.000)	(0.000)	(0.000)	(0.000)
kw	0.047	-0.007		
	(0.052)	(0.022)		
kwh	-0.010		-0.003	
	(0.008)		(0.004)	
contract length	0.004	-0.028	-0.017	-0.030
	(0.163)	(0.161)	(0.162)	(0.161)
green	0.161	0.159	0.155	0.162
	(0.234)	(0.234)	(0.234)	(0.234)
constant	30.116***	30.242***	30.212***	30.237***
	(0.600)	(0.590)	(0.591)	(0.590)
Fstatistics	129.29	136.00	136.07	143.65
R-squared	0.6575	0.672	0.6573	0.6571
# of obs.	1368	1368	1368	1368

Notes: Dependent variable is average bid (yen/kwh). (1) to (4) include district and year dummies. SEs are in parenthesis.

Table 3: Estimation results:Basic specification

	(1)	(2)	(3)	(4)
Incumbent wins	0.652*	0.648*	0.657*	0.639*
	(0.340)	(0.340)	(0.340)	(0.339)
Number of bidders	-0.401***	-0.404***	-0.406***	-0.402***
	(0.135)	(0.135)	(0.135)	(0.135)
Single	-0.946***	-0.946***	-0.954***	-0.937***
	(0.362)	(0.362)	(0.362)	(0.361)
high voltage	-1.122***	-1.123***	-1.111***	-1.157***
	(0.215)	(0.211)	(0.204)	(0.197)
Load	-0.554***	-0.555***	-0.555***	-0.554***
	(0.166)	(0.017)	(0.017)	(0.166)
load^2	0.004***	0.004***	0.004***	0.004***
	(0.000)	(0.000)	(0.000)	(0.000)
kw	0.044	-0.010		
	(0.052)	(0.022)		
kwh	-0.010		-0.003	
	(0.008)		(0.004)	
contract length	0.002	-0.030	-0.017	-0.032
	(0.163)	(0.161)	(0.161)	(0.160)
green	0.139	0.136	0.132	0.141
	(0.234)	(0.234)	(0.234)	(0.234)
constant	30.780***	30.905***	30.874***	30.893***
	(0.650)	(0.641)	(0.341)	(0.640)
Fstatistics	123.99	130.10	130.19	137.02
R-squared	0.6592	0.6589	0.6590	0.6589
# of obs.	1368	1368	1368	1368

Notes: Dependent variable is average bid (yen/kwh). (1) to (4) include district and year dummies.SEs are in parenthesis.

Table 4: Estimation results: controlling for auctions with incumbent only

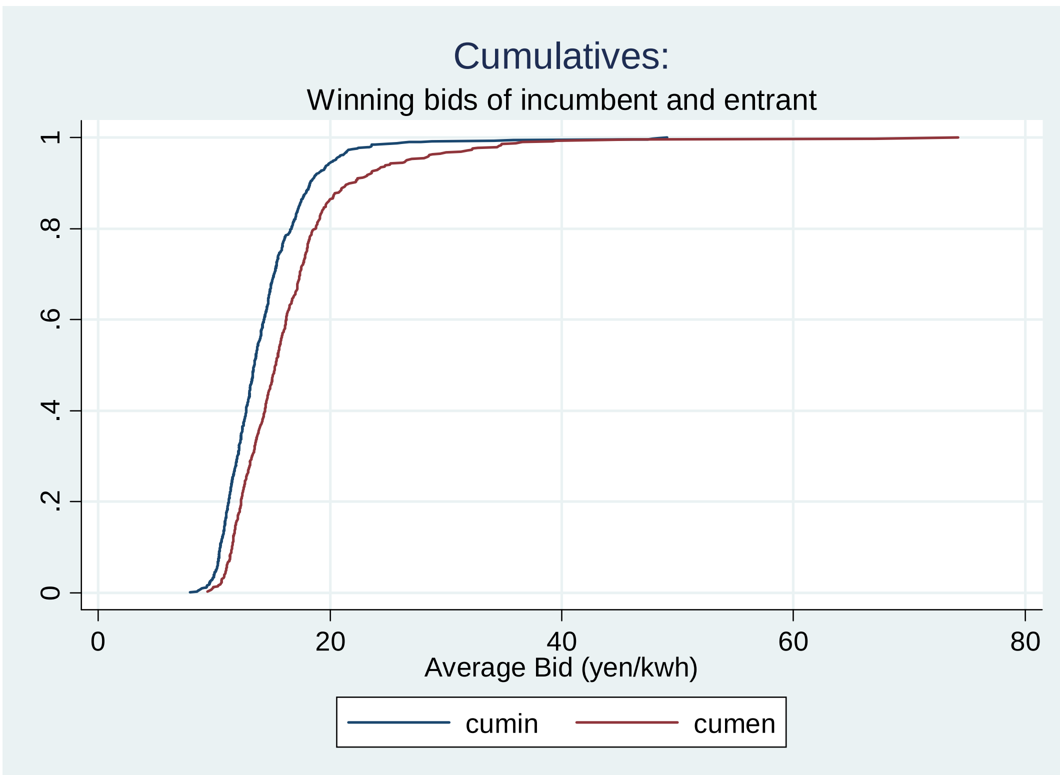

Figure 1: Winning Bid Distributions of incumbents and entrants

	mean	sd	min	max
Incumbent				
Bid	13.62	2.49	9.88	21.89
Cost	7.86	3.39	0.44	14.01
Margin	5.77	2.13	2.55	14.31
Entrant				
Bid	15.43	3.41	9.40	28.13
Cost	13.63	3.80	6.50	27.59
Margin	1.80	0.82	0.01	5.23

Table: Average bid and estimated firms' cost and margin (yen/kWh)

Figure 2: Average bid and estimated firms' cost and margin (yen/kwh)

Dependent	Cost	Margin
Incumbent	-2.874	3.684
	(0.245)	(0.251)
Load	-16.389	2.22
	(0.675)	(0.482)
kW	-0.0002	0
	(0.000)	(0.000)
# bidder		0.073
		(0.082)
year	0.114	0.205
	(0.093)	(0.067)
constant	-209.282	-410.375
	(185.846)	(134.011)
Obs.	476	476
Adj. R2	0.763	0.616

Table: Auction characteristic
and cost/margin

Figure 3: Auction characteristic and cost/margin

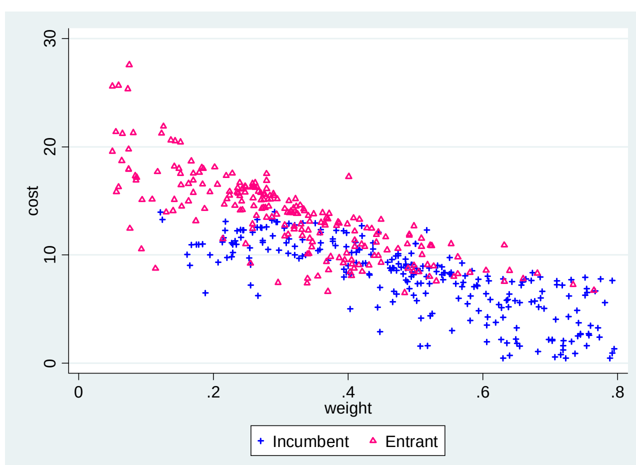

Figure 4: The estimated costs with load factor

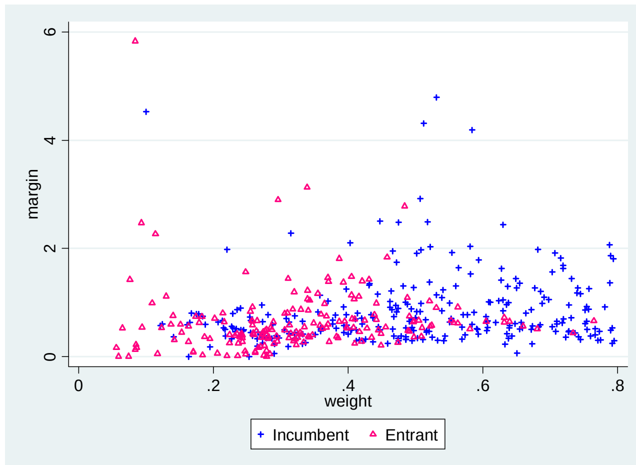

Figure 5: The estimated margin with load factor.

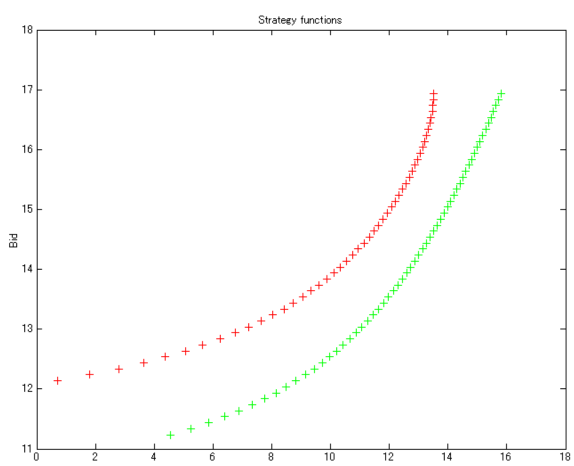

Figure 6: The equilibrium strategy of incumbent (red) and entrant (green)