# Asymmetric bidding and participation between incumbents and entrants in electric power procurement auctions*

Ayako Suzuki†

Waseda University

February 23, 2011

**Abstract**

We explore the asymmetry between new firms (entrants) and former local monopolists (incumbents) in electric power procurement auctions. Using a structural model where auction participation is endogenous, we explore the reasons for the persistently low participation rate of entrants and the effects of preferential treatment aimed at enhancing the participation of entrants. The results indicate that entrants have a lower project cost but a higher participation cost. We find bid discounts have little effect on entrant participation and that a lump-sum subsidy to entrants is more cost effective by enhancing participation of entrants.

## 1 Introduction

This study investigates the bidding patterns of entrant and incumbent firms in electric power procurement auctions in Japan. In the Japanese retail electricity market, ten electric power companies (EPCos) originally supplied electricity as local monopolists. However, beginning in 2000, partial liberalization allowed new firms, known as Power Producers and Suppliers

*I would like to thank Hidehiko Ichimura for useful suggestions and guidance and Takeshi Tsuchiya for computational advice. I would also like to acknowledge the helpful comments of Flavio Menezes, Hideo Owan, Viplav Saini, and Yosuke Yasuda, attendees at the 2010 International Industrial Organization Conference, the 2010 Japan Economic Association Spring Meeting, and the 2010 National Bureau of Economic Research Japan Project Meeting, along with seminar participants at various institutions.

†School of International Liberal Studies, Waseda University. 1-6-1 Nishi-waseda, Shinjuku, Tokyo 169-8050 Japan. Tel: +81-3-5286-8425. Fax: +81-3-3208-8401. Email: a-suzuki@aoni.waseda.jp

(PPSs), to enter the market and supply electricity to large users with power and voltage requirements greater than 2,000 kW and 20,000V, respectively, at unregulated rates. Given this wave of liberalization, public agencies have now begun to utilize sealed-bid auctions for the procurement of electric power. As the liberalization targets have since expanded, the number of auctions conducted by public agencies has increased dramatically, with more than 850 auctions in 2007 alone.

Nevertheless, the participation rate of PPSs in these auctions remains very low, implying the significant disadvantage of PPSs compared with EPCos. The PPSs, which we refer to as entrants, participate in only 44.0% of auctions on average, whereas the EPCos, which we refer to as incumbents, participate in almost all auctions in their local service area. This has raised some concerns with interested parties in the industry, especially the regulatory authority (the Ministry of Economy, Trade and Industry or METI), which has been investigating closely the effects of industry restructuring.

Japan applied its unique step-by-step approach towards restructuring. For example, vertical integration of the EPCos has continued, even while the wholesale and retail markets have been deregulated. A wholesale power exchange market (the Japan Electric Power Exchange or JEPX) has been created, but without a mandatory pool. However, further restructuring is subject to ongoing debate, and it is important to understand the complexity of market behavior to inform and design future market reform. This study contributes to the body of work in this area by shedding light on the behavior of entrants and incumbents in procurement auctions. More specifically, we investigate the reasons for the relatively low participation rate of entrants, and consider opportunities to facilitate the participation of entrants and the enhancement of competition in these auctions.

In brief, we particularly consider the introduction of preference treatments to facilitate the participation of entrants in auctions. The literature has shown that when facing asymmetric bidders, the auctioneer may be better off implementing a price-preference treatment and exploiting the asymmetry (see Krishna 2002; Myerson 1981). The typical finding is that the effects of such preferential treatment depends on the extent of asymmetry between the favored and nonfavored firms.[1] Therefore, we first empirically analyze the asymmetry between incumbents and entrants by estimating the distribution of firm costs for electric power supply contracts[2] and the firm costs needed to participate in auctions[3]. Having obtained the project and participation costs, we then simulate the effects of preferential treatment with various preferential rates on auction participation and procurement costs.

Interestingly, the cost structures of entrants and incumbents in this market differ significantly. For instance, whereas all of the incumbent firms are vertically integrated and incorporate their own production divisions, most entrants purchase their electricity from outside sources, including their parent companies and the JEPX. Even for entrants with production divisions, cost disadvantages still arise because they usually only own fossil fuel power plants. These incur higher costs generating electricity than the comparable nuclear power plants owned by most incumbents. Furthermore, the transmission network is operated by incumbents, and so entrants must rent the network from the incumbents to supply electricity. Together, these structural disadvantages may suggest that the cost of electric power supply by entrants is higher than that of incumbents. In contrast, incumbents, as owners of the transmission and distribution network, also bear the maintenance costs of the network. Furthermore, incumbents have ultimate responsibility for serving as the provider of last resort in their service area when no contract has been signed between a customer and a supplier. Together, these factors may make incumbents higher-cost firms. Therefore, the direction of asymmetry is ambiguous, and assessing its direction and magnitude is of interest in its own right.

We model the bidding and participation behavior of incumbents and entrants assuming that firms make a participation decision followed by a bidding decision. We then nonparametrically estimate the project-cost distribution of an incumbent and entrants in the Tokyo

[1] Under general assumptions, Cantillon (2008) has shown that the auctioneer's expected revenue becomes lower as bidders become more asymmetric. Accordingly, serious asymmetry may imply greater potential to improve competition through a preferential policy.

[2] Following the existing literature, we term these as "project costs" hereafter. Therefore, our "project costs" do not refer to the costs associated with investing in an electricity project (such as power plant), but rather represent the costs of fulfilling a electricity contract.

[3] Following the existing literature, we term these as "participation costs" hereafter

area following Guerre et al.'s (2000) suggestion that the cost distributions can be recovered from the bid distributions. However, because we only have access to winning bids and not all bids (including losing bids), we only estimate the winning-bid distribution and use the theoretical relationship between the winning-bid and all-bids distributions to recover the latter. Having obtained the project-cost distributions, we quantify the participation costs that explain the present participation situation. Once we obtain the underlying project-cost distributions and participation costs, we undertake counterfactual analyses to discern the effects of the different levels of preferential treatment.

We find that the incumbent has higher project costs than the entrants in most electric supply contracts. In fact, in our auctions the mean of the incumbent's project cost distributions is, on average, 1.25 times higher than that of the entrants. However, the entrants incur economically significant participation costs, whereas the incumbents are likely to have negligible participation costs. Therefore, it seems likely that entrants are prevented from participating in auctions because of the higher participation costs, not because of the lower expected profit resulting from the auctions.

Because we obtained the empirical result that strong bidders, in the sense of lower "project cost", have higher "participation cost", the effect of preference treatment given such asymmetry is of great interest. The results of our counterfactual analysis show that the price-preferential treatment would also not have much effect on the entrants' participation rates. We also find that a preference for the weak bidder, the incumbent, would not improve the government's procurement cost, although the theory suggests a preference for weak bidders may enhance competition between strong bidders and thereby decrease the government's procurement cost. We find that the government cost is actually minimized with a small preference for entrants (the strong bidders) by increasing the number of bidders slightly and making the bidders bid more aggressively, whereas not significantly reducing the probability the incumbent (the nonfavored firm) wins.

We find economically significant asymmetry between entrant and incumbent firms. Although asymmetries among bidders arising from many sources have already been examined in the literature, the asymmetries between incumbent and entrant firms have received little attention. The notable exception is De Silva et al.'s (2003) investigation of the differences in the bidding patterns of entrants and incumbents in road construction auctions in Oklahoma. De Silva et al. (2003) find that entrants are less efficient and their distribution of costs has greater dispersion. However, De Silva et al. (2003) seek asymmetries in firm experience or the information-gathering process, whereas we focus more on the structural differences between entrants and incumbents.[4]

Our preferential treatment study includes endogenous participation because our purpose is to investigate the effects of preferential treatment on entrants' participation in auctions. Although a number of previous studies have empirically examined the effect of preferential treatment on procurement costs and efficiency (see, for example, Flambard and Perrigne 2006 and Marion 2007, 2009), few studies explicitly include firms' participation decision in the model. Just a few studies allow for endogenous participation, including Krasnokutskaya and Seim (2009), Nakabayashi (2009), Athey et al. (2010), and Hubbard and Paarsch (2009). In particular, Krasnokutskaya and Seim (2009) show that when participation effects are included, both the cost-minimizing level of the preference rate and the group receiving the preference may change. In their empirical analysis of the California Small Business Preference program, Krasnokutskaya and Seim (2009) found that the group that should receive the preference sometimes comprises strong bidders. This contrasts with existing studies where firm participation is fixed. Although our model differs from Krasnokutskaya and Seim (2009) in the process of participation, our results reinforce their findings in that we both conclude that the group receiving the preference treatment can actually be strong bidders when endogenous participation is considered.[5]

[4]While it is also surely in our interest to consider any asymmetry arising from experience or the information-gathering process, we focus on structural differences because we consider them especially large and economically significant in this particular market.

[5]Our model relies on the two assumptions also used in Krasnokutskaya and Seim (2009). First, a potential bidder does not observe his project-cost realization at the time of his participation decision, but learns it through the investment of bid-preparation costs. Second, bidders know the number of their competitors when they decide on a bid level. However, we assume that the decision on participation for incumbents and entrants is made sequentially to fit the nature of auctions in the industry, while they are assumed simultaneous in Krasnokutskaya and Seim (2009).

The article proceeds as follows. Section 2 provides a brief overview of structure and liberalization in the Japanese electricity industry. We also summarize the letting process of electric power procurement auctions in this industry. Section 3 describes the data. Section 4 outlines the model of firm participation and bidding decisions and our estimation methodology. Section 5 provides the results and Section 6 contains an analysis of the alternative preferential programs. The final section concludes.

# 2 Electricity industry

## 2.1 Structure and deregulation of the industry

This section briefly describes structure and deregulation in Japan's electric power industry. Figure 1 represents the current structure of the electric power industry. Currently, Japan's electric power industry comprises four types of players: the EPCos, wholesale electric utilities, wholesale suppliers, and PPSs.[6] The EPCos are vertically integrated utilities that include all of generation, transmission and distribution, and retail operations. These are private companies, each of which supplies customers with electric power on a retail basis in its service area. There are currently ten such integrated utilities: Hokkaido, Tohoku, Tokyo, Chubu, Hokuriku, Kansai, Chugoku, Shikoku, Kyushu, and Okinawa. Wholesale electric utilities, including the Electric Power Development Company (J-Power) and the Japan Atomic Power Company (JAPC), sell electric power to the EPCos on a wholesale basis using long-term bilateral contracts. The Japanese government and interested parties respectively created J-Power and JAPC in the early 1950s to supplement the generation of the EPCos nationwide.

Wholesale suppliers or independent power producers (IPPs) were the newcomers in this industry in the first stage of deregulation in 1995 as a result of amendments to the Electricity Utility Law permitting EPCos to purchase electricity from outside sources. At the time, EPCos conducted auctions to determine the companies from which they wished to purchase

[6] There also exist self-generators.

electricity. IPPs are plant operators selected through these competitive tendering by each EPC to supply that EPC. In turn, most of the IPPs were iron and steel companies, which already had the existing infrastructure to generate electricity. The contracts are usually for 15 years, and the existing contracts between the EPCos and the IPPs are mostly those made in the late 1990s and therefore about to expire in the next several years.

The PPSs are new entrants in the retail market following partial deregulation in 2000. In March 2000, the retail supply market was deregulated for customers with electric power supplied at 20 kilovolts (kV) or above with a contracted supply of 2000 kilowatts (kW) or higher. The free-entry principle made PPSs enter the retail market for this range of customers, and the rates for these eligible customers are determined through negotiations between the customer and the PPSs. PPSs use the transmission network of the EPCos to engage in retail electric power sales to deregulated customers. Most PPSs are owned by large parent companies, including trading, gas, and telecommunication firms or manufacturers with self-generating facilities, whereas some PPSs are themselves self-generators.[7] Currently there are 23 PPSs, of which 8 companies have their own power plants, and the other 15 companies purchase electricity from outside sources, including their parent companies and the JEPX, where the latter was established in 2005 with this wave of restructuring. The liberalization target was later expanded to users with power and voltage requirements greater than 500 kW and $6,000$ V in 2004, and again to 50 kW in 2005.[8]

The JEPX started in April 2005 with this wave of restructuring. The JEPX is the only wholesale exchange market consisting of spot and forward markets. The JEPX was expected to act for many important roles. For example, through the JEPX, electricity can be supplied from the cheapest generators to meet demand that changes every seconds. Thus, the industry can always keep the most efficient portfolio of the power sources due to the

[7]For instance, Ennet, the largest PPS, is owned by NTT (telecom), Tokyo Gas, and Osaka Gas, Diamond power is owned by the Mitsubishi Corporation (a trading company) and Summit Energy is owned by Sumitomo Corporation (a trading company).

[8]The customers with power and voltage requirements greater than 2000 kW and 20 kV include large industrial factories, department stores, hotels, and office buildings. The customers deregulated most recently (greater than 50 kW) include small factories and supermarkets. Smaller customers such as convenience stores and households usually require less than 50 kW, and still operate under regulation.

price adjustment in the JEPX. It was also expected that the congestion in transmission lines can be mitigated by the price adjustment. However, this is a voluntary exchange market without mandatory pool. Furthermore, only the members can trade on the JEPX. To be a member, a firm has to have at least $1,000kW$ of generation capacity or retail demand and 10 *million* yen of net worth. Therefore, the JEPX is still very thin market. In 2009, the total traded volume was 3,545,122 mWh, which is less than 1 percent of the wholesale demand. Currently, firms mostly use the JEPX when they have unexpected demand, for example due to power down. The current thin liquidity on this exchange market is an issue in the industry.

Despite the attempts at deregulation, the EPCos remain the dominant firms in the industry. Figure 2 depicts electric power generation in 2009 by type of generator. As shown, total electric power generation in 2009 is 925,392,115 mWh, most of which is generated by the EPCos.[9] In 2009, whole electric power demand was 1,001 million megawatt-hours (mWh), of which the EPCos supplied 859 million mWh whereas the PPSs supplied only 15 million mWh. Demand from deregulated customers was 544 million mWh in the same year. Therefore, the share of the PPSs in the deregulated customer market in 2009 was only 2.82%, 3.95% for high-voltage supplied customers and 2.00% for extra-high-voltage supplied customers. Figure 3 plots the PPSs' share of deregulated customers between 2005 and 2009. Although their share remains small, we can see that it has been increasing since the latest deregulation in 2005.

## 2.2 Electric power procurement auction

As discussed, the partial liberalization of the Japanese retail electricity market has already taken place, allowing new firms, the PPSs, to enter retail markets. In this article, we define the firms that operated before liberalization and that have continued to operate afterwards (i.e. the EPCos) as incumbents, and firms that entered the retail market after liberalization (i.e. the PPSs) as entrants. From the beginning of the liberalization, the main focus

[9] Self-generation is not included in this figure.

for competition between the incumbents and entrants were large commercial customers, particularly the government and other public facilities (Asano 2006). Given this wave of deregulation, the government and public agencies have started to employ first-price sealed-bid auctions to procure electric power for public facilities, including waterworks, roadway facilities, schools, hospitals, and markets.[10] Our analysis draws upon these auctions held between April 2004 and March 2008.[11] Some 2,334 contracts and 17 million mWh were auctioned during this period.[12] The share of electricity demand included in these auctions as a share of total demand by deregulated customers is, however, very small, accounting for only 0.7% of the entire demand from deregulated customers. Nonetheless, the regulatory authorities and researchers have paid much attention to the outcomes of these auctions in order to analyze the effects of liberalization. This is because we can observe the contract conditions and the outcomes, such as prices, very clearly in these auctions; it is difficult to observe this information in the bilateral contracts between other private customers and suppliers.

Public agencies conduct an auction for an electricity contract for each public facility they hold. Therefore, one agency may conduct multiple auctions. The typical electricity contract is a one-year contract from April to March as Japan's fiscal year is from April to March. Most of public agencies conduct auctions between December and March in the previous fiscal year to the fiscal year when the contract is actually enforced.

The auction-letting process is as follows. Each public agency advertises auctions on its webpage, in its official gazette, or in newspapers. The auctioneers show detailed information including the contract period, the required maximum (peak) power ($kW$), the (expected)

[10] The first electric power procurement auction was conducted by the METI, as the ministry responsible for the industry, to create an electricity contract for the METI building in August 2000. After this, the number of such auctions increased significantly. For example, about 350 electricity contracts were auctioned off by public agencies in fiscal year (FY) 2004 and FY 2005, about 770 in FY 2006, and about 860 in FY 2007.

[11] The Japanese fiscal year begins in April. Hereafter, we use "year" to indicate the fiscal year unless otherwise noted. The contracts offered in 2004 were operated in 2005, where the deregulated customers are those with power requirements of 50 kW or more. Therefore, even in some auctions in 2004, we can see contracts with power and voltage requirements less than 500 kW and $6,000$ V.

[12] Contracts are sometimes bundled together to be auctioned. Therefore, the number of contracts and the number of auctions do not always match.

amount of electricity they use during the contract period ($kWh$), the detailed plan for usage including the peak demand, day-time demand, night-time demand and summer demand, the place of delivery, the qualifications needed for participating in the tendering process, and the time limit for tenders. The electricity companies calculate and submit the total charge, including the fixed and variable rates, for the amount of electricity they would supply for the whole contract period on the description written by the auctioneer. Only the total charge matters to decide the winner.

The means of tendering differ depending on auctineers. Some public agencies have established elecric tendering system while for many auctioneers, bidders must assemble at one place to submit their bids. Some agencies require firms to send their bids by post. The firm submitting the lowest bid wins the auction if the bid is lower than the reserve price. Although a reserve price exists, it is usually not announced (even after the bids have been opened). If the lowest bid is higher than the reserve price, then the contract is not offered. In this case, the agency either conducts a second auction or enters into bargaining with one of the bidders. In the case of the latter, a supplier will eventually supply the electricity at a negotiated rate. The second auction may be offered immediately after the bids are opened, or a few weeks after the original auction.

For the incumbents, these contracts auctioned off by public agencies are not major activities, accounting as they do for less than 1% of their total supply to deregulated customers. Instead, their focus remains on large private users, to which they supply electricity at publicly announced rates, or at rates determined by a bargaining process. Therefore, capacity constraints are unlikely to be binding for the incumbents in these auctions. In fact, the incumbents actually began supplying these public agencies before the auctions began, clearly showing that the incumbents hold sufficient capacity.

In contrast, public agencies are relatively more important customers for the entrants, with the amount supplied through these auctions accounting for 14.9%, 10.0%, 10.3%, and 7.0% of their total supply in 2004, 2005, 2006, and 2007, respectively. Nevertheless, we can also expect that capacity constraints are also unlikely to be binding for the entrants. To see why, we compare the total power requirements in these contracts and the plant capacity of the entrants. The total electric power requirements for these contracts are 729 megawatts (mW), 523 mW, 1108 mW, and 1338 mW in 2004, 2005, 2006, and 2007, respectively. To find the entrants' generation capacity, we should include both their own plant capacity and their outside generation sources, with which the PPSs undertake bilateral contracts. Although it is difficult to precisely measure this outside capacity, Asano (2006) estimates that the total capacity of the PPSs was 2.3 gigawatts (GW) in 2002 and is estimated to reach 4.6 GW in 2010. Therefore, the generation capacities of the PPSs are likely to be much larger than the total power required by these auctions.

In these auctions, incumbents and entrants are expected to have different bidding strategies, as their cost structures differ significantly. This is because all of the incumbent firms are vertically integrated and incorporate their own production divisions, whereas most entrants purchase their electricity from outside sources, including their parent companies and the JEPX. We can then expect that the incumbents enjoy efficiencies from vertical integration. Even for entrants with production divisions, cost disadvantages still arise because they only own fossil fuel power stations, which generally incur higher costs generating electricity than the comparable nuclear power plants owned by the incumbents (34.0 percent of the incumbents' generation in 2009 was from nuclear power plants, with 58.31 percent from fossil suel power and 7.37 percent from hydraulic plants).

Furthermore, the transmission network is operated by the incumbents, and hence entrants must use the wheeling service of the incumbents with service fee.[13] The entrants must match the amount of electricity they supply for each customer and the amount each customer uses for every 30 minutes. When they cannot match them, they must pay imbalance fees. These structural disadvantages suggest that the cost of electric power supply by entrants is higher than that of incumbents.

[13]Unlike other countries that completed legal unbundling or that established the independent system operator for transmission networks, Japan kept its vertical structure of incumbents. That is, transmission network is still owned by the incumbents. Instead of unbundling, behavior regulations were imposed such as: transparent and objective rule making for transmission, blocking information between transmission section and generation/retail sections by fire wall, and prohibiting discriminating treatments.

In contrast, incumbents, as owners of transmission and distribution networks, also bear the maintenance costs of these networks. Furthermore, incumbents have ultimate responsibility for serving as the provider of last resort in their service area when no contract has been signed between a customer and a supplier, whereas entrants are under no legal supply obligation. Incumbents are also supposed to supplement the supply of entrants when entrants cannot meet the supply written in their contracts because of, say, the powering down of plants. These factors may imply higher costs for incumbents than entrants.

Also the relevant cost of fulfilling an electricity contract for a public agency is the opportunity cost for selling the electricity elsewhere, that includes through wholesale power markets and through bilateral contracts. If the JEPX had enough liquidity, then the JEPX price would become the opportunity cost, and would be same for all the firms. However, as noted earlier, this is a very thin market where the price does not reflect the industry's demand and supply. Therefore, firms opportunity cost should mainly reflect that for selling the electricity through bilateral contracts. Unfortunately, we cannot observe the prices on firms' bilateral contracts. However, it is possible that prices on bilateral contracts with incumbents and with entrants are different because these prices are not announced. More specifically, it is possibly the case that entrants' suggested prices for bilateral contracts are lower than incumbents' if we consider customers' switching costs: as the incumbents have been served the customers for a long time, customers may be reluctant to switch generators unless new generators offer enough low rates.

Therefore, although we expect that cost asymmetry exists, its exact direction is ambiguous. In the following sections, we empirically analyze the direction and extent of these cost asymmetries using the bidding data.

Firms' participation costs may differ among incumbents and entrants. Firms' participation costs include all transaction costs associated with bidding, such as the costs involved in learning the value of the auctioned object or the auction rules, and the opportunity cost incurred during the bidding process. In the case of electricity auctions, firms must calculate the cost of fulfilling the contract. To calculate it, firms must learn the detailed load profile of the customer. Although the daily load profile is given by the customer in the contract, it is expected load profile, and firms anyway have to supply if the actual demand exceeds the contract. Therefore, firms need to consider what would be the actual load profile. Learning such costs may be easier and less costly for incumbents because they have been supplying electricity to these customers before the liberalization, and therefore have the historical data of load profile for these customers. The opportunity cost incurred during the auction process may include human resources needed during the auction process, that could be used for other jobs within the firm. This may be higher for entrants because all entrant firms are much smaller than incumbent firms.

# 3 Data

## 3.1 Winning-bid data

This section describes our data set collected by *Electric Daily News*, a newspaper specializing in electricity markets. The data covers all electric power procurement auctions conducted throughout Japan between 2004 and 2007. The data contains information on the date when bids opened, the government agency (the auctioneer), the required maximum power ($kW$), the amount of electricity required ($kWh$), the year- load factor, the contract period, the place of delivery, the winner of each auction, the winning bid, either the identification or number of other bidders, and other descriptive auction information, including whether there is a restriction on $CO_2$ emissions.[14] Whereas the data contains a rich number of observations, its disadvantages are that it does not include losing bids (i.e. we only have winning bids), and identification of losing bidders is not revealed for many observations.

Nineteen different firms, comprising nine incumbents and ten entrants, participate in these auctions in the period analyzed. *Electric Daily News* provides the lists of companies

[14] The Environmental Conscious Contract Law has been enforced in Japan since November 2007. This 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 and architects, are subject to law. In light of this law, public agencies have begun to set numerical targets, such as the maximum $CO_2$ emission coefficient, as a qualification for participation in auctions.

that are observed in auctions in each incumbent's area each year. Therefore, we can identify the potential bidders in each area each year. It is known that incumbent, in general, participate all auctions, probably because they have supply obligations.[15] In general, incumbent firms continue to operate only in their local service area following liberalization. Therefore, we do not observe any auctions where multiple incumbents bid. On the other hand, entrants may participate in auctions in multiple incumbents' local areas throughout Japan.[16]

Table 1 provides some summary statistics. We have 1,351 observations without missing information. As shown in the table, the auctions are not very competitive, with the average number of active participants ranging from 1.50 to 2.05. Because the incumbents are observed to participate in all auctions in their local areas, the incumbent is the only bidder in many auctions. We can also see that the number of bidders increased in 2005, but decreased thereafter. This may reflect the fact that the number of auctions with $CO_2$ emission restrictions has gradually increased since 2006. Because entrants usually only have fossil fuel power stations that generate more $CO_2$, they tend to be disadvantaged in auctions with $CO_2$ emission restrictions (see Hattori and Saegusa 2010). Therefore, entrants are less likely to participate in auctions with $CO_2$ restrictions. Here *Green* is a dummy variable that takes a value of 1 if the auction has any restrictions on $CO_2$ emissions; zero otherwise. As shown, this applies to 42% of auctions in 2006 and 34% of auctions in 2007.

The winning bids per kWh (yen/kWh) have also been increasing during this period. Both the maximum (peak) power ($kW$) and the size ($kWh$) decreased until 2006, but increased in 2007. The downward trends in power and size until 2006 reflect the fact that the number of auctions of relatively small size increased as liberalization progressed. In 2007, we observe many public agencies that bundle several contracts for offer at one auction. This

[15] Because the dataset sometimes do not show the identification of losing bidders, we cannot confirm if incumbents actually participate all auctions. Specifically, in 73 observations where the winner is an entrant, the dataset fails to show the identification of losing bidders. However, it is well-known fact that incumbents participate all the auctions offered by government agencies (Hattori and Saegusa, 2010).

[16] In actuality, each entrant is active in different local areas. For example, Ennet, the largest PPS, is active in all incumbent service areas except Shikoku and Hokuriku, while JX, also a PPS, is active only in the Tokyo area. Therefore, the number of observed entrants differs across the incumbents' local areas. We observe only one entrant in Hokkaido, three in Tohoku, nine in Tokyo, five in Chubu, six in Kansai, two in Chugoku, and four in the Kyushu area. No entrants participated in auctions in the Hokuriku and Shikoku areas.

may also account for the increased size in 2007. *Load* refers to the load factor: the ratio between the average and maximum (peak) usage of electricity during the contract period. This 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 firms need to hold capacity that is not used most of the time for peak usage. The average load factor is around 40% during this period.

### 3.2 Some evidence of asymmetry

This subsection empirically investigates the asymmetry between the incumbents and entrants. To assess the presence of asymmetry, we first propose to check whether some bidders are more likely to win auctions than others. In total, incumbents submitted 1,351 bids, of which 867 won contracts, whereas 1,080 bids were submitted by entrants, of which 484 won contracts. Therefore, the winning rate of incumbents and entrants is 64.2% and 44.8%, respectively. Incumbents then, are clearly more likely to win auctions. However, if we remove the auctions where an incumbent is the only bidder, incumbents submitted 594 bids, of which 110 won contracts. The winning rate of incumbents and entrants in these auctions is 18.5% and 44.8%, respectively. Here, entrants are more likely to win auctions.

The load factor also appears to play an important role in the firms' participation and bidding decisions. Table 2 presents summary statistics of the winning bids and participation rates by load factor. As shown in the third and fourth columns, winning bids decrease as the load factor increases, implying that firms can enjoy efficiency with high load factors. In the fifth column, we can see that the percentage of auctions with entrants decreases with the load factor. Similarly, in the sixth column, the percentage of auctions with the entrant as winner decreases with the load factor. It appears, then, that entrants have a significant disadvantage in auctions with high load factors. As an explanation, Takagi and Hosoe (2007) argue that petroleum thermal generation, on which entrants depend, are peak power supplies, and that it is difficult to supply electricity for an entire day using this form of generation. Therefore, in auctions requiring high load factors, entrants are likely to have a disadvantage. We can also see that entrants on average participate in only 44.0% of auctions, whereas incumbents participate in all auctions in their service areas. The last column shows, however, that the percentage of auctions where the entrant is the winner given the entrants' participation is very high, except when the load factor is between 60% and 80%. Put simply, once at least some entrants decide to participate in an auction, the incumbents are unlikely to win that auction. Table 2 also shows, in the third and forth columns, that winning bids between incumbents and entrants differ: winning bids of entrants are consistently lower than those of incumbents, except when the load factor is higher than 80%.

To further assess the presence of asymmetry, we run a simple regression and see if their winning bids differ statistically significantly. Our regression equation is as follows:

$$y_l = X_l B + D + T + \varepsilon_l,$$

where the subscript $l$ refers to the auction. Because we have winning-bid data, the data is at the auction level.[17] We specify the dependent variable, the winning bid per amount of electricity served ($yen/kWh$), throughout our analysis. The independent variables include three sets of controls: $X's$ controls for the auction-level variables, $D$ is a vector of district fixed effects, and $T$ is a vector of variables that control for the time trend. Because there is only one incumbent in each district, $D$ can also be considered as incumbent fixed effects. We use two types of $T$ variables. The first is a vector of year dummies. This is because we wish to control for trends in such variables as oil prices and technological progress. The second $T$ variable we use is the monthly spot transaction price of the Japan Electric Power Exchange (JEPX) market. The JEPX is the only wholesale electricity exchange market in Japan, and is one of the main sources of input for entrants. Therefore, by controlling for the JEPX prices, we can partially control for the entrants' input costs in supplying electricity. Furthermore, the JEPX price should also indirectly reflect the oil prices and technological

[17] During the four years observed, some contracts for the same public places are offered repeatedly, because most contracts are renewed each year. For simplicity, however, we pool the observations rather than using them as panel data.

progress we would also like to control for using the $T$ variable. In addition, entrants can sell their electricity to the JEPX when the JEPX price is sufficiently high, rather than supplying electricity to public agencies through auction. Therefore, the JEPX prices can effectively account for the opportunity cost of entrants in participating in auctions.

With respect to the auction characteristics $X$, we include the following variables. To start with, in order to distinguish between entrants and incumbents, we simply include an incumbent dummy variable that takes a value of 1 if the winner is an incumbent and zero otherwise. We also include the number of bidders. We expect that auctions will be more competitive and bids more aggressive as the number of bidders increases.[18]

The load factor is also included as an independent variable. Because bids appear to increase with the load factor (but not linearly), we include its square. We also include a high-voltage dummy that takes a value of 1 if the contract for auction is for voltage greater than $20,000$V. The peak power (kW) and the size (kWh) are also included. However, because the two variables $kW$ and $kWh$ are highly correlated, we include only one in the regression. These two variables are also highly correlated with the high-voltage dummy. Therefore, we present the regression results with and without the high-voltage dummy. We expect that the size variables ($kW$ and $kWh$) negatively affect winning bids as firms can enjoy scale economies with larger size. For similar reasons, 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 earlier auction studies using this type of reduced-form regression, bidder characteristics (such as the winning rate and bidder backlogs) are commonly included in the empirical specification. Typically, the winning rate represents firm efficiency, whereas the backlog indicates the firm's capacity constraints. Unfortunately, because we are unable to identify the losing firms in most of the auctions in our dataset, we cannot construct these variables using our sample. This is a significant disadvantage of our data when undertaking reduced-form analysis. As for the capacity constraint, however, we believe that it is not binding

[18] The number of bidders, however, may have a negative effect on bids if the auction objects have a common value because of the phenomenon of winner's curse in common-value auctions.

because the supply of electric power to the public sector is often a secondary activity for both incumbents and entrants. Although project types (place of delivery) also vary in the sample data, we do not include this because it would appear that once we control for the load factor, the project type does not appear to matter for electricity suppliers (see Takagi and Hosoe 2007).

Finally, we include the dummy variable *single*, which takes a value of 1 if no entrant participates in the auction and zero otherwise. Because we do not typically observe multiple incumbents in an auction, if this variable takes a value of one, there is only one bidder (who is the incumbent) in the auction. We therefore include this variable in order to control for the participation decision of entrants. As shown in Table 2, we find that entrants do not participate in all auctions. For example, we only observe entrants in 3.1% of auctions when the load factor is greater than 80%. Therefore, if we cannot control for all of the variables that affect the entrant's participation decision and the bidding behavior simultaneously, our results are likely to be biased. Gilley and Karels (1981), for instance, point out the importance of the link between the dichotomous bidding decision (bid, do not bid) and the bid-level decision, and suggest the use of Heckman's two-stage estimation (Heckman 1979). However, as we do not have access to information on losing bids and cannot identify losing firms, we cannot employ this particular estimation method. That is, we are unable to identify whether firms participated in an auction if they did not win. Therefore, we control for this variable, *single,* and assume that it proxies for all auction characteristics upon which entrants make decision of participation decision.

Table 3 presents the estimation results. The dependent variable is the winning bid per amount of electricity (yen/$kWh$). Whereas each specification includes the district and year dummies, the monthly spot price on the JEPX is used in place of the year dummies in the fifth and sixth specifications. We can discern similar results for the different specifications. First, the incumbent dummy has a positive and significant effect on the winning bid. That is, for similar types of auctions, the incumbent's winning bid is higher than those of the entrants. This may suggest that the incumbents' bid distribution is higher, implying that incumbents are actually weak bidders in these types of auctions.[19] Second, the number of bidders has a negative and significant effect on the average bid.

Third, the high-voltage dummy has a negative and significant effect: that is, high-voltage contracts are nearly always won with a lower bid. As expected, the load factor has a negative and significant effect on the winning bid, and the effect is not linear. Fourth, the estimated coefficients for size (kWh or kW) and contract length are also negative, implying that scale economies exist. The latter effect is, however, not statistically significant. Further, the effects of size become insignificant when we include the high-voltage dummy. Fifth, the effect of *green* on the winning bid was also not confirmed using this estimation. Finally, and as expected, the JEPX transaction price has a positive and significant effect on the winning bid. Overall, the comparison of firm participation, probabilities of winning, and bidding behavior suggest that there is some asymmetry between incumbents and entrants in these auctions.

## 4 Model and estimation strategy

We employ a structural approach that incorporates firm bidding and participation decisions to further investigate the asymmetry across firms. The recovered structural elements can then be used for conducting the analysis of alternative economic policies. In this section, we develop a model of firm participation and bidding decisions and then present the estimation strategies from the model.

Similar to other work on auction participation, we model a potential bidder's decision as a two-stage process (Samuelson 1985, Levin and Smith 1994, McAfee and McMillan 1987). In the first stage, each potential bidder decides whether to participate in the auction. If the bidder decides to participate, it will incur a fixed cost of participation, which we call the participation cost. In the second stage, firms that choose to participate submit their bids. Here, firms decide the bid amounts to maximize their expected profits. In turn,

[19] Maskin and Riley (2000a) have shown that when asymmetry among bidders' cost distributions exists in the sense of first-order stochastic dominance, their bids also exhibit first-order stochastic dominance.

these depend on their costs of completing the contracts, which we refer to as project costs hereafter.

In general, the literature analyzing endogenous participation differs in the timing of participation and the realization of the private project cost (Li and Zheng 2007). That is, a typical model assumes that potential bidders learn their private costs before they decide whether to participate in the auction, whereas another model assumes that potential bidders do not draw their private costs until after they decide to participate in the auction. In the former, the participation cost is effectively the bid-preparation cost, whereas in the latter, the participation cost includes both the bid-preparation cost and the costs of investigating the contract conditions and estimating the project costs. Studies like Samuelson (1985) exemplify the former model, whereas Levin and Smith (1994) represents the latter; Li and Zheng (2007) test which of these models best applies to timber sale auctions in Michigan.

In the case of Japan's electricity procurement auctions, firms first have to register for auctions several weeks prior to the auction date. This registration can be considered as an expression of the intention to participate. However, we know that firms sometimes decline to bid in bidding places, even after they declare that they will participate in the auction. This behavior may imply that firms do not know their private costs when they make the participation decision, otherwise firms would never "enter and decline" if participation is costly and they know their private costs. Therefore, we follow the latter model and assume that bidders do not draw their private costs until after they decide to enter.

The next assumption we make is that firms learn which other firms have entered the auction by the time of actual bidding and once they decide to participate in the auction. The applicability of this assumption should also be carefully considered, because changes in this assumption significantly alter the outcome. In the majority of our auctions, firms need to assemble at a specified place to make a tender. In such a case, bidders can observe their rivals at the bidding place, supporting our assumption. Even it is not the case, it is highly possible that bidders obtain information on who is going to be bidding in an auction, because the number of potential bidders in this industry is very small.

We also assume that the participation decision is made sequentially, as in McAfee and McMillan (1987) and Nakabayashi (2009), such that the incumbent first makes a participation decision followed by entrants.[20] More specifically, we assume that incumbents always participate in auctions as observed in reality. Having known that there will always be an incumbent in an auction, the entrants make their participation decision.

When deciding upon participation, a potential bidder from the entrant firms knows his own participation cost (which we assume is common to all entrants), the distribution of the incumbent and entrant project costs, and the number of incumbents that will tender in the auction (always 1). The entrant firms choose to participate in the auction only if the expected profit from the auction is higher than the participation cost. Therefore, we can find the equilibrium number of entrants when the expected profit is equal to the participation cost. If the bidder decides to participate in the auction, it incurs participation costs and learns the costs of completing the contract, along with the number of actual competitors.

In the second stage of bidding, we consider an asymmetric auction model with independent costs. The relevant cost of fulfilling an electricity contract for a public agency is the opportunity cost for selling the electricity elsewhere. Cost independence is a reasonable approximation, because firms have different opportunity costs resulting from their various principal activities. If the JEPX functioned very well like in other countires' wholesale exchange markets, there would be a substantial common value component in these auctions because the JEPX would arbitrage away the cost heterogeneity and firms would form estimates of what will be the JEPX price during the contract period. However, as described earlier, the JEPX is still a very thin market and the reality is that firms do not care about future JEPX price much because they know that demand on this market will not be large enough. Therefore, we believe that firms' opportunity costs consist of substantial private components.

It is also the case that some common factors, such as input prices, may move firms' private costs to the same directions. We assume that all of these factors are observed

[20] Levin and Smith (1994) show that the number of actual bidders will be stochastic if participation is simultaneous. The assumption of sequential participation decision enable us to find a pure Nash equilibrium.

and will be controlled. It would be also desirable to control for unobserved factors. Li, Perrigne and Vuong (2002), Krasnokutskaya and Seim (2010), and Athey, Coey, and Levin (2010) consider unobserved components and allow for affiliation of project costs. However, because of data limitation, it is hard to apply their methods in the current study. Therefore, although realizing that an unobserved components may exist, we assume this as negligible in these auctions.

The observed auctions have secret reserve prices: that is, the reserve prices are never announced. In fact, most reserve prices are not announced, even after the bids have been opened. However, public documents show that the reserve price in electricity procurement auctions is generally the publicly listed power rate offered by the incumbent. Therefore, we assume that both the incumbents and entrants know the reserve price precisely, even though they are not announced. Importantly, the reserve price introduces truncation in the bid distribution if it is binding, and causes the number of firms actually participating in the auction to vary from the potential number of firms. Here, however, we assume that the reserve price is not binding, because entrants do not enter the industry unless they can supply electricity cheaper than the listed fees of their local incumbent in the first instance. Therefore, the only factor that causes the number of actual firms to deviate from the number of potential firms in our study is the participation cost in the first stage.[21]

[21] We observe 2,227 auctions in our dataset, of which 101 were not successful, either because all bids were higher than the reserve price or all bidders declined to bid (we cannot distinguish the exact reason for each auction). That is, reserve prices were either unkown to bidders or binding in 4.5% of all auctions. However, 78 (76.2%) of these unsuccessful auctions are confined to March 2008. During this month, oil prices skyrocketed, and the PPSs switched to selling their electricity on the JEPX rather than to public agencies through these auctions. In these circumstances, an incumbent is likely to be the only participant in the auction. If the incumbent anticipates this, it may submit bids lower than the reserve price, hoping to negotiate a higher rate when the auction is found to be unsuccessful. This may be the reason for the large number of unsuccessful auctions in March 2008. We regard this month as an exceptional month, and keep the assumptions that bidders know the reserve price and it is not binding, even though we observe unsuccessful auctions (these unsuccessful auctions are excluded from our observations because we do not observe winning bids).

In addition, and as described earlier, when no bids are lower than the reserve price, the auctioneer either conducts a second auction or enters into bargaining with one of the bidders. Thus, the emergence of re-auctions and negotiation stages influences bidder strategies, and such changes should be incorporated in the model. However, because we have only a small number of unsuccessful auctions, and an even smaller number of second auctions, and given we do not observe failed bids and cannot identify failed bidders, we do not attempt to take into account such influences. See, for example, Lu and Li (2008) who construct a dynamic bidding model in multi-round procurement auctions with secret reserve prices and re-auctions, and examine

We present our estimation strategies for incumbent and entrant project and participation costs in the following subsections.

## 4.1 The second stage estimation

Here, we estimate our model backwards, and therefore first examine the second stage conditional on first-stage participation. In the second or bidding stage, we apply the nonparametric approach in Guerre et al. (2000) to estimate firm costs and strategies. Flambard and Perrigne (2006) use the same approach for asymmetric bidders and a binding reserve price, and show that the independent private value (IPV) model with a binding reserve price is nonparametrically identified. Their approach involves first identifying the relationship between bid and cost from the theoretical model. They then estimate the bid distribution nonparametrically, and recover the cost distribution using the theoretical relationship. Because we only observe winning bids, we additionally need to identify the relationship between the winning-bid distribution and the all-bids distribution before fully applying this approach. That is, we first estimate the winning-bid distribution nonparametrically, and recover the all-bids distribution using the theoretical relationship. We then recover the cost distribution using the all-bids distribution thus obtained.

### 4.1.1 The bidding model

We consider a procurement auction in which $n$ risk-neutral firms compete for a contract to provide electricity throughout the contract period. Before bidding begins, each firm $i$ forms an estimate of its cost to complete the task. The cost estimate is then firm $i$'s private information. Thus, firm $i$ knows its own cost estimate but does not know the cost estimates of the 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 the incumbent (entrant). Types 1 and 0 consist of $n_1 = 1$ and $n_0 = n-1$ firms, respectively: we assume that there is one and only one incumbent in any auction,

bidders' strategies over these rounds.

as in reality. Firms are assumed to know the number of participants $n$ (and therefore, $n_0 = n - 1$) before they enter the second stage. Let $c_1$ and $c_0$ denote the costs of the incumbent and entrant, respectively, drawn respectively from distributions $F_1(\cdot)$ and $F_0(\cdot)$, defined on the common support $[\underline{c}, \overline{c}]$.[22] Both distributions are continuous, with densities $f_1(\cdot)$ and $f_0(\cdot)$. We consider a first-price sealed-bid auction. We follow Maskin and Riley (2000b), who establish the existence of Bayesian equilibrium in asymmetric auctions with a common support.

For the reasons described earlier, we assume that both the incumbents and entrants can compute the reserve price $p$ precisely because it is the incumbents' electricity rate, and that the reserve price is nonbinding. However, when the number of bidders is one, that is, when the incumbent is the only participant ($n = n_1 = 1$), the incumbent bids the reserve price.[23] In other cases, firm $i$ must submit the bid that is lowest among the participants and lower than the reserve price in order to win the contract. In the following model, we consider the case where $n \neq 1$.

If firm $i$ submits a bid $b_i$, 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 $\phi_j$ is the inverse strategy function that maps the equilibrium bids to costs. At the Bayesian–Nash equilibrium, each firm $i$ chooses its bid $b$ to maximize expected profit:

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

As we can see, firm $i$'s expected profit is a markup times the probability that firm $i$ is

[22] Under this common-support assumption, firms always have a nonzero probability of winning the auction, and therefore always tender bids in the second stage once they learn their private costs. However, as described earlier, some firms participate in auctions but decline to submit bids in the second stage. These firms presumably decline to bid because they have learned that there is no probability of winning. Therefore, to explain this behavior, we need to relax either the assumption of common support or the assumption of a nonbinding reserve price. However, as we do not observe the reserve price for auctions firms actually declined to bid in (because we only observe winning bids), it is not possible to examine this issue further. Therefore, we use these assumptions for simplicity.

[23] As discussed, the incumbents may bid lower than the reserve price, aiming to obtain a higher rate in the negotiation stage. However, we do not consider this case. In fact, we exclude observations in which an incumbent is the only bidder from our estimation.

the lowest bidder. Differentiating (1) with respect to $b_i$ gives the following two first-order conditions for type 1 and 0, respectively.

$$c_{1i} = b_{1i} - \frac{1}{(n-1)\frac{f_0(\phi_0(b_{1i}))\phi_0'(b_{1i})}{1-F_0(\phi_0(b_{1i}))}} \tag{2a}$$

$$c_{0i} = b_{0i} - \frac{1}{\frac{f_1(\phi_1(b_{0i}))\phi_1'(b_{0i})}{1-F_1(\phi_1(b_{0i}))} + (n-2)\frac{f_0(\phi_0(b_{0i}))\phi_0'(b_{0i})}{1-F_0(\phi_0(b_{0i}))}} \tag{2b}$$

with boundary conditions (Maskin and Riley (2000a))

$$\phi_k(\bar{c}) = \bar{c} \text{ for } k = 0, 1 \tag{3a}$$

$$\exists \beta \text{ s.t. } \phi_k(\beta) = \underline{c} \text{ for } k = 0, 1 \tag{3b}$$

#### 4.1.2 Identification and the estimation method for the bidding model

In a first-price sealed-bid auction, the bids and number of actual bidders are typically observed, whereas the bidders' costs and their distributions are not. The typical problem of identification reduces to whether $F_1(\cdot), F_0(\cdot)$ are identified from the observed bids and the number of actual bidders $n$. For such a typical case where all bids are observed, Guerre et al. (2000) and Flambard and Perrigne (2006) show that the cost distribution is identified as follows. Let $G_1(\cdot)$ be the distribution of bids for the incumbent bidder with the density function $g_1(\cdot)$. Let $G_0(\cdot)$ be the marginal distribution of bids for the other bidders with the density function $g_0(\cdot)$. Because the observed bids are the equilibrium bids, we have, for every $b \in [\underline{b}, \bar{c}]$, $G_1(b) = F_1(\phi_1(b)) = F_1(c)$, and $G_0(b) = F_0(\phi_0(b)) = F_0(c)$.[24] Similarly, $g_k(b) = G_k'(b) = f_k \cdot \phi_k'(b)$ for $k = 1, 0$. The system of equations (2a) and (2b) can then be rewritten as:

$$c_1 = b_1 - \frac{1}{(n-1)\frac{g_0(b_1)}{1-G_0(b_1)}} \tag{4a}$$

$$c_0 = b_0 - \frac{1}{\frac{g_1(b_0)}{1-G_1(b_0)} + (n-2)\frac{g_0(b_0)}{1-G_0(b_0)}} \tag{4b}$$

[24] Subscript $i$ is dropped for simplicity hereafter unless specifically required.

That is, knowledge of $G_1(\cdot), G_0(\cdot), g_1(\cdot), g_0(\cdot), n$ determines the costs $c_1$ and $c_0$ in Equations (4a) and (4b) for any bid value. We can then estimate the cost distribution using $c_1$ and $c_0$ for each observed bid: that is, the cost distributions are identified from the observed bids and the number of participants.

Given we only have access to winning bids, we need to transfer Equations (4a) and (4b) to those that relate to the cost and winning-bid distributions. Let $W_i(\cdot)$ be the distribution of bidder $i's$ winning bids. Then, as in Brendstrup and Paarsch (2003) and Athey and Haile (2007), Berman's (1963) derivation yields the relation:

$$G_i(b_i) = 1 - \exp\left[-\int_{-\infty}^{b_i} \frac{dW_i(t)}{1 - \sum_{j=1}^{n} W_j(t)}\right] \tag{5}$$

for a given $n$ (see the appendix for the derivation). Therefore, for each type, we have:

$$\begin{aligned}
G_1(b) &= 1 - \exp\left[-\int_{-\infty}^{b} \frac{dW_1(t)}{1 - W_1(t) - (n-1)W_0(t)}\right] && \text{(6a)}\\
G_0(b) &= 1 - \exp\left[-\int_{-\infty}^{b} \frac{dW_0(t)}{1 - W_1(t) - (n-1)W_0(t)}\right] && \text{(6b)}\\
g_1(b) &= [1 - G_1(b)] \times \frac{dW_1(t)}{1 - W_1(t) - (n-1)W_0(t)} && \text{(6c)}\\
g_0(b) &= [1 - G_0(b)] \times \frac{dW_1(t)}{1 - W_1(t) - (n-1)W_0(t)}. && \text{(6d)}
\end{aligned}$$

Then, we estimate the winning-bid distributions $W_1$ and $W_0$ and density $w_1 = dW_1$ and $w_0 = dW_0$ nonparametrically and obtain estimates for $G_1, G_0, g_1, g_0$ or $\hat{G}_1, \hat{G}_0, \hat{g}_1, \hat{g}_0$ from the above relationship. Then, the cost of the winner corresponding to each observed auction $l$ is recovered as:

$$\begin{aligned}
c_{1l}^w &= b_{1l}^w - \frac{1}{(n-1)\frac{\hat{g}_0(b_{1l}^w)}{1-\hat{G}_0(b_{1l}^w)}} \text{ if type 1 is the winner} && \text{(7a)}\\
c_{0l}^w &= b_{0l}^w - \frac{1}{\frac{\hat{g}_1(b_{0l}^w)}{1-\hat{G}_1(b_{0l}^w)} + (n-2)\frac{\hat{g}_0(b_{0l}^w)}{1-\hat{G}_0(b_{0l}^w)}} \text{ if type 0 is the winner} && \text{(7b)}
\end{aligned}$$

where $c_{kl}^w$ and $b_{kl}^w$ are the cost and bid of a type-$k$ winner in auction $l$. That is, the knowledge of $W_1(\cdot), W_0(\cdot), w_1(\cdot), w_0(\cdot), n$ determines the costs $c_1^w$ and $c_0^w$ for any winning-bid value from Equations (6a) to (7b).

Next, we consider controlling for heterogeneity in the auctions. We consider $L$ auctions indexed by $l$, $l = 1, ..., L$. Let $\mathbf{x}_l$ be a vector of variables characterizing auction $l$. We assume that all of the information characterizing the auctioned object is available to the analyst, and that any unobserved heterogeneity arises only from the differences in the bidders' private costs, which are unobserved random terms in the model. The model is conditional on the vector $\mathbf{x}_l$ and the number of bidders in auction $l$, $n_l$. The bid distributions in the $l-$th auction become the conditional distributions $G_1(\cdot|\mathbf{x}_l, n_l)$, $G_0(\cdot|\mathbf{x}_l, n_l)$. The cost distributions are varying across auctions through $\mathbf{x}_l$ and $n_l$. Then, Equations (7a) and (7b) become:

$$c_{1l}^w = b_{1l}^w - \frac{1}{(n_l - 1)\frac{\hat{g}_0(b_{1l}^w|\mathbf{x}_l,n_l)}{1-\hat{G}_0(b_{1l}^w|\mathbf{x}_l,n_l)}} \tag{8a}$$

$$c_{0l}^w = b_{0l}^w - \frac{1}{\frac{\hat{g}_1(b_{0l}^w|\mathbf{x}_l,n_l)}{1-\hat{G}_1(b_{0l}^w|\mathbf{x}_l,n_l)} + (n_l - 2)\frac{g_{0l}^*(b_{0l}^w|\mathbf{x}_l,n_l)}{1-G_{0l}^*(b_{0l}^w|\mathbf{x}_l,n_l)}}. \tag{8b}$$

Similarly, the winning-bid distribution can be written conditionally on $\mathbf{x}_l$ and the number of actual bidders $n_l$. Following Guerre et al. (2000) and Brendstrup and Paarsch (2003), we nonparametrically estimate these winning-bid distributions and densities. Note that $W_k(\cdot|\mathbf{x}_l, n_l) = W_k(\cdot, \mathbf{x}_l, n_l)/f_{xn}(\mathbf{x}_l, n_l)$ for $k = 0, 1$ where $f_{xn}(\mathbf{x}_l, n_l)$ is the joint density of $\mathbf{x}_l$ and $n_l$. Similarly, $w_k(\cdot|\mathbf{x}_l, n_l) = w_k(\cdot, \mathbf{x}_l, n_l)/f_{xn}(\mathbf{x}_l, n_l)$ for $k = 0, 1$. We employ the following nonparametric estimators.

$$\hat{W}_k(b^w, \mathbf{x}, n) = \frac{1}{Lh_{Wxk}h_{Wnk}} \sum_{l=1}^{L_k} 1(b_{kl}^w \leq b^w) K_G\left(\frac{\mathbf{x} - \mathbf{x}_l}{h_{Wxk}}, \frac{n - n_l}{h_{Wnk}}\right),$$

$$\hat{w}_k(b^w, \mathbf{x}, n) = \frac{1}{Lh_{wbk}h_{wxk}h_{wnk}} \sum_{l=1}^{L_k} K_g\left(\frac{b^w - {b^w}_{kl}}{h_{wbk}}, \frac{\mathbf{x} - \mathbf{x}_l}{h_{wxk}}, \frac{n - n_l}{h_{wnk}}\right),$$

$$\hat{f}_{xn}(\mathbf{x}, n) = \frac{1}{Lh_{fx}h_{fn}} \sum_{l=1}^{L} K_x(\frac{\mathbf{x} - \mathbf{x}_l}{h_{fx}}, \frac{n - n_l}{h_{fn}}).$$

for $k = 0, 1$, where $L$ is the number of total auctions, $L_k$ is the number of auctions where type $k$ is the winner, $\mathit{1}(\cdot)$ is the indicator function, $K_G, K_g$ and $K_x$ are some kernels defined on compact supports, and $h_{Wxk}, h_{Wnk}, h_{wbk}, h_{wxk}, h_{wnk}, h_{fx}$ and $h_{fn}$ are some smoothing parameters. The choice of kernels and smoothing parameters are discussed in the appendix. Then, following Equations (6a) to (6d), we obtain $\hat{G}_k(\cdot|\mathbf{x}_l, n_l)$ and $\hat{g}_k(\cdot|\mathbf{x}_l, n_l)$ for $k = 0, 1$ using $\hat{W}_k$ and $\hat{w}_k$. Equations (8a) and (8b) recover the winner's cost $c_l^w$ for $l = 1...L$. We then calculate the type-$k$ winner's rent in $l$-th auction by $b_{kl}^w - c_{kl}^w$.

We specifically control for the auction characteristics that statistically significantly affect winning bids in the reduced-form estimation in Section 2.2. We choose specification (5) in Table 3 and control for the load factor, the peak power ($kW$), the district, and the JEPX price. We conduct a separate nonparametric estimation for each district in order to control for the district effect because the auction and participant characteristics differ significantly across districts. However, we only show the results for Tokyo district because of the limited number of observations in other districts. We also remove observations with a load factor of less than 10%, because in such auctions the bids are significantly higher than in other auctions. We then have 408 observations. We also exclude observations with single=1, because in these auctions only the bidder (the incumbent) bids the reserve price. The final number of observations is 241. Summary statistics for the Tokyo district are shown in Table 4. Because of the relatively small size of our data set and the use of nonparametric estimators, we reduce the dimension of $X_l$ by constructing a single variable to capture auction heterogeneity, for which we employ principal component analysis. See the appendix for details.

Next, we consider obtaining the strategies of the two types. In order to obtain the equilibrium strategies of the two types of firms, we need to obtain the corresponding cost for each bid, including the losing bids of firms. However, unlike previous studies, we do not observe all of the bids. Therefore, we rely on simulation. More specifically, we obtain $T$ random draws from the estimated bid distributions $\hat{G}_1(\cdot|\mathbf{x}_l, n_l)$ and $\hat{G}_0(\cdot|\mathbf{x}_l, n_l)$ for each observed auction $l$ with the values of $\mathbf{x}_l$ and $n_l$, by the inverse transform method (Brandimarte (2006)). For each draw $b_{1l}^t$, $t = 1...T$ from $\hat{G}_1(\cdot|\mathbf{x}_l, n_l)$ and $b_{0l}^t$, $t = 1...T$ from $\hat{G}_0(\cdot|\mathbf{x}_l, n_l)$, we calculate the pseudo cost $\hat{c}^t_{1l}$ and $\hat{c}^t_{0l}$ from Equations (8a) and (8b) using the estimated bid densities and distributions,$\hat{g}_1(\cdot|\mathbf{x}_l, n_l), \hat{g}_0(\cdot|\mathbf{x}_l, n_l), \hat{G}_1(\cdot|\mathbf{x}_l, n_l)$ and $\hat{G}_0(\cdot|\mathbf{x}_l, n_l)$ :

$$\hat{c}^t_{1l} = b^t_{1l} - \frac{1}{(n-1)\frac{\hat{g}^*_0(b^t_{1l}|\mathbf{x}_l,n_l)}{1-\hat{G}^*_0(b^t_{1l}|\mathbf{x}_l,n_l)}} \tag{9a}$$

$$\hat{c}^t_{0l} = b^t_{0l} - \frac{1}{\frac{\hat{g}^*_1(b^t_{0l}|\mathbf{x}_l,n_l)}{1-\hat{G}^*_1(b^t_{0l}|\mathbf{x}_l,n_l)} + (n-2)\frac{\hat{g}^*_0(b^t_{0l}|\mathbf{x}_l,n_l)}{1-\hat{G}^*_0(b^t_{0l}|\mathbf{x}_l,n_l)}} \tag{9b}$$

for $t = 1...T$ . By plotting $b^t_k$ against $\hat{c}^t_k$ for $k = 0, 1$, we can show the firms' bidding strategies of type 0 and 1 in auction $l$. Further, we can nonparametrically estimate $F_{kl}(\cdot|\mathbf{x}_l)$ and $f_{kl}(\cdot|\mathbf{x}_l)$ from $\hat{c}^t_{kl}$ for $k = 0, 1$.

## 4.2 The first-stage estimation

In this subsection, we consider the first stage, where firms decide whether they will participate in an auction. Once a potential bidder enters an auction, it will incur a participation cost $e_k$. Therefore, a firm participates in an auction only if its expected profit from the auction is higher than the participation cost. We assume that the participation cost differs between incumbents and entrants. More specifically, and as discussed earlier, we assume that the participation cost for incumbents, $e_1$, is negligible, and that the incumbents participate in any auction. Further, we assume that incumbents continue to operate only in their former monopoly service areas. Therefore, there is always one incumbent bidder in each auction. We assume that the incumbents' decision in the first stage and firms' participation cost $e_k$ for $k = 1, 2$ are common knowledge for all bidders.

We follow the entry process of McAfee and McMillan (1987) and Nakabayashi (2009), and assume that the participation decisions are made sequentially. More specifically, we assume that entrants make their participation decision on the basis that there always exists one and only one incumbent in an auction. Entrants enter an auction until their expected profits are driven down to equal the entry cost $e_0$. We assume that the participation cost $e_0$ is binding, because in each area we do not observe any auction where all of the potential entrants participate: for instance, in the Tokyo area, we have eight potential entrants, whereas the observed maximum number of entrants in Tokyo area auctions is five. Therefore, the entrants are marginal bidders whose *ex ante* payoff is zero.[25]

An entrant's expected profit for auction $l$, given $c_0$ and $n_0$, is:

$$\pi_{0l}(c_0, n_0) = (\beta_l(c_0, n_0) - c_0)\,\Pr(win|c_0, n_0)$$

where $\beta_l$ is the equilibrium strategy that maps cost to bid. Then, the *ex ante* expected profit for auction $l$ given $n_0$ is:

$$V_{0l}(n_0) = \int_{c_0} \pi_{0l}(\hat{c}, n_0) dF_0(\hat{c}|\mathbf{x}_l). \tag{10}$$

The unique entry equilibrium must satisfy:

$$V_{0l}(n_0) = e_{0l}$$

subject to $n_0 \leq n_0^h$ where $n_0^h$ is the maximum number of entrants in the area. The participation cost $e_{0l}$ varies by auction because of the auction characteristics.

Using the estimated strategy function in the second stage and the observed number of entrants in auction $l$, we obtain $\hat{\pi}_{0l}$ for any value of $c_0$ in the support of $\hat{f}_0(\cdot|\mathbf{x}_l)$. Then, using the estimated cost density $\hat{f}_0(\cdot|\mathbf{x}_l)$, we obtain $\hat{V}_{0l}$ for any observed auction $l$, thereby obtaining the participation cost $e_{0l}$ for auction $l$.[26]

## 5 Estimation results

Table 5 provides summary statistics on the estimated costs of winners ($c_{1l}^w$ if the winner is type 1 and $c_{0l}^w$ if the winner is type 0) in the observed Tokyo auctions. The average estimated

[25] We temporarily ignore the fact that the number of bidders must be an integer.

[26] Because the number of entrants is discrete, the estimated $e_0$ is the maximum possible participation cost given the number of entrants $n_0$. We can only estimate the range of the participation cost by additionally computing $V_{l0}(n_0 + 1)$, which is the minimum possible participation cost given $n_0$.

costs of the type-1 (incumbent) and type-0 (entrant) winner are 9.03 $yen/kWh$ and 10.11 $yen/kWh$, respectively, and the average rents are 0.39 $yen/kWh$ and 0.34 $yen/kWh$, respectively, without controlling for auction characteristics. The cost of a type-1 (incumbent) winner is, on average, lower than that of a type-0 (entrant) winner, presumably because incumbents win auctions with high load-factor requirements more often than entrants: put differently, contracts with high load-factor requirements are less costly. The incumbent's rent is probably higher for a similar reason: that is, contracts with high load-factor requirements are more profitable. Table 6 provides the estimated costs and rents of winners on auction characteristics.[27] Once we control for auction characteristics in the Tokyo area, we can see that the incumbent winner's cost is higher than that of entrants, whereas the incumbent's rent is lower than that of entrants.

Next, we draw $T$ random bids from the estimated bid distribution $\hat{G}_k(\cdot|\mathbf{x}_l, n_l)$ for all observed values of $\mathbf{x}_l$ and $n_l$, and estimate the corresponding cost distributions $F_{1l}(c_1|\mathbf{x}_l), F_{0l}(c_0|\mathbf{x}_l)$ from Equations (9a) and (9b).[28] Then from $F_{1l}(c_1|\mathbf{x}_l), F_{0l}(c_0|\mathbf{x}_l)$, we obtain the mean of these cost distributions, $E_l(c_1|\mathbf{x}_l), E_l(c_0|\mathbf{x}_l)$, and the standard deviations of the cost distributions $sd_l(c_1|\mathbf{x}_l), sd_l(c_0|\mathbf{x}_l)$ for each auction $l$. Table 7 provides summary statistics of these estimated means and standard deviations of cost distributions. We can see that on average, the incumbent has a higher mean and a lower standard deviation. Figure 4 displays the estimated cost densities of entrants and the incumbent in the Tokyo area, given the median value of auction characteristics and the number of bidders (Peak power = 1,340 kW, Load factor = 34.33%, JEPX price = 8.60 yen/kWh, one incumbent and one entrant). This is a typical cost density of two types. We can see that the density of the incumbent has a higher mean, whereas that of the entrant has a higher variance. Figure 5 plots the estimated equilibrium strategies for the same auction. We can see that the incumbent bids more aggressively than the entrants: that is, as the theory suggests, for the same cost value, the incumbent, as the weaker bidder, submits a lower bid.

[27] Because the number of bidders should not affect firm costs, it only enters the regression for the firm rents.

[28] For now, we set $T = 100,000$.

Our findings show that the incumbent has a higher cost for electricity supply contracts despite its production structure advantage (vertical integration and efficient power generation by diversified generation means). As discussed, incumbents must bear the maintenance costs of transmission networks. Moreover, they need to hold capacity as the provider of last resort. Presumably, these factors make incumbents "weak bidders" in the sense that they have higher costs of fulfilling the contract. It can be also the case that incumbents' opportunity costs for selling the electricity elsewhere through bilateral contracts are higher, and reflected in this results. Table 8 provides the result from the regression of the difference of the mean cost of the incumbent and the entrants ($E(c_1|\mathbf{x}_l) - E(c_0|\mathbf{x}_l)$) on auction characteristics. We can see that the cost difference becomes smaller the higher the load factor and the greater the power. This implies that the incumbents' cost disadvantages disappear with scale. In the bilateral contracts, the customers with high load factor and greater power are strong customers with greater negotiation power. Therefore, incumbents might already have offered low rates for such customers, and therefore, the opportunity cost for selling the electricity for these customers may not be so different between incumbents and entrants.

Another factor may also potentially explain the higher costs of incumbents: namely, the opportunity cost of winning auctions. As described, the contracts auctioned off by public agencies are very small secondary activities for most incumbents, and their focus remains on large private users, to which the incumbents supply electricity at publicly announced rates, or rates determined by a bargaining process. If incumbents submit low bids to public agencies and win auctions, this will reveal their ability to supply electricity at lower rates to private users. Then, when the contracts with these private users are to be renewed, these users may demand lower rates. That is, winning auctions at lower bids may sacrifice future profits for the incumbents from private users. These foregone profits are then the incumbents' opportunity costs of winning auctions, and this may contribute to the higher estimated costs of the incumbent.

Our result from the bidding stage implies that the factor that is responsible for the entrants' low participation rate is not project costs. If the participation costs of entrants were at the same level as the incumbents, the entrants could have participated in auctions more frequently, because they are actually strong bidders in the bidding stage. We then calculate the participation cost of entrants. We calculate the participation cost for an auction with average characteristics (with a mean value of $z_l$ :peak power = 3,200 kW, load factor = 33.1%, amount = $9,270$ thousand kWh, JEPX = 8.605yen/kWh. The observed number of participants in this auction with the mean value $z_l$ is 5). We obtain a range of participation costs from $3,697$ to $4,206$ thousand yen for this auction.[29] This is comparable to the estimates in Krasnokutskaya and Seim (2008), though the auction objects are different. In the following section, we consider various rates of preferential treatment for this auction with average characteristics.

Our estimation relies on the assumption that the only factor that determines the number of bidders is the participation cost. To test the robustness of this assumption, we experimented with alternative models. The first alternative model assumes that the reserve price is binding, and so it is the reserve price that determines the number of bidders. This model generally produced negative markups over a large range of bid levels. The second model assumes that $F_1$ and $F_0$ have different support. More specifically, we assumed that the support of $F_0$ is right-shifted, and if an entrant draws a cost $c_0$ that has zero expected profit, the firm does not participate in the auction. This model produced nonincreasing strategy functions. Although we admit that these results from alternative models do not mean the current model fits best, we decided to stick with the current assumptions because the results are most reasonable.

## 6 Counterfactual analyses

We use the estimation results shown in the previous section to assess the effects of hypothetical preferential treatment to facilitate the participation of entrants. We also compare the costs to the government (the auctioneer) under different settings of the preference rate

[29] As discussed, because the number of entrants is considered discrete, we can only obtain the range of participation costs. We use the mean value of the obtained range in the following counterfactual analysis.

$\delta$. With a bid preference rate of $\delta$, if a preferred firm has tendered a bid of $b$, then the auctioneer would consider the preferred firm's tender a bid of $b/(1+\delta)$, but still pays $b$ for the contract. Krasnokutskaya and Seim (2009) have shown that the role of participation under such policy experiments is important. In the empirical analysis, we saw that the entrants are strong bidders in the sense that they have lower project costs than the incumbent. The earlier (theoretical) study shows that the cost-minimizing discount, if any, should be given to the incumbent in this case. However, Krasnokutskaya and Seim (2009) show that both the cost-minimizing level of the discount and the group receiving the discount may change when participation effects are taken into account. We examine the effect of various preference rates on the government cost by explicitly taking into account the participation of entrants. Such analysis is of particular interest here because the strong bidders, the entrants, have higher participation costs.

As noted in Hubbard and Paarsch (2009), the introduction o

f preferential treatment has three effects. First, firms receiving preferential treatment can inflate their bids and still win the auction: this is referred to as the *preference effect.* Second, nonpreferred firms will behave more competitively than under the equal treatment of bids: this is the *competitive effect.* Finally, if preferential treatment changes the expected profits of firms, it will also affect their participation behavior: this is the *participation effect.* We now examine the net effect of these three individual effects on government procurement costs under different bid preference rates.

In order to evaluate the auction outcomes under alternative settings, we need to simulate bidding strategies that take the policy parameters into account. More specifically, we need to modify the first-order conditions (2a) (2b), which are based on the common-support assumption, to those that incorporate the bid preference $\delta$ as follows (see Krasnokutskaya and Seim (2008)). When a preference is given to incumbents:

$$c_1 = b_1 - \frac{1}{(n-1)/(1+\delta)\frac{f_0(\phi_0(b_1/(1+\delta)))\phi_0'(b_1/(1+\delta))}{1-F_0(\phi_0(b_1/(1+\delta)))}} \tag{11a}$$

$$c_0 = b_0 - \frac{1}{\frac{(1+\delta)f_1(\phi_1(b_0(1+\delta)))\phi_1'(b_0(1+\delta))}{1-F_1(\phi_1(b_0(1+\delta)))} + (n-2)\frac{f_0(\phi_0(b_0))\phi_0'(b_0)}{1-F_0(\phi_0(b_0))}} \tag{11b}$$

with boundary conditions,

$$\phi_0(\bar{c}) = \bar{c} = \bar{b}_0, \tag{12a}$$

$$\phi_1(\bar{b}_1) = \bar{c} \textit{ and } \bar{b}_1 > \bar{b}_0. \tag{12b}$$

$$\exists\beta \text{ s.t. } \phi_0(\beta) = \underline{c} \textit{ and } \phi_1(\beta(1+\delta)) = \underline{c} \tag{12c}$$

where,

$$\bar{b}_1 = \arg\max_b (b-\bar{c})(1-F_0(b/(1+\delta))^{n_0}.$$

When a bid preference $\delta$ is given to entrants, the first-order conditions are:

$$c_1 = b_1 - \frac{1}{(n-1)(1+\delta)\frac{f_0(\phi_0(b_1(1+\delta)))\phi_0'(b_1(1+\delta))}{1-F_0(\phi_0(b_1(1+\delta)))}} \tag{13a}$$

$$c_0 = b_0 - \frac{1}{\frac{f_1(\phi_1(b_0/(1+\delta)))\phi_1'(b_0/(1+\delta))}{(1+\delta)(1-F_1(\phi_1(b_0/(1+\delta))))} + (n-2)\frac{f_0(\phi_0(b_0))\phi_0'(b_0)}{1-F_0(\phi_0(b_0))}} \tag{13b}$$

with boundary conditions,

$$\phi_k(\bar{c}) = \bar{c} \text{ for } k = 0, 1. \tag{14a}$$

$$\exists\beta \text{ s.t. } \phi_1(\beta) = \underline{c} \textit{ and } \phi_0(\beta(1+\delta)) = \underline{c}. \tag{14b}$$

The first-order conditions hold for $c_{m^{-1}} \in (\underline{c}, \bar{b}_m/(1+\delta))$ and $c_m \in (\underline{c}, \bar{c})$ where $m$ is the preferred bidder. Nonpreferred bidders with cost $c_{m^{-1}} \in (\bar{b}_m/(1+\delta), \bar{c})$ cannot submit a winning bid that would cover their cost. We assume that in this range of cost realization, they bid their cost. This system of differential equations does not have a closed-form solution, and therefore needs to be solved numerically. We follow Marshall et al. (1994) and solve the differential equations forwards.[30] As noted by Marshall et al. (1994), the numerical determination of $\beta$ is a critical component of the problem to be solved. We conduct a forward recursive algorithm starting at a lower boundary value $\beta$ chosen to result in an endpoint that satisfies the upper boundary condition. We embed this forward algorithm in a routine that searches for a starting point that also satisfies the lower boundary condition.

The counterfactual analyses are conducted for the particular auction that has a mean value of $z_l$ (peak power = 3,200 kW, load factor = 33.1%, amount = 9,270 thousand kWh, JEPX= 8.605yen/kWh). Table 9 presents the results of the counterfactual analyses. The upper panel presents the simulation results when preferential treatment is awarded to the entrants. $\delta$ is the preference rate. $E(rent1)$ and $E(rent0)$ are the (*ex-ante*) expected profit of the incumbent and entrants, respectively. $E(\text{winbid})$ is the expected winning bid discounted by the preference rate $1 + \delta$ when a preferred bidder is the winner. $E(\text{cost})$ is the government's expected procurement cost. $E(incumbent\ win)$ is the expected rate of the incumbent winning. We can see that the preference for entrants has little effect on the number of bidders when the rate is small. When the rate increases from 0 to 0.05 the number of entrants increases by one. After this, although the expected profit for entrants increases as the discount increases, the sixth entrant cannot enter, because if it did the expected profit would be less than the participation cost. When the preference rate reaches 20%, the number of bidders jumps to nine. However, the government cost increases significantly with this high rate of discount.

The expected profit of the incumbent decreases with the discount rate for entrants. This is firstly because the incumbent bids more aggressively the higher the preference to entrants, and secondly, because it becomes more difficult for the incumbent to win the auction. However, when the discount is 20%, the incumbent's expected profit increases, presumably because the probability of the incumbent winning increases because entrants

[30] Marshall et al. (1994) solves a high-bid auction, and suggests solving the problem backwards. Here, we consider a low-bid auction and solve the problem forwards.

become much less aggressive given the high preference rate granted to them. The expected winning bid decreases with the discount rate, reflecting discounted bids by the entrants and more aggressive bids by the incumbent. When the discount is 20%, however, the expected winning bid increases, presumably reflecting much less aggressive bids by the entrants.

The second panel presents the simulation results when preferential treatment is awarded to the incumbent. Theory suggests that a preference for weak bidders may enhance competition among strong bidders, and thereby improve the government's procurement cost. We can see, however, that a preference for the incumbent does not improve the government's procurement cost. Not surprisingly, the expected profit of the incumbent increases with the preference rate for the incumbent, whereas that of the entrants decreases. However, the competition effect on the entrants is not sufficient to offset the preference effect on the incumbent, thereby increasing the government procurement cost. The reason for this small competition effect may be that each entrant already bids aggressively, even without preferential treatment for the incumbent, in order to compete with other entrants. Because of the small competition effect, the preference for the incumbent merely increases the probability of winning by an incumbent that has preferential treatment, and this increases the government's cost.

The government's procurement cost has nonmonotonic movement with the discount rate. We can see that the government cost is minimized with a preference rate of 5% awarded for entrants for this particular auction. At this discount rate, the competitive effect on the incumbent and the participation effect on the entrants offset the preference effect on the entrants. Therefore, for this particular auction, the group that should receive preferential treatment is that comprised of strong bidders.

We also consider an alternative preference mechanism that relies on a lump-sum participation subsidy. More specifically, we consider granting entrants a subsidy that equals their participation cost. The result is shown in the last panel. We can see that the subsidy policy can further reduce the government procurement cost than the cost-minimizing bid discount. Under this subsidy, there are nine bidders, the maximum potential number, and so by definition all entrants participate in the auction.

## 7 Conclusion

This article studies the bidding patterns of entrant and incumbent firms in electric power procurement auctions in Japan. In the Japanese retail electricity market, ten firms that supplied electricity acted as local monopolists. Partial liberalization began in 2000, allowing PPSs to enter the market and supply electricity to large users with power and voltage requirements greater than $2,000$kW and $20,000$V, respectively. Accompanying this wave of market liberalization, public agencies began to utilize sealed bidding systems for electric power supply contracts. Although PPSs are now allowed to participate in any auctions with power requirements exceeding $50kW$, their participation rate remains very low, implying a significant cost disadvantage of entrants relative to incumbents. Conversely, the incumbents are responsible for the large fixed and maintenance costs associated with nuclear plants and transmission networks. We assess the extent of asymmetry between the incumbent and entrant cost distributions, and whether preferential treatment on one or the other can improve the participation of entrants and decrease the government's procurement costs.

We model the bidding and participation behavior of the incumbents and the entrants in a two-stage game and recover the cost distributions using the structural estimation method proposed by Guerre et al. (2000). Because we only have access to winning bids, we non-parametrically estimate the winning-bid distribution, and use its theoretical relationship with the all-bids distribution to apply the approach in Guerre et al. (2000). We then calculate the participation cost that explains the present participation situation using the estimated cost distributions. We find that an incumbent has a much higher cost for a given auction than the entrants, despite its advantages in production structure. Our results also indicate that the entrants are strong bidders in the bidding stage, and therefore their low participation rate is only explained by the large asymmetry in participation costs.

Having estimated the bid and cost distributions, we are able to simulate auction outcomes under alternative price-preference policy scenarios. We find that a preference discount for the weak bidder, the incumbent, does not improve the government's procurement cost, although theory suggests that a preference for weak bidders may enhance competition among strong bidders and thereby improve the government's procurement cost. In fact, government cost is minimized with only a small preference for entrants (5%) when the participation effect is considered, by increasing the participation of entrants slightly whereas not significantly reducing the probability of the incumbent winning. Unfortunately, the preference policy is found to have little effect on the participation of entrants. In contrast, a lump-sum subsidy policy is found to be more cost effective and to more effectively facilitate participation.

Some points that should be considered remain outstanding in our analysis. First, we do not consider heterogeneity among entrants. In reality, entrants have very different characteristics, such as size. However, because our data set does not permit the identification of entrants when they do not win, it is not possible to consider the heterogeneity among entrants here. We are currently gathering all auction bids (not just the winning bid) for further study. Second, our study considers only the static effects of preference treatment. Further research is needed to assess preference policy in a dynamic setting. We believe that the incumbent and the entrants have very different dynamic strategies: that is, the entrants should have more myopic strategies, because they depend on their parent companies' surplus supplies of electric power. We would like to see a dynamic setting including long-run (incumbent) and short-run (entrants) players considered in future research.

# A Proof of the relationship between the winning-bid and all-bid distributions

The identification of each marginal bid distribution $G_i$ from the observation of the winning bid is formally equivalent to the identification of the competing risks model with independent nonidentically distributed risks (see Brendstrup and Paarsch (2003); Athey and Haile (2007)). The distribution of the winning bid of firm $i$, $W_i(y)$, is the union of two disjointed events, $b_i$ being $\min(b_1, ..., b_n)$ and $b_i \leq y$.

$$\begin{aligned}
W_i(y) &= \Pr(Y \leq y, \text{winner is } i) \\
&= \int_{-\infty}^{y} \prod_{j \neq i} [1 - G_j(t)]\, g_i(t) dt \\
&= \int_{-\infty}^{y} \frac{\prod_{j=1}^{n} [1 - G_j(t)]}{1 - G_i(t)} g_i(t) dt \\
&= \int_{-\infty}^{y} \frac{1 - \Pr(y \leq t)}{1 - G_i(t)} g_i(t) dt \\
&= \int_{-\infty}^{y} \frac{1 - \sum_{j=1}^{n} W_j(t)}{1 - G_i(t)} g_i(t) dt \\
&= \int_{-\infty}^{y} - \left[ 1 - \sum_{j=1}^{n} W_j(t) \right] d \log(1 - G_i(t)) \qquad (15)
\end{aligned}$$

where $n$ is the number of bidders who actually participated in the auction. Rearranging the above equation, we obtain the relationships between the winning-bid distribution and the all-bids distribution and between the winning-bid density and the all-bids density as follows.

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

# B Auction characteristics, choice of kernels, and bandwidths

Because of the relatively small size of our data set, we employ principal component analysis following Flambard and Perrigne (2006) to reduce the dimension of $\mathbf{x}_l$ to 1. Three variables characterize the auction, namely the load factor, power, and the JEPX price. We construct the following variable $z_l = 0.6813L_l + 0.5100P_l - 0.5252t_l$, where $L_l, P_l$ and $t_l$ are standardized variables for load factor, power, and JEPX price, respectively. We obtain a $z_l$ varying from $-2.16$ to $7.54$ with a mean equal to 0 and a variance of 1.12.

Following Flambard and Perrigne (2006), we select the biweight kernel: $K(u) = (15/16)(1-u^2)^2 \mathit{1}(|u| \leq 1)$. $K_G(\cdot,\cdot), K_g(\cdot,\cdot,\cdot)$ and $K_x(\cdot,\cdot,\cdot)$ are the products of two and three univariate biweight kernels. We have a total of seven bandwidths. Following Guerre et al. (2000), the bandwidths are of the following form $h = c(L^{-1/(d+4)})$, where $d$ is the dimension of conditional variables and $c$ is some constant.

The constant is determined by a diagonal data-based bandwidth (Simonoff 1996, p.105), and equal to $2.623 \times (\frac{4}{d+2})^{1/(d+4)} \times \hat{\sigma}$, where $\hat{\sigma}$ is the empirical standard deviation of observations. The factor 2.623 is a correction resulting from the use of a biweight kernel instead of a Gaussian kernel. Then, for our kernel estimators for winning-bid distributions, we find $h_{Wxk} = 2.623 \times \hat{\sigma}_{zk} \times L^{-1/6}, h_{Wnk} = 2.623 \times \hat{\sigma}_{nk} \times L^{-1/6}$ for $k = 1, 0$ where $\hat{\sigma}_{zk}$ and $\hat{\sigma}_{nk}$ are the empirical standard deviations of $z$ and $n$ in observations with a type-$k$ winner. For our estimators of the winning-bid densities, we have $h_{wbk} = 2.623 \times 0.969 \times \hat{\sigma}_{b^w k} \times L^{-1/7}$, $h_{wxk} = 2.623 \times 0.969 \times \hat{\sigma}_{zk} \times L^{-1/7}$, and $h_{wnk} = 2.623 \times 0.969 \times \hat{\sigma}_{nk} \times L^{-1/7}$ where $\hat{\sigma}_{b^w k}$ is the empirical standard deviation of the winning bid of a type-$k$ winner. The $h_{fx}$ and $h_{fn}$ for $f_{xn}(\mathbf{x}, n)$ are obtained similarly:$h_{fx} = 2.623 \times 1 \times \hat{\sigma}_{zk} \times L^{-1/6}, h_{fn} = 2.623 \times 1 \times \hat{\sigma}_{nk} \times L^{-1/6}$.

## References


[1] Asano, H. “Regulatory Reform of the Electricity Industry in Japan: What Is the Next Step of Deregulation?” *Energy Policy*, Vol. 34 (2006), pp. 2491–2497.

[2] Athey, S., Coey, D. and Levin, J. "Set-asides and subsidies in auctions." Mimeo. Department of Economic, Stanford University, 2010.

[3] Athey, S. and Haile, P. A. “Nonparametric Approaches to auctions.” In J.J. Heckman and E.E. Leamer, eds., *The Handbook of Econometrics* New York: North-Holland, 2007.

[4] Bajari, P. “The First Price Sealed Bid Auction with Asymmetric Bidders: Theory and Applications.” Ph.D. Thesis, Department of Economics, University of Minnesota, 1997.

[5] Brandimarte, P. *Numerical Methods in Finance and Economics*. New Jersey: John Wiley & Sons Inc, 2006.

[6] Brendstrup, B. and Paarsch, H. J. “Nonparametric Estimation of Dutch and First-Price, Sealed-Bid Auction Models with Asymmetric Bidders.” Mimeo. Department of Economics, University of Iowa, 2003.

[7] Cantillon, E. "The Effect of Bidders' Asymmetries on Expected Revenue in Auctions." *Games and Economic Behavior,* Vol. 62 (2008), pp. 1–25.

[8] De Silva, D. G., Dunne, T., and Kosmopoulou, G. "An Empirical Analysis of Entrant and Incumbent Bidding in Road Construction Auctions." *Journal of Industrial Economics*, Vol. 51 (2003), pp. 295–316.

[9] Flambard, V. and Perrigne, I. "Asymmetry in Procurement Auctions: Evidence from Snow Removal Contracts." *Economic Journal*, Vol. 116 (2006), pp. 1014–1036.

[10] Gilley, O. and Karels, G. "The Competitive Effect in Bonus Bidding: New Evidence." *Bell Journal of Economics*, Vol. 12 (1981), pp. 637–648.

[11] Guerre, E., Perrigne, I., and Vuong, Q. "Optimal Nonparametric Estimation of First-Price Auctions." *Econometrica*, Vol. 68 (2000), pp. 525–74.

[12] Haile, P. A., Hong, H., and Shum, M. "Nonparametric Tests for Common Values at First-Price Sealed Bid Auctions." Working Paper. No. 10105, NBER, 2003.

[13] Hattori, T. and Saegusa, M. "Empirical Analyses of the Green Contracts in Competitive Power Procurements by Government Entities. Assessment of the Impacts of Environmental Quality Thresholds." Working Paper No. Y09002, Socio-economic Research Center, 2010.

[14] Heckman, J. "Sample Selection Bias as a Specification Error." *Econometrica*, Vol. 47 (1979), pp. 153–61.

[15] Hubbard, T. P. and Paarsch, H. J. "Investigating Bid Preferences at Low-Price, Sealed-Bid Auctions with Endogenous Participation." *International Journal of Industrial Organization*, Vol. 27 (2009), pp. 1–14.

[16] Jofre-Bonet, M. and Pesendorfer, M. "Estimation of a Dynamic Auction Game." *Econometrica*, Vol. 71 (2003), pp. 1443–89.

[17] Krasnokutskaya, E. “Identification and Estimation in Highway Procurement Auctions under Unobserved Auction Heterogeneity.” *Review of Economic Studies* (forthcoming).

[18] Krasnokutskaya, E. and Seim, K. “Bid preference programs and participation in highway procurement auctions.” *American Economic Review* (forthcoming).

[19] Krishna, V. *Auction Theory*. London: Academic Press, 2002.

[20] Laffont, J. J., Ossard, H., and Vuong, Q. “Econometrics of First-Price Auctions.” *Econometrica*, Vol. 63 (1995), pp. 953–80.

[21] Levin, D. and Smith, J. L. “Equilibrium in Auctions with Entry.” *American Economic Review*, Vol. 84 (1994), pp. 585–599.

[22] Li, T., Perrigne, I and Vuong, Q. "Structural estimation of the affiliated private value auction model." RAND Journal of Economics, Vol. 33 (2002), pp. 171-193.

[23] Li, T. and Zheng, X. “Information Acquisition or/and Bid Preparation: A Structural Analysis of Entry and Bidding in Timber Sale Auctions.” Mimeo. Department of Economics, Vanderbilt University, 2007.

[24] Lu, J. and Li, T. "Multi-Round Procurement Auctions with Secret Reserve Prices: Theory and Evidence." *Journal of Applied Econometrics*, Vol. 23 (2008), pp. 897-923.

[25] Marion, J. "Are Bid Preferences Benign? The Effect of Small Business Subsidies in Highway Procurement Auctions." *Journal of Public Economics*, Vol. 91 (2007), pp. 1591-1624.

[26] Marion, J. "How Costly Is Affirmative Action? Government Contracting and California’s Proposition 209." *Review of Economics and Statistics*, Vol. 91 (2009), pp. 503-522.

[27] Marshall, R. C., Meurer, M. J., Richard, J. F., and Stromquist, W. “Numerical Analysis of Asymmetric First Price Auctions.” *Games and Economic Behavior*, Vol. 7 (1994), pp. 193–220.

[28] Maskin, E. and Riley, J. "Asymmetric Auctions." *Review of Economic Studies*, Vol. 67 (2000a), pp. 413–38.

[29] Maskin, E. and Riley, J. "Existence of Equilibrium in Sealed High Bid Auctions." *Review of Economic Studies*, Vol. 67 (2000b), pp. 439–54.

[30] McAfee, R. P. and McMillan, J. "Auctions and Bidding." *Journal of Economic Literature*, Vol. 25 (1987), pp. 699–738.

[31] Myerson, R. "Optimal Auction Design." *Mathematics of Operations Research*, Vol. 6 (1981), pp. 58–73.

[32] Nakabayashi, J. "Small Business Set-Asides in Procurement Auctions: An Empirical Analysis." Working Paper No. 2009-005, Graduate School of Humanities and Social Sciences, University of Tsukuba, 2009.

[33] Pinkse, J. and Tan, G. "The Affiliation Effect in First-Price Auctions." Mimeo. Department of economics, Pennsylvania State University, 2002.

[34] Samuelson, W. F. "Competitive Bidding With Entry Costs." *Economics Letters,* Vol. 17 (1985), pp. 53–57.

[35] Simonoff, J. S. *Smoothing Methods in Statistics*. New York: Springer, 1996.

[36] Takagi, S. and Hosoe, N. "Measuring Effects of Competition Promoted by Deregulation in Japan's Electric Power Retailing Markets (in Japanese)." Discussion Paper 08-J. RIETI, 2007.

| FY | # of auctions | # of bidders | | Winning bids (yen/kWh) | | Peak power (mW) | | Amount (thousand mWh) | | Contract length (year) | | Load | | Green | | JEPX price (yen) | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 2004 | 335 | 1.50 | (1.00) | 14.25 | (5.13) | 2.11 | (3.12) | 9.57 | (17.07) | 1.11 | (0.46) | 0.44 | (0.19) | 0.00 | (0.00) | 7.67 | - |
| 2005 | 279 | 2.05 | (1.25) | 14.75 | (5.42) | 2.05 | (3.02) | 8.77 | (16.59) | 1.09 | (0.46) | 0.41 | (0.19) | 0.00 | (0.00) | 11.48 | 2.69 |
| 2006 | 324 | 1.97 | (1.25) | 15.11 | (3.98) | 1.68 | (4.27) | 6.76 | (20.73) | 1.20 | (0.59) | 0.38 | (0.19) | 0.42 | (0.49) | 8.44 | 0.53 |
| 2007 | 413 | 1.75 | (0.98) | 15.74 | (5.36) | 2.17 | (5.10) | 9.69 | (36.57) | 1.16 | (0.56) | 0.38 | (0.19) | 0.32 | (0.47) | 13.68 | 2.10 |
| Total | 1351 | 1.80 | (1.13) | 15.02 | (5.05) | 4.08 | (8.77) | 8.77 | (25.32) | 1.14 | (0.53) | 0.40 | (0.19) | 0.20 | (0.40) | 10.48 | 3.03 |

Table 1: Summary Statistics: Auctions from FY 2004 to FY 2007 throughout Japan

| Load factor | # of auctions | Win bid of incumbent | Win bid of entrant | % with entrant | % entrant wins | %entrant win given entrant entry |
|---|---|---|---|---|---|---|
| −10% | 59 | 37.08 | 27.12 | 83.1% | 83.1% | 100% |
| 10 − 20% | 125 | 20.24 | 20.23 | 56.0% | 52.8% | 94.3% |
| 20 − 40% | 524 | 16.09 | 15.48 | 50.2% | 45.8% | 91.3% |
| 40 − 60% | 413 | 12.87 | 12.32 | 42.1% | 27.9% | 66.1% |
| 60 − 80% | 198 | 11.05 | 10.62 | 18.7% | 6.6% | 35.1% |
| 80%− | 32 | 10.56 | 11.50 | 3.1% | 3.1% | 100% |
| *Total* | 1351 | 14.23 | 16.41 | 44.0% | 35.8% | 81.5% |

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

| | (1) | (2) | (3) | (4) | (5) | (6) |
|---|---|---|---|---|---|---|
| Incumbent wins | 0.704** | 0.711** | 0.694** | 0.687* | 0.654* | 0.647* |
| | (0.342) | (0.342) | (0.346) | (0.346) | (0.346) | (0.346) |
| Number of bidders | −0.362*** | −0.363*** | −0.464*** | −0.465*** | −0.467*** | −0.467*** |
| | (0.136) | (0.136) | (0.137) | (0.137) | (0.135) | (0.136) |
| Single | −0.988*** | −0.994*** | −0.795*** | −0.772** | −0.740** | −0.717* |
| | (0.365) | (0.364) | (0.361) | (0.367) | (0.368) | (0.367) |
| High voltage | −1.123*** | −1.218*** | | | | |
| | (0.214) | (0.206) | | | | |
| Load | −0.554*** | −0.555*** | −0.553*** | −0.552*** | −0.550*** | −0.549*** |
| | (0.017) | (0.017) | (0.017) | (0.017) | (0.017) | (0.017) |
| Load^2 | 0.004*** | 0.004*** | 0.004*** | 0.004*** | 0.004*** | 0.004*** |
| | (0.000) | (0.000) | (0.000) | (0.000) | (0.000) | (0.000) |
| KW | −0.010 | | −0.055*** | | −0.053** | |
| | (0.022) | | (0.021) | | (0.021) | |
| KWh | | −0.003 | | −0.008** | | −0.008** |
| | | (0.004) | | (0.004) | | (0.003) |
| Contract length | −0.021 | −0.010 | −0.051 | −0.029 | −0.065 | −0.043 |
| | (0.159) | (0.160) | (0.161) | (0.162) | (0.160) | (0.161) |
| Green | −0.008 | 0.009 | 0.023 | −0.015 | −0.132 | −0.122 |
| | (0.239) | (0.239) | (0.242) | (0.242) | (0.216) | (0.216) |
| JEPX | | | | | 0.067** | 0.068** |
| | | | | | (0.028) | (0.028) |
| Constant | 30.865*** | 30.836*** | 30.740*** | 30.611*** | 30.106*** | 29.966*** |
| | (0.645) | (0.644) | (0.652) | (0.651) | (0.724) | (0.723) |
| F(P-value) | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| Adj. R-squared | 0.654 | 0.654 | 0.646 | 0.645 | 0.646 | 0.646 |
| # of obs. | 1349 | 1349 | 1349 | 1349 | 1349 | 1349 |

Notes: Dependent variable is average winning bid (yen/kWh). (1) to (4) include district and year dummies. (5) and (6) include district dummies. SEs are in parentheses.

Table 3: Simple regression estimation results

| Variables | # of obs. | Mean | Std. Dev. | Median |
|---|---|---|---|---|
| Winning bid (yen/kWh) | 241 | 14.56 | 2.95 | 14.27 |
| Peak power (thousand kW) | 241 | 2.48 | 3.70 | 1.34 |
| Load factor (%) | 241 | 36.59 | 14.98 | 34.33 |
| # of actual bidders | 241 | 3.38 | 1.34 | 3.00 |
| Incumbent dummy | 241 | 0.19 | 0.39 | 0.00 |
| JEPX (yen/kWh) | 241 | 10.12 | 2.820 | 8.60 |

Table 4: Summary statistics of Tokyo area

| Variables | Mean | S.D. |
|---|---|---|
| Incumbent | | |
| Bid | 14.13 | 3.33 |
| Cost | 9.03 | 4.92 |
| Rent | 0.39 | 0.22 |
| Entrants | | |
| Bid | 15.01 | 2.58 |
| Cost | 10.11 | 4.32 |
| Rent | 0.34 | 0.20 |

Table 5: Summary statistics of estimated winner's cost and rent in Tokyo area

| Dependent var. | Cost | Rent |
|---|---|---|
| Incumbent wins | 1.750** | −0.103*** |
| | (0.611) | (0.0334) |
| Number of bidders | | −0.048*** |
| | | (0.013) |
| Load | −66.903*** | 2.580*** |
| | (6.383) | (0.334) |
| Load$^2$ | 56.130*** | −2.385*** |
| | (7.458) | (0.391) |
| KW | −0.283** | 0.012** |
| | (0.116) | (0.006) |
| JEPX | −0.435*** | 0.030*** |
| | (0.092) | (0.005) |
| Constant | 30.060*** | −0.359*** |
| | (1.737) | (0.109) |
| F(P-value) | 0.000 | 0.000 |
| Adj. R-squared | 0.518 | 0.387 |

Notes: SEs are in parentheses.

Table 6: Regression of estimated winner's cost and rent

| Variables | Average | S.D. |
|---|---|---|
| Incumbent | | |
| Mean of cost | 16.98 | 3.72 |
| S.D. of cost | 3.34 | 1.49 |
| Entrants | | |
| Mean of cost | 13.57 | 2.95 |
| S.D. of cost | 4.34 | 1.34 |

Table 7: Summary statistics of estimated mean and standard deviation of cost distributions in Tokyo area

| Variables | Difference $(E(c_1) - E(c_0))$ | |
|---|---|---|
| Load | $-9.526$ | $(1.307)^{***}$ |
| KW | $-0.134$ | $(0.077)^{*}$ |
| JEPX | 0.385 | $(0.069)^{***}$ |
| Constant | 3.262 | $(0.972)^{***}$ |
| F(P-value) | 44.30 | |
| Adj. R-squared | 0.364 | |
| # observations | 228 | |

Notes: SEs are in parenthesis.

Table 8: Regression on the difference between estimated mean cost of incumbent and entrants in the Tokyo area

| Discount on entrants ($\delta$) | # bidders | E(rent1) (yen/kWh) | E(rent0) (yen/kWh) | E(winbid) (yen/kWh) | E(cost) (yen/kWh) | E(incumbent wins) |
|---|---|---|---|---|---|---|
| 0 | 4 | 0.186 | 0.485 | 13.826 | 13.826 | 0.151 |
| 0.05 | 5 | 0.081 | 0.427 | 12.941 | 13.541 | 0.068 |
| 0.10 | 5 | 0.048 | 0.433 | 12.378 | 13.555 | 0.046 |
| 0.15 | 5 | 0.026 | 0.436 | 11.834 | 13.555 | 0.029 |
| 0.20 | 9 | 0.160 | 0.956 | 12.518 | 15.011 | 0.041 |
| Discount on incumbents ($\delta$) | # bidders | E(rent1) (yen/kWh) | E(rent0) (yen/kWh) | E(winbid) (yen/kWh) | E(cost) (yen/kWh) | E(incumbent wins) |
| 0.05 | 4 | 0.291 | 0.476 | 13.778 | 13.893 | 0.158 |
| 0.10 | 4 | 0.410 | 0.464 | 13.737 | 13.980 | 0.168 |
| 0.15 | 4 | 0.531 | 0.453 | 13.684 | 14.066 | 0.176 |
| 0.20 | 4 | 0.678 | 0.486 | 13.623 | 14.170 | 0.190 |
| Subsidy | | | | | | |
| 0.426 yen/kWh | 9 | 0.059 | 0.262 | 12.921 | 13.347 | 0.037 |

Table 9: Simulation results of bid discount program

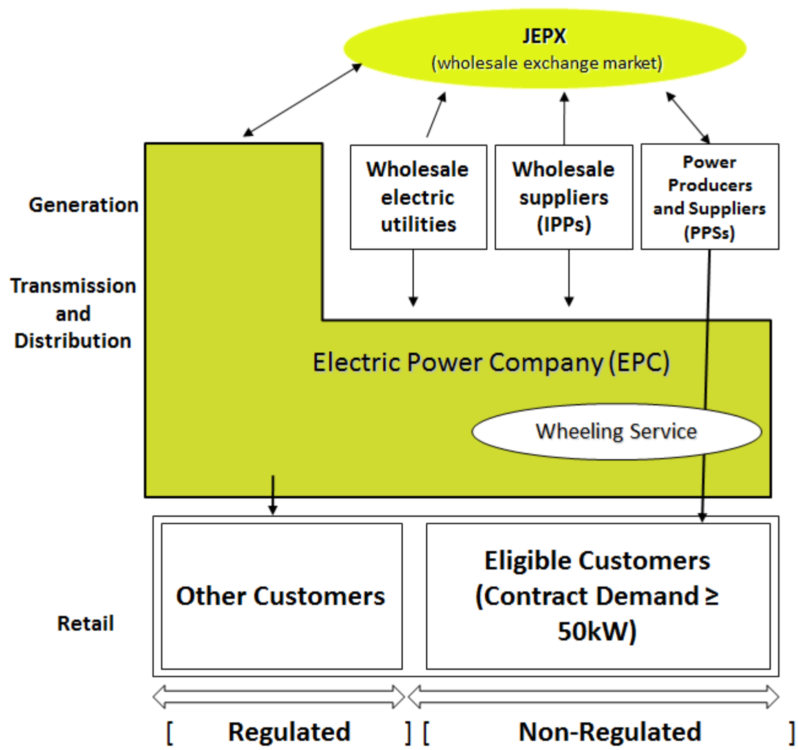


Figure 1: The structure of Japan's electric nidustry. Source: *TEPCO* (arranged by the author)

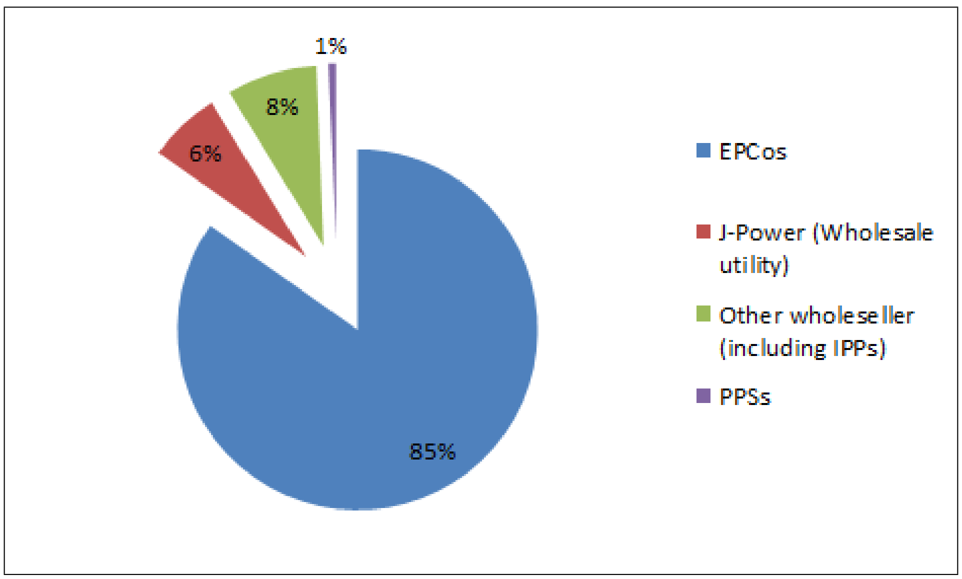


Figure 2: Electric power generation in 2009 by generator type (Total 925,392 thousand mWh. Constructed by the author from METI.)

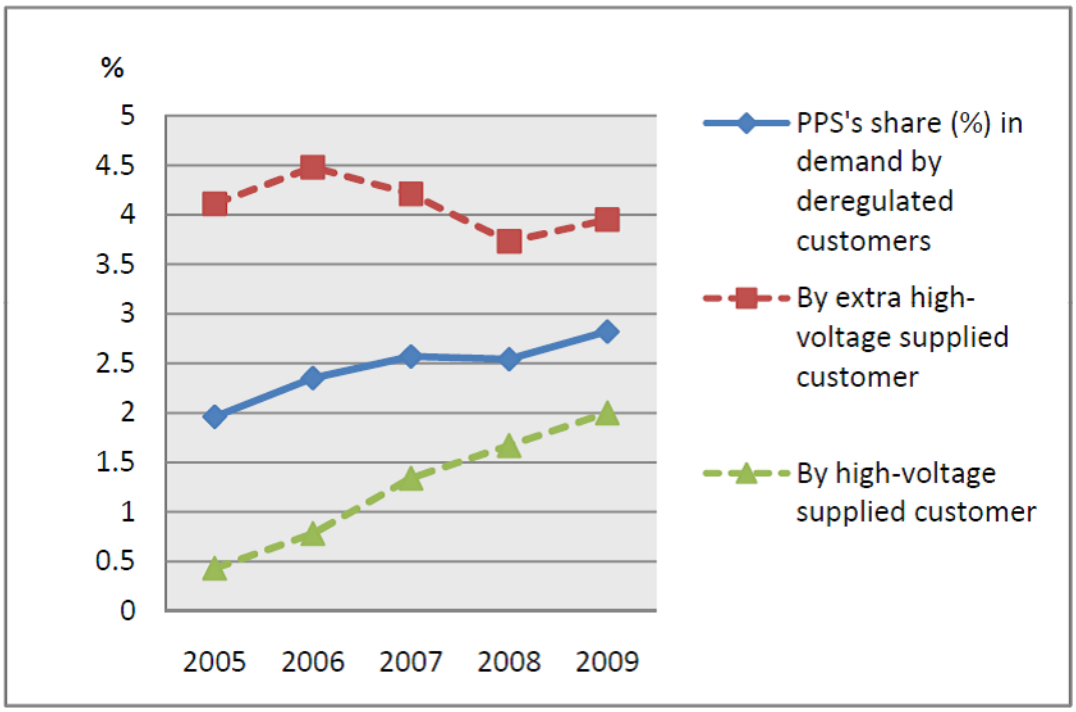


Figure 3: PPS share in the deregulated retail market

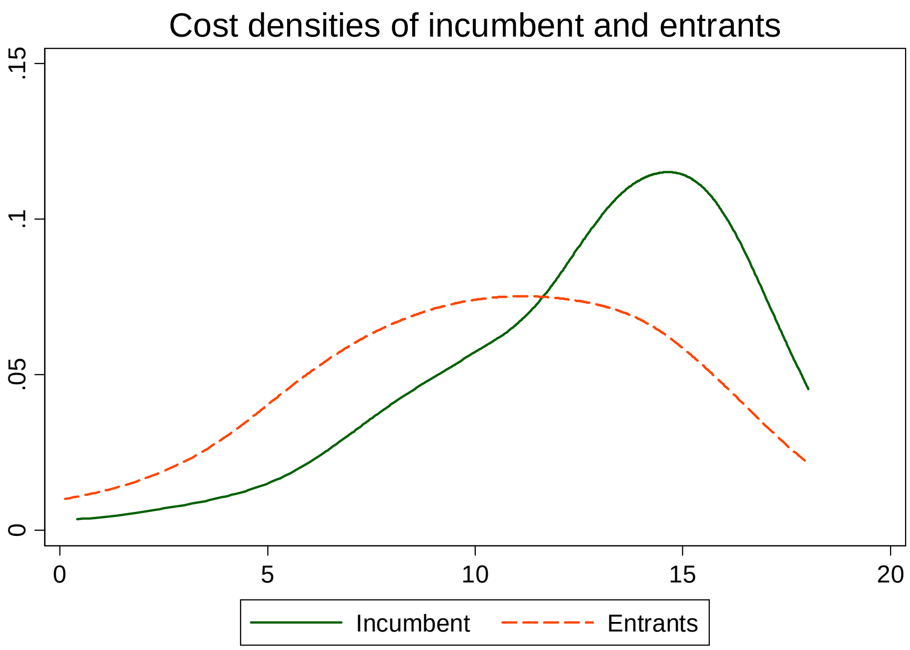


Figure 4: Estimated cost densities of incumbent and entrants for the median covariates (Peak power = 1340 kW, Load factor = 34.33%,JEPX price = 8.60 yen/kWh, one incumbent and one entrant)

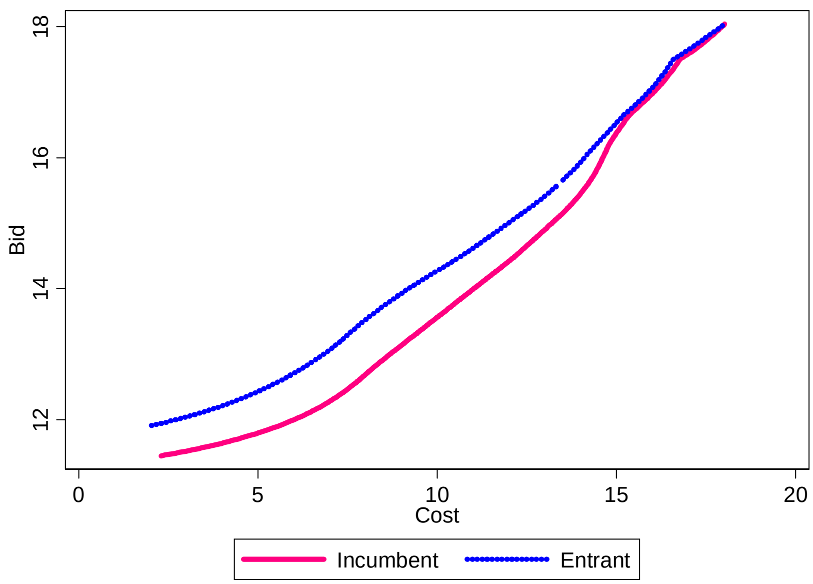


Figure 5: Equilibrium bidding strategies of incumbent and entrants for the median covariates (Peak power =1340 kW, Load factor = 34.33%, JEPX price = 8.60 yen/kWh, one incumbent and one entrant)