# THE EFFECT OF CROSS-CONTROL ON BIDDING BEHAVIOR AND PRICES IN ELECTRICITY AUCTION MARKETS

**An Economic Report to the American Public Power Association**

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**September 2010**

# Acknowledgments

Gratitude is expressed to the American Public Power Association for financial support for this research. Research assistance was provided primarily by Vladlena Sabodash, with additional contributions from George Ivanov and Evgenia Shumilkina.

# EXECUTIVE SUMMARY

Auction markets for electricity generation have been designed to operate like competitive markets and thereby bring the benefits of competition to consumers and producers alike. In practice, however, these markets have often deviated from that ideal. This Report investigates one such deviation, stemming from the ability of a bidder in an electricity auction market to acquire information about the costs of rival bidders' generation units. Such cost information reduces the uncertainty associated with rivals' bids, in particular, alleviating the threat that rivals might bid in their output at a lower price. The effect is to allow the bidder with such information to raise its own bid price and shift market price upwards.

This Report first presents the economic theory of such bidding markets, focusing on the role of information about rivals' costs. This theory establishes the proposition that information about rivals' costs can elevate bids and thus the final market price. The Report goes on to examine the New York Independent System Operator (ISO) auction market for electricity for evidence of such an effect. Using a variety of statistical techniques, it finds an extensive amount of disclosure of information about rivals' costs, and a significant upward effect of that disclosure on bidding and prices.

The mechanism by which a bidder gains information about rivals' costs in the New York ISO market is simple. Bidders need not be the owners of generation units themselves, and if not, they can have supply contracts with any number of actual generation owners whose output they bid into the auction. Crucially, bidders can alter their portfolio of such contracts as often as they wish. As a result any single bidder will have nearly-current information about other generation units with which it had recent (but expired) contracts. This contractual control conveys information about rivals–notably, their costs–that is not available in truly competitive markets and permits bidding into the auction market at levels higher than otherwise would be the case.

The practical importance of this effect is established by analysis of data from operation of the New York ISO auction market for electricity in 2006-2008. The Report finds that during this time period on average any single bidder controlled about twelve different generators in the 6-month period preceding any bid that it made. An examination of bidding practices finds that the level of bid submitted by any one bidder increases with the number of contracts that the bidder previously held, that is, the number of rival generators whose unit cost data were revealed to it by recent cross-control. For the average bidder with twelve such recent contracts, that bidder's bid price rises by 7 percent relative to a bidder with only a single generating unit under its control.

This Report examines all marginal bidders–that is, those that set the market-clearing price in each hour--as well as other bidders with prices near the marginal price and who therefore were most likely affected by these incentives to raise price. All of these bidders raised their prices based on their degree of prior cross-control, resulting in higher market-clearing price in the auction market. This effect is further corroborated by consideration of those bidders whose number of contracts varied most widely over the time period studied, to see if their bidding behavior over time tracks the degree of cost information that they acquire through these contracts. Again, the effect on bid price and market-clearing price is confirmed.

The Report concludes that permissive market rules on cross-control have significant anticompetitive effects in the New York auction market for electricity. Analysis of this possible effect in other Regional Transmission Organizations (RTOs) and ISOs is hampered by the practice of nondisclosure of information at the level of individual bidders.

## 1. INTRODUCTION

Deregulation and restructuring of the wholesale electric power sector in the U.S. and elsewhere have typically involved the creation of organized auction markets run by Regional Transmission Organizations (RTOs)[1] to elicit supply of bulk power from a merchant generation sector. In these markets bidders generally offer power on an hour-by-hour basis for the next day. The auction market operator– referred to as either an RTO or Independent Service Operator (ISO)–combines the collective supply offers with forecasted demand to establish a uniform market-clearing price. This in turn determines the identity of the bidders that will provide power, and their quantities, in each hour.

Modeled after well-functioning economic markets, this auction process is intended to bring the benefits of competition to consumers and producers in the electricity supply sector. In contrast to those markets, however, it appears that nothing in RTO market rules prevents different bidders over time from bidding the same generation unit's supply into the wholesale auction markets. The result is that a bidder at any one point in time may have information about the costs and other operating characteristics of competing generation units with which it had recent (but subsequently expired) contracts. Since those contracts can be quite short in duration, the information gained from these contractual arrangements remains relevant.

Confidential information about direct rivals violates a crucial assumption of competition. The reason is that information about rivals' costs and other operating characteristics reduces the uncertainty and the threat that rivals might bid in their output at a low price. Especially for those

[1] There are six RTOs under the jurisdiction of the Federal Energy Regulatory Commission (FERC): ISO New England (ISO NE); the New York ISO (NY ISO); the PJM Interconnection (PJM); the Midwest ISO (MISO); the California ISO (CAISO); and the Southwest Power Pool (SPP). The ERCOT ISO in Texas is entirely within the intrastate transmission grid and is therefore subject only to state authority.

bidders whose units are likely to be marginal in the market[2], such knowledge permits them to raise their marginal bid prices. For these reasons, if information about rivals' costs were exchanged directly among bidders, it would likely be subject to antitrust challenge. Yet the market rules in RTOs permit revelation of much the same information.

This report investigates the effect of this temporary cross-control over rivals' output, and the resulting access to information about rivals, on bidding behavior and pricing in electricity markets. It first establishes the general proposition that a bidder in an auction market that is informed about its rivals' costs will raise its own bid price relative to the case where the bidder is uncertain about its rivals' costs. Empirical evidence is then developed on the extent and effects of this practice, focusing on the New York Independent System Operator (New York ISO) in the years 2006-2008. The New York ISO is examined since it appears to be the sole ISO that provides publicly-available data showing the extent of such "cross-control" of generating units.

In any hour during the 2006-2008 period in New York, there were on average about 300 generation units controlled by 65 active bidders. The extent of information available to a single bidder in any hour can be measured by the total number and the size of all the generation units that the bidder controlled (by ownership or, more likely, contract) during the preceding six months. For marginal bidders, that number averages 12 generators, but it ranges from a high of 65 down to zero. The latter indicates the absence of other generator during the past six months, but the data suggest more typically a considerable degree of "churn" in the portfolio of generation units controlled by any single bidder, and hence a considerable degree of access to information about rival generators.

[2] A marginal unit is the unit with the highest offer to sell power that is dispatched in a given hour and sets the clearing price.

The key question investigated in this report concerns the effect on actual bidding behavior of such access to information about rivals. Using statistical techniques appropriate to these data, and controlling for other possible influences, the analysis establishes that bidders with a greater number and size of previously controlled generators indeed do bid their marginal units into the market at a higher price than bidders with fewer recent opportunities to acquire information about rivals. In particular, other things being equal, each additional generation unit previously controlled is found to result in a bid that is 0.6 percent higher. For the average bidder, with 12 previously controlled units, this implies a 7 percent increase in marginal bid price. Cross-control of units as allowed under RTO operating rules is therefore seen as permitting access to cost and other information about direct rivals that alters bidder behavior and causes the market outcome to diverge significantly from the competitive norm.

The remainder of this report is organized as follows. The next section outlines the economic theory demonstrating the value of information about rivals' costs in reducing a bidder's uncertainty about rivals, and hence the bidder's incentive to raise its bid price. This is followed by some background on the institutional setting, in particular, the operating rules that in New York and certain other electricity auction markets permit access to information about rivals. The New York ISO is then analyzed in detail. The data are used to establish the distorting effect on bidder behavior and market prices of information that is revealed by such control over rival generators. More extensive discussion of both the theory and the statistical results can be found in Appendix A and B, respectively.

## 2. ECONOMIC BACKGROUND

Direct competitors do not ordinarily have information about each others' costs, capacity, production plans, operating constraints, and so forth. In economics it is well understood that the exchange of cost and demand information throughout an industry may alter competitive behavior and equilibrium market price.[3] The reason is straightforward: Knowing rivals' costs sets a lower bound on what those rivals might charge and hence a lower bound on what one needs to charge to avoid being underbid. For this reason information exchanges among direct competitors are generally viewed as anticompetitive by antitrust authorities.[4]

This section outlines the economic theory demonstrating these effects in an auction market setting like that for wholesale electricity. The key elements are apparent from a deliberately simplified scenario involving two bidders, A and B, each with ownership or control of multiple generation units. It is further assumed that all generation units are of identical size, and that each produces either at full capacity or no output at all. These assumptions permit output effects to be characterized simply by the count or number of generation units in operation. All of B's generation units are assumed to have the same unit costs, while all but one of bidder A's units have costs lower than B's units. The cost of A's highest cost ("marginal") unit is greater than for its others, but it may or may not exceed the uniform cost of bidder B's units.

[3] Relevant theory is presented in C. Shapiro, "Exchange of Cost Information in Oligopoly," *Review of Economic Studies* (1986), and M. Raith, "A General Model of Information Sharing in Oligopoly," *Review of Economic Studies* (1996), among other sources. An especially useful outline of cases and results is found in K.-U. Kuhn and X. Vives, "Information Exchanges Among Firsts and their Impact on Competition," Barcelona, CSIC Working Paper (1994).

[4] See, for example, M. Motta, *Competition Policy: Theory and Practice*, Cambridge University Press (2004), ch. 4, for a review of antitrust policy toward information exchange among competitors.

To motivate this scenario, it is assumed that that to satisfy market demand, only one marginal unit – either A's or B's – is required. Bidder B is assumed simply to bid all its generation units into the market at their uniform unit cost, but bidder A can choose the price at which to bid its marginal unit.[5] As will become apparent, bidder A's strategy differs depending on its certainty vs. uncertainty about B's cost and therefore its bids.

Certainty about B's cost implies simply that bidder A actually knows bidder B's unit cost and hence its bid price. In this case if B's cost is lower than the cost of A's marginal unit, then A cannot profitably bid that unit into the market and concedes that last unit sale to B. On the other hand, if bidder B's cost is higher than that of A's marginal unit, A can bid its last unit into the market at a price just barely below B's cost, resulting in A's unit being dispatched instead of B's. Bidder A's bid thereby becomes the market price and it earns the difference between that price (essentially B's cost) and its actual lower cost on its marginal unit, plus the difference between that price and its lower costs on all of its other ("inframarginal") units.

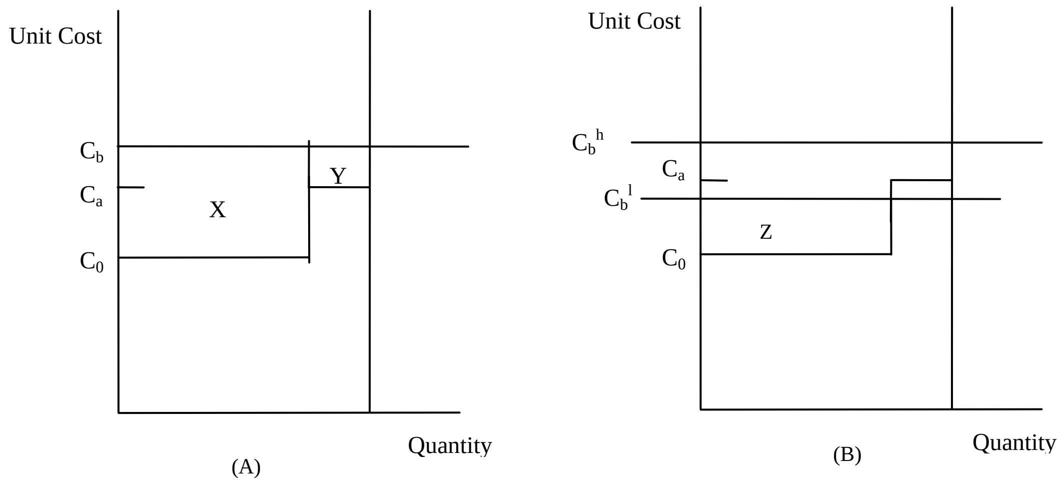
This outcome is shown in Figure 1, panel (A). There, bidder B's unit cost is denoted $c_b$, while bidder A's costs on its inframarginal and marginal units are labeled $c_0$ and $c_a$, respectively. With market price set essentially at $c_b$, A earns the two profit areas X and Y.

[5] RTO-operated markets do not require that bids are equal to actual cost.

**FIGURE 1**

Pricing Under Certainty and Uncertainty About Rival's Cost

(A) Certainty (B) Uncertainty




The alternative assumption involves uncertainty. Specifically, suppose bidder A does not know whether bidder B's unit cost lies above or below the unit cost of its own marginal unit, i.e., $c_a$. Under such uncertainty, bidder A has a more complicated strategy involving the following trade-off: [6] On the one hand, bidding a higher price can result in a higher market equilibrium price and greater profits on all of A's units. On the other hand, a higher bid price runs a greater risk of exceeding bidder B's unknown cost, in which case A's marginal unit is not called upon to produce power at all (although bidder A still earns profits on its lower-cost inframarginal units).

These considerations are illustrated in Figure 1, panel (B). There bidder A's offer curve, based on its costs $c_0$ and $c_a$, is the same as before, but now there are two possibilities for bidder

[6] This proposition applies to so-called sealed bid auctions, which is technically the model of auctions represented by wholesale electricity markets. See P. Milgrom, "Auctions and Bidding: A Primer," *Journal of Economic Perspectives* (1989), p. 4: and C. Wolfram, "Strategic Bidding in a Multi-Unit Auction: An Empirical Analysis of Bids to Supply Electricity in England and Wales," *Rand Journal of Economics* (1998). An application of the proposition to mergers can be found in "Roundtable on Competition in Bidding Markets: A Note by the US Department of Justice and the US Federal Trade Commission," OECD, DAF/COMP/WD(2006)77.

B's cost. Bidder B's uniform unit cost may be at the same level as before (i.e., $c_b$) or alternatively it may be lower. The low level of cost is denoted in the graph as $c_b^l$ and the high cost as $c_b^h$ (which, to repeat, equals $c_b$). If B's cost is $c_b^h$ and A in fact bids just below than B's cost as in the certainty scenario, A will earn profits as large as those shown in panel (A). On the other hand, if B's cost is low ($C_b^1$), this same high bid by A will result in its marginal unit not being dispatched, although it will continue to earn profits in the amount labeled Z on its inframarginal units.

The final step is a comparison of A's profit when it has knowledge of B's cost (i.e., the certainty case) with its expected value of profit under uncertainty about B's cost, other things (notably, its bid price) equal. The latter expected value is the sum of the probability that B is high cost times the corresponding profit outcome to A (X +Y), plus the probability that B is low cost times A's profit if that is the case (Z). The difference between this sum—the expected value under uncertainty--and the profit under certainty is the gain from eliminating uncertainty, that is, the value of information about a key rival's cost. That comparison (detailed in Appendix A) shows that the gain in bidder A's profit is greater:

(1) when the cost difference for marginal units of the two bidders is greater,

(2) when the difference between the costs of A's inframarginal units and its marginal unit is lower,

(3) when A's inframarginal quantity is greater, and

(4) when A's marginal quantity is greater (if units are of different size).

These factors constitute the foundation of the empirical analysis that follows.

## 3. INSTITUTIONAL BACKGROUND

The setting for this study is the New York ISO auction market for wholesale electricity. According to the procedures of the ISO, by 05:00 (5 AM) of each day, each bidder must submit an offer schedule for each of its generating units for each hour of the following day. Each offer schedule may consist of up to 12 price-quantity pairs, together with information about certain other characteristics of the generator (e.g., startup costs, minimum dispatch, must take energy). Figure 2 gives an illustrative actual offer schedule from one particular bidder for a single hour in 2008, described in terms of its price-quantity pairs.

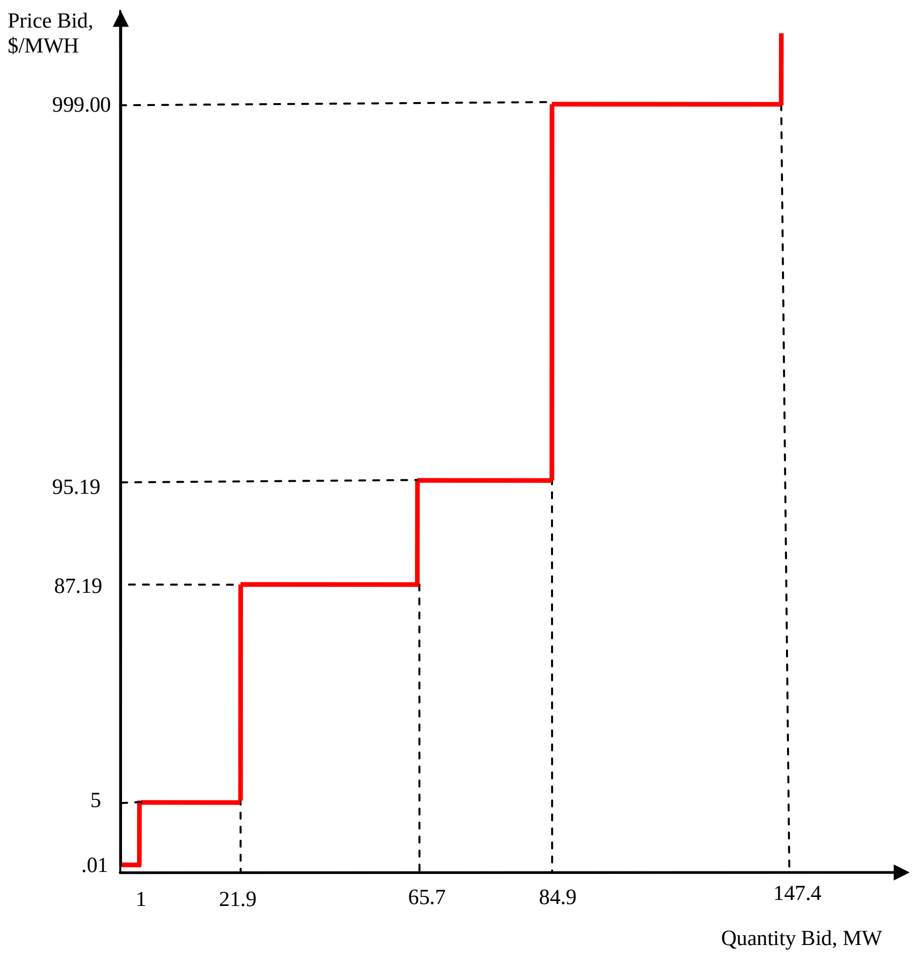
After all offer schedules are submitted, the New York ISO ranks all generating units based on their bids and constructs a total market supply schedule. This market supply schedule is combined with a load forecast, prepared by the ISO, for each hour of the following day, which determines the projected market-clearing price. In the absence of constraints on supply or transmission, sophisticated optimization software is used to determine the optimal (i.e., least cost) generation dispatch throughout New York. Modifications are required to incorporate anticipated constraints.[7] In any case, a uniform price is established, and that price in turn determines which generation units are actually dispatched (that is, designated to supply) and in what amounts. All dispatched units are paid the single market-clearing price, which is the offer price of the marginal unit needed to meet market demand.[8] Technically, such a market is termed

[7] A so-called "reference bus price" is nonetheless calculated and applies to the entire ISO area. It may be adjusted to reflect market conditions in any of the eleven zones served by the New York ISO.

[8] The market monitor may mitigate an offer if it finds that the offer (a) exceeds a "reference price" (an average of offers accepted during "competitive conditions") and (b) will significantly increase energy prices. See Market Services Tariff, Attachment H, NY ISO, http://www.nyiso.com/public/webdocs/documents/tariffs/market_services/ms_attachments/att_h.pdf

a simultaneous-move uniform-price multi-unit auction market.

**FIGURE 2**




| Quantity Bid, MW | Price Bid, $/MWh |
|---|---|
| 1 | .01 |
| 21.9 | 5 |
| 65.7 | 87.19 |
| 84.9 | 95.19 |
| 147.4 | 999 |

Day-ahead Offer Schedule of Bidder 75755750 for generating unit 29636180 for January 16, 2008, 16:00

Among the several markets organized on these principles in the U.S., there are two different protocols for the submission of offer curves. In one type, illustrated by the PJM and ISO New England, bidders submit the same offer curves for their generation units for each of the 24 hours of the following day. This type of bid procedure, called "long-lived bids," can be contrasted to the "short-lived bids" in the New York ISO. In the latter, bidders submit separate sets of bids for each hour of the upcoming day. Short-lived bids obviously allow generators to tailor their bids to expected differences in hourly demand and other conditions, thus yielding real-time market prices that more closely reflect within-day conditions. Yet short-lived bids reveal considerably more information about rivals and may in fact permit more strategic behavior by individual bidders.[9]

What permits the behavior examined in this report are rules in the New York market concerning bidders. Bidders may be owners of one or more generators, but ownership of actual generation facilities is not a requirement for bidding.[10] Rather, a bidder may simply have a contractual arrangement with one or more generators, on whose behalf it submits bids to the ISO.

[9] Research has shown that uniform auctions with long-lived bids result in lower average prices than auctions with short-lived bids. See N. Farbe, N.-H. von der Fehr, and D. Harbord, "Designing Electricity Auctions," *Rand Journal of Economics* (2006).

[10] Submission of bids can in fact be done by any entity in or out of the electric power sector that registers with the New York ISO and satisfies certain credit requirements (see Attachment K of the NY ISO Market Services Tariff, http://www.nyiso.com/public/webdocs/documents/tariffs/market_services/ms_attachments/att_k.pdf). Thus, they may include merchant generation companies, electricity-related companies from outside New York, non-electric power companies, and financial companies such as hedge funds and others interested in energy trading. The latter are engaged in what is generally termed "virtual bidding," in that they control no physical assets. Other than these credit requirements, the only requirements submitting bids are in the New York ISO Market Services Tariff (http://www.nyiso.com/public/webdocs/documents/tariffs/market_services/services_tariff.pdf) and Attachment D regarding data requirements (http://www.nyiso.com/public/webdocs/documents/tariffs/market_services/ms_attachments/att_d.pdf). Neither states that submission of bids must be done by the generation owner. For example, p. 75 of the Market Services Tariff states: "Customers shall inform the ISO, in accordance with the ISO Procedures, of the Availability of Generators within the NYCA subject to a Customer's control by *Energy contract, ownership or otherwise*." (Emphasis added.) In Attachment D, Data Requirements for LBMP Bidders, Table 19.1 states that: "Multiple organizations can be authorized to submit Bids with the ISO accepting the most recent."

Crucially, such contractual arrangements are not subject to any minimum duration requirements. The result is that a bidder for a single unit at the present time may in fact have had control over other generators in the recent past and thereby be privy to all the operating and financial information that contractual control (or ownership) conveys. The bidder thus submits bids for its current portfolio of generators with knowledge of the costs of some rival generators–information that is not available to firms in truly competitive markets.[11]

This issue can be illustrated with a simple two-period model. A single registered bidder may have generators j= 1,.. n under contract at time t = 1, and then switch to generators j = n+1, ...m at time t = 2.[12] As a result, that bidder's bidding strategy for generators j=n+1,...m in period 2 is informed by its knowledge of the costs and operating characteristics of generating units j = 1,...n from the previous period. Moreover, over additional periods, the bidder may acquire information about more rivals' costs by continuing to change its portfolio of generation units.

While the information revealed by this sequence of contracts is not exactly contemporaneous, it remains valuable to the bidder for two reasons: First, there is substantial persistence over time in the costs and other relevant characteristics of the generation units that the bidder previously controlled. As a result, the value of information about those generation units is not likely to diminish very rapidly. Secondly, the contract periods may in fact be quite short so that any single bidder may acquire nearly contemporaneous information about a considerable number of rival generators. Indeed, by bidding in their supply even briefly, the

[11] Apparently independent bidders may have other channels of communication. Some, for example, may be employed by the same company and share information about generators.

[12] In this stylized example all generating units are assumed to be of equal size. Note that a bidder may also have other wholly owned generators, but changing ownership is more expensive and less likely than changing contractual arrangements. Obviously, too, the bidder need not change all of its contracts in each time period.

bidder acquires competitively useful information for potentially many subsequent periods in which it bids its new portfolio of generation units.[13]

The extent of this “churn” in contractual arrangements and its implications for the stock of information are made clear from the summary statistics for the New York ISO in Table 1. The data set consists of information on all bidders, generation units, and offer schedules for each hour in calendar years 2006, 2007, and 2008–a total of 26,304 hours. As described in this table, there were 348 different generation units and 199 bidders in the market in the single year 2008, which was typical of all three years. On average approximately 300 of these generation units and 65 bidders were present in any hour. While the number of generation units per bidder averaged 4.7, this varied from a single generation unit to nearly 60.

With respect to generation units, about one-third of the total number--107, to be exact–were each controlled by a single bidder throughout the year 2008. Only 28 units were controlled by a single bidder throughout the three year period. It is reasonable to suppose that most of these involved ownership of a single generation unit by a particular bidder, although nondisclosure of information by the New York ISO makes it impossible to determine the exact nature of any relationship. The remaining two-thirds of the total units were bid into the market by more than a single bidder during each year. The number of different bidders controlling any single generation unit during a year averaged about five, although this varied from one to as many as 16.

[13] Exactly how short the contract periods may be was made clear from personal conversation with an employee of a major energy trading company: “In NY it is quite likely that a marketer has the ability to bid a unit into the market, and they may have an arrangement with the owner that they can bid in that unit during, say, on-peak hours. So, that unit might get bid in by the owner from midnight to 6am, by the marketer for the next 16 hours, and then by the gen owner again at night on any given weekday.” (Personal conversation, December 1, 2009)

**Table 1**
**Summary Statistics of New York ISO Day-Ahead Market Participation**

| Characteristic | New York ISO 2006 | 2007 | 2008 | Over Three Years |
|---|---|---|---|---|
| Bidders (Total) | 211 | 202 | 199 | 332 |
| Bidders / Hour (Mean) | 65 | 65 | 63 | 64 |
| Generation Units (Total) | 345 | 349 | 348 | 362 |
| Generation Units / Hour (Mean) | 304 | 301 | 303 | 303 |
| Generation Units / Bidder (Hour) | | | | |
| Mean | 4.66 | 4.63 | 4.82 | 4.70 |
| Minimum | 1 | 1 | 1 | 1 |
| Maximum | 58 | 57 | 57 | 58 |
| Bidders / Generationr Unit (Total) | | | | |
| Mean | 6 | 5 | 5 | 7 |
| Minimum | 1 | 1 | 1 | 1 |
| Maximum | 16 | 15 | 15 | 22 |
| Generation Units with a Single Bidder (Total) | 35 | 107 | 107 | 28 |

The operating rules of other RTOs have also been investigated to determine whether they allow for similar short-term exchanges of control and whether the available data on bids in other RTO markets allow for an analysis of the extent of this practice. Nothing that was found in the rules elsewhere appears to prevent such short-term exchanges of control[14], but only the New York ISO appears to provide data that are disaggregated by bidder, as is necessary to conduct this analysis. ISO New England by contrast, reports the data at a different and higher level of

[14] For example, the PJM Operating Agreement contains several references to ownership *or control* of a resource, e.g, Section 1.9.4; http://www.pjm.com/documents/agreements/~/media/documents/agreements/oa.ashx. In addition, the ISO New England Tariff states that the Lead Participant may arrange a "bilateral agreement for the sale or *control* of energy, capacity, or ancillary services from the Resource…" (emphasis added); http://www.iso-ne.com/regulatory/tariff/sect_1/section_1.pdf

aggregation-- specifically, at the level of the so-called "Lead Participant"--but does not disclose whether the Lead Participant is contracting with a different bidder for control of the generating unit. PJM data only include codes for generation units while MISO contains owner and unit codes but not bidders. Bid data from the CA ISO and SPP could not be located on their web sites. As a result, examination of the effect of these bidding rules on pricing outcomes is not possible in other RTOs.

## 4. THE DATA AND MODEL

The statistical work conducted in this report focuses on bidders with marginal generation units, that is, with units that are, or are likely to be, the marginal units bid into the auction market in each period. Theory implies that if such a marginal bidder somehow obtains information about its rivals' costs, the first bidder will likely find it profitable to raise the bid price at which it offers its quantity into the market. While in the present case there is no way to know what a bidder actually learns about its rivals, it is possible to identify and measure the opportunities that a bidder has to gain such information. Those opportunities derive from each bidder's recent (but expired) contracts with generation units that are currently bid into the auction market by its rivals. Each past contractual arrangement potentially provides insights into costs and other information about what are now the bidder's directly competing rivals.

Two different measures of access to information are employed. The first is a simple count of the number of different generation units with which the bidder had contractual arrangements during the preceding six months (other than those that are currently under its control).[15] Since in

[15] Examination of alternative three months and twelve month periods made little difference in the results.

practice those generation units are of different size, control of larger units conveys information about a larger fraction of competing output. Accordingly, a second measure of information is calculated as the total capacity of those recently-controlled generation units. As will be seen, these two measures are highly correlated (r = .95), so that there is little practical difference between them.

The data used in this analysis are extracted from those compiled by and available on the website of the New York ISO. Although the ISO does not disclose the names of generation units or bidders, it does identify each with a unique ID number. These IDs remain unchanged over time, thus permitting determination of the history of contractual or ownership control and of bidding behavior. The data in this study cover the three calendar years 2006, 2007, and 2008.

For present purposes, these data need considerable processing. To begin, the generation units controlled by each bidder in each hour must be identified and linked to that bidder by hour. Once this is done, the number of generation units controlled by each bidder during the six months preceding each hour of this three-year period must be calculated. The result of this exercise yields the first of the two information variables, labeled the Number of Prior Generation Units. The ISO data set also includes information about the bid quantities and capacity of each generation unit. Aggregating these magnitudes for the generation units controlled by each bidder for each hour during the preceding six months produces the second information variable, denoted the Size of Prior Generation Units.

The focus of this research, of course, is on the effect of the revealed information about rivals' costs on the incentives of a potential marginal bidder to raise its bid price. In order to test for this effect, it is necessary to determine which generation unit is or is likely to be the marginal unit in the market and which bidder controls that unit. This is accomplished by constructing all bidders' hourly offer curves and then defining each bidder's marginal unit as the last unit offered at a price at or just below market-clearing price. Since the analysis only applies to those bidders whose pricing decisions are likely to affect market price determination, only a small percentage of all bidders are of interest, specifically, those that are price-determining or are close to being price-determining. Three alternative data sets are used to capture these various sets of relevant bidders.

The first data set consists of only the actual marginal bidders for each hour, i.e., those bidders whose marginal units were in fact bid at a price equal to or close to the market-clearing price. The bid prices on these marginal generating units for each of the 26,000 hours comprise the first data set.[16] The second and third data sets reflect the fact that the bidding strategy described in the theory applies to any bidders who ex ante expected that they might be marginal, not just those that ex post were in fact marginal. Accordingly, these data sets consist of marginal bids in each hour for all bidders whose marginal bids lie within 1 percent and then within 3 percent of the market-clearing price.[17]

The statistical analysis focuses on the effect of such information revelation on the market Marginal Bid Price. The specific question is whether those bidders with greater information, as measured by the number or size of previously controlled generation units, bid their current capacity into the market at a higher price, holding other relevant factors equal. The other relevant

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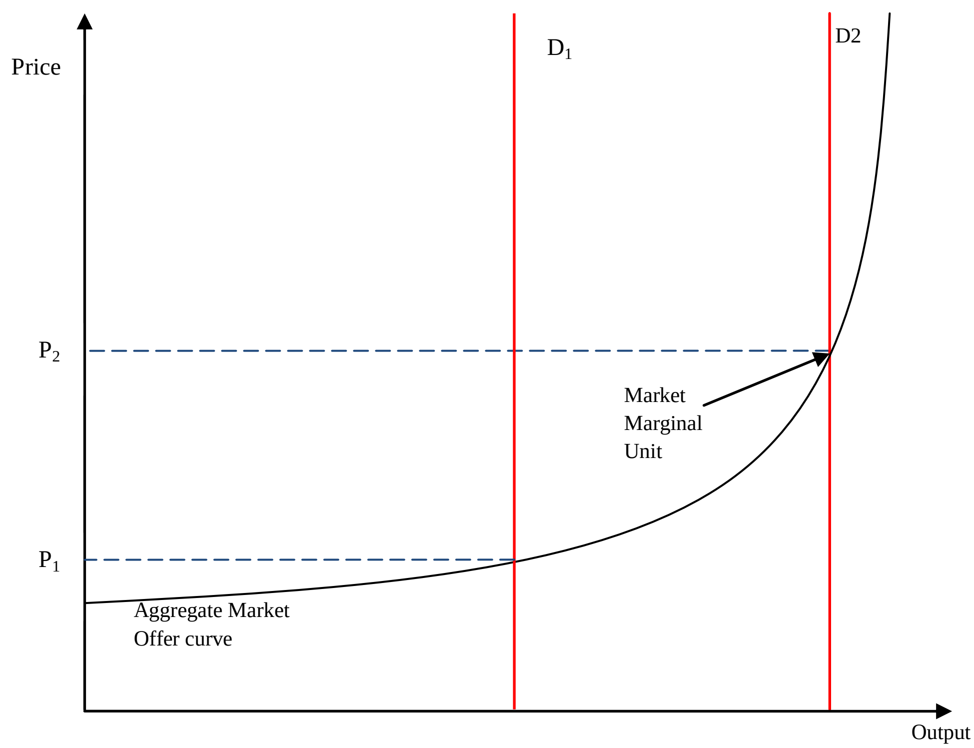
[16] This price applies to the entire marginal block of the marginal bidder, of course. Moreover, for some number of hours, two or more bidders may have submitted the same marginal bid, all of whom are therefore treated as marginal.

[17]The alternatives of 5 percent and 10 percent are also examined. Results are broadly consistent.

factors are identified from economic theory and other considerations as factors likely to impact price. They are (a) market load forecast, (b) the bidder's inframarginal bid quantity, and (c) its inframarginal rents, as will now be explained.

Load forecast is relevant since the greater the anticipated market demand, the greater the opportunity for strategic bidding by any single bidder. As shown in Figure 3, when market demand is low ($D_1$), equilibrium price will likely fall along the horizontal portion of the market supply curve, reducing or eliminating the ability to alter that price. Load forecast data for each hour is common knowledge to all bidders, is available from the New York ISO website, and a higher load forecast should be positively related to the market price.

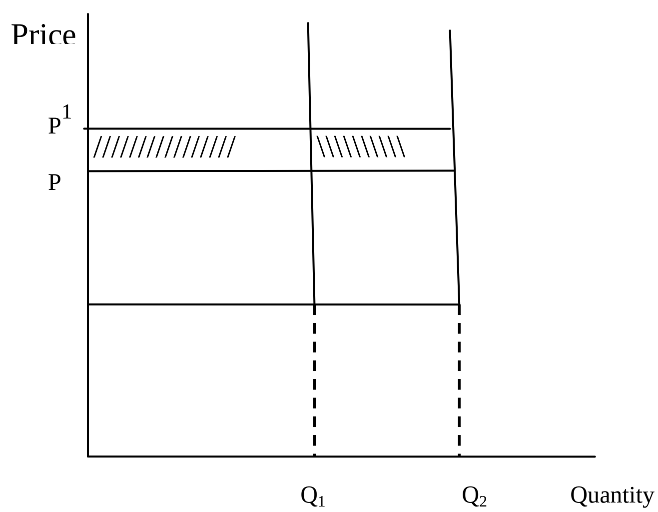
**FIGURE 3**
**Price Implications of Low Demand vs. High Demand Conditions**



Inframarginal bid quantity (or the amount of power offered at prices expected to be below the clearing price) measures a bidder's incentive to raise its bid price, since a greater quantity of inframarginal power gains correspondingly more on its inframarginal units from a higher market-clearing price. This is shown in Figure 4, which contrasts two bidders with identical unit costs up to capacity, but as their respective capacities, represented by the lines $Q_1$ and $Q_2$ differ, so will the amount of incremental profit they can realize from an increase in price from P to $P_1$.

**FIGURE 4**

**Value of Higher Price for Small vs. Large Bidders**




Finally, there is a need to represent the harm to a bidder from bidding its marginal unit so high that it risks not being called upon to supply power at all. This harm is related to the magnitude of the bidder's inframarginal generation capacity and the cost of that capacity relative to the cost of the marginal unit. The reason is as follows: a bidder with a great deal of low-cost inframarginal capacity has strong incentive to ensure that such capacity is dispatched, since the large quantity and the large margin together produce considerable inframarginal rents. The bidder can ensure that outcome simply by bidding that capacity at its (low) marginal cost, but it can bid its marginal unit as aggressively as it wants without jeopardizing dispatch of its inframarginal units.

By contrast, a bidder with relatively constant costs at the level of its marginal unit has small inframarginal rents (as illustrated in Figure 5) and hence must bid its units more cautiously in order to ensure that any of them are in fact dispatched. In particular, bidding above marginal cost runs the risk that not only the marginal unit, but all others at the same unit cost, may not be called upon. For these reasons, the harm to the bidder is related to the amount of low cost inframarginal output. Capacity data are available but data on costs are not. As a proxy for the latter, inframarginal bid prices are used. Aggregating the differences between the clearing price and bid prices across all inframarginal units yields the necessary aggregate value to the bidder, known in economics as “inframarginal rents.” Greater rents should be associated with greater bid prices on marginal units.

**FIGURE 5**

**Harm to Bidder from Over-pricing Marginal Unit,**
**Low vs. High Costs of Inframarginal Output**

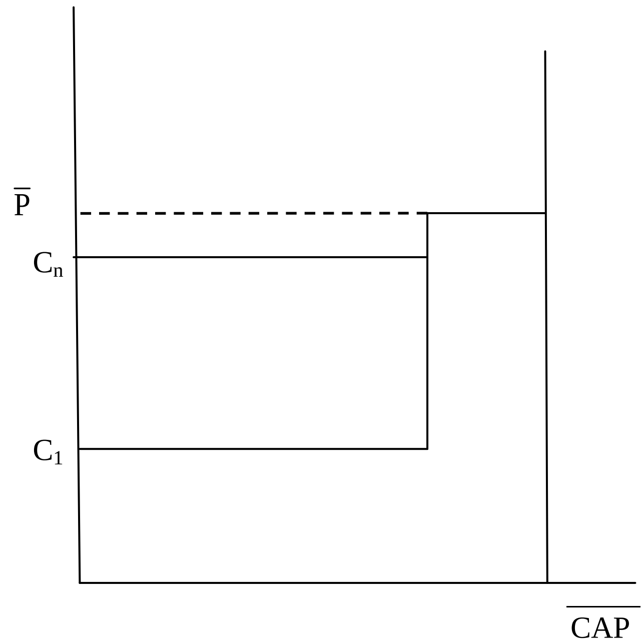



Table 2 provides summary statistics on these data sets and variables. The number of observations on the top single bidder data set is 23,436, a number that doubles and then doubles again for the 1 percent and 3 percent data sets, respectively. Marginal bid prices average between \$60 and \$70 per mwh, ranging to more than \$190 per mwh in peak hours. Regarding the crucial information variables, the number of different generation units under each bidder's control in the preceding 6 months averages between 12 and 20, but ranges from zero (that is, none other than currently controlled generation units) to 65. With these data sets, the hypotheses can now be tested.

**Table 2**
**Summary Statistics for the Three Data Sets Used in the Analysis**

| Market Characteristic | Top Bidder | Top 1% | Top 3% |
|---|---|---|---|
| Number of Observations | 23,436 | 48,312 | 103,475 |
| Marginal Bid Price | | | |
| Mean | 61.21 | 69.23 | 68.61 |
| Minimum | 5 | 10 | 5 |
| Maximum | 191.19 | 191.19 | 191.19 |
| Number of Prior Generation Units | | | |
| Mean | 12 | 20 | 17 |
| Minimum | 0 | 0 | 0 |
| Maximum | 65 | 65 | 65 |
| Total Size of Prior Generation Units | | | |
| Mean | 829 | 1,331 | 1,180 |
| Minimum | 0 | 0 | 0 |
| Maximum | 5,158 | 5,170 | 5,170 |

## 5. ESTIMATION RESULTS

Based on the above, the following empirical model is estimated:

*Marginal Bid Price =*

$\beta_1$ · *Number or size of previously controlled generating units +*

$\beta_2$ · *Load forecast +*

$\beta_3$ · *Total inframarginal quantity +*

$\beta_4$ · *Total inframarginal rents +*

*Constant term*

Details of the econometrics are discussed in Appendix B and the results of the estimations are presented in Table 3.

The first two columns of Table 3 are based on the data set of unique marginal bidders in each hour, followed in turn by the data sets of the top 1 percent of bidders and then the top 3 percent of bidders. As previously noted, the rationale for these more inclusive data sets is that the bidding behavior described in the theory should apply to all bidders who, ex ante, expect that their bid price might be marginal. Taking the top 1 percent and then the top 3 percent of bidders should include most of those other bidders whose behavior might have been influenced by the prospect of being marginal. In each pair of regressions on the three data sets, the extent of exposure to rivals' costs and other information is measured first by the number of previously controlled generation units and then by their collective capacity (size). In all regressions, control variables for the other factors discussed above are also included.

**Table 3**
**Results of Statistical Analysis of Marginal Bid Price**

| | Top Bidders | | Top 1% | | Top 3% | |
|---|---|---|---|---|---|---|
| | (a) | (b) | (c) | (d) | (e) | (f) |
| Number of Prior Contacts | 0.285*** | - | 0.400*** | - | 0.352*** | - |
| Prior Capacity ($10^3$) | - | 4.915*** | - | 6.931*** | - | 6.651*** |
| Load Forecast ($10^3$) | 3.217*** | 3.213*** | 2.835*** | 2.862*** | 2.847*** | 2.859*** |
| Bid Quantity ($10^3$) | -1.318*** | - 1.134*** | -1.627*** | -1.283*** | -1.887*** | -1.535*** |
| Inframarginal Rents ($10^3$) | .104*** | .106*** | .104*** | .105*** | .108*** | .109*** |
| Number of Observations | 23,436 | 23,436 | 48,312 | 48,312 | 103,475 | 103,475 |
| Adjusted $R^2$ | .57 | .58 | .44 | .45 | .46 | .45 |

Statistical significance of estimates:
*** - coefficient significant at 1% level
** - coefficient significant at 5% level,
* - coefficient significant at 10% level

With respect to the information variables, the results are quite clear: In all data sets and models, a larger number – or size – of previously controlled generation units is associated with a significantly higher bid price. Without exception the estimates of these effects are statistically highly significant. This is true for the 1 percent and 3 percent bidder data set as well as for the top bidders only. It is true when contact is measured by the size of previously controlled units as well as for their number. Access to cost and other information about rivals appears clearly to alter bidding behavior.

The estimated magnitude of the effect is nontrivial in size. Each previous exposure to an additional generation unit is associated with an increase in bid price in the range of $.29 mwh to $.40 per mwh.[18] Relative to mean market price of $61.08, this constitutes a 0.5 percent to 0.7 percent price distortion per exposure. Since the mean number of such exposures is 12, this implies a typical price distortion of about 6.0 percent to 8.4 percent, which is a very substantial effect.

The control variables generally have the expected signs and are highly significant. Load Forecast behaves very much as anticipated, with higher bid prices when demand is expected to be high. As described further in Appendix B, including either the variable Bid Quantity or the variable Inframarginal Rents results in the expected positive and significant sign, indicating higher prices for bidders with greater inframarginal output and with more lower-cost output, as suggested by theory. With both variables in the model simultaneously, however, collinearity

[18] The other measure of exposure–capacity of previously controlled units–does not lend itself so easily to a calculation of effect on bid price. Recall, however, that capacity and numbers were highly correlated.

between the two (r = .83) reverses the sign on the output variable. For reasons detailed in Appendix B, regression results with both variables are nonetheless reported.

The effects of prior contacts with rival generation units can be further illuminated by examining a small number of bidders with the highest variation over time in the number of previously controlled generators. Specifically, fifteen bidders with the highest variation in their yearly number of previously controlled generation units are identified–that is, those that in one period of time have few previously controlled generation units while at other times very many. If sound, the theory should show that these bidders alter their bidding behavior over time as their contact with and information from rival generation units changes over time.

Table 4 reports the results of estimating the same model as before on these high-variation bidders. As can be seen, the effect of previous control over a larger number of generation units remains positive and statistically significant, and indeed, larger in magnitude than in the baseline results in Table 4. Clearly, high-variation bidders do bid higher in periods when they have greater information about their rivals, but temper their bids at other times.

While there may be other explanations for this statistical result,[19] the evidence certainly bears out the hypothesis that top bidders, together with others with reason to think their marginal price bids might determine market price, bid differently as a result of greater contact with rival generation units and greater access to information about those rivals' costs.

[19] There may be other channels of communication between firms (e.g., footnote 11 observed that two or more bidders may belong to the same organization, something that cannot be identified here), or the group of bidders that control many generators over time are fundamentally different players than those that do not (yet the present results hold for both groups).

**Table 4**
**Analysis of Bidders with High Variation in the Number of Controlled Generators from Year to Year**

| | (a)<br>Top Single Bidder | (b)<br>Bidder Within 1% | (c)<br>Bidder Within 3% |
|---|---|---|---|
| Number of Prior Contacts | .759*** | .984*** | .780*** |
| Load Forecast ($10^3$) | 3.591*** | 3.030*** | 3.025*** |
| Bid Quantity ($10^3$) | -1.483*** | -1.197 | -1.345*** |
| Inframarginal Rents ($10^3$) | .159*** | .151*** | .143*** |
| Constant | -13.167*** | -.957 | -.326 |
| Number of Observations | 1,858 | 4,696 | 9,680 |
| Adjusted $R^2$ | .54 | .44 | .45 |

Statistical significance of estimates:
*** - coefficient significant at 1% level
** - coefficient significant at 5% level,
* - coefficient significant at 10% level

## 6. CONCLUSIONS

Antitrust standards for price fixing ordinarily prohibit direct competitors from sharing information about their respective costs or other aspects of their operation. The reason for such prohibitions on information sharing is straightforward–information about a rival's costs assists each competitor in its pricing decision, since a rival's costs sets a limit on that rival's ability to bid low. Economics therefore predicts that exchange of such information between important direct competitors will result in higher bids and a higher market price.

Rules that afford bidders in electricity auction markets the opportunity to learn about their rivals' costs and other characteristics of their recent operations serve as a substitute for direct information exchange between rivals. This Report has investigated those practices in the New York ISO. In particular, it has examined whether, and the extent to which, access to such information in fact results in bid price distortion.

The statistical evidence presented in this Report indicates that bidders that are or expect to be "marginal in the market"— that is, the last dispatched unit, and hence determinative of the uniform market price — indeed do bid more aggressively when they have greater information about rivals. The effect is both statistically significant and also sizeable in practice. It underscores concerns about auction markets that create such channels of information between rival suppliers, and thereby compromise their competitiveness.

This research covers only the New York ISO. It is not known whether this cross-control occurs to the same extent in other RTOs and ISOs since the data necessary to document and examine this important question are not disclosed. The existence and effects of this practice in the NY ISO, however, demonstrate the need for such disclosure and examination of practices in the remaining RTOs.

# APPENDIX A

A stylized model of bidding behavior demonstrates the role information about rivals' costs, as well as other factors, in this strategy choice.[20] Exactly two bidders, A and B, are assumed, each with exactly one unit to be bid into the auction but only one is required. Whichever unit is dispatched will be market-marginal and hence price determinative. Further, suppose constant marginal costs for each unit, denoted by $c_a$ and $c_b$, with B's marginal costs higher:

$$c_b = c_a + \delta, \quad \delta \geq 0 \tag{1}$$

If $\delta$ is strictly positive and bidder A knows its value with certainty, obviously A will bid its unit into the auction at a price just short of $c_b$, thereby setting market price at $c_b$ and earning profits of

$$\pi_1^c = c_b - c_a = \delta \tag{2}$$

This case can be generalized by supposing that A has multiple generating units. Its marginal unit—the Nth--again has costs given by $c_a$, but its other (N – 1) units have lower but identical costs $c_0 < c_a$ and play no role in market price determination. As before, A's last unit may be market-marginal, but now A's inframarginal units represent additional sources of profit (i.e., rents). The same strategy of bidding up to B's known and higher costs $c_b$ now yields total profit to A in the amount

[20] This model borrows from those of Kuhn and Vives and of Wolfram, although neither of those directly captures the present issues.

$$\pi_N^C = \delta + (N - 1)\cdot(c_a + \delta - c_0) \quad (3)$$

This exceeds the previously calculated amount since by elevating the uniform price A earns rents profit o on all its other units as well.

Next this certainty outcome can be contrasted with the profits that bidder A can expect from bidding its marginal unit into the auction at $c_a$ plus some increment $\theta$, but now without knowledge of B's actual costs. Assume with probability $p$ that $\delta > \theta$, so that B's costs are in fact higher than A's bid price $(c_a + \theta)$. In this case A will earn

$$\theta + (N - 1)\cdot(c_a + \theta - c_0) \quad (4)$$

This expression is similar to that from bidding with certainty, and would be identical if A's chosen $\theta$ happened to exactly equal the cost difference $\delta$. Otherwise, A's profits fall short of their maximum possible value, as obtained under certainty.

Moreover, with probability $(1 - p)$, $\delta < \theta$ so that B's cost on its marginal unit is actually less than A's marginal bid of $(c_a + \theta)$. In this case bidder A's marginal unit is not dispatched, but A does collect profits on all its $(N - 1)$ inframarginal units, since they have costs $c_0$ that are exceeded by the eventual market-clearing price $c_b$. A's total profit now becomes

$$(N - 1)\cdot(c_b - c_0) \quad (5a)$$

which by virtue of equation (1) can be written

$$(N - 1) \cdot (c_a + \delta - c_0) \quad (5b)$$

Overall, then, under uncertainty bidder A's expected profit is given by

$$E(\pi_N^U) = p\cdot [\theta + (N - 1)\cdot(c_a + \theta - c_0)] + (1-p)\cdot [(N - 1)\cdot( c_a + \delta - c_0)] \quad (6)$$

Simplification of this expression provides further insight into the determining factors for a bidder to raise its marginal bid price with the expectation of increasing its profit. Specifically, simplification yields the following condition:

$$E(\pi_N^U) = (N - 1) \cdot (c_a - c_0) + \delta \cdot (N - 1) \cdot (1 - p) + p \cdot \theta \cdot N \quad (7)$$

The determining factors are therefore seen to be the number of inframarginal units, the rents associated with those units, cost difference between the bidders' marginal units, and the likelihood of excessive bidding by A.

Further generalizations of this model are possible to reflect cost differences among bidder A's inframarginal units, size differences among bidder A's generating units, and multiple units for bidder B. The essential results from the present model are preserved.

# APPENDIX B

The data set created and employed in the statistical analysis conducted in this report is panel data, that is, a combination of so-called cross-section data on many bidders, but also time series on each (that is, over many hours). The estimation proceeds with econometric techniques appropriate to this structure for the data. In addition, the model employs fixed effects rather than random effects, based on the results of a Hausman test indicating greater efficiency from the former. A test for heteroskedasticity implies the need for Huber-White estimates of standard errors. All standard errors reflect such corrections, although differences from uncorrected values are only modest. Finally, all models have been run both in linear and in log forms, with somewhat better fits (but otherwise similar results) from the linear form.

Text tables 3 and 4 indicate statistical significance of the coefficient estimates at the 1 percent, 5 percent, or 10 percent levels by use of one or more asterisks. Here we report the same regression models and coefficient estimates, but with the actual t-statistics based on Huber-White corrected standard errors. Table B.1 matches text Table 3, while Table B.2 mirrors text Table 4.

As noted in the text, two of the control variables--Bid Quantity and Inframarginal Rents--are statistically highly correlated, with a simple correlation coefficient r = 0.83. As is common for highly correlated variables, including both in the same regression leads to erratic coefficient estimates and incorrectly estimated statistical significance.  Their separate importance can nonetheless be established by estimating the basic regression model with each of the variables by itself.

**Table B.1**
**Results of Statistical Analysis of Marginal Bid Price**

| | Top Bidders | | Top 1% | | Top 3% | |
|---|---|---|---|---|---|---|
| | (a) | (b) | (c) | (d) | (e) | (f) |
| Number of Prior Contacts | 0.285*** | - | 0.400*** | - | 0.352*** | - |
| | (5.63) | | (9.99) | | (13.19) | |
| Total Previous Capacity ($10^3$) | - | 4.915*** | - | 6.931*** | - | 6.651*** |
| | | (14.12) | | (24.68) | | (34.52) |
| Load Forecast ($10^3$) | 3.217*** | 3.213*** | 2.835*** | 2.862*** | 2.847*** | 2.859*** |
| | (77.47) | (78.77) | (106.08) | (107.76) | (156.36) | (158.81) |
| Bid Quantity ($10^3$) | -1.318*** | -1.134*** | -1.627*** | -1.283*** | -1.887*** | -1.535*** |
| | (11.25) | (9.84) | (17.85) | (14.31) | (30.04) | (24.83) |
| Inframarginal Rents ($10^3$) | .104*** | .106*** | .104*** | .105*** | .108*** | .109*** |
| | (19.74) | (9.74) | (28.45) | (27.96) | (44.88) | (44.07) |
| Number of Observations | 23,436 | 23,436 | 48,312 | 48,312 | 103,475 | 103,475 |
| F | 2,574 | 2,612 | 4,382 | 4,475 | 10,001 | 10,189 |
| Adjusted $R^2$ | .57 | .58 | .44 | .45 | .46 | .45 |

T-statistics are given in the parentheses:
*** - coefficient significant at 1% level
** - coefficient significant at 5% level,
* - coefficient significant at 10% level

**Table B.2**
**Analysis of Bidders with High Variation in the Number of Controlled Generators from Year to Year**

| | (a) Top Single Bidder | (b) Bidder Within 1% | (c) Bidder Within 3% |
|---|---|---|---|
| Number of Prior Contacts | .759*** | .984*** | .780*** |
| | (6.19) | (11.24) | (13.51) |
| Load Forecast ($10^3$) | 3.591*** | 3.030*** | 3.025*** |
| | (25.69) | (35.71) | (51.68) |
| Bid Quantity ($10^3$) | -1.483*** | -1.197 | -1.345*** |
| | (2.96) | (3.53) | (5.81) |
| Inframarginal Rents ($10^3$) | .159*** | .151*** | .143*** |
| | (8.56) | (12.27) | (18.84) |
| Constant | -13.167*** | -.957 | -.326 |
| | (5.41) | (.62) | (.30) |
| Number of Observations | 1,858 | 4,696 | 9,680 |
| F | 309.0 | 650.3 | 1,229.0 |
| Adjusted $R^2$ | .54 | .44 | .45 |

t-statistics are given in the parentheses:
*** - coefficient significant at 1% level
** - coefficient significant at 5% level,
* - coefficient significant at 10% level

In Table B.3, successive pairs of columns report results for top bidders, top 1 percent of bidders, and top 3 percent of bidders, much as was done in text Table 4. Within each pair of regressions, the first shows the results with only Bid Quantity, followed by the same model with only Inframarginal Rents. Note that these results focus on the models with Number of Prior Contacts, although entirely equivalent results are obtained using Size of Prior Contacts.

**Table B.3**
**Alternative Specifications of Regression Model Explaining Marginal Bid Price**

| | Top Bidder | | Top 1% | | Top 3% | |
|---|---|---|---|---|---|---|
| | (a) | (b) | (c) | (d) | (e) | (f) |
| Number of Prior Contacts | .226*** | .294*** | .365*** | .415*** | .311*** | .364** |
| | (4.40) | (5.58) | (8.91) | (10.04) | (11.19) | (13.02) |
| Load Forecast ($10^3$) | 3.500*** | 3.177*** | 3.031*** | 2.794*** | 3.068*** | 2.805*** |
| | (83.75) | (76.94) | (110.99) | (105.23) | (164.82) | (155.33) |
| Bid Quantity ($10^3$) | 1.167*** | | 1.135*** | | 1.160*** | |
| | (18.70) | | (23.01) | | (34.14) | |
| Inframarginal Rents ($10^3$) | | .077*** | | .072*** | | .072*** |
| | | (26.28) | | (38.57) | | (58.46) |
| Constant | -8.469** | -3.992*** | -1.132 | 1.819* | -.480*** | 2.928*** |
| | (8.50) | (4.10) | (1.16) | (1.90) | (11.19) | (4.92) |
| Number of Observations | 23,436 | 23,436 | 48,312 | 48,312 | 103,475 | 103,475 |
| F | 2911 | 3350 | 5006 | 5826 | 11,328 | 13,210 |
| Adjusted $R^2$ | .42 | .42 | .24 | .24 | .26 | .26 |

t-statistics are given in the parentheses:

*** - coefficient significant at 1% level

** - coefficient significant at 5% level,

* - coefficient significant at 10% level

As is evident, all the results either with the Bid Quantity or with Inframarginal Rents separately have the expected signs on the variable, in each instance with a high degree of statistical significance. This makes clear that each of these variables is related to bid price much as theory predicts, and significantly so, and that the anomalous sign on Bid Quantity in Table 4 when both are included is indeed the result of collinearity. It should also be noted in Table B.3 that the estimated coefficient on the Number of Prior Contacts is positive and significant throughout. Its magnitude lies in the range of the estimates reported in Table 4 in both specifications–that with Bid Quantity and that with Inframarginal Rents.

Faced with such collinearity between these two variables, the research might report results including just one of them, or including both. The latter approach has been adopted in the text regressions in order to ensure that all other possible factors are fully controlled for. Moreover, since neither of these two variables is of key interest and neither affects the magnitude or significance of those that are key, reporting results in this manner does not affect the major conclusions of this report.