# Characterization, Determinants and Efficiency of Strategic Bidding in Multi-unit Auctions: Evidence from Electricity Markets

Ezgi Avci
Rotterdam School of Management, Erasmus University, The Netherlands

## Overview

Auctions play a critical role in the modern society: governments use auctions to sell treasury bills and many other assets; firms use auctions to buy services and raw materials; individuals also participate in auctions of various consumer products such as antiques, cars (Klemperer, 1999, Hortacsu, 2011). With advancements in information technologies, online auction markets have been introduced (Kambil and van Heck, 2002) providing the necessary institutional framework to facilitate online trading (Bakos 1998). Despite the great promise they hold, online auctions also pose many new challenges since in the traditional auction theory literature, bidders are assumed to be homogeneous and therefore they adopt the game theory perspective and apply Bayesian-Nash equilibrium approaches to find optimal solutions (McAfee and McMillan, 1987; Milgrom, 1989; Myerson, 1981). However, as the number of online auctions increase, availability of bidder-level data has made all these traditional assumptions questionable (e.g. Ariely and Simonson, 2003; Bajari and Hortacsu 2004); revealed the existence of significant heterogeneity in bidders' strategies (e.g. Kauffman and Wood, 2006; Hortacsu and Puller, 2008; Bapna et al., 2004,2009; Goes et al., 2010, 2012; Lu et al., 2016) leading to different economic consequences; raised the need for more complex stylization of supply function equilibrium models and given rise to theory-driven empirical work on auctions (Hortacsu, 2011).

Further, this electronic trading environment has arisen complex big trading-data sets including millions of transactions at bidder-level which brings challenges particularly for the Auctioneers/scholars targeting profiling traders and understanding intent/determinants of observed trading behaviour/strategy. Thus research investigating bidders' motivation in adopting these strategies has started to increase and raise the most fundamental and interesting research question about the gap in the traditional auction theory; Why professional (real-life) bidders give their orders as they do? In other words, What are the determinants of this heterogeneous conduct within bidders? (Engelbrecht-Wiggans 2000). From the auctioneer's perspective; What are the economic consequences (surplus) of these heterogeneous strategies? and Which of these strategies (can) lead to market distortions? From the beginning of 2000s, IS and economics scholars have been attempting to answer these questions for different auction contexts.

Previous empirical research on investigating the heterogeneity in bidding behaviour has focused on B2C, B2B and internet auctions where bidding activities are mainly determined by willingness to pay and bidders are only allowed to submit single prices rather than a bid function. In this study we draw upon a very interesting auction context, Electricity Day Ahead (EDA) Auctions, due to unique characteristics of electricity. The characteristics of the product and the technology used to produce it make EDA extremely susceptible to the exercise of unilateral market power. The real-time demand for electricity is close to perfectly price inelastic. For bidders that own a substantial fraction of the offer capacity in the auction, the combination of this inelastic demand with a limited supply response from competitors causes these EDA bidders to face steep residual demand curves. In an oligopolistic industry, the more inelastic the residual demand curve a firm faces, the greater is its unilateral ability to withhold output to raise market prices through higher offer prices or less output made available at the same offer price. The susceptibility of EDA to the exercise of unilateral market power makes them an ideal environment in which to study the determinants of oligopolistic bidder behavior and outcomes. Moreover demand-inelastic setting of EDA auctions introduce the importance of willingness to sell for strategy formation besides willingness to pay. Further being a multi-unit auction allows participants partially fulfil their orders, for accepted orders that are below the market clearing price. Thus each bid is not an `all-or-nothing' proposition, but rather will have portions that are accepted and rejected. Therefore almost all equilibriums in a multi-unit auction contain some strategic bidding (Wang and Zender, 2002). In addition, being uniform-price arises the incentive to bid `untruthfully' by overstating marginal costs (Wilson, 1979; Ausubel and Cramton, 2002). Last but not least, in electricity wholesale markets, most of the electricity is traded through bilateral forward contracts between producers and users of electricity. These contract obligations determine the bidders' net buy or net sell positions in the spot market, and therefore affect bidding incentives (Hortacsu and Puller, 2008). An additional advantage of studying EDA is the fact that they produce vast amounts of data each day about the strategies bidders employ to exercise unilateral market power. Each market participant is required to submit its willingness-to-sell and buy electricity for each hour or half-hour of the day for all possible market prices. In addition, the regulated or government owned monopoly history of these auctions implies that there is publicly available data on the technological characteristics (e.g. type, diversity etc.) of bidders (Wolak, 2010). Due to all of these unique properties, characterization of EDA bidders' strategies brings many research questions and challenges.

Our main research questions are as follows: (1) What bidding strategies do bidders adopt in multi-unit uniform-price auction markets? (2) What are the determinants of bidders' choosing these strategies?(3) What is the outcome efficiency of these strategies? (4) How can we leverage these strategies to develop more realistic agent-based models for policy simulation? (5) How can we use our approach of strategic behaviour analysis for enhancing Commodity Market Surveillance?

## Methods/Results

Using a unique and extensive data set from Turkish electricity day-ahead auctions, we address each of these questions through employing a three-stage analysis approach:

In the first stage, we use an inductive, data-driven approach to characterize strategic behaviour. We develop initial constructs before developing our hypotheses. The initial challenge was to identify observable classification variables that could be obtained from our EDA auction dataset. The variables had to have a sound theoretical basis in the auction's price formation process. In addition, we want to work with extrinsic variables that could subsequently be used by the Market Surveillance Committee to monitor the market abuse behaviour. Therefore, we are not interested in measuring intrinsic bidder attributes like risk profile that could not be altered by modifying the mechanism. We introduce five hourly classification variables- number of orders (for both bid and ask), max bid price, minimum ask price, ask price and supply withholding ratio- to characterize bidders' behaviour in double sided multi-unit auctions. Note that the introduction of these hourly classification variables is a novel contribution to the characterization of bidding strategies in multi-unit uniform-price auction markets. Given that bidders participating in EDA auctions differ with respect to their size, forward commitment, generation technology and portfolio diversity; our novel classification variables can help us to better relate the observed bidding behaviour with the business profiles and needs of different bidders. We find five different strategic behaviour, namely- Naïve, Economic Withholders, Physical Withholders, Opportunists, Risk Averse.

The second stage is intended to explain why bidders choose different bidding strategies through using an econometric model. Drawing upon prior literature related to firm behaviour in power markets, we identify four bidder-level factors that are critical to bidders' strategic choices: forward commitment, size, type and diversity. To test our hypotheses, we develop an explanatory model of bidders' strategic choices, using multinomial logistic regression (MNL). We find that bidders with high forward commitment ratios are more likely choose inframarginal strategy over economic-, physical-withholding and opportunist strategies. They are also more likely to choose the risk averse strategy over other strategies. Larger bidders are more likely choose the sophisticated strategy over either a inframarginal or risk averse strategy. They are also more likely choose physical withholding strategy over other strategies. On the other hand small bidders are more likely choose an opportunist strategy. Hydro dam bidders are more likely to choose a physical withholding strategy over other strategies. Canal and wind bidders are more likely to choose either inframarginal or risk-averse strategy over other strategies. Conventional bidders are more likely to choose the opportunist strategy. Portfolio bidders are more likely to choose either inframarginal or risk-averse strategy over other strategies. More diversified bidders are more likely to choose PW, EW and opportunist strategies over inframarginal and risk-averse strategies.

In the last stage, we analyse outcome efficiency and winning likelihood of each strategy. Inframarginal and physical withholders have significantly higher winning proportions than economic withholders, opportunists and forward traders. This result reflects that opportunist and economic withholding strategies have brought less DA market profit to their adapters. Our results show that the inframarginal bidders and forward traders are best at minimizing surplus. However interpretation for forward traders is different from forward traders in terms of surplus, such that; since forward traders do not offer to the spot market, they do not have any spot market-surplus. For the inframarginals since they offer their supply at very low prices, they are able to sell all their supply reserved for the spot market. Next best are physical withholders, followed by economic withholders. On average, opportunists have the largest losses of surplus.

## Conclusions

Our approach for examining strategic bidding in a multiunit uniform-price auction market reveals significant empirical regularities, which lead to our taxonomy of strategies. The taxonomy identifies distinct strategic behaviour in EDA auctions. This result can be viewed as a micro-segmentation of the bidders (Bapna et al. 2004) and is useful in facilitating the auctioneers to optimize the auction process (Bichler et al. 2010). Our findings have important implications for theory and practice.

From the theoretical perspective, the identification of distinctive strategic behaviour in the EDA challenges the conventional view that bidders' strategies will converge as they gain experience from participating in the competition repeatedly. More specifically for the EDA auctions, it challenges the assumptions behind the Bayesian Nash equilibrium models which are rationality and mutual consistency of bidders. Thus it calls for a dynamic view in studying bidding behaviour in a complex auction environments, especially while developing agent-based models.

From the managerial perspective, our results provide useful insights to auctioneers in their Market Monitoring and Surveillance responsibility. The auctioneers in the EDA represent the Energy Exchanges. As such, their main objective is to minimize market clearing price with maximum security of supply. Just looking at the events in the transaction log is not meaningful without looking at the order book and market conditions before and after each event. In other words, identifying emerging patterns and benchmarking them against the norms is the key to discovering the intent behind the trading. Thus, behavioural analysis approaches should be adopted to discover meaningful patterns through searching for bidders that behave unusually or winning in most of the auctions with following aggressive and manipulative strategies.