Electricity markets: Designing auctions where suppliers have uncertain costs

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Overview

We analyze multi-unit auctions where producers submit offers before demand, production capacities and production costs are fully known. Our model accounts for asymmetric information in suppliers' production costs and considers unexpected outages and intermittent output, such as those from renewable energy sources. Our analysis is, for example, of relevance for European wholesale electricity markets, where the European Commission has introduced regulations that increase the market transparency, so that uncertainties and information asymmetries are reduced. According to EU No. 543/2013, the hourly production in every single plant should be published. EU No. 1227/2011 (REMIT) mandates all electricity market participants to disclose insider information, such as scheduled availability of plants. We are interested in how such regulations and the auction format influence the competitiveness of the resulting market outcomes when suppliers face various uncertainties about their competitor's costs and their own output. Our results are also applicable to multi-unit auctions that, for example, trade securities and emission permits.

In electricity markets, marginal cost can be estimated from public engineering data on plant characteristics and input fuel price indexes. Still, a generation unit owner has private information about the actual price paid for its input fuel and how the plant is maintained and operated, which creates cost uncertainty about a firm's competitors. We believe that the cost uncertainty and information asymmetry is greatest in hydro-dominated markets. The opportunity cost of using water stored in the reservoir behind a specific generation unit is typically estimated by solving a stochastic dynamic program based on estimates of the probability distribution of future water inflows and future offer prices of thermal generation units, which can leave significant scope for differences across market participants in their estimates of the generation unit-specific opportunity cost of water. This uncertainty is exacerbated by political risks such as the possibility of regulatory intervention and each producers' subjective beliefs about the probability of these events occurring during the planning period. The influence of these political risks on cost uncertainty are likely to be greatest during extreme system conditions when water is scarce and the probability of regulatory intervention is high.

Methods

We consider a multi-unit auction with two capacity-constrained producers facing an uncertain demand, where offers from both suppliers must be accepted in high demand states. These accepted offers are either paid a uniform or a discriminatory price. In the uniform-price procurement auctions, all accepted offers are paid the clearing price, which is set by the highest accepted offer price. In a discriminatory auction, all accepted offers are paid their own offer price. The uncertain demand is realized after offers have been submitted. Similar to von der Fehr and Harbord (1993), each firm offers its entire production capacity at one unit price in a one shot game. We generalize von der Fehr and Harbord (1993) by introducing uncertain interdependent costs. Analogous to Milgrom and Weber's (1982) auction for single objects, each firm makes its own estimate of production costs based on private imperfect information that it receives, and then makes an offer. As is customary in game theory, we refer to this private information as a private signal. Similar to Milgrom and Weber (1982), we solve for a Bayesian NE and consider signals that are drawn from a bivariate distribution that is known to the suppliers.

There are no welfare losses in our setting, because demand is inelastic, each producer has constant marginal costs and offers its whole capacity at one price. Moreover, producers are symmetric ex-ante and offer prices are increasing with respect to a each supplier's cost signal. Thus our analysis focuses on bidding behaviour and how the auction design and information structure influence the payoff of the auctioneer.

Results

As in von der Fehr and Harbord's (1993) study of the uniform-price auction, our results depend on whether producers are pivotal or not. A producer is pivotal if its competitors do not have enough production capacity to meet

the realized demand. Producers are never pivotal in single object auctions with at least two participants, while the number of pivotal producers in wholesale electricity markets depends on the season and the time-of-day (Genc and Reynolds, 2011), but also on market shocks. Pivotal status indicators as measures of the ability to exercise unilateral market power have been evaluated by Bushnell et. al. (1999) and Twomey et al. (2005) and have been applied by the Federal Energy Regulator Commission (FERC) in its surveillance of electricity markets in U.S. Such binary indicators are supported by von der Fehr and Harbord's (1993) pure-strategy NE in uniform-price auctions, where the market price is either at the marginal cost of highest cost accepted supplier or the reservation price, depending on whether producers are pivotal or non-pivotal with certainty. Our equilibrium is more subtle, the pivotal status is typically uncertain before offers are submitted and the expected market price increases when producers are expected to be pivotal with a larger margin.

Most wholesale electricity markets use uniform pricing. One exception is the real time market in Britain, which uses discriminatory pricing. We show that equilibrium offers in a discriminatory auction are determined by the expected sales of the highest and lowest bidder, respectively. In our setting, the variance in these sales after offers have been submitted -- due to demand shocks, outages and intermittent renewable production -- will not influence the bidding behaviour of producers in the discriminatory auction. Bidding in the uniform-price auction is also insensitive to this variance in sales, as long as these shocks are not sufficiently large to occasionally change the pivotal status of at least one producer. Even if the possibility of large shocks would influence bidding behaviour in uniform-price auctions, it is still the case that the probability that producers are pivotal does not influence payoffs for given expected sales and independent signals.

Conclusions

We show that uniform and discriminatory pricing are equivalent when signals are independent. An auctioneer tends to favour discriminatory pricing when signals become more correlated at higher values. The opposite is true when signals are less correlated at higher values. Advantages and disadvantages with uniform pricing tend to be amplified if producers are pivotal with a higher probability. We also argue that bidding formats that, as in practice, restrict the number of steps in a producer's supply schedule reduce the mark-ups of offer prices over marginal cost in uniform-price auctions and makes the uniform-price auction more attractive to consumers relative to the discriminatory auction, especially when producers have common uncertainties in their costs.

Independent of the auction format, we find that mark-ups decrease if producers' signals are more positively correlated, i.e. when they receive similar information before offers are submitted. This is related to Vives (2011) who finds that mark-ups decrease when producers receive less noisy cost information before competing in a uniform-price auction. It is also known from previous work that disclosure of information before bids are submitted improves competition in single object auctions (Milgrom and Weber, 1982). Taken together, these results suggest that publicly available information of relevance for production costs -- such as weather conditions, fuel prices, prices of emission permits -- is likely to improve the competitiveness of market outcomes. It is also easier for a producer to estimate the marginal cost of its competitors if the market operator discloses detailed historical bid data and/or detailed production data. Thus, our results support the argument that the transparency increasing measures of the European Commission should improve the performance of European electricity markets. In addition, information provision about outcomes from financial markets just ahead of the operation of related physical markets should lower the market uncertainty. Therefore, trading of long-term contracts which help producers predict future electricity prices, should lower this uncertainty and reduce the extent of informational asymmetries among suppliers about the opportunity cost of water.

Extending this logic further, our results suggest that regulatory risks are particularly harmful for competition in hydro-dominated wholesale electricity markets, especially when water is scarce, because of the potential informational asymmetries about the likelihood of regulatory interventions. Thus, we recommend clearly defined contingency plans for intervention by the regulator in case of extreme system conditions. This could potentially mitigate the extraordinarily high-priced periods that typically accompany low-water conditions in hydro-dominated markets such as California, Colombia, and New Zealand.

Because increased transparency lowers the payoff of producers in our model, we would not expect producers to agree to voluntarily disclose production cost-relevant information. This has similarities to Gal-Or (1986) who shows that producers that play a Bertrand equilibrium would try to conceal their costs from each other.

According to our results, increased transparency would only be helpful up to a point, because there is a lower bound on equilibrium mark-ups when producers are pivotal. Another caveat is that we only consider a single shot game. As argued by von der Fehr (2013), there is a risk that increased transparency in European electricity markets can facilitate tacit collusion in a repeated game.

References

Bushnell, J., Knittel, C. R, and Wolak, F. (1999), `Estimating the Opportunities for Market Power in a Deregulated Wisconsin Electricity Market', The Journal of Industrial Economics 47.

von der Fehr, N-H. M. and D. Harbord (1993). `Spot Market Competition in the UK Electricity Industry', Economic Journal 103 (418), pp. 531-46.

von der Fehr, N. H. M. (2013). `Transparency in electricity markets', Economics of Energy & Environmental Policy 2(2), pp. 87-105.

Gal-Or, E. (1986). Information transmission--Cournot and Bertrand equilibria. The Review of Economic Studies LIII, pp. 85-92.

Genc, T. S., and Reynolds, S. S. (2011). `Supply function equilibria with capacity constraints and pivotal suppliers', International Journal of Industrial Organization 29(4), pp. 432-442.

Milgrom, P.R. and R.J. Weber (1982). `A theory of auctions and competitive bidding', Econometrica 50 (5), pp. 1089-1122.

Twomey, P., Green, R., Neuhoff, K. and Newbery, D. (2005). `A Review of the Monitoring of Market Power: The Possible Roles of Transmission System Operators in Monitoring for Market Power Issues in Congested Transmission Systems', Journal of Energy Literature 11(2), pp. 3-54.

Vives, X. (2011), `Strategic supply function competition with private information', Econometrica 79(6), pp. 1919--1966.