

UNIFORM AND DISCRIMINATORY AUCTIONS IN POWER MARKETS: LITERATURE REVIEW COMPARISON

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Overview

Debates about electricity market reforms, market design and its pricing mechanisms often start from a political claim (KAHN et al, 2001), trying to find which scheme delivers lower power prices to consumers while ensuring returns and incentivizing investments from producers. Competitive prices often lead to scarcity rents that are greater than what is needed to cover variable and fixed costs amortization, driving the perception of overpayment for electricity from consumers. In turn, a more recent debate in electricity markets focuses on the *'missing money problem'* that appears from a higher renewable penetration with very low variable cost. This problem results in an underpayment for producers that are unable to recover their fixed costs, then requiring some sort of capacity payment outside the market to survive (JOSKOW, 2013).

Electricity market design has a decisive role in fostering competition and achieving efficient price signalling to agents (STOFT, 2002; HUNT, 2002). It is critical for resource allocation and to maximize global social welfare. In this context, wholesale markets are commonly designed as auctions, bringing together producers and consumers (or their representatives) to bid their respective intrinsic values and trade power. Bidding in actual wholesale electricity markets requires from agents a reasonable set of information about the past, the present and a future market outlook to build their bidding strategies.

Indeed, the bidding process itself is also affected by how the auction is designed, contradicting the *'revenue equivalence theorem'* (RET). From the auction theory, this theorem states that, given certain conditions¹, any auction mechanism would result in the same allocation outcomes and same expected revenue (KLEMPERER, 2004).

There are four types of auctions in the literature (STOFT, 2002):

- **English:** Buyers start bidding at a low price. The highest bidder wins and pays the last price bid.
- **Vickrey** (second-price): Buyers submit sealed bids, and the winner pays the price of the highest losing bid.
- **Dutch:** The auctioneer starts at a very high price and calls out progressively lower prices. The first buyer to accept the price wins and pays that price.
- **Sealed-Bid** (first-price): Buyers submit sealed bids, and the winner pays the price that is bid.

The auction theory also considers differences between agents values, such as:

- **Private Value:** different values for the same object from various bidders
- **Common Value:** the value of the object is approximately the same for all bidders.

According to RET, all four types of auctions produce the same revenue if the bidders have private values; and, if they have common values, their revenues are in the listed order with English producing the most. However, RET does not be perfectly applied for non-homogeneous multi-unit auctions, as electricity markets. Contracts, day-ahead, balancing and other types of power market auctions might vary in design.

Three types of sealed-bid pricing schemes are particularly important (CRAMTON, 2004): (1) uniform pricing (non-discriminatory payment), (2) pay-as-bid pricing (discriminatory payment), and (3) Vickrey pricing.

The most common design discussed in the literature for electricity markets is the so-called uniform price (UP) and the pay-as-bid (PAB)².

¹Such as agents are risk-neutral and have independent private values (otherwise, it can lead to the *'Winners' curse'*), be symmetric and make or receive payments as a function of bids alone.

² Cramton (2004) discusses that vickrey pricing is rarely applied due the perception of unfair results, merge incentives from large bidders, distortions coming from forward positions and revenue deficit for two-sided markets.

Methods

This paper analyses the pros and cons among uniform pricing and pay-as-bid applied to electricity markets from a literature review mostly based on game theoretical approaches. An electricity auction can be described as a game, due to the interaction among agents considering their strategies and behaviors aiming to maximize their utility/payoffs. Then, approaches can range from:

- Analytical models;
- Supply function equilibria (SFE);
- Agent-based simulation (with learning algorithms);
- Experimental sessions;
- Mixed integral programming (MIP).

Moreover, as described by Baldick (2007), electricity market equilibrium can be formulated through three types of models or a mixture of them:

- **Physical model:** a (notionally) exact model of physical characteristics.
- **Commercial model:** the model used in the actual market.
- **Economic model:** the model used in the equilibrium formulation.

Therefore, the literature review will be framed by approaches, model types and its conclusions regarding which auction delivers best results or if they are equivalent (i.e. RET holds).

Results

From this literature review it could be found that several debates arise from the comparison between UP and PAB such as: (i) electricity markets described as “seller’s auctions”; (ii) influence of price’s volatility in agents’ strategies; (iii) efficient dispatch considerations; (iv) long-lived vs. short-lived bids; (v) long run investment incentives; (vi) existence of windfall profits; (vii) the importance of scarcity rents.

The literature review shows that depending on assumptions made there is no best mechanism for all circumstances that electricity markets may present. However, some papers have shown that equivalence may arise, but it does not seem to be reasonable for actual markets.

Conclusions

A variety of approaches have been tested including more realistic assumptions. And as the mathematical problem is becoming treatable, the debate may remain. Market imperfections are extremely difficult to be tackled by any auction design. At the end both alternatives are being implemented to some extent, but the UP scheme is the most used in electricity spot markets.

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(and several others for the literature review)