

## **When is a Pay-as Bid Preferable to Uniform Price in Electricity Markets.**

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Most economists will agree that at least in the case of a liquid and unconcentrated market for a homogeneous commodity, a uniform clearing price auction is superior to a pay-as-bid rule. While revenue equivalence results suggest that the expected payments in a uniform price procurement auction will be the same as the expected payment in a pay-as-bid auction, other considerations make the uniform price more attractive. Specifically, the revenue equivalence results hinges on the assumption that all bidders have perfect knowledge of each other's cost and consequently their equilibrium markup in a pay-as-bid setting will not distort merit order so that the resulting dispatch is still efficient. In reality, the markup tends to flatten the supply function and small errors due to imperfect information about costs will result in distortion of the merit order and inefficient dispatch. In uniform price auctions bidders have an incentive to reveal their true cost and therefore, the dispatch will be efficient. On the other hand, one must recognize that if demand is uncertain a uniform clearing price will reflect that entire uncertainty and will be more volatile than the average procurement price in a pay-as-bid auction. The lower volatility results from the fact that in a pay-as-bid setting the markup function which balances bidders' desire to get a higher price against their fear of not being selected, tends to absorb part of the demand uncertainty. In principle the system operator conducting the auction should be risk neutral and not care about price volatility. Furthermore, one may argue that suppressing price volatility is undesirable since it may also suppress demand response when possible. Nevertheless reduced price volatility is one of the arguments used, for instance by the UK NETA proponents, to advocate a pay-as-bid settlement rule.

In real electricity markets the auctioned products are not completely homogeneous and the markets are not complete. Consequently winner determination is often based on attributes such as location, ramp rate, reactive power capability etc. that are not explicitly priced in the auction. In some cases such heterogeneity leads to product fragmentation where the distinct products are procured through separate auctions conducted in a

coordinated fashion in series, in parallel or simultaneously. Designing such auctions so as to take into consideration the partial substitutability among the different products is challenging. Furthermore, such fragmentation reduces the liquidity in each of the separate auctions to the point where some of the underlying assumptions favoring the uniform clearing price approach may no longer be valid.

Reserve markets are good examples of such market fragmentation where reserve capacity is categorized based on response time (e.g. Regulation, Spinning Reserves, Non-Spinning Reserves) and auctioned as separate products in sequential or simultaneous auctions. In places like NY where reserve requirements are also location based the reserve products are further categorized by location. In the NYPP for instance, the reserves are identified according to three geographic categories resulting in nine distinct reserve products. Under these circumstances the assumption of liquidity, homogeneity and unconcentrated supply are no longer valid and one must reexamine the wisdom of having a uniform clearing price auction for each separate product as opposed to a pay-as-bid approach.

In the case of reserves some of the auctions like in California and NYPP are conducted simultaneously in a co-optimized fashion that allows each tender to be offered once and the clearing mechanism assigns it to the best use taking into account partial substitutability among the products. In the California market this simultaneous auction for reserves is known as the “rational buyer” approach. In such design a uniform clearing price approach must determine whether the uniform price should be based on the category of the offer or based on the category of the demand which the tender was assigned to serve. When demand for the different product categories is uncertain, it can be shown that revenue equivalence between the uniform price settlement and a pay as bid approach may no longer hold.

Limited simulation studies of equilibrium bidding in hierarchical reserve markets with simultaneous clearing confirm that a social welfare maximizing clearing mechanism with uniform clearing prices based on tender type achieves the best social efficiency

results but at a high procurement cost. At the other extreme, the “rational buyer “ approach that also pays uniform prices based on tender type but clears the auction so as to explicitly minimize procurement cost, does so at significant efficiency losses. By comparison to the above two approaches a pay as bid approach achieves nearly first best efficiency results with only a modest increase in procurement cost above the “rational buyer” method.

These results suggest that in situations where the non-homogeneous nature of the product and market incompleteness necessitate a high degree of product fragmentation, a pay as bid settlement approach with optimized assignment based on requirements and multiattribute specifications of the tender, may be promising.