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# Multi-unit demand auctions with synergies: behavior in sealed-bid versus ascending-bid uniform-price auctions

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**Abstract**

We construct a relatively simple model of bidding with synergies and solve it for both open out-cry and sealed-bid uniform-price auctions. The essential behavioral forces involved in these auctions are: (1) A demand reduction force resulting from the monopsony power that bidders with multiple-unit demands have when synergies are relatively inconsequential, and (2) Bidding above stand-alone values in order to capture significant complementarities between units. The latter creates a potential "exposure problem," as bidders may win only parts of a package and earn negative profits. Bidding outcomes are closer to equilibrium in clock compared to sealed-bid auctions. However, there are substantial and systematic deviations from equilibrium, with patterns of out-of-equilibrium play differing systematically between the two auction formats. These patterns of out-of-equilibrium play are analyzed, along with their effects on revenue and efficiency.
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*JEL classification:* D44; C92; D80

*Keywords:* Auction; Synergies; Exposure problem; Experiment

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The FCC spectrum auctions have reinvigorated theoretical and empirical research on auctions in efforts to better understand the effects of different auction institutions when individual bidders demand multiple units of a given commodity. One line of research has focused on the performance of auctions with uniform-price rules, where all winning bids pay the same highest rejected bid.[1] It is well known by now that in such auctions, when valuations are non-increasing, bidders have an incentive to reduce demand on some of their units in order to exploit the monopsony power they have when demanding multiple units. This strategy may result in winning fewer units, but when it does, it also reduces the price on units earned. (See, for example, Ausubel and Cramton, 1996 and Engelbrecht-Wiggans and Kahn, 1998.) Demand reduction reduces economic efficiency and revenue relative to full demand revelation. Experimental, and quasi-experimental research confirms that the demand reduction incentives are reasonably transparent and practiced even by relatively naive bidders (Kagel and Levin, 2001; List and Lucking-Reiley, 2000). Further, experiments comparing sealed-bid auctions with ascending-price clock auctions reveal that although both auctions have the same normal form game representation, bidding is significantly closer to equilibrium in the clock auction, suggesting there are behavioral elements not fully captured in the theory (Kagel and Levin, 2001).

Uniform-price auctions which involve synergies, or complementarities, provide additional incentives and generate radically different bidding strategies than the same auctions without synergies. Synergies create an opposite incentive to the demand reduction force: aggressive bidding in order to acquire desired packages with their super additive value. Further, in sealed-bid uniform-price auctions, that do not permit package bids, the existence of synergies commonly dictates submitting bids above the stand-alone values for individual units in order to increase the probability of winning a package with its super additive value. However, this strategy is risky since if a bidder fails to acquire the whole package and wins only parts instead, she is likely to earn negative profits. Thus, in addition to the competing equilibrium incentives, an important "behavioral" force may affect bidding as well: Depending on the size of the potential loss, and risk preferences, bidders may refrain from such aggressive bidding in order to avoid exposure to such losses, despite the benefits of doing so (Bykowsky et al., 1995; Ausubel et al., 1997; Rothkopf et al., 1998). This avoidance has been referred to as the "exposure problem," a serious concern in some quarters at least, in designing auctions in the absence of package bids.[2]

The present paper reports the results of an experiment in a highly simplified auction environment designed to maintain the essential richness of the economic and behavioral forces present in multi-unit demand auctions with synergies. We first construct a tractable

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[1] Particular attention has been given to the effects of uniform-price auction rules because they are relatively easy to characterize and to implement, and are reasonably close in format to the one employed in the spectrum auctions (see Cramton, 1995).

[2] Bykowsky et al. (1995) discuss two types of exposure problems that may exist in complex environments with synergies. In our simple environment only the first of these potential problems exists, namely exposure to bidding above the stand-alone value and not obtaining the desired package, or obtaining it but at higher prices than anticipated. Bidder responsiveness to the exposure problem in this case is akin to *loss aversion* (Kahneman and Tversky, 1979). Package bidding has its own problems. These include the free rider/threshold problem and the computational complexity problem (Charles River Associates, Inc., and Market Design, Inc., 1998).