

# Efficiency, Auctioneer Revenue, and Bidding Behavior in the Combinatorial Clock Auction

Martin Bichler, Pasha Shabalin, and Jürgen Wolf

Dept. of Informatics, TU München, Munich, Germany [bichler@in.tum.de](mailto:bichler@in.tum.de),

WWW home page: <http://dss.in.tum.de>

## Abstract

The Combinatorial Clock Auction (CCA) is a two-phase auction format which was designed for high efficiency and to incentivize truthful bidding. The auction has recently been used for spectrum sales in a number of countries. In this study we experimentally analyze the performance of the CCA in comparison to the Simultaneous Multi-Round Auctions (SMRA), which was used for spectrum sales worldwide for more than 15 years.

The study highlights behavioral patterns, which have largely been ignored in the discussion on spectrum auction design, but are important for regulators and for the further development of combinatorial auction designs. In particular, our results indicate that in a multiband setting with thousands of possible packages efficiency and revenue of the CCA can be significantly lower than that of the SMRA.

We conducted *experiments* (i) in a base setting which closely resembles the 2.6 GHz auction setting of many countries and (ii) in a multi-band setting resembling an environment in which different spectrum bands are sold simultaneously. To account for the high levels of bidder preparation in spectrum auctions in the field and to improve the external validity of our experiments we also conducted *competitions*. Subjects in these treatments received additional information about known auction tactics and equilibrium strategies. They participated in teams of two people and were asked to prepare a bidding strategy two weeks prior to the lab session.

A main result of our experiments is that the CCA did not yield higher efficiency in the smaller base value model, but efficiency was significantly lower than in the SMRA in the multiband value model. Also, revenue was significantly lower in all treatments and sometimes items remained unsold in spite of sufficient demand. This was due to the low number of bundle bids and the CCA payment rule. In numerical experiments we show that if bidders submitted bids on all possible bundles truthfully the CCA revenue in our setting would have been similar to the revenue of SMRA in the lab.

In the CCA, bidders only submitted a small subset of all possible bundle bids. In the multiband value model only 8.33 bids out of 2,400 possible bids were submitted by bidders in the supplementary bids round, which was a major reason for inefficiency and unsold items. Bidders used heuristics to select bundles, mainly based on their strength and the synergies in the value model. In the base

value model, strong bidders avoided bids on small bundles, while weak bidders bid on smaller combinations as well. According to theoretical predictions bundle bids were either at or slightly below the valuation.

The observed restrictive bundle selection is more difficult to explain theoretically. The bidders had sufficient time to submit as many bundle bids as they wanted. One explanation is that neither bidders in the lab nor in the competition had fully understood the theory of core-selecting payment rules. It is also possible that bidders felt unable to submit all possible bundle bids in the multiband value model, and they bid on those that either had the highest payoff after the primary bid rounds (suggesting they had the highest chance of winning), or that had the highest synergies. Such behavior could be explained as satisficing, since bidding optimally did not seem practical.

Bidding behavior in CCA was not significantly different in competitions than in the lab. All results from the lab carry over to the competition. In SMRA treatments bidder payoff was significantly higher than in the lab indicating the successful bidder preparation.

The results need to be interpreted with the necessary care. We aimed to provide an implementation of both the CCA and the SMRA, which exactly mirrors the relevant auction rules used in the field to address external validity. We also tried to reflect the main characteristics of valuations telecoms had for spectrum in the recent spectrum sales across Europe. At the same time we limited the complexity, which bidders were exposed to in the lab. The synergies in our valuations were considerable (up to 80%), but one could also argue for even stronger synergies in some settings. Also, our experiments were conducted in a pure private values environment, while in some applications values might be affiliated.